# Competition Robotics FIRST

**WPILib**

**מאי 27, 2023**

[redacted]

[illegible] Competition. Robotics ®*FIRST* [illegible]
![illegible]

.[illegible] ,[illegible]

## Teams Returning

and 2023 to 2022 from changes of overview the out check please team, returning a are you If issues. known the

*Changelog*

*Issues Known*

## Teams New

![illegible] ,[illegible]

*Robotto-Zero- to Go*

## Overview Hardware

.[illegible]

*Overview Hardware to Go*

## Overview Software

.[illegible]

*Overview Software to Go*

## Basics Programming

.[illegible]

articles View

## Programming Advanced

.[illegible] ,[illegible]

articles View

## Hardware

.[illegible]

articles View

## Robot Romi

WPILIb.-[illegible] Pi, Raspberry [illegible] ,[illegible]

*articles View*

## Documentation API

C++.-[illegible] Java [illegible]

Java

C++

## Tools Software

.[illegible] Tool Imaging roboRIO Dashboards, Station, Driver FRC [illegible]

articles View

## Projects Example

Code. VS-□ □□□□□□ □□□□□□□ □□□□□□□ □□□□□□□□ □□□□□□□ □□□□□□□□□ □□□□□ □□ □□□

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### Reference Quick Light Status

FRC. □□□□□□□ □□□□□□□ □□□□□ □□□□□□ □□ □□□□□ □□□□□□

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### libraries Party 3rd

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[illegible] FIRST® Robotics Competition [illegible] WPILib. [illegible] FRC® [illegible] ([illegible], [illegible], [illegible]) [illegible] WPILib.

## 1.1 חדשים בתכנות?

[illegible] WPILib [illegible] FRC [illegible]. [illegible], [illegible]:

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[illegible]: [illegible]. [illegible], [illegible].

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### 1.1.1 Java

- Code Academy
- Head First Java 2nd Edition [illegible] Java-[illegible] ([illegible]: 0596009208).

### 1.1.2 C++

- LearnCPP
- Programming: Principles and Practice Using C++ 2nd Edition [illegible] C++-[illegible] [illegible] ([illegible]: 0321992784).
- C++ Primer Plus 6th Edition ([illegible]: 0321776402).

### 1.1.3 LabVIEW

- LabVIEW Learn NI

## 1.2 מאפס לרובוט

[illegible]. [illegible], [illegible], [illegible]. [illegible], [illegible] **Next** [illegible]. [illegible], [illegible] **Next** [illegible] WPILib ‏C++/Java-[illegible] [illegible].

# 2

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## Wiring Robot FRC to Introduction 2.1

allow to or kitbot the for board electronics basic a of wiring the details document This :□□□□ testing. drivetrain basic

SPARK using System Control Robot a for setup the reflect section this in shown images Some other for similar be should layout and diagram Wiring Controllers. Motor MAX SPARK or connections show to provided are images of sets two appropriate, Where controllers. motor wires. integrated without and with controllers using

### Overview 2.1.1

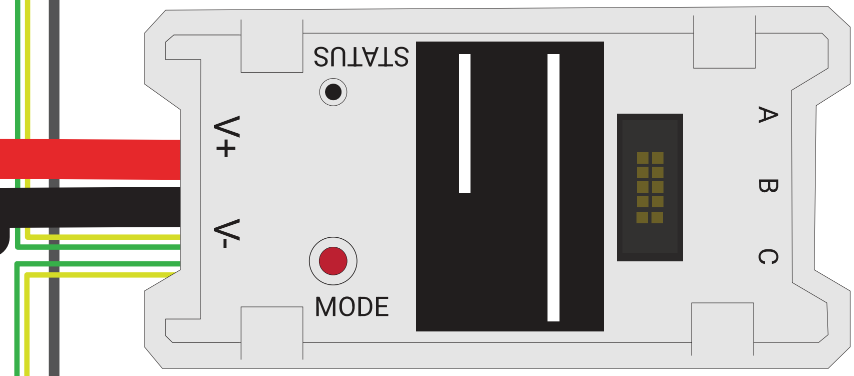
REV

CTR

### Materials Gather 2.1.2

tools and components system control following the Locate

- Materials: Kit
  - (PDP) Panel Distribution Power / (PH) Hub Distribution Power
  - roboRIO
  - (PCM) Module Control Pneumatics / (PH) Hub Pneumatics
  - (VRM) Module Regulator Voltage / (RPM) Module Power Radio
  - cable) Ethernet and cable power (with radio OpenMesh
  - (RSL) Light Signal Robot

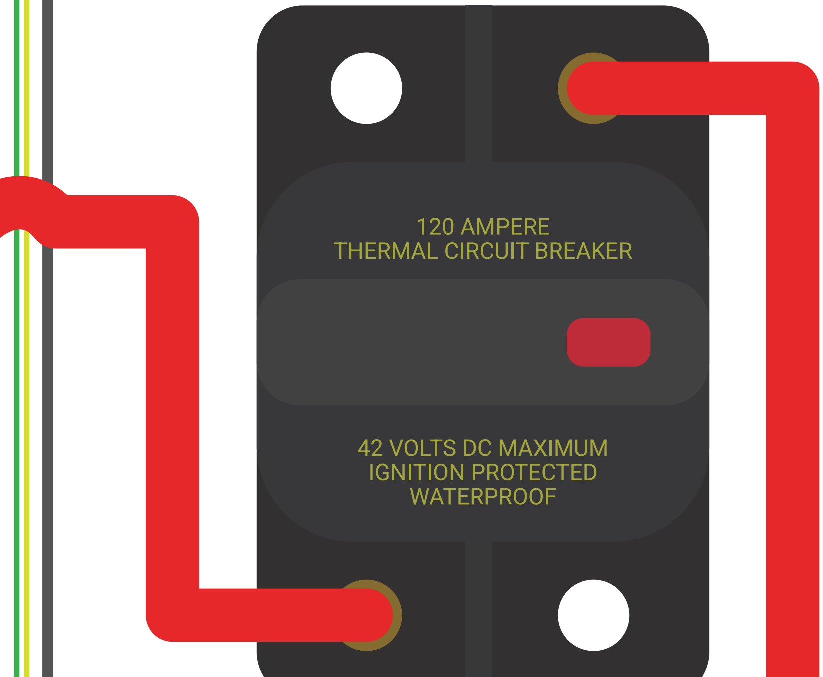


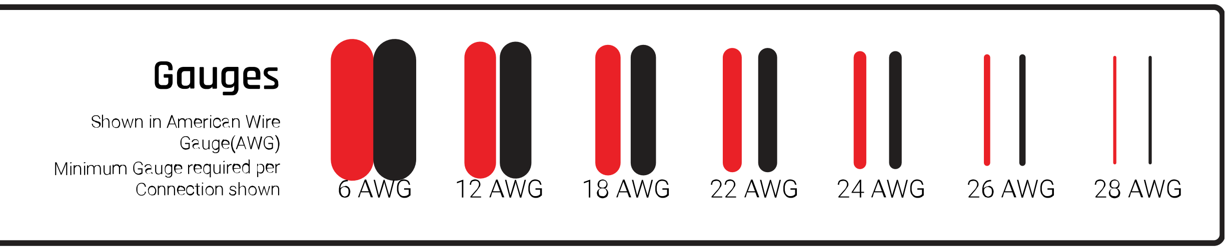
Spark MAX

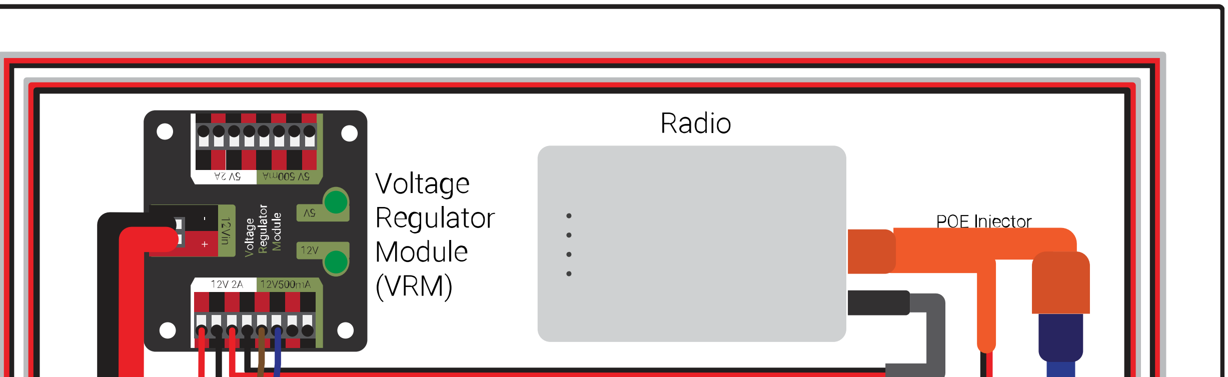
## DISCRETE
## MOTOR CONTROLLERS
### (CAN/PWM Controlled)

More Information about
the FRC Control System can be found
at **https://docs.wpilib.org/**

120A Breaker




Gauges
Shown in American Wire Gauge(AWG)
Minimum Gauge required per Connection shown
6 AWG
12 AWG
18 AWG
22 AWG
24 AWG
26 AWG
28 AWG


Radio
Voltage Regulator Module (VRM)
POE Injector
5V 2A
5V 500mA
12Vin
Voltage Regulator Module
5V
12V
12V 2A
12V500mA

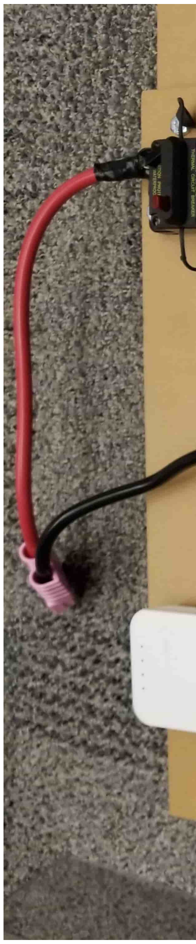
  - controllers motor other or MAX SPARK 4x
  - cablesy- PWM 2x
  - breaker Circuit 120A
  - breaker Circuit 40A 4x
  - wire Red )$mm^2$ (16 AWG 6
  - wire Red/Black )$mm^2$ (6 AWG 10
  - wire Red/Black )$mm^2$ (1 AWG 18
  - cable CAN twisted Yellow/Green )$mm^2$ (0.5 AWG 22
  - ring (16x terminals disconnect quick (Yellow) )$mm^2$ 6 - (4 AWG 1210- of Pairs 8x controllers) wire integrated using if terminals
  - connectors battery SB50 Anderson 2x
  - lugs Terminal )$mm^2$ (16 AWG 6
  - Battery 12V
  - tape Electrical Red/Black
  - fasteners or material Lock Dual
  - ties Zip
  - plywood mm) 12(6- 1/2“ or 1/4“
- Required: Tools
  - screwdriver headflat- small or Tool Wago
  - size) repair (eyeglass screwdriver head flat small Very
  - crimpers and strippers, cutters, Wire
  - driver nut or wrench end box unavailable) is imperial if work may mm (11 7/16“
  - driver screw head Philips or driver wrench/nut 7/16“ Additional
  - unavailable) is metric if work may (3/16“ key Hex mm 5 only: PDP CTR For
  - key Hex 1/16“ only: PDP CTR For

### System Control the for Base the Create 2.1.3

approximately plastic) or (wood material mm) 12(6- 1/2“ or 1/4“ of piece cut board, test a For supporting the see board control Build Quick Robot a For cm). 40 x (60 16“ x 24“ configuration. chassis chosen the for board size proper the for documentation

### Components System Control Core the Layout 2.1.4

REV



CTR

above. image the in shown is layout example An board. the on components the out Lay

### Components Fasten 2.1.5

FRC many in that Note board. the to components all fasten hardware, or Lock Dual the Using up stand to unlikely is alone Lock Dual and substantial be may contact robotto-robot- games fasteners bolt and nut use to wish may Teams components. electronic many for fastener a as to devices secure to Lock Dual without or with ties, cable above) image the in shown (as or board. the

### Connector Battery Side Robot Attach 2.1.6

REV

connectors, Wago the use To PDH. the on connectors Wago the using involve will step next The found are connector Wago of sizes Two lever. the close then wire, the insert lever, the open PDH: the on

- (~3/4“) mm 20 strip ),$mm^2$ 25 - (.75 AWG 18 - 4 Accept connectors: power Main
- (~1/2“) mm 12 strip ),$mm^2$ 10 - (.25 AWG 24 - 8 Accept connectors: channel current High

tinned be not should wires resistance connection minimize and force pullout maximize To connector. Wago the into inserting before twisted) not ideally (and

end Box mm) (11 7/16“ lugs, terminal )$mm^2$ (16 AWG 6 Connector, Battery Requires:

wire. black the off .75“ Strip connector. battery of wire (red) positive to lug terminal Attach

place. into clicks it until PDH the on terminal input power main black the above lever the Lift wire. the secure to down lever the Pull wire. the Insert

breaker main the of side ”Batt“ the on nut the remove wrench, end box mm) (11 7/16“ a Using connector battery the of terminal positive the secure and

CTR

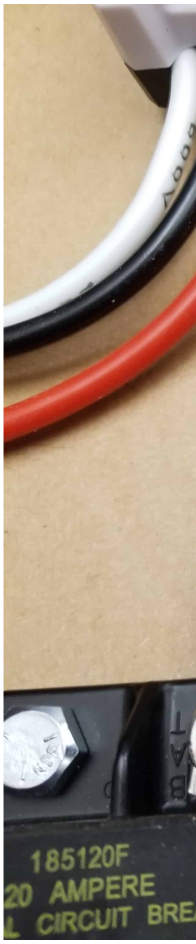
7/16“ Allen, mm 5 Allen, 1/16“ lugs, terminal )$mm^2$ (16 AWG 6 Connector, Battery Requires: end Box mm) (11

connector. battery to lugs terminal Attach

1. cover. terminal PDP the securing screws two the remove wrench, Allen 1/16“ a Using
2. the from washer and bolt )(- negative the remove (3/16“), wrench Allen mm 5 a Using connector. battery the of terminal negative the fasten and PDP
3. main the of side ”Batt“ the on nut the remove wrench, end box mm) (11 7/16“ a Using connector battery the of terminal positive the secure and breaker

## Distribution Power to Breaker Wire 2.1.7

REV



wrench mm) (11 7/16“ lugs, terminal )$mm^2$ (16 AWG 6 1x wire, red )$mm^2$ (16 AWG 6 Requires:

mm) (11 7/16“ the Using wire. red )$mm^2$ (16 AWG 6 the of end the to lug terminal one Secure terminal the place and breaker main 120A the of side ”AUX“ the from nut the remove wrench, the strip and cut to shortly it remove to wish may (you nut the secure Loosely stud. the over terminal positive the reach to required wire of length the out Measure wire). the of end other PDH. the of

wire. red the of end other the strip and Cut 1.

main 120A the of side ”AUX“ the to wire the secure wrench, mm) (11 7/16“ the Using 2.
breaker.

close then wire, the insert PDH, the of terminal input (red) positive the on lever the Lift 3.
terminal. the

CTR

(11 7/16“ Allen, mm 5 lugs, terminal )$mm^2$ (16 AWG 6 2x wire, red )$mm^2$ (16 AWG 6 Requires: end box mm)

(11 7/16“ the Using wire. red )$mm^2$ (16 AWG 6 the of end the to lug terminal one Secure the place and breaker main 120A the of side ”AUX“ the from nut the remove end, box mm) strip, cut, to shortly it remove to wish may (you nut the secure Loosely stud. the over terminal the reach to required wire of length the out Measure wire). the of end other the crimp and PDP. the of terminal positive

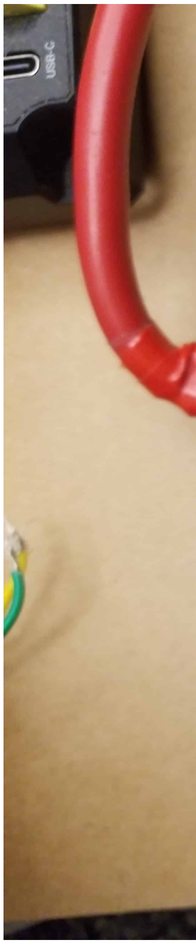
wire. )$mm^2$ (16 AWG 6 red the of end 2nd the to terminal the crimp and strip, Cut, 1.

main 120A the of side ”AUX“ the to wire the secure end, box mm) (11 7/16“ the Using breaker. 2.

terminal. positive PDP the to end other the secure wrench, Allen mm 5 the Using 3.

### connections power Insulate 2.1.8

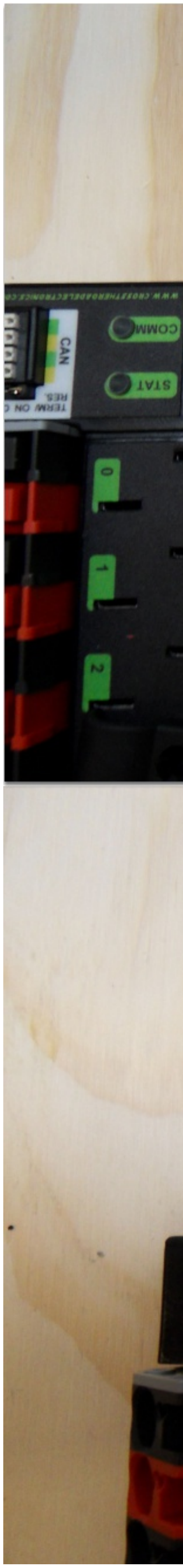
REV



tape Electrical Requires:

breaker. 120A the to connections two the insulate tape, electrical Using

CTR



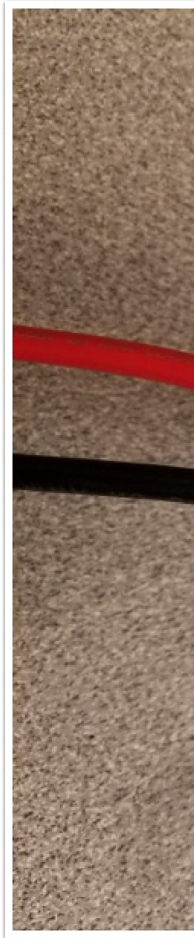
Requires: 1/16“ Allen, Electrical tape

insulate Also breaker. 120A the to connections two the insulate tape, electrical Using 1.
replaced. is cover the when exposed be will which terminals PDP the of part any

cover terminal PDP the replace wrench, Allen 1/16“ the Using 2.

### Power Controller Motor 2.1.9

REV



12 or 10 , wire )$mm^2$ 6 - (4 AWG 12 or 10 only: Controllers Terminal Stripper Wire Requires:
crimper wire terminals, fork/ring )$mm^2$ 6 - (4 AWG

image): (top controllers motor integrated wire other or MAX SPARK For

Wago the of one into insert then wires, input power black and red the strip and Cut •
pairs. terminal

image): (bottom controllers motor terminal For

terminal Wago the of one from reach to length appropriate to wire black and red Cut 1.
will that length the for extra little a (with controller motor the of side input the to pairs
end) each on terminals the into inserted be

terminals. Wago the into insert then wires, the of each of end one Strip 2.

terminal fork or ring a on crimp and wire, each of end other the Strip 3.

)- to black +, to (red terminals input controller motor the to terminal the Attach 4.

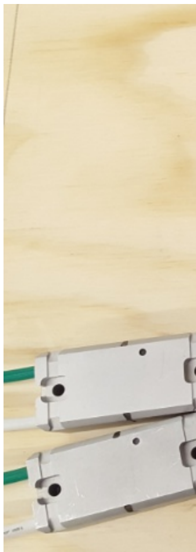
CTR

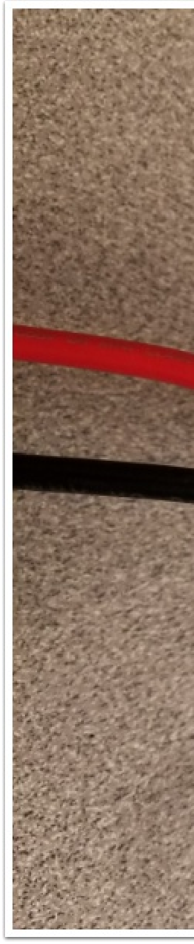
connectors, Wago the use To PDP. the on connectors Wago the using involve will step next The
the angle then angle shallow a at hole rectangular the into screwdriver blade flat small a insert
terminal. the opening lever, the actuate to in press to continue you as upwards screwdriver
PDP: the on found are connector Wago of sizes Two

(~7/16“) mm 1211- strip ),$mm^2$ 6 - (0.25 AWG 24 - 10 Accepts connector: Wago Small •

- (~1/2“) mm 1312- strip ),$mm^2$ 16 - (4 AWG 12 - 6 Accepts connector: Wago Large

tinned be not should wires resistance connection minimize and force pullout maximize To (and ideally not twisted) before inserting into the Wago connector.





(4 AWG 12 or 10 only: Controllers Terminal Screwdriver, Flat Small Stripper, Wire Requires: crimper wire terminals, fork/ring )$mm^2$ 6 - (4 AWG 12 or 10 wire, )$mm^2$ 6 -

image): (top controllers motor integrated wire other or MAX SPARK For

- (larger) 40A the of one into insert then wires, input power black and red the strip and Cut pairs. terminal Wago

image): (bottom controllers motor terminal For

1. Wago (larger) 40A the of one from reach to length appropriate to wire black and red Cut length the for extra little a (with controller motor the of side input the to pairs terminal end) each on terminals the into inserted be will that
2. terminals. Wago the into insert then wires, the of each of end one Strip
3. terminal fork or ring a on crimp and wire, each of end other the Strip
4. )- to black +, to (red terminals input controller motor the to terminal the Attach

### Connectors Weidmuller 2.1.10

wire- series LSF Weidmuller a use system the in connectors power and CAN the of number A for connector this using when mind in keep to things few a are There connector. boardto- results: best

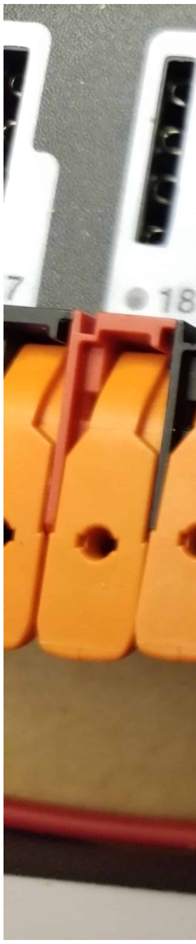
- required verify to rules (consult )$mm^2$ (0.25 AWG 24 to )$mm^2$ (1.5 AWG 16 be should Wire wiring) power for gauge
- mm)“ (~8 5/16 approximately stripped be should ends Wire
- the open to ”button“ corresponding the on down press wire, the remove or insert To terminal

secure: and clean is it that sure be to check connection the making After

- circuit short a cause may that connector the outside ”whiskers“ no are there that Verify
- correct the is and out comes wire the If fully. seated is it that verify to wire the on Tug the Occasionally further. back stripped and/or further inserted be to needs it gauge if even released button the and inserted wire the with open stuck remain may terminal a out and in wire the wiggling cases these in properly; inserted and stripped is wire the wire. the grip and shut latch to connector the allow often will amount small

### Power roboRIO 2.1.11

REV



and Red )$mm^2$ (1 AWG 18 screwdriver, flat small very stripper, Wire fuse, mini 10A Requires: Black

22).(20- channels fused switchablenon- the of one in PDH the into fuse 10A the Insert 1.

to connect and wire )$mm^2$ (1 AWG 18 black and red the both on mm) (~8 ~5/16“ Strip 2.
installed was fuse the where channel PDH the on terminals corresponding the

leave to care Take roboRIO. the on input power the reach to length required the Measure 3.
and battery the as such components other any around wires the route to length enough
management. cable or relief strain any for allow to

wire. the strip and Cut 4.

of connector input power the to wires the connect screwdriver flat small very a Using 5.
screwed is connector power the that sure make Also C). to black V, to (red roboRIO the
roboRIO. the to securely down

CTR

)$mm^2$ (1 AWG 18 screwdriver, flat small very stripper, Wire fuses, mini 10A/20A Requires:

Black and Red

screen silk the on shown locations the in PDP the in fuses mini 20A and 10A the Insert 1.
above) image the in (and

to connect and wire )$mm^2$ (1 AWG 18 black and red the both on mm) (~8 ~5/16“ Strip 2.
PDB the on terminals PWR“ Controller ”Vbat the

leave to care Take roboRIO. the on input power the reach to length required the Measure 3.
and battery the as such components other any around wires the route to length enough
management. cable or relief strain any for allow to

wire. the strip and Cut 4.

of connector input power the to wires the connect screwdriver flat small very a Using 5.
screwed is connector power the that sure make Also C). to black V, to (red roboRIO the
roboRIO. the to securely down

### Power Radio 2.1.12

REV

wire: black and red )$mm^2$ (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:

22).(20- channels fused switchablenon- the of one in PDH the into fuse 10A the Insert 1.

connect and wire )$mm^2$ (1 AWG 18 black and red the of end the on mm) (~8 ~5/16“ Strip 2.
PDH. the on terminals corresponding the to wire the

Power Radio the on terminals Input“ ”12V the reach to required length the Measure 3.
other any around wires the route to length enough leave to care Take Module.
management. cable or relief strain any for allow to and battery the as such components

wire. the of end the from mm) (~8 ~5/16“ strip and Cut 4.

terminals. Input 12V RPM the to wire the Connect 5.

CTR

wire: black and red )$mm^2$ (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:

wire. )$mm^2$ (1 AWG 18 black and red the of end the on mm) (~8 ~5/16“ Strip 1.

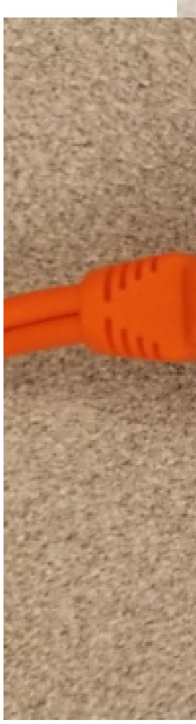
the on PWR“ PCM VRM ”Vbat labeled pairs terminal two the of one to wire the Connect 2.
PDP.

to care Take VRM. the on terminals ”12Vin“ the reach to required length the Measure 3.
battery the as such components other any around wires the route to length enough leave
management. cable or relief strain any for allow to and

wire. the of end the from mm) (~8 ~5/16“ strip and Cut 4.

terminals. 12Vin VRM the to wire the Connect 5.

The roboRIO. the to directly cable injector POE passive Rev the connect NOT DO **:□□□□□**
cable Ethernet additional an using cable the of end socket the to connect MUST roboRIO
step. next the in shown as



cable PoE radio Rev (optional), screwdriver flat Small Requires:

colored corresponding the into cable injector PoE passive the of ferrules the Insert 1.
VRM. the of section 12V/2A the on terminals

radio the on port Ethernet the into cable the of end plug (Ethernet) RJ45 the Connect 2.
POE) 24v18- (labeled connector barrel the to closest

## (Optional) Power Pneumatics 2.1.13

REV

wire black and red )$mm^2$ (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:

a with PDH the on port fused switchablenon- a either to wired be can Hub Pneumatics The 20A. to up breaker a with port protected breaker circuit a to or fuse smaller or 15A

wire. )$mm^2$ (1 AWG 18 black and red the of end the on mm) (~8 ~5/16“ Strip 1.

above described ways two the of one in PDH the to wire the Connect 2.

labeled PH the of end short the on terminals red the reach to required length the Measure components other any around wires the route to length enough leave to care Take .+/- management. cable or relief strain any for allow to and battery the as such 3.

wire. the of end other the from mm) (~8 ~5/16“ strip and Cut 4.

terminals. input PH the to wire the Connect 5.

CTR

wire black and red )$mm^2$ (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:

wire. )$mm^2$ (1 AWG 18 black and red the of end the on mm) (~8 ~5/16“ Strip 1.

the on PWR“ PCM VRM ”Vbat labeled pairs terminal two the of one to wire the Connect 2. PDP.

leave to care Take PCM. the on terminals ”Vin“ the reach to required length the Measure 3. and battery the as such components other any around wires the route to length enough management. cable or relief strain any for allow to

wire. the of end the from mm) (~8 ~5/16“ strip and Cut 4.

terminals. 12Vin PCM the to wire the Connect 5.

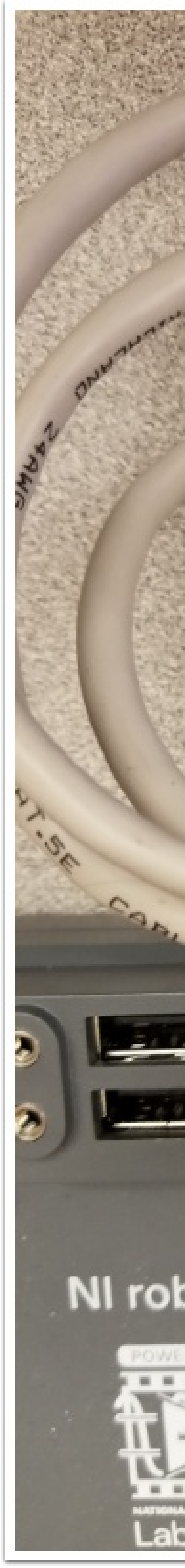
### Cables Ethernet 2.1.14

REV

Requires: 2x Ethernet cables

1. Connect an Ethernet cable from the RJ45 (Ethernet) socket of the roboRIO to the port on the Radio Power Module labeled roboRIO.
2. Connect an Ethernet cable from the RJ45 socket of the radio closest to the barrel connector socket (labeled 18-24v POE) to the socket labeled WiFi Radio on the RPM

CTR



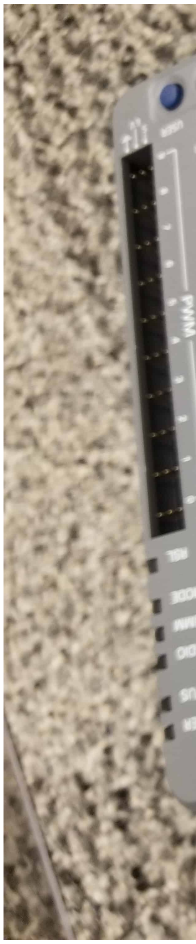
cable Ethernet Requires:

to cable POE Passive Rev the of socket (Ethernet) RJ45 the from cable Ethernet an Connect roboRIO. the on port (Ethernet) RJ45 the

## Devices CAN 2.1.15

### CAN Pneumatics to roboRIO

REV



cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

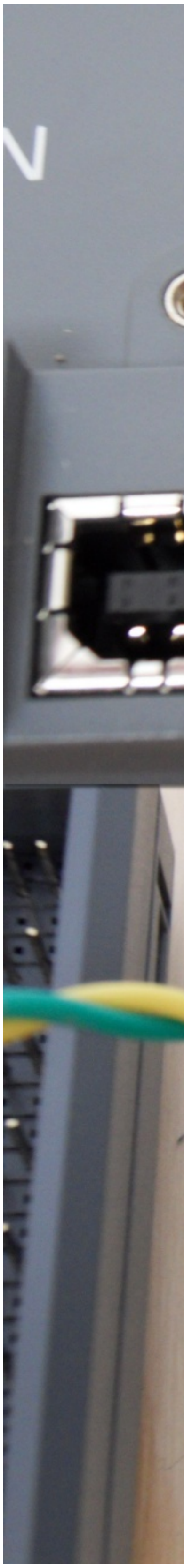
wires. CAN the of each of off mm) (~8 ~5/16“ Strip 1.

>YEL,(Yellow- roboRIO the on terminals CAN appropriate the into wires the Insert 2.
>GRN).Green-

two the of (either PCM the of terminals CAN the reach to required length the Measure 3.
wires. the of end this off mm) (~8 ~5/16“ strip and Cut pairs). available

use may You PH. the on terminals CAN coded color appropriate the into wires the Insert 4.
out. or in defined no is there PH, the on pairs terminal Yellow/Green the of either

CTR



cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

wires. CAN the of each of off mm) (~8 ~5/16“ Strip 1.

>YEL,(Yellow- roboRIO the on terminals CAN appropriate the into wires the Insert 2.
>GRN).Green-

two the of (either PCM the of terminals CAN the reach to required length the Measure 3.
wires. the of end this off mm) (~8 ~5/16“ strip and Cut pairs). available

may You PCM. the on terminals CAN coded color appropriate the into wires the Insert 4.
out. or in defined no is there PCM, the on pairs terminal Yellow/Green the of either use

## CAN PD to Pneumatics

REV

cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

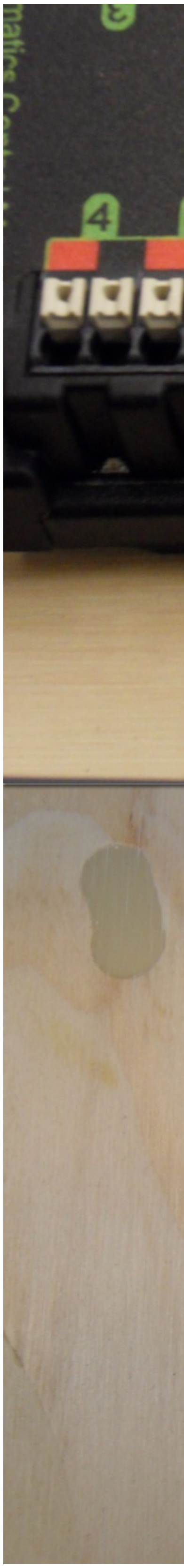
wires. CAN the of each of off mm) (~8 ~5/16“ Strip 1.

PH. the on terminals CAN appropriate the into wires the Insert 2.

two the of (either PDH the of terminals CAN the reach to required length the Measure 3.
wires. the of end this off mm) (~8 ~5/16“ strip and Cut pairs). available

may You PDH. the on terminals CAN coded color appropriate the into wires the Insert 4.
out. or in defined no is there PDH, the on pairs terminal Yellow/Green the of either use

CTR



cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

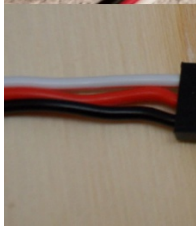
1. wires. CAN the of each of off mm) (~8 ~5/16“ Strip
2. PCM. the on terminals CAN appropriate the into wires the Insert
3. two the of (either PDP the of terminals CAN the reach to required length the Measure
   wires. the of end this off mm) (~8 ~5/16“ strip and Cut pairs). available
4. may You PDP. the on terminals CAN coded color appropriate the into wires the Insert
   out. or in defined no is there PDP, the on pairs terminal Yellow/Green the of either use

### Wires Signal Controller Motor 2.1.16

PWM


LabVIEW
NATIONAL INSTRUMENTS


V+



is This signaling. PWM using controllers MAX SPARK the wire to how details section This CAN than troubleshoot to easier and complex less is it as point starting recommended a using wired be also can controllers) motor FRC other many (and MAXs SPARK The operation. and data diagnostic better functionality, advanced configuration, easier unlocks which *CAN* needed. wire of amount the reduces

controllers (if cables PWM 4x MAX), SPARK using (if adapters PWM MAX SPARK 4x Requires: (Optional) cableY- PWM 2x optional), otherwise adapters, or wires integrated without

connect): (Direct 1 Option

1. a with adapter (small MAX SPARK the to adapter PWM the attach MAX, SPARK using If wires). black/white with connector pin 3
2. controller the On adapter. or controller the to cables extension PWM attach needed, If wiring, green/yellow have may controllers (some markings or colors the match side, black). to connect should green
3. outside the towards wire black the with roboRIO the to cable the of end other the Attach right the and 1 and 0 PWM to side left the connect to recommended is It roboRIO. the of any but experience, programming straightforward most the for 3 and 2 PWM to side the adjust and channel which to goes side which note you as long as work will channel accordingly. code

cable):(Y- 2 Option

1. a with adapter (small MAX SPARK the to adapter PWM the attach MAX, SPARK using If wires). black/white with connector pin 3
2. PWM the and adapter or controller the between cables extension PWM attach needed, If have may controllers (some markings or colors the match side, controller the On cable.Y- black). to connect should green wiring, green/yellow
3. side each controlling controllers the for cables PWM 2 the to cableY- PWM 1 Connect PWM the on wire black the match should cableY- the on wire brown The robot. the of cable.
4. be should wire brown The roboRIO. the on ports PWM the to cablesY- PWM the Connect 0 PWM to side left the connect to recommended is It roboRIO. the of outside the towards but experience, programming straightforward most the for 1 PWM to side right the and adjust and channel which to goes side which note you as long as work will channel any accordingly. code the

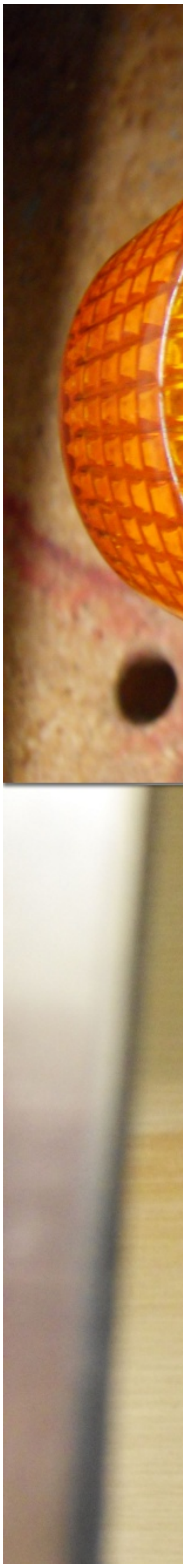
CAN

is objective the CAN wiring When CAN. using wired be also can controllers MAX Spark The through running and end one on roboRIO the from running bus complete single a create to at device Distribution Power either have to recommended is It robot. the on devices CAN all locate to wish not do you If termination. inbuilt- have they because bus the of end other the terminating about info for *Basics Wiring CAN* see bus the of end the at devices these of one yourself.

connectors. with terminatedpre- are that cables CAN with come controllers MAX Spark The larger bridge to cables extension build or buy or directly, together cables these chain can You distribution power controllers, pneumatics as such devices CAN other to connect To gaps. connectors terminatedpre- these of one off cut either to need will you roboRIO the or boards, a just with extension own your build or extension, an on connector a off cut controller, the on connector. single

the use to sure make connectors, provided the using together controllers chaining When electrical ziptie, small a with connection the secure unavailable, If clip. retaining provided method. similar other or tape,

## Light Signal Robot 2.1.17



small very wire, red )$mm^2$ (1 AWG 18 Light, Signal Robot cable, pin 2 stripper, Wire Requires: screwdriver flat

wires both strip and cable pin 2 the of off end one Cut 1.

terminal. the tighten and terminal ”N“ center, the into wire black the Insert 2.

the tighten and terminal ”La“ the into insert and wire red )$mm^2$ (1 AWG 18 the Strip 3.
terminal.

terminal ”Lb“ the into insert to wire )$mm^2$ (1 AWG 18 the of end other the strip and Cut 4.

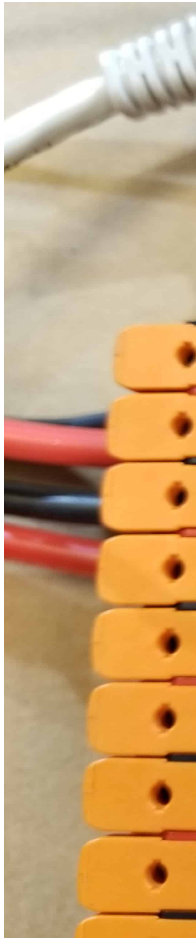
(1 AWG 18 the with terminal ”Lb“ the into cable pin two the from wire red the Insert 5.
terminal. the tighten and wire red )$mm^2$

should wire black The roboRIO. the on port RSL the to connector pintwo- the Connect 6.
roboRIO. the of outside the to closest be

or ties cable using board control the to RSL the secure temporarily to wish may You **:**
being is robot the as location visible more a to RSL the move to recommended is (it Lock Dual constructed)

### Breakers Circuit 2.1.18

REV



breakers circuit 40A 4x Requires:

Wago the with corresponding PDH the on positions the into Breakers Circuit amp40- Insert indicates graphic white the that Note to. connected are controllers motor the connectors pairs. terminal which with associated are breakers which

before chassis robot the into board the insert and here stop Build, Quick Robot a on working If continuing.

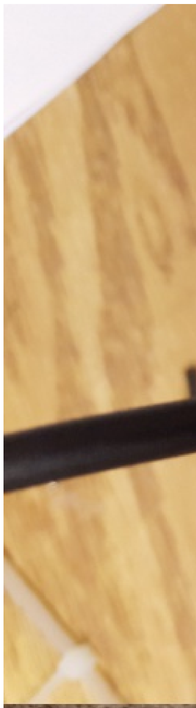
CTR

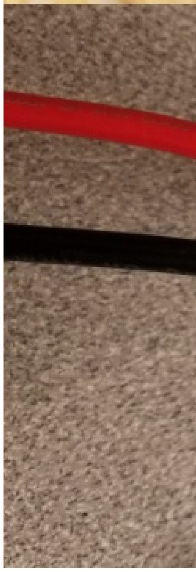
breakers circuit 40A 4x Requires:

Wago the with corresponding PDP the on positions the into Breakers Circuit amp40- Insert breaker the breakers, all for that, Note to. connected are controllers motor the connectors negative All above). graphic (see terminal (red) positive nearest the with corresponds internally. connected directly are board the on terminals

before chassis robot the into board the insert and here stop Build, Quick Robot a on working If continuing.

## Power Motor 2.1.19





hardware connecting wire screwdriver, head phillips crimper, wire stripper, Wire Requires:

motor: CIM each For

- CIM the from wires black and red the of ends the Strip

image): (top MAX SPARK including controllers wire integrated For

1. SPARK (the controller the from wires) green and white (or wires black and red the Strip and secured be should it CIM, the as such motors brushed for unused is wire white MAX method). insulation other or tape electrical with such insulated be should end the
2. with controllers (for wires output controller matching the to wires motor the Connect an show above images The black). to green and white to red connect white/green,

KOP. Rookie the in provided are which terminals disconnect quick using example image): (bottom controllers wireintegrated-non- other or SPARK the For

wires. motor the of each on terminal ring/fork a Crimp 1.

)- to black +, to (red controller motor the of side output the to wires the Attach 2.

## STOP 2.1.20

> the with made been have connections all sure make battery, the in plugging Before :□□□□ all sure make to check robot the wire not did that someone have Ideally polarity. proper correct. are connections

terminal positive the to connected is wire red the that verify and battery the with Start •

the of terminal + the to and breaker main the through passes wire red the that Check terminal. - the to directly travels wire black the that and PDP •

the to terminal PDP red the from goes wire red the that verify controller, motor each For M+!!!!) (not controller motor the on terminal V+ •

- terminal red a from runs wire red the that verify device, controller motornon- each For
  component. the on terminal red a to connects PD the on
- roboRIO! THE NOT radio the into directly plugged is cable PoE the that sure Make

---

ground the off are wheels the so blocks on robot the put to recommended also is It **:□□□**
dangerous. becoming from movement unexpected any prevent will This proceeding. before

---

### Wires Manage 2.1.21

ties Zip Requires:

---

before wires the of some manage to ties zip few a add to time good a be may Now **:□□□**
neat. wiring robot the keep help will This proceeding.

---

### Battery Connect 2.1.22

by robot the on Power connector. Anderson the of side robot the to battery the Connect
housing. the of top the on ridge the into breaker main 120A the of top the on lever the moving

the power smoke, any see or clicking, any hear you If right. it did probably you blinks, stuff If
tripping. breakers circuit of sound the likely is clicking immediately, off system

to step configuration more one is there controllers, MAX SPARK using if on, moving Before
by motor brushless a control to configured are controllers motor MAX SPARK The complete.
cyan either blinking is controller the on light the that checking by this verify can You default.
brushed to change To respectively). coast brushless or brake brushless (indicating magenta or
color. changes LED status the until seconds 43- for button mode the hold and press mode,
brushed in is controller the that indicating yellow, or blue either to change should LED The
how controls which mode, coast or brake the change To respectively). coast or (brake mode
briefly. button mode the press applied, is signal neutral a when down slows motor the quickly

---

test to how including controllers, motor MAX SPARK the on information more For **:□□□**
the see Client, Hardware REV the using by code any writing without motors/controllers your
.guide Quickstart MAX SPARK

---

code! your uploading try and roboRIO the to connect should you here, From

# 3

[redacted]

[illegible].

## 3.1 הכנה להתקנה Offline

[illegible] Offline [illegible].

---

[illegible]: [illegible] (Offline) [illegible].

---

[illegible]: [illegible] Java [illegible] C++. [illegible] LabVIEW [illegible] FRC Game Tools [illegible].

---

### 3.1.1 תיעוד

[illegible]. [illegible] PDF [illegible].

### 3.1.2 מתקינים (Installers)

#### כל הקבוצות

- FRC 2023 Game Tools (Note: Click on link for "Individual Offline Installers")
- FRC 2023 Radio Configuration Utility or FRC 2023 Radio Configuration Utility Israel Version
- Acer/Classmate PC Image ([illegible] - [illegible])

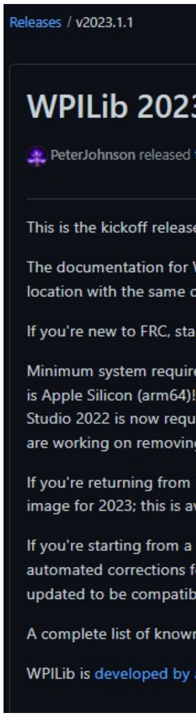
### LabVIEW קבוצות

- Offline ”Individual ▯▯▯▯ ▯▯▯▯▯ ▯▯▯▯ :▯▯▯▯) ▯▯▯▯▯ ▯▯ Choice) ®*FIRST*-▯) USB LabVIEW Installers“)

### C++ או Java קבוצות

- Installer WPILib Java/C++

page. the of bottom the at section assets the to scroll page, releases GitHub the on Once



Releases / v2023.1.1

WPILib 2023

PeterJohnson released

This is the kickoff release

The documentation for
location with the same

If you're new to FRC, sta

Minimum system require
is Apple Silicon (arm64)!
Studio 2022 is now requ
are working on removin

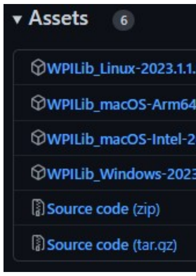
If you're returning from
image for 2023; this is a

If you're starting from a
automated corrections f
updated to be compatib

A complete list of know

WPILib is developed by

download. the begin to architecture and OS your for binary correct the on click Then



Assets 6

WPILib_Linux-2023.1.1.
WPILib_macOS-Arm64
WPILib_macOS-Intel-2
WPILib_Windows-2023
Source code (zip)
Source code (tar.gz)

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▯▯▯▯▯ ▯▯▯ ▯▯▯ ▯▯▯▯ ▯▯▯▯▯▯ WPILib, Java/C++ ▯▯ (installer) ▯▯▯▯▯▯ ▯▯▯▯▯ ▯▯▯▯▯ ▯▯▯▯ :▯▯▯▯ ▯▯▯▯▯ ,▯▯▯▯▯▯▯▯▯ *other with share to zip Code VS Create* ▯▯▯ ▯▯▯▯ ,*User this for Install* ▯▯▯▯ ▯▯ ▯▯▯▯▯▯ ▯▯▯▯ ▯▯▯▯ Code VS ▯▯ zip-▯ ▯▯▯▯ ▯▯ ▯▯▯▯▯ *install offline for computers/OSes* .▯▯▯▯▯▯▯ ▯▯▯▯▯▯▯▯

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### 3.1.3 ספריות ותוכנות של צד שלישי

.□□□□□□ □□□ □□□□□□□ :□□□□ □□□□□□ WPILib-□ □□□□□□□□□ □□□□□□□ □□□□□□ □□ □□□□□□□ □□ □□□□□□

## 3.2 התקנת LabVIEW עבור LabVIEW FRC) בלבד)

---

□□□□: Assistant Vision NI using or LabVIEW in programming teams for is installation This should and LabVIEW install to need not do features these using not teams Java and C++ only. .*Tools Game FRC the Installing* to proceed

---

connection internet and computer with widely vary will times installation and Download installation and download file large a involves process this that note however specifications, complete. to hour an least at take likely will and

### 3.2.1 דרישות

- NI, by supported officially not is 11 Windows 11). 10, (Windows higher or 10 Windows work. to tested been has but

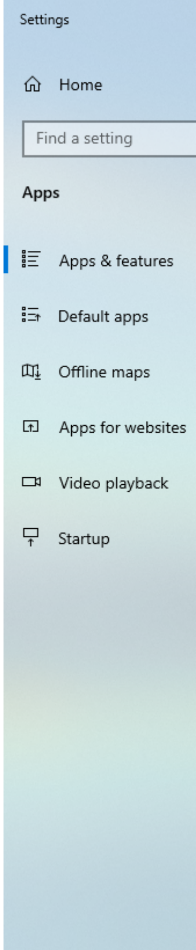
### 3.2.2 הסרת גרסאות ישנות (מומלץ)

---

□□□□: LabVIEW of install an maintain to need will you cRIOs programming keep to wish you If versions these While extended. been has license 2014 FRC for LabVIEW The 2014. FRC® for been has that configuration a not is this computer, single a on existco- to able be should tested. extensively

---

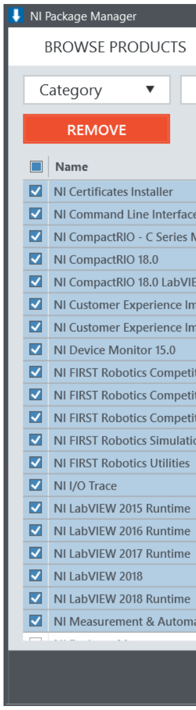
versions. old any remove to recommended is it LabVIEW of version new the installing Before with done been has testing all but version, old the with existco- likely will version new The Data“ ”User\LabVIEW the in located code team any up back to sure Make only. 2023 FRC the Locate Programs. Remove or Add >> Start click Then installing.un- before directory Uninstall. select and Software“, ”NI labeled entry



### בחרו רכיבים להסרה

selectde- to is this do to way easiest The  entries. all select appears, that box dialog the In Remove. Click ”Name“. of left the to boxcheck- the select and boxcheck- Only“ ”Products the prompted. if reboot and complete to uninstaller the for Wait

**:□□□□□** These instructions assume that no other NI software is installed. If you have other NI software installed, it is necessary to uncheck the software that should not be uninstalled.



NI Package Manager

BROWSE PRODUCTS

Category ▼

REMOVE

☐ Name

☑ NI Certificates Installer

☑ NI Command Line Interface

☑ NI CompactRIO - C Series M

☑ NI CompactRIO 18.0

☑ NI CompactRIO 18.0 LabVIE

☑ NI Customer Experience Im

☑ NI Customer Experience Im

☑ NI Device Monitor 15.0

☑ NI FIRST Robotics Competi

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☑ NI FIRST Robotics Simulatio

☑ NI FIRST Robotics Utilities

☑ NI I/O Trace

☑ NI LabVIEW 2015 Runtime

☑ NI LabVIEW 2016 Runtime

☑ NI LabVIEW 2017 Runtime

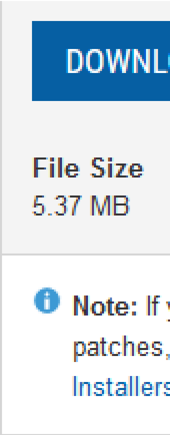
☑ NI LabVIEW 2018

☑ NI LabVIEW 2018 Runtime

☑ NI Measurement & Automa

## installer LabVIEW Getting 3.2.3

2023 FRC for LabVIEW the download or Drive USB LabVIEW the insert and locate Either down.drop- the from version correct the select to sure Be NI. from installer



DOWNL

File Size
5.37 MB

Note: If
patches,
Installers

If you wish to install on other machines offline, do not click the Download button, click **Individual Offline Installers** and then click Download, to download the full installer.

---

:□□□□□ This is a large download (~9GB). It is recommended to use a fast internet connection and to use the NI Downloader to allow the download to resume if interrupted.

---

### LabVIEW התקנת 3.2.4

the of 31st January until active is license season's Each license. a requires LabVIEW NI 2021) 31, January on expires season 2020 the for license the (e.g. year following

subject needed, as computers team many as on software the install to permitted are Teams provided and software, applicable the accompany that terms license and restrictions the to use to Rights FRC. for solely and software, the use mentors or members team only that during shown are that agreements license the of terms the by solely governed are LabVIEW software. applicable the of installation the

#### Install Starting

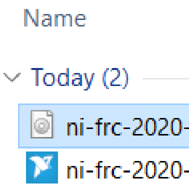
Installer Online

Security Windows a if *Yes* Click process. install the start to file exe downloaded the Run prompt

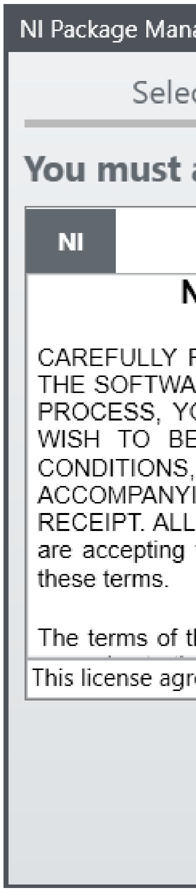
10+) (Windows Installer Offline

mounted the from install.exe Run mount. select and file iso downloaded the on click Right prompt Security Windows a if ”Yes“ Click iso.

not may option mount the and files iso with associate may programs installed other :□□□□ install then file, iso the extract or mount to option the give not does software that If appear. iso. the extract to that use and Zip7-



### Manager Package NI רישיון



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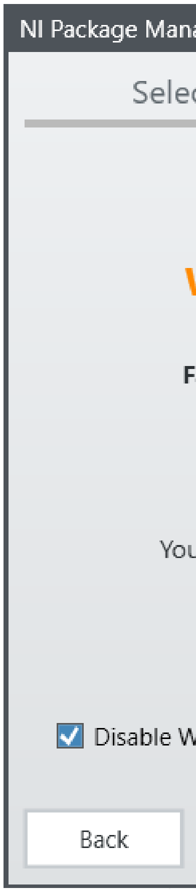

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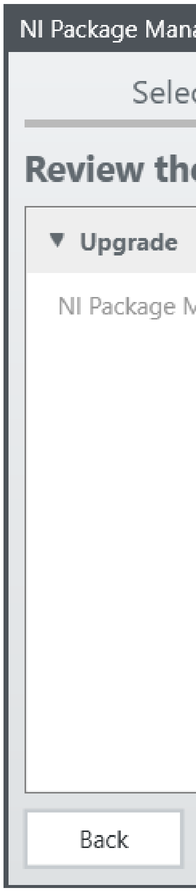
### Manager Package NI סקירת



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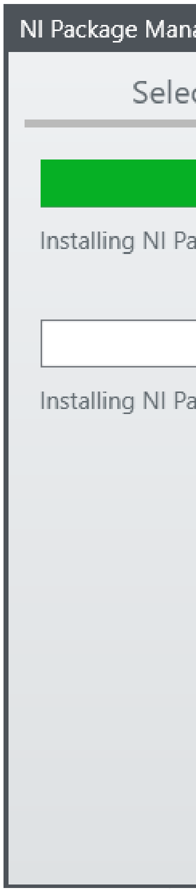
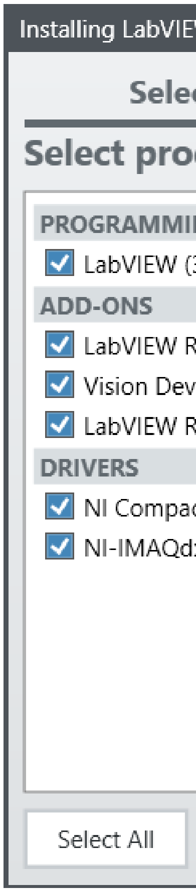
## Manager Package NI התקנת



window this in tracked be will Manager Package NI the of progress Installation

### List Product



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ADD-ONS

☑ LabVIEW R

☑ Vision Dev

☑ LabVIEW R

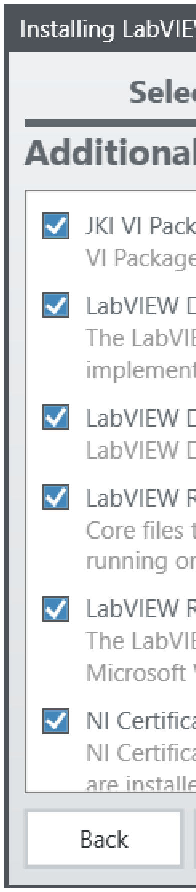
DRIVERS

☑ NI Compac

☑ NI-IMAQd

*Next* Click

### Packages Additional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☑ LabVIEW D
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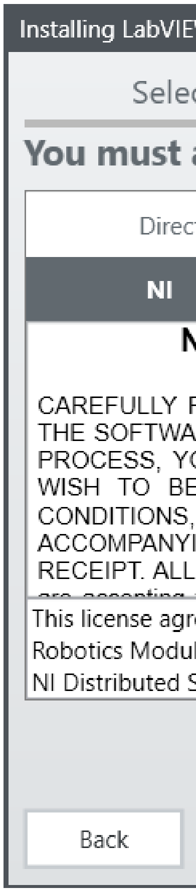

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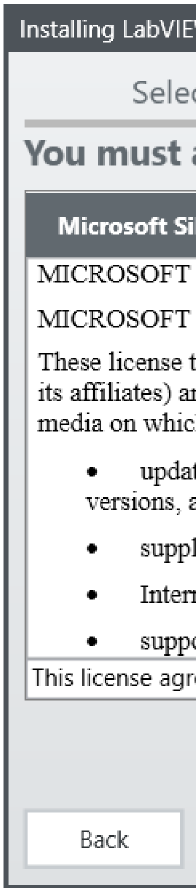

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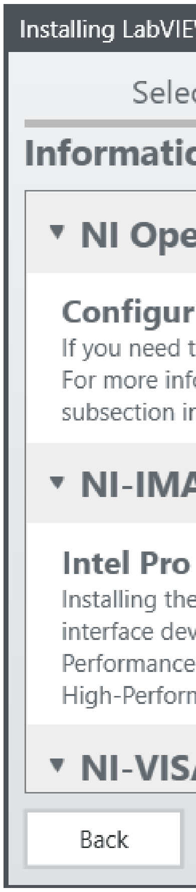
## Information Product



Installing LabVIE
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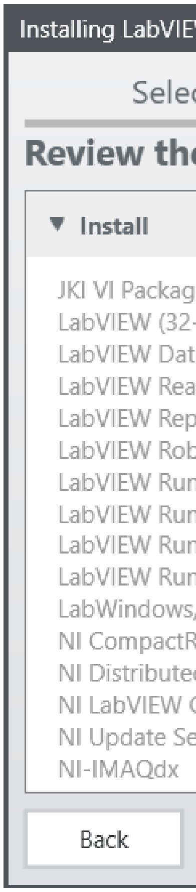
### Installation Start



Installing LabVIE

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▼ Install

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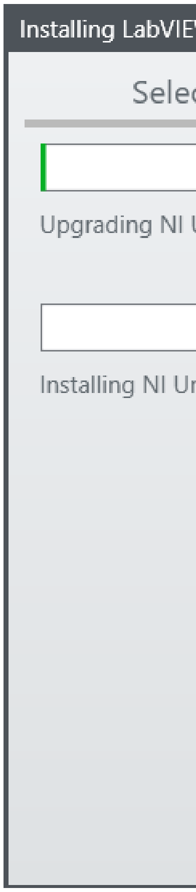
NI Distribute
NI LabVIEW C
NI Update Se
NI-IMAQdx

*Next* Click

### Progress Overall


Installing LabVIE
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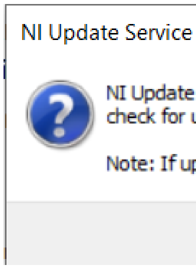
window this in tracked be will progress installation Overall

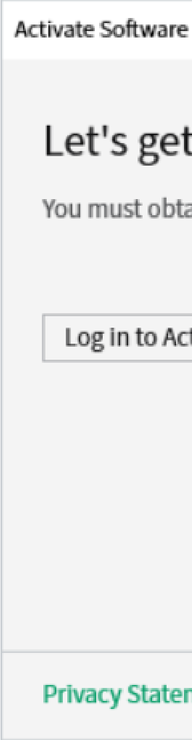
## Service Update NI 3.2.5


NI Update Service
NI Update
check for u
Note: If up

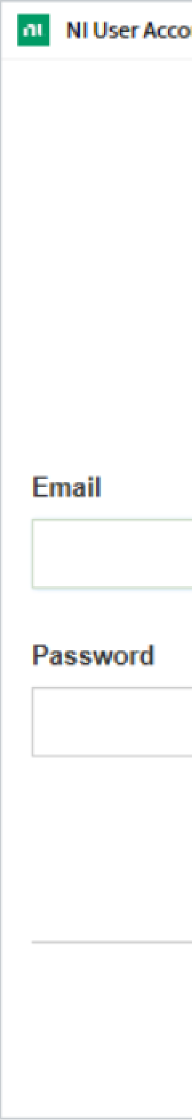
enable not to choose can You service. update NI the enable to whether prompted be will You service. update the

> through FRC by directed unless updates these install to recommended not is It :□□□□□□ Blasts). mailE- or Updates Team Blog, (FRC channels communication usual our

### Wizard Activation NI



button. *Activate to in Log* the Click

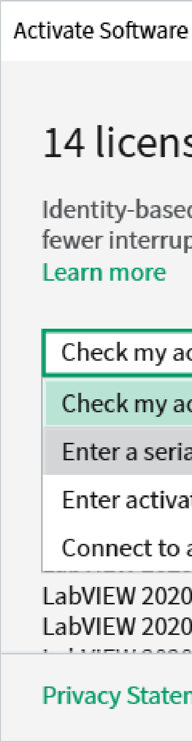


NI User Acco

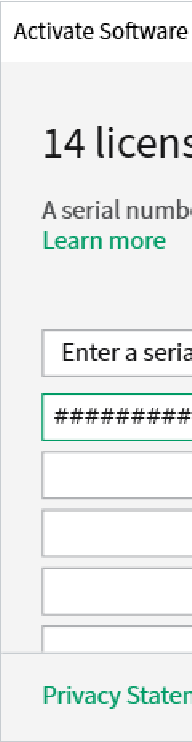
Email

Password

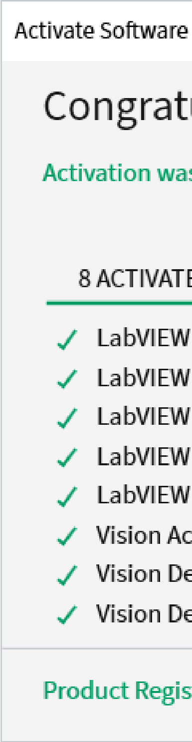
create to *account Create* select account, an have don’t you If account. ni.com your into Log account. free a



number serial a enter select down,drop- the From



.*Activate* Click boxes. the all in number serial the Enter



Activate Software

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✓ LabVIEW

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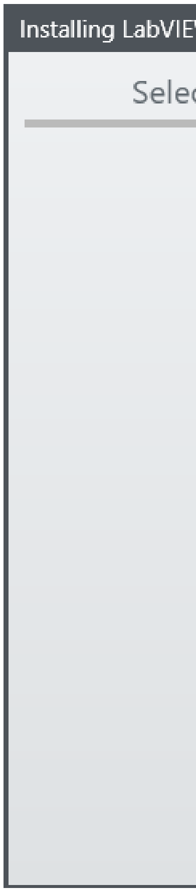
the If appear. will message Successful“ ”Activation an successfully, activate products your If and number the enterre- can you and box text a you give will it incorrect, was number serial activated everything If activate. to expected not are above shown items The .*Again Try* select .*Finish* click successfully,

### Restart



programs. open any closing after *Now Reboot* Select

## Tools Game FRC-ה התקנת 3.3

:□□□□□□ □□□□□□□ □□□□□□ □□ □□□□□ Tools Game FRC®-□

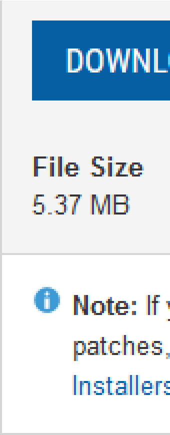
- LabVIEW □□□□□□
- Station Driver FRC
- Images and Tool Imaging roboRIO FRC

are Tool Imaging and Station Driver the for required components runtime LabVIEW The package. this in included

**:□□□□** running for required are package FRC for Software LabVIEW the from components No Tool. Imaging or Station Driver the either

### דרישות 3.3.1

- 11). 10, (Windows higher or 10 Windows
- NI. from Tools Game FRC the Download



DOWNL

File Size
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**Note:** If y
patches,
Installers

□□□□ *Installers Offline Individual* □□ □□□□□ ,□□□□□□ □□ □□□□ □□□□□□ □□□□□□□□ □□□□□□□ □□□□□□□□ □□ □□□□□ □□□□□□□ □□ *Download* □□□ □□□□□□□ □□ □□□□□□□ □□□□□.

### הסרת גרסאות ישנות (מומלץ) 3.3.2

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□□□□ □□□□□□□ LabVIEW □□□□□□□ .□□□□□ □□□□□□ □□ ,□□ □□□□ □□□□□□□ □□□□ LabVIEW □□□□□□□ :□□□□□ □□□□□ □□□□□□.

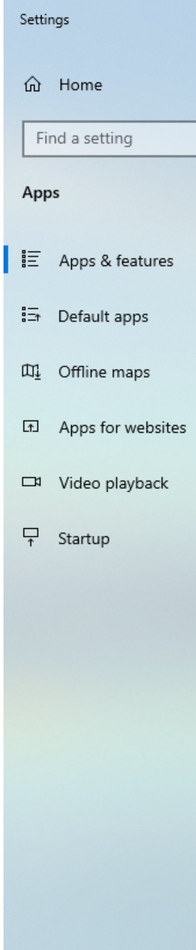
---

any remove to recommended is it Tools Game FRC the of version new the installing Before will DS the that (note version old the with existco- likely will version new The versions. old Start click Then only. 2022 FRC with done been has testing all but versions), old overwrite *Uninstall* select and Software“, ”NI labeled entry the Locate Programs. Remove or Add >> .

---

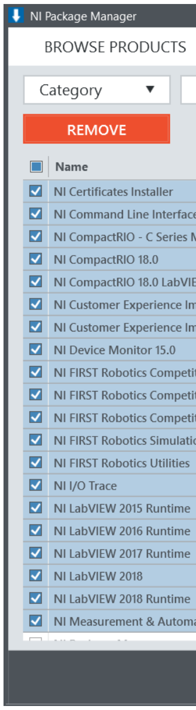
tools. year’s new a installing when versions previous uninstall to necessary only is It :□□□□□ to necessary not is It tools. 2022 the installing before tools 2021 the uninstall example, For tools. game 2022 the of update new a to upgrading before uninstall

---



### בחר רכיבים להסרה

the selectde- to is this do to way easiest The entries. all select appears, that box dialog the In
Wait .*Remove* Click ”Name“. of left the to boxcheck- the select and boxcheck- *Only Products*
prompted. if reboot and complete to uninstaller the for



| ☑ | Name |
|---|---|
| ☑ | NI Certificates Installer |
| ☑ | NI Command Line Interface |
| ☑ | NI CompactRIO - C Series M |
| ☑ | NI CompactRIO 18.0 |
| ☑ | NI CompactRIO 18.0 LabVIE |
| ☑ | NI Customer Experience Im |
| ☑ | NI Customer Experience Im |
| ☑ | NI Device Monitor 15.0 |
| ☑ | NI FIRST Robotics Competi |
| ☑ | NI FIRST Robotics Competi |
| ☑ | NI FIRST Robotics Competi |
| ☑ | NI FIRST Robotics Simulatio |
| ☑ | NI FIRST Robotics Utilities |
| ☑ | NI I/O Trace |
| ☑ | NI LabVIEW 2015 Runtime |
| ☑ | NI LabVIEW 2016 Runtime |
| ☑ | NI LabVIEW 2017 Runtime |
| ☑ | NI LabVIEW 2018 |
| ☑ | NI LabVIEW 2018 Runtime |
| ☑ | NI Measurement & Automa |

### התקנה 3.3.3

---

updated be to needs 4.6.2 Framework .NET that prompt may installer Tools Game The :□□□□ if rebooting including installation, the complete to screenon- prompts Follow installed. or if installer the restarting Tools, Game FRC the of installation the resume Then requested. necessary.

---

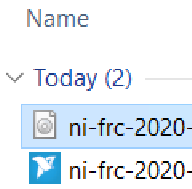
#### חילוץ

□□□□□ □□□

Windows a if *Yes* Click process. install the start to file executable downloaded the Run appears. prompt Security

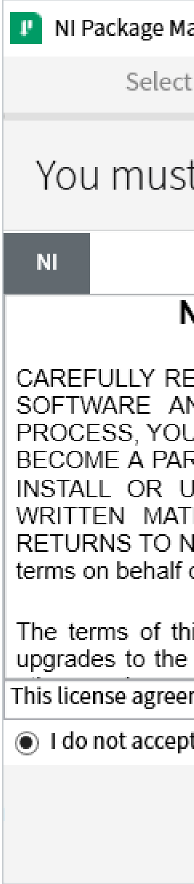
10+) (Windows Offline

mounted the from `install.exe` Run *.mount* select and file iso downloaded the on click Right appears. prompt Security Windows a if *Yes* Click iso.



not may option *mount* the and files iso with associate may programs installed Other :□□□□ install then file, iso the extract or mount to option the give not does software that If appear. iso. the extract to that use and Zip7-

### Manager Package NI רישיון



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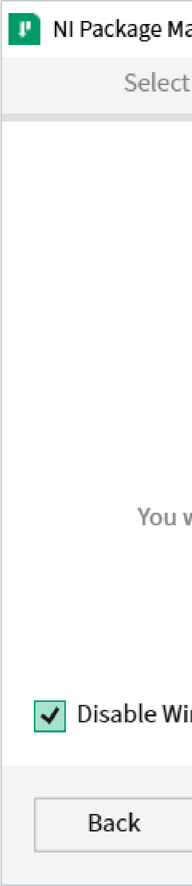
## ביטול ההפעלה המהירה של Windows



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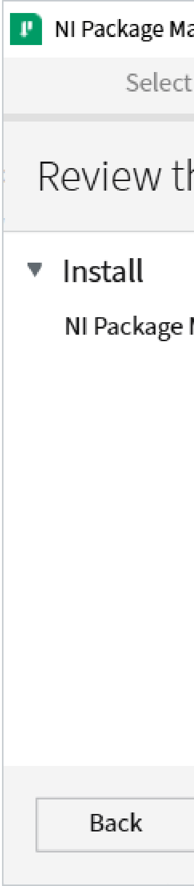
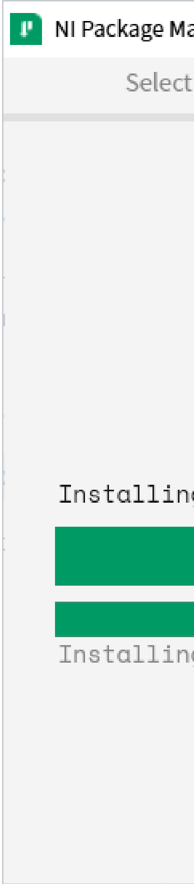
□□ NI □□□□□□□□ □□□□□□□ □-roboRIO. □□□□□ *Next*.

### Review Manager Package NI



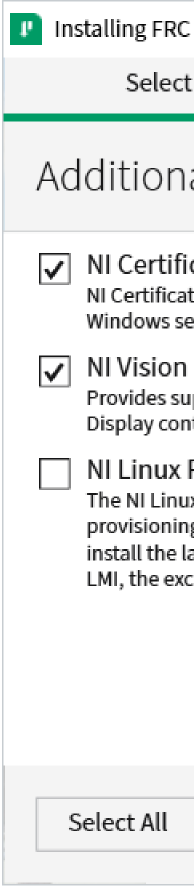
.*Next* [illegible]

### Installation Manager Package NI



window. this in tracked be will Manager Package NI the of progress Installation

## תוכנה נוספת



Additiona

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☐ NI Linux R
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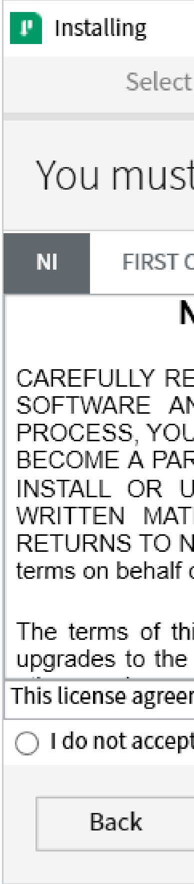
### הסכמי רישיון



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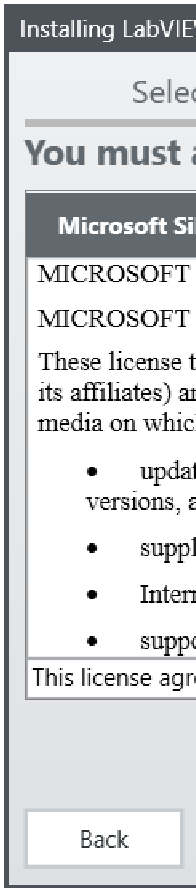

Installing LabVIE

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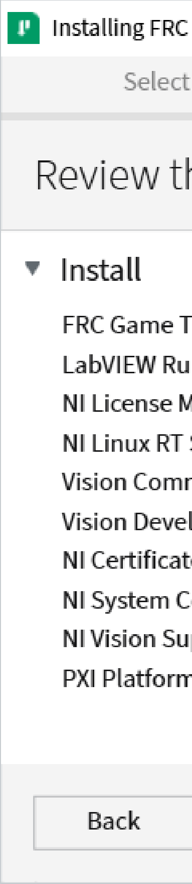
License NI the to agree you that confirming ,*Next* click then *accept… I* press and ahead Go agreement.

### Summary Review



Installing FRC

Select

Review th

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NI Linux RT

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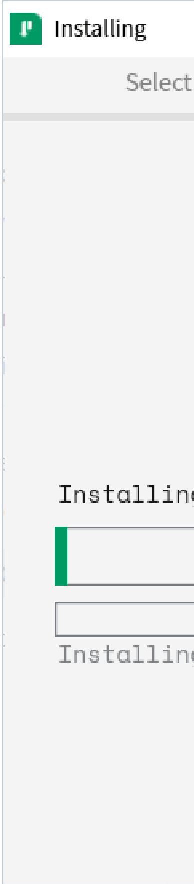
NI Vision Su

PXI Platform

*.Next* □□□□

### פרטי ההתקדמות



Installing

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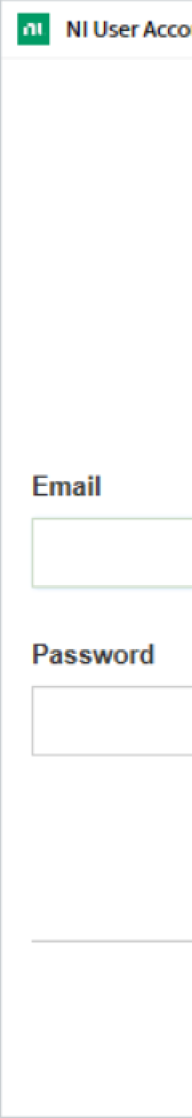
finished. it’s when *Next* press and ahead go process, installation the showcases screen This

## Wizard Activation NI



□□□□□□ □□□ *account Create* □□□□ ,□□□□□□ □□□□□□ □□□ □□□□ □□□□□□ .□□□□ ni.com-□ □□□□□□□ □□□□□□□
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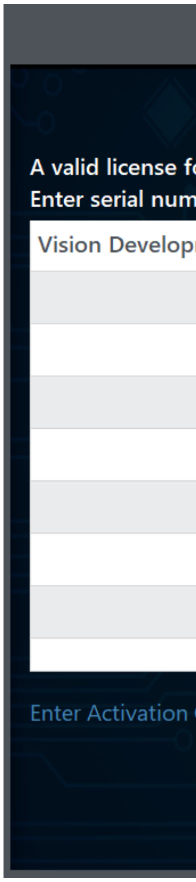

A valid license fo
Enter serial num
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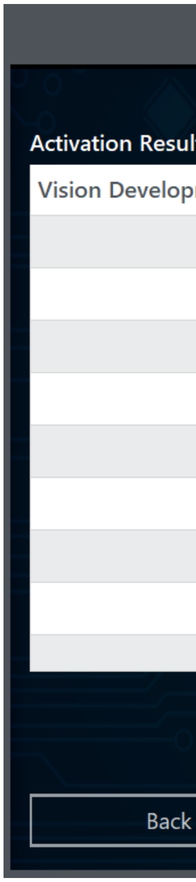
Enter Activation

*.Activate* □□□□ .□□□□□□□□ □□□□□□ □□ □□□□□□

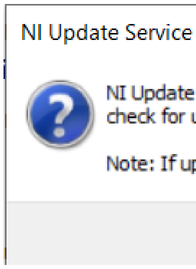
:□□□□ the see will you account, this on software year's this activating time first the is this If this. ignore can You found. being not license valid a about above shown message



the If  appear. will message *Successful Activation* an successfully, activate products your If and number the enterre- can you and box text a you give will it incorrect, was number serial .*Next* click successfully, activated everything If .*Again Try* select

.*Close*

## Service Update NI


NI Update Service

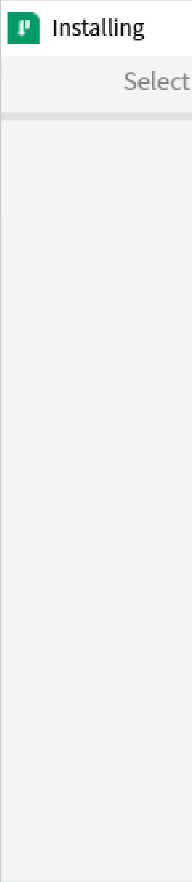
NI Update
check for u

Note: If up

enable not to choose can You service. update NI the enable to whether prompted be will You service. update the

> through FRC by directed unless updates these install to recommended not is It **:** Blasts). mailE- or Updates Team Blog, (FRC channels communication usual our

### אתחל מחדש להתקנה מלאה 3.3.4



programs. open any closing after *Now Reboot* select prompted, If

## WPILib מדריך התקנת 3.4

*LabVIEW* □□□□□ to skip can teams LabVIEW teams. C++ and Java for intended is guide This steps the but 10, Windows shows tutorial below the Additionally, .(□□□□ *(LabVIEW FRC* □□□□ shown. be will systems operating differentiating Notes systems. operating all for identical are

### דרישות מקדימות 3.4.1

**Architectures: and Systems Operating Supported**

- supported not are Arm and bit 32 only. bit 64 11, & 10 Windows
- but work, may 2.34 >= glibc with distributions Linux Other bit. 64 22.04, Ubuntu unsupported are
- Arm. and Intel both higher, or 11 macOS

20.04, & 18.04 Ubuntu 10.15, macOS supported: longer no are OSes following The :□□□□□
Windows. bit32- any and 8.1, Windows 7, Windows

necessary not is it that so years, different for folders different to install to designed is WPILib
WPILib. year’s this installing before version previous a uninstall to

## Downloading 3.4.2

Installer WPILib

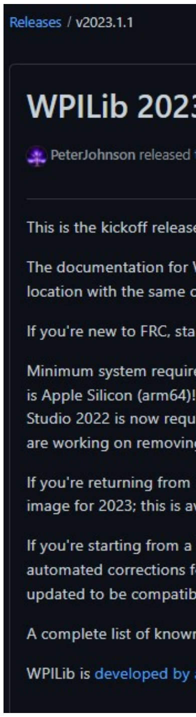
Downloads 2023 29, March - Release 2023.4.3 WPILib

platforms other for Downloads

### Notes Release

.GitHub from installer the of release latest the download can You

page. the of bottom the at section assets the to scroll page, releases GitHub the on Once



Releases / v2023.1.1

WPILib 202

PeterJohnson released

This is the kickoff releas

The documentation for
location with the same

If you're new to FRC, sta

Minimum system requir
is Apple Silicon (arm64)!
Studio 2022 is now requ
are working on removin

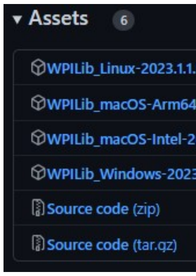
If you're returning from
image for 2023; this is a

If you're starting from a
automated corrections f
updated to be compatib

A complete list of know

WPILib is developed by

download. the begin to architecture and OS your for binary correct the on click Then

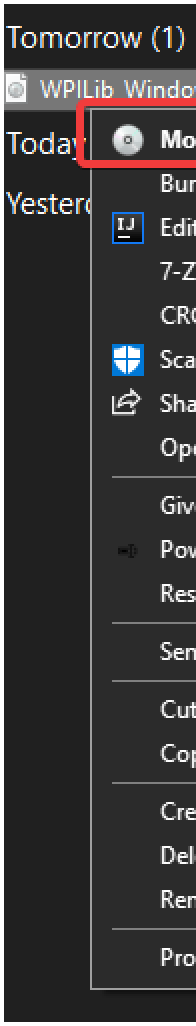


### חילוץ המתקין 3.4.3

□□□□ Windows, □□□□ `iso.` □□□□ □□□□□ □□□□□ □□□□ □□□ WPILib,-□ □□□□□ □□ □□□□□ □□□ □□□□ macOS. □□□□ `DMG` □□ ,□□□□□□ □□□□ `tar.gz.`

10+ Windows

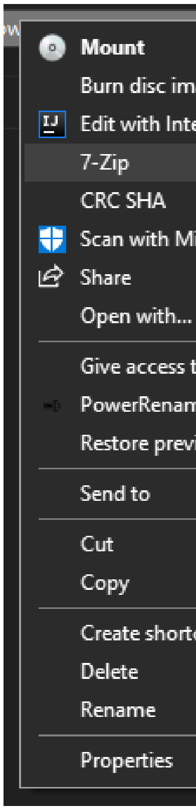
open to *Mount* select and image disk downloaded the on click right can users 10+ Windows .`WPILibInstaller.exe` launch Then it.



not may option *mount* the and files iso with associate may programs installed Other :□□□□

follow then file, iso the extract or mount to option the give not does software that If appear. below. directions the

selecting and *Zip7-* selecting clicking,right- by image disk the extract to zip7- use can You the of bottom the at *options more Show* select to need may users 11 Windows *.to... Extract* menu. context



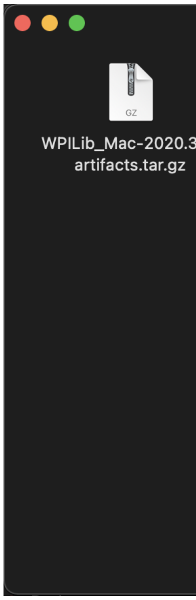
.`WPILibInstaller.exe` opening by installer the launch file, `iso.` the opening After

protected ”Windows titled window a display may Windows installer, the launching After **:□□□□** installer. the run to *anyway Run* select then *,info More* Click PC“. your

macOS

installed Tools Line Command Xcode the have to need will users macOS release, this For release. future a in requirement this removing on working are we installer; the running before Terminal. the in `install-- select-xcode` running by done be can This

”WPILibInstaller“ □□□□□ □□□ □□□□□□□ ”DMG“-□ □□ □□□□□ □□□□□ □□□□□ □□□□□□ macOS □□□□□□ .□□□□□□ □□□□□□



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.`WPILibInstaller` launch then and `tar.gz.` downloaded the extract should users Linux won’t clickingdouble- so libraries, shared as explorer file the in executables treats Ubuntu with replaced `><version` with instead terminal a in commands following the Run them. run installing. you’re version the

```
WPILib_Linux-<version>.tar.gz xf- tar $
        WPILib_Linux-<version>/ cd $
                WPILibInstaller/. $
```

### הרצת המתקין 3.4.4

.*Start* □□ □□□□□ .□□□□□□ □□□□□ □□□□□ □□□□ □□□□□ ,□□□□□□□ □□ □□□□□□ □□□□□


WPILib Install


WPILib Install
Back

installation. WPILib the with included options of list a showcases This

- SysID, RobotBuilder, Shuffleboard, (Pathweaver, tools WPILib the just installs *Only Tools* JDK. and OutlineViewer) and Glass,
- all extensions, Code, (VS environment development full the installs *Everything* JDK. and tools, WPILib dependencies),

*User this for Install*-[illegible] .*Users all for Install*-[illegible] *User this for Install* ,[illegible] [illegible] *Users all for Install* ,[illegible] .[illegible] macOS [illegible] *Users all for Install* .[illegible] .[illegible]

---

through access administrator for prompt will Windows Users, all for Install select you If **:[illegible]** installation. during UAC

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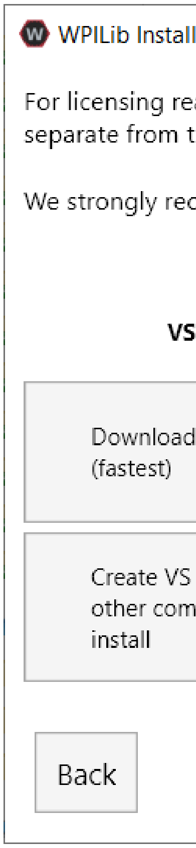
.[illegible] ,[illegible]

.[illegible] Code VS [illegible] ,[illegible] Code. VS [illegible]



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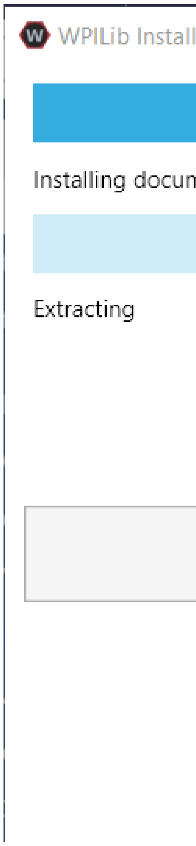
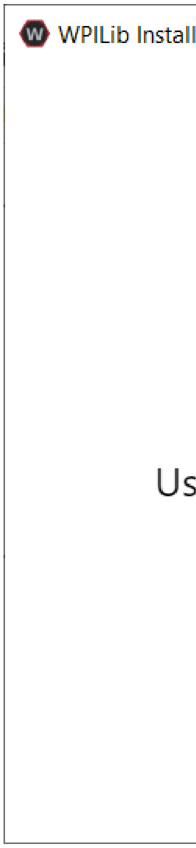
  - [illegible] Code VS [illegible], [illegible].

process download the begin will This *.only computer this for Download* select and ahead Go is download the Once ~100MB). (it’s connectivity internet on depending bit a take can and below. one the to similar looks that screen a with presented be should You *.Next* select done,



[illegible].



existing already an use not does It Code. VS of version separate a installs WPILib :[illegible]
VS WPILib IE: year. the with appended tools the of copy own it's has year Each installation.
copy! installed system a not and Code VS WPILib the launch Please .2022 Code

[illegible] ,[illegible] [illegible] [illegible] WPILib [illegible] [illegible] [illegible]! [illegible]
.[illegible]

## לאחר ההתקנה 3.4.5

.[illegible]

macOS

Dock.-[illegible] Code VS [illegible] Code. VS WPILib-[illegible] ,[illegible]
.[illegible] WPILibInstaller [illegible]

[illegible]

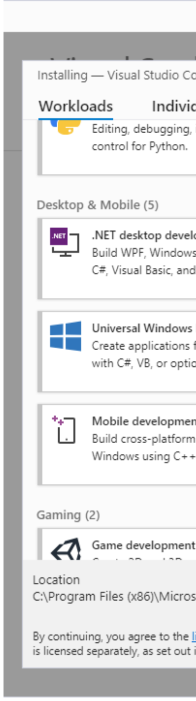
[illegible] 20.04) Ubuntu [illegible]) [illegible]
Launching. Allow [illegible] .[illegible]

YYYY called desktop the on folder a create will rebooting and tools desktop Installing :□□□□ on available not are shortcuts tool Desktop year. current the is YYYY where ,`Tools WPILib` macOS. and Linux

## Simulation for Installation C++ Additional 3.4.6

would this Windows, For installed. be to compiler native a that requires simulation robot C++ (Ubuntu) Linux and ,later or 13 Xcode requires macOS Code), VS **not**( 2022 Studio Visual be package. `essential-build` the requires

installer Studio Visual the in checked is option *C++ with Development Desktop* the Ensure support. simulation for



## 3.4.7 מה הותקן?

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]:

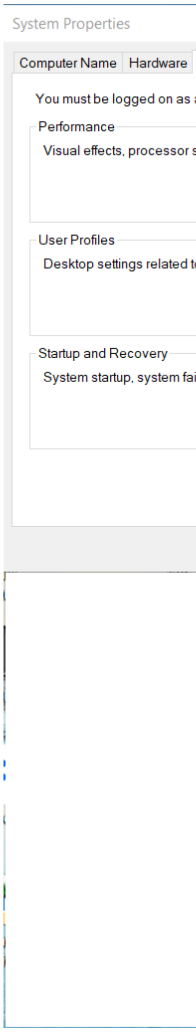
- **Visual Studio Code** - [illegible]-IDE [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]-2019. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] VS Code [illegible], WPILib [illegible] [illegible] [illegible] [illegible] VS Code [illegible]. [illegible] [illegible] [illegible] [illegible] [illegible]-WPILib [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]-VS Code [illegible].
- **C++ Compiler** - [illegible] [illegible] [illegible] C++ [illegible] [illegible]-roboRIO
- **Gradle** - [illegible] [illegible]-Gradle [illegible] [illegible]/[illegible] [illegible] [illegible]-C++ [illegible] Java
- **Java JDK/JRE** - [illegible] [illegible] Java JDK/JRE [illegible] [illegible] [illegible] Java [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Java ([illegible] [illegible] [illegible]). [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]-JDK [illegible] [illegible] [illegible] [illegible] [illegible] JAVA_HOME.
- **WPILib Tools** - SmartDashboard, Shuffleboard, RobotBuilder, Outline Viewer, Pathweaver, Glass, SysID
- **WPILib Dependencies** - [illegible], OpenCV, [illegible].
- **[illegible] VS Code** - [illegible] WPILib [illegible] [illegible] [illegible] [illegible]-VS Code

### 3.4.8 הסרת ההתקנה

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible] WPILib [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ,[illegible] [illegible] ,[illegible] [illegible] .[illegible] [illegible] WPILib [illegible] [illegible] [illegible] [illegible] WPILib. [illegible] [illegible] [illegible]

Windows

1. the is YYYY where `YYYY\wpilib\Public\Users\c:`( folder wpilib appropriate the Delete uninstall) to year
2. `Desktop Public\Public\Users\C:`-[illegible] [illegible] [illegible] [illegible]
3. .[illegible] [illegible] [illegible] [illegible] [illegible]
   1. variables“ environment system the ”edit [illegible] environment [illegible] ,[illegible] [illegible]
   2. 1) [illegible]) Variables Environment-[illegible] [illegible] [illegible] [illegible]
   3. 3) [illegible]) Edit [illegible] 2) [illegible]) Path-[illegible] [illegible] Variables, User-[illegible]
   4. 5). [illegible]) Delete [illegible] 4) [illegible]) `bin\roborio` [illegible] [illegible] [illegible]
   5. 5). [illegible]) Delete [illegible] `frccode` [illegible] [illegible] [illegible]
   6. Variable. Systems-[illegible] [illegible] 63- [illegible] [illegible] [illegible]



macOS

1. uninstall) to year the is YYYY where `~/wpilib/YYYY`( folder wpilib appropriate the Delete

[illegible]

1. uninstall). to year the is YYYY where `~/wpilib/YYYY`( folder wpilib appropriate the Delete `~/wpilib/YYYY rf- rm` eg

### 3.4.9 פתרון בעיות

[illegible] .[illegible] .[illegible] Repository-[illegible] ,[illegible]
.[illegible] ,[illegible]

## 3.5 השלבים הבאים

[illegible] 3 [illegible] ![illegible] 2 [illegible] ![illegible]
VS-[illegible] 4 [illegible] ,[illegible]
[illegible] *Code VS* [illegible] (IDE). Environment Development Integrated Code
IDE.-[illegible]

:[illegible]

- *Basics Code Studio Visual*
- *Code Studio Visual in Commands WPILib*
- *Program Robot a Creating*
- *Code Robot Deploying and Building*
- *Libraries Party 3rd Installing*

[illegible] .[illegible] ,[illegible]
.[illegible]

---

*Installing* the at look controllers motor CAN party3rd- using teams that important It's :[illegible]
devices. these for code to required are steps extra as article *Libraries Party 3rd*

---

# 4

[redacted]

## 2 roboRIO your Imaging 4.1

.here are 1.0 roboRIO NI the for instructions imaging The :□□□□

image boot appropriate an with configured card microSD a from boots 2.0 roboRIO NI The microSD The FRC. to specific libraries and drivers, OS, TimeReal- Linux NI the containing this on instructions the per application burner SD an and laptop a with imaged be must card page.

supported. not is Tool Imaging roboRIO the with directly 2 roboRIO the Imaging :□□□□

### Requirements microSD 4.1.1

2GB with card a use to recommended is It cards. microSD all supports 2.0 roboRIO NI The capacity. of more or

### Tips Operation 4.1.2

order in image valid a containing card microSD inserted fully a requires 2.0 roboRIO NI The intended. as operate and boot to

microSD the Once hang. will roboRIO the powered, while removed is card microSD the If power be or button, reset the using restarted be to need will roboRIO the replaced, is card cycled.

best but powered, while insertion or removal card microSD from result will damage No unpowered. while operations these perform to is practice

*FRC* the of installation completed have must you roboRIO, your imaging Before :□□□□□
Power CTRE the to wired properly power roboRIO the have must also You .*Tools Game*

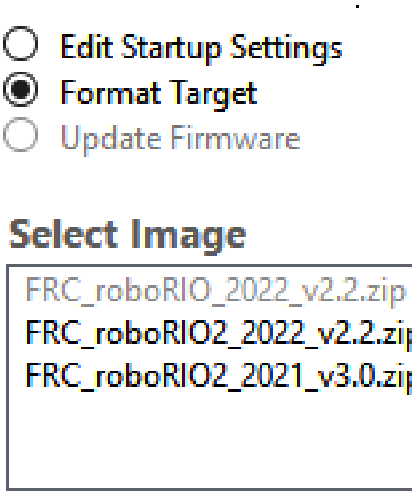
> the to wires power the sure Make Hub. Distribution Power REV or Panel Distribution screws total (4 roboRIO the to firmly secure is connector the that and secure are roboRIO check). to

## Card microSD the to Directly Imaging 4.1.3

utility, writing specialized a using card microSD the to transferred be will image The write can that tools most but below, listed are utilities Several burner. a called sometimes bootable a produce also will boards dev similar or Pi Raspberry a booting for images arbitrary 2.0. roboRIO for card SD

locate can You `.FRC_roboRIO2_YEAR_VERSION.img.zip` named are files image Supported `SD` the to navigating then and tool Imaging roboRIO the in button SD the clicking by them `Images` folder. It is generally best to use the latest version of the image. image. the of version latest the use to best generally is It folder. `Images`

computer. that to file image this copy to need will you OS Windows non a using If



○ Edit Startup Settings
● Format Target
○ Update Firmware

Select Image

FRC_roboRIO_2022_v2.2.zip
FRC_roboRIO2_2022_v2.2.zi
FRC_roboRIO2_2021_v3.0.zi

cards. microSD to writing for well works dongle USB to microSD A

---

**:□□□□** are drivers and OS the because roboRIO a on boot not will images Pi Raspberry controller Pi Raspberry with compatible not is image roboRIO a Similarly, incompatible. boards.

---

### balenaEtcher with image the Writing

- .balenaEtcher install and Download
- Launch
- card microSD the to copy to want you file image the locate >- *file from Flash*
- device microSD destination the select >- *target Select*
- *Flash* Press

### Imager Pi Raspberry with image the Writing

- .Imager Pi Raspberry from install and Download
- Launch
- card microSD the to copy to want you file image the select >- *Custom Use* >- *OS Choose*
- device microSD destination the select >- *Storage Choose*
- *Write* Press

> reformat, not Do drive. the format to prompt may Windows image, the writing After :□□□□□
> again. image the write to need will you else or

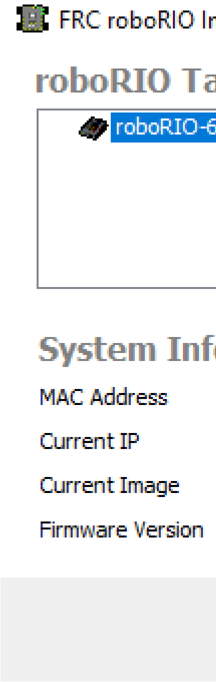
### Number Team roboRIO the Setting

to need will teams this fix To number. team a set not does above process writing image The Imaging roboRIO the With robot. the to connect and robRIO the in card microSD the insert .*Apply* hit and box *Number Team* the out fill Next, .*Settings Startup Edit* to go Tool

## 1 roboRIO your Imaging 4.2

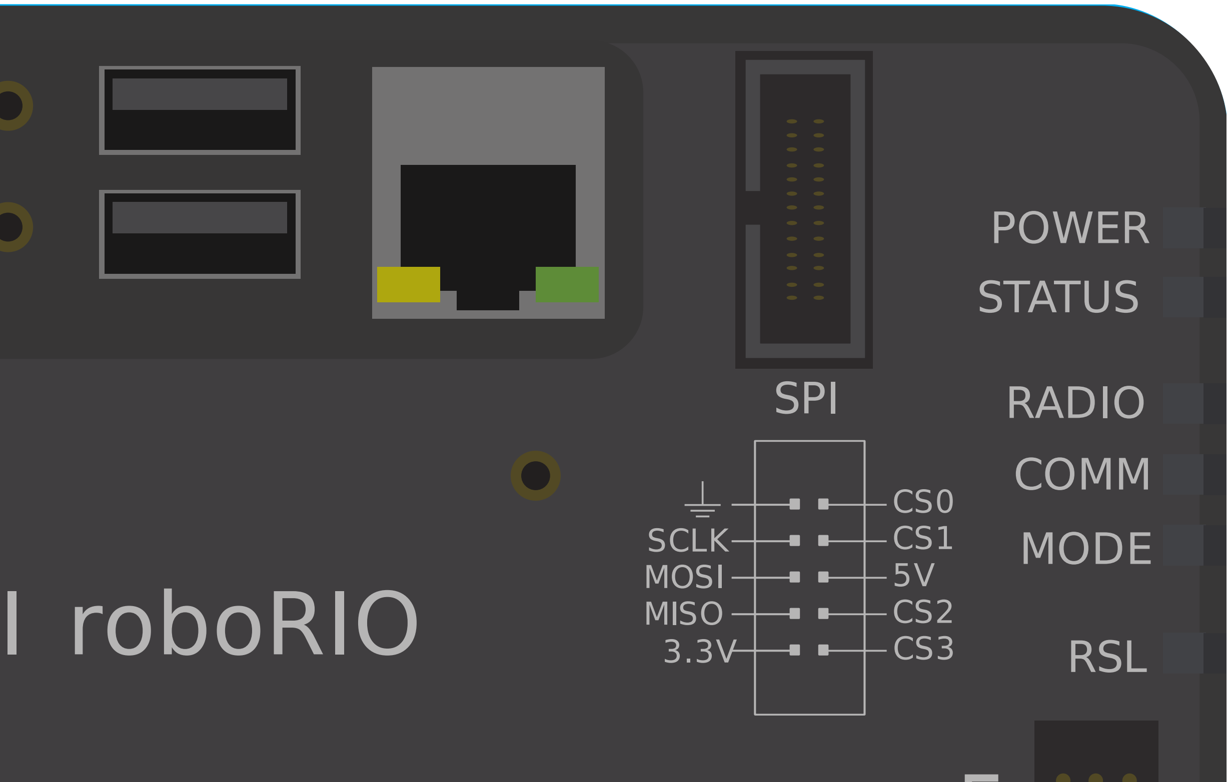
> the of installation completed have must you roboRIO, your imaging Before :□□□□□
> Power the to wired properly power roboRIO the have must also You .*Tools Game FRC*
> the that and secure are roboRIO the to wires power the sure Make Panel. Distribution
> check). to screws total (4 roboRIO the to firmly secure is connector

.*here* are 2.0 roboRIO NI the for instructions imaging The :□□□□



## roboRIO the Configuring 4.2.1

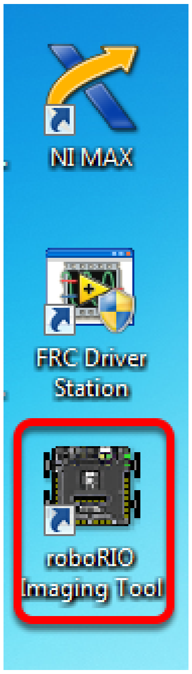
software. latest the with roboRIO your image to used be will Tool Imaging roboRIO The


POWER
STATUS
SPI
RADIO
COMM
MODE
RSL
CS0
SCLK
CS1
MOSI
5V
MISO
CS2
3.3V
CS3
I roboRIO

## Installation Driver

bottom the in uppop- Device“ ”New a see you If automatically. install should driver device The continuing. before complete to install driver the for wait screen, the of right

### Tool Imaging the Launching 4.2.2



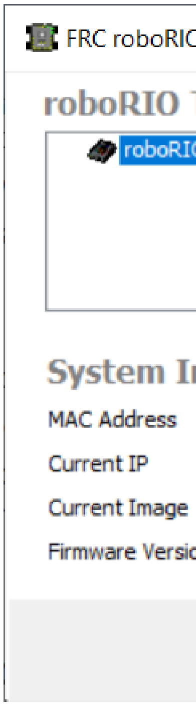
Tools. Game FRC® NI the with installed are image latest and tool imaging roboRIO The have you If Desktop. the on shortcut the on clicking double by tool imaging the Launch selecting and icon the on clickingright- try to need may you roboRIO, your imaging difficulties instead. Administrator as Run

---

`National\(x86) Files Program\C:` at located also is tool imaging roboRIO The :□□□□
`Tool roboRIO\project\2020 LabVIEW\Instruments`

---

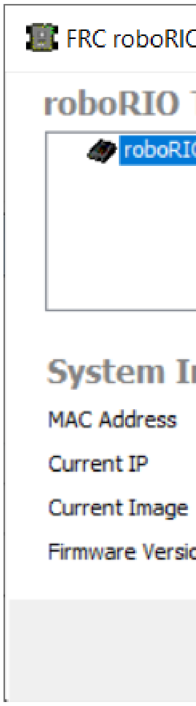
## 4.2.3 roboRIO Imaging Tool



After launching, the roboRIO Imaging Tool will scan for available roboRIOs and indicate any found in the top left box. The bottom left box will show information and settings for the roboRIO currently selected. The right hand pane contains controls for modifying the roboRIO settings:

- **Edit Startup Settings** - This option is used when you want to configure the startup settings of the roboRIO (the settings in the right pane), without imaging the roboRIO.
- **Format Target** - This option is used when you want to load a new image on the roboRIO (or reflash the existing image). This is the most common option.
- **Update Firmware** - This option is used to update the roboRIO firmware. For this season, the imaging tool will require roboRIO firmware to be version 5.0 or greater.

## Firmware Updating

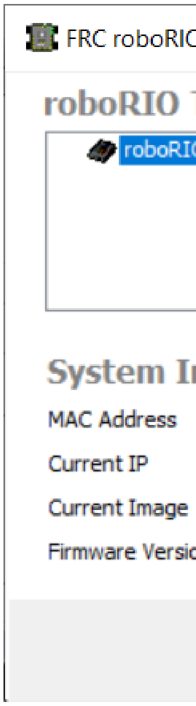


roboRIO your If image. later or 2019 the with work to v5.0 least at be must firmware roboRIO to need not do you tool) imaging the of left bottom the in shown (as 5.0 version least at is update.

firmware: roboRIO update To

1. pane. left top the in selected is roboRIO your sure Make
2. pane right top the in Firmware Update Select
3. box Number Team the in number team a Enter
4. right bottom the in file firmware latest the Select
5. button **Update** the Click

### roboRIO the Imaging 4.2.4



pane left top the in selected is roboRIO the sure Make 1.

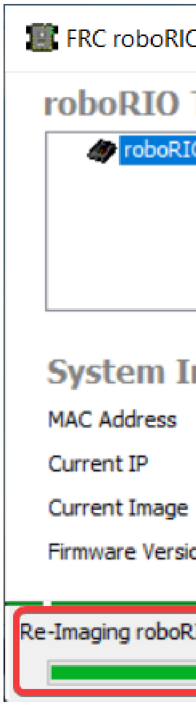
pane right the in Target Format Select 2.

box the in number team your Enter 3.

box. the in version image latest the Select 4.

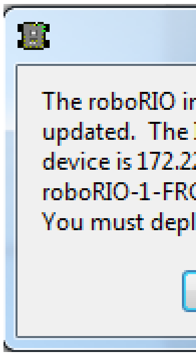
process. imaging the begin to Reformat Click 5.

## Progress Imaging 4.2.5



left bottom the in bar progress A minutes. 103- approximately take will process imaging The progress. indicate will window the of

## Complete Imaging 4.2.6



The roboRIO i
updated. The
device is 172.2
roboRIO-1-FRC
You must depl

Close the click then Ok, Click above. dialog the see should you completes imaging the When Reset the using roboRIO the Reboot tool. imaging the close to right bottom the at button button to have the new team number take effect.

### 4.2.7 פתרון בעיות

include: steps troubleshooting roboRIO, your image to unable are you If

- Desktop the on clickingright- by Administrator as Tool Imaging roboRIO the running Try it. launch to icon
- and/or `http://172.22.11.2/` at browserweb- a with webpage roboRIO the accessing Try Control the in Adapters Network of list your in appears adapter network NI the that verify PC. different a try or Tools Game FRC NI the installingre- try not, If Panel.
- *adapters network other all Disable*
- off. turned is firewall your sure Make
- the of name device the if fails imaging where issue an experienced have teams Some a using (or computer the renaming Try it. in )-( dash a has using you're computer PC). different
- at for button reset the holding and pressing by Mode Safe into roboRIO the booting Try seconds. 5 least
- Cable USB different a Try
- PC different a Try

## 4.3 כנפוג הראוטר

to software Utility Configuration Radio FRC® the use to how you show will guide This events. FRC of outside use for bridge wireless robot's your configure

### 4.3.1 דרישות מקדימות

the configure to privileges administrator requires Utility Configuration Radio FRC The privileges necessary the request should program The machine. your on settings network you if but account), administratornon- a from run if password a require (may automatically account. administrator an from it running try trouble, having are

links: following the from Installer Utility Configuration Radio FRC latest the Download

23.0.2 Configuration Radio FRC

Version Israel 23.0.2 Configuration Radio FRC

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□□□□□□□ □□□□□□ □□ OM5PAC □□□□□□ □□□□ □□□□□□ □□□□□□□□ □□□□□□□ □□□□□□ _IL □□□□ **:□□□□□** .□□□□□□ □□□□□ □□□□

---

:□□□□□□ □□□□□□ □□□□□

1. *adapters network other all Disable*
2. the to closest port ethernet bridge wireless the into computer your from directly Plug If ethernet. via computer your to connected are devices other no sure Make jack. power the of side socket the into PC the from cable Ethernet an plug PoE, via radio the powering configuring issues experience you If in). plug would roboRIO the (where adapter PoE

the on port alternate the to PC the connecting try may you adapter, PoE the through radio.

> however DAP1522, LinkD- the as plug power same the use AC and ANOM5P- The **:□□□□□**
> pin(center- VRM the on terminals 2A 12V the to radio the Wire radios. 12V are they positive).

## Notes Application 4.3.2

4Mbps the enforce to radio the program will Utility Configuration Radio the default, By home the In interface. wireless the over radio the exiting traffic on limit bandwidth streaming that means This limit. client per a not total, a is this mode) (AP configuration recommended. not is clients multiple to video

systems, operating other on work may It 10. and 8 7, Windows on tested been has Utility The tested. been not has but

### Configuration Programmed

radio the into settings configuration of number a programs Utility Configuration Radio The include: These events). at (including modes all in radio the to apply settings These run. when

- `10.TE.AM.1` of IP static a Set
- programming future for `192.168.1.1` of side wired the on IP alternate an Set
- interchangeably used be may they so ports wired the Bridge
- above. graphic the in noted configuration LED The
- disabled be (may interface wireless the of side outbound the on limit bandwidth 4Mb/s use) home for

- to packets which and buffer internal (affects prioritization packet internal for rules QoS are: rules These reached). is limit bandwidth if discard
  - )1150 ,1115 ,1110 (UDP Status and Control Robot
  - )1740 ,1735 (TCP *NetworkTables* & TCP Robot
  - disabled) is limit BW if (disabled traffic). other (All Bulk
- out: Serves enabled. server DHCP
  - side wired the on `10.TE.AM.111` - `10.TE.AM.11`
  - side wireless the on `10.TE.AM.237` - `10.TE.AM.138`
  - `255.255.255.0` of mask Subnet
  - `10.TE.AM.255` address Broadcast
- the of part as served are `)lan.(` suffix domain and IP server DNS enabled. server DNS DHCP.

only: home At

- multiple distinguish to number team the to appended Name“ ”Robot a have may SSID networks.
- found be may ports (open rules firewall field the mimic to enabled be may option Firewall Manual) Game the in

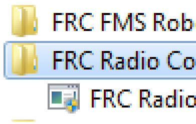
> manually. configuration the modify to possible not is It :□□□□□

### Software the Install 4.3.3

the Follow installer. the launch to `FRC_Radio_Configuration_VERSION.exe` on click Double installation. the complete to prompts

The present. already not is it if Npcap installing include will prompts installation the of Part leave should You install. the configure to checkboxes of number a contains installer Npcap defaults. the as options the

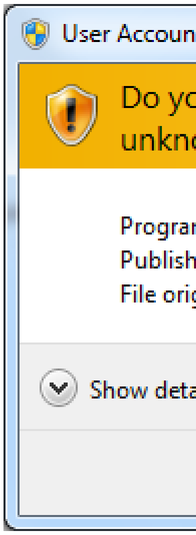
### software the Launch 4.3.4



program. the launch to shortcut desktop or menu Start the Use

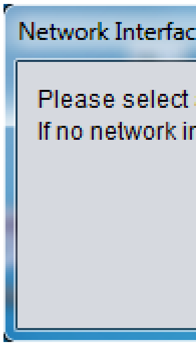
`FRC\(x86) Files Program\C:` to installed is it program, the locate to need you If :□□□□ `FRC\Files Program\C:` is path the machines bit32- For `.Utility Configuration Radio` `Utility Configuration Radio`

### prompted if changes, make to program the Allow 4.3.5



A prompt may appear about allowing the configuration utility to make changes to the computer. Click *Yes* if the prompt appears.

### interface network the Select 4.3.6



will utility configuration the interface ethernet which the select to window uppop- the Use are interfaces ethernet machines, Windows On bridge. wireless the with communicate to use bridge a program not can utility configuration The Connection". Area "Local named typically connection. wireless a over

1. interfaces. available for scanre- to *Refresh* click listed, are interfaces ethernet no If
2. list. downdrop- the from use to want you interface the Select
3. .*OK* Click

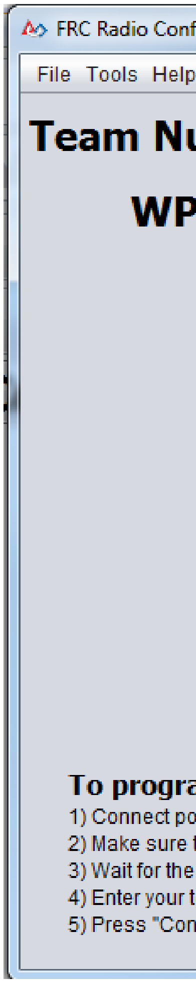
### Note Firmware Mesh Open 4.3.7

the radio, ACOM5P- and ANOM5P- the program to Utility Configuration Radio FRC the For firmware. OpenWRT the of build specific FRC an running be must radio

step. next the skip firmware, the loadre- or update to need not do you If

> **:□□□□□** before updated be to need **not do** 2019/2020/2021/2022 in used Radios firmware. 2019 same the uses tool 2023 the configuring,

### Radio Mesh Open to Firmware FRC Loading 4.3.8



Radio FRC the using so do can you radio), the reset (or firmware FRC the load to need you If Utility. Configuration

1. the select and program the launch software, the install to above instructions the Follow interface. Ethernet
2. dropdown. Radio the in selected is radio Mesh Open the sure Make
3. Ethernet. via PC the to connected is radio the sure Make

the unplugging be also will this cable, PoE a using (If radio. the from power the Unplug 4.
fine) is this PC, the to Ethernet

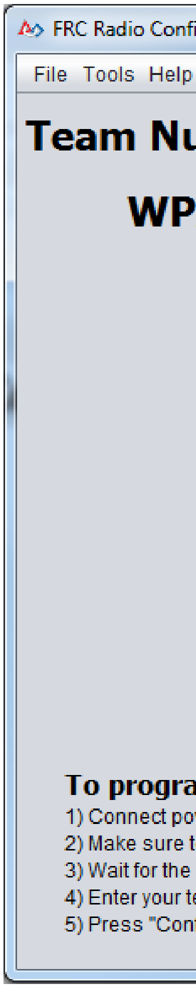
button Firmware Load the Press 5.

the load radio, the detect should software The power. radio the in plug prompted, When 6.
complete. when you prompt and firmware

one the than other adapters all disabling try name, NPF about error an see you If :□□□□□
to attempt should tool the found, is adapter one only If radio. the program to used being
info. more for *Adapters Network Disabling* in steps the See one. that use

other languages for configured Systems Operating with error this see also may Teams
foreign a on programming or firmware loading issues experience you If English. US than
Locale the setting or PC provided KOP the on as such OS, English an using try OS, language
.page this on described as ”en_us“ to setting

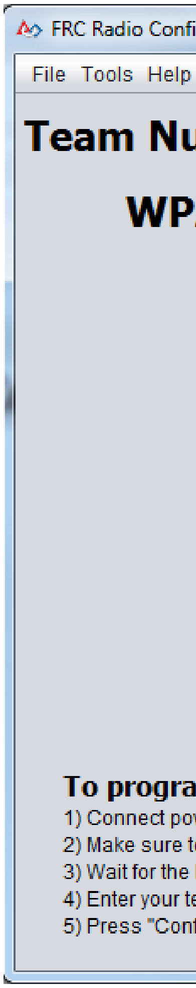
### Mode Operating and Radio Select 4.3.9



list. downdrop- the using configuring are you radio which Select 1.

selection default the cases, most For configure. to want you mode operating which Select 2.
mode AP 5GHz the it, support computers your If sufficient. be will Point Access 2.4GHz of
environments. many in congested less is 5GHz as recommended, is

### Options Select 4.3.10



teams, most of case use the match to selected been have options the of values default The
scenario: specific your to options these customize to wish may you however,

This radio. the by used SSID the to appended gets that string a is This **Name: Robot** 1.
to able be still and number team same the with networks multiple have to you allows
them. distinguish

mimic to attempt to configured be will firewall radio the checked, is box this If **Firewall:** 2.
open of list a For field. FRC the on present firewall the of behavior blocking port the
Manual. Game FRC the see please ports,

does it like limit bandwidth Mbps 4 a enforces radio the checked, is box this If **Limit: BW** 3.
streaming so client, per not limit, total a is that Note events. at programmed when
behavior. undesired cause may simultaneously clients multiple to video

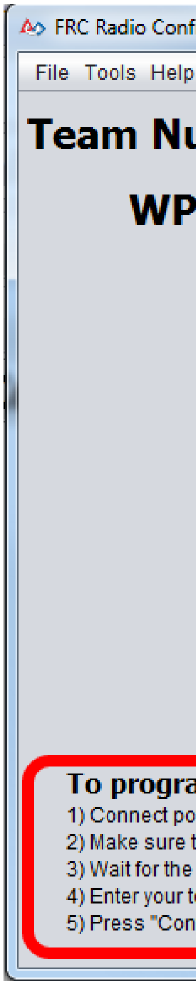
---

no have options These radios. Mesh Open the to apply only Limit BW and Firewall :□□□□

radios. LinkD- on effect

means This firewall. field the emulate to radio the configures option ”Firewall“ The :□□□□□ useful is This enabled. option this with wirelessly code deploy to able be not will you that competitions. at exist may that ports blocked simulating for

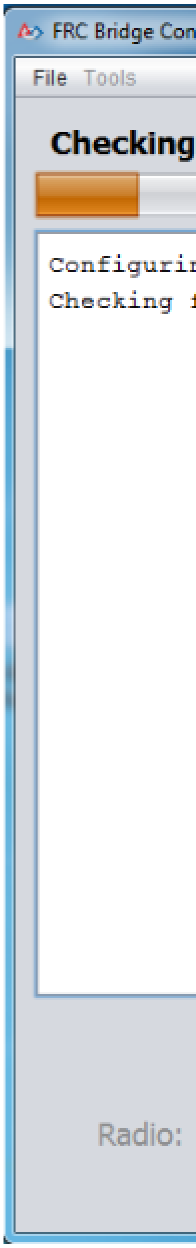
### Process Configuration the Starting 4.3.11



To progra
1) Connect po
2) Make sure t
3) Wait for the
4) Enter your t
5) Press "Con

settings the entering bridge, wireless your preparing for instructions screenon- the Follow screenon- These process. configuration the starting and with, configured be will bridge the chosen. mode operating and model bridge the match to update instructions

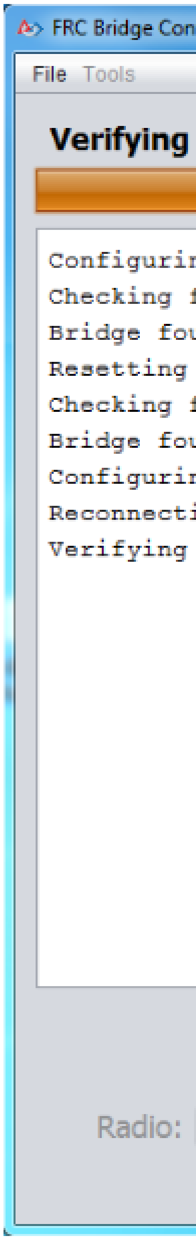
### 4.3.12 Configuration Progress



Throughout the configuration process, the window will indicate:

1. The step currently being executed.
2. The overall progress of the configuration process.
3. All steps executed so far.

## 4.3.13 Completed Configuration



Verifying

```
Configurin
Checking f
Bridge fou
Resetting
Checking f
Bridge fou
Configurin
Reconnecti
Verifying
```

Once the configuration is complete:

1. Press *OK* on the dialog window.
2. Press *OK* on the main window to return to the settings screen.

### Errors Configuration 4.3.14

error the in instructions the follow process, configuration the during occurs error an If problem. the correct to message

### 4.3.15 פתרון בעיות

- .*adapters network other all Disable*
- seconds. 10 for solid stayed has light power the that enough long wait you sure Make
- the in listed is interface one only and interface, network correct the have you sure Make
  down.drop-
- off. turned is firewall your sure Make
- devices other no sure make and bridge wireless the into computer your from directly Plug
  ethernet. via computer your to connected are
- wireless the on jack power the to closest port the into plugged is ethernet the Ensure
  bridge.
- using try English, US than other languages for configured System Operating an using If
  ”en_us“ to setting Locale the setting or PC provided KOP the on as such OS, English an
  .page this on described as
- the resolve doesn’t this If .1.60 npcap installing after success reported have users Some
  radio the reinstall then and tool radio the and npcap uninstall to recommended it’s issue,
  configuration. known a to back get to order in tool
- computer. different a try fails, else all If

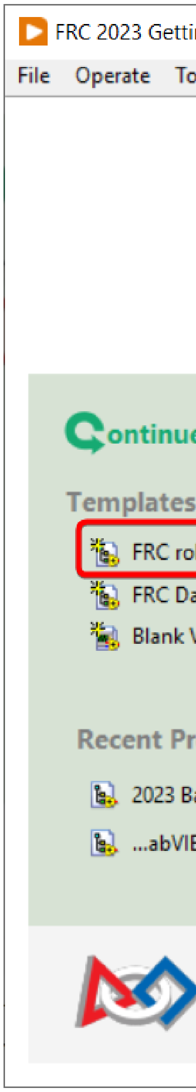
# 5

[redacted]

## 5.1 Creating your Test Drivetrain Program (LabVIEW)

□□□□: This document covers how to create, build and load a basic FRC® LabVIEW program for a drivetrain onto a roboRIO. Before beginning, make sure that you have installed LabVIEW for FRC and the FRC Game Tools and that you have configured and imaged your roboRIO as described in the *Zero-to-Robot tutorial*.

### Project a Creating 5.1.1



New Create the display to link Project Robot roboRIO FRC the click and LabVIEW Launch box. dialog Project Robot FRC

### Project Configuring 5.1.2

Create New

Select proj

Project nar

2022 Robo

Project folc

C:\Users\J
Robot Proj

Team num

330

● Arcade
○ Comma
○ Learn La
○ Learn La
○ Learn La

Dialog: Project FRC New Create the in Fill

project your for name a Pick 1.

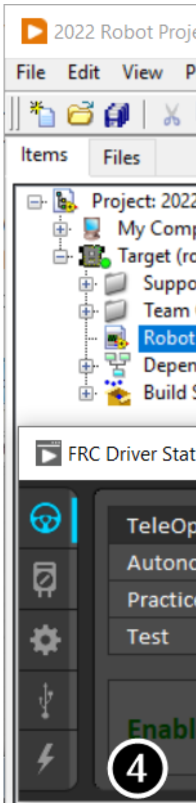
in. project the place to folder a Select 2.

number team your Enter 3.

.*Drive Arcade* select unsure, If type. project a Select 4.

*Finish* Click 5.

## Program the Running 5.1.3



a after roboRIO the on remain not will manner this in deployed program a that Note :□□□□ step, next the follow starts roboRIO the time every run to program a deploy To cycle. power program. the Deploying

Robot the open to item Main.vi Robot the clickdouble- window, Explorer Project the In 1. VI. Main

deploy to VI Main Robot the of ribbon) top the on Arrow (White button Run the Click 2. the and VI, the by required items all VI, the deploys LabVIEW roboRIO. the to VI the all on Save click VIs, any save to prompted If roboRIO. the on memory to settings target prompts.

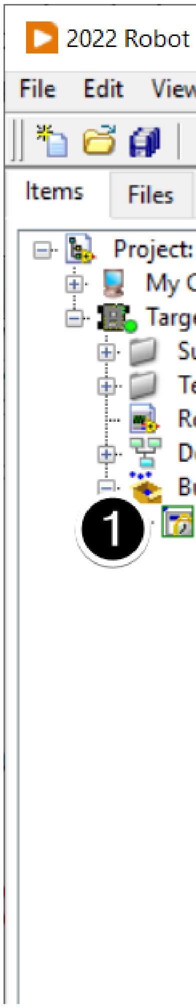
on information more For Mode. Teleop in robot the put software, Station Driver the Using 3. Software Station Driver FRC the see software, Station Driver the using and configuring article.

Enable. Click 4.

responds. robot the how observe and joysticks the Move 5.

a deploy you When stops. VI the that Notice VI. Main Robot the of button Abort the Click 6. manipulate can you but roboRIO, the on runs program the button, Run the with program computer. host the from program the of objects panel front the

## Program the Deploying 5.1.4



the allows This roboRIO. your to program a deploy to need will you competition, the in run To debugging same the allow doesn't but controller, the of reboots across survive to program deploy To panel. front the from running as execution) highlight probes, panel, (front features program: your

it. expand to Specifications Build to next + the click Explorer, Project the In 1.

to build the for Wait Build. select and Deployment upBoot- Robot FRC on clickRight- 2.
complete.

you If Startup. as Run select and Deployment UpBoot- Robot FRC on again clickRight- 3.
a currently is there that indicates simply dialog This OK. click dialog, conflict a receive terminated/replaced. be will which roboRIO the on program

click or completion successful on window deployment the close to box the check Either 4.
completes. deployment the when button close the

of seconds few a within code deployed the running start automatically will roboRIO The 5.
closing. dialog the

## (C++/Java) Program Drivetrain Test your Creating 5.2

with comes WPILib program. robot a create to ready we’re installed, is everything Once for recommended highly is templates these of Use programs. robot for templates several scratch. from code robot own their write to free are users advanced however, users; new has which examples provided the of one from project a creating through walks article This robot. basic a drive to written already code some

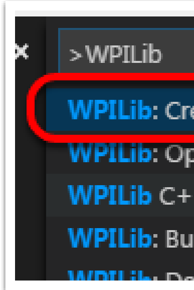
---

convenience the for hardware vendor involve that examples code includes guide This :□□□□ The KOP. the in included controller motor the to refers PWM document, this In user. the of similar is usage but motor), 500 (Falcon controller motor FX Talon the references tab CTRE a controlling MAX SPARK CAN the references tab REV The VictorSPX. and TalonSRX for has user the that assumption an is There motor. brushed for similar it’s but motor, brushless firmware, (update device(s) the configured and *vendordeps* required the installed already ).REV CTRE( documentation manufacturer the to according etc) IDs, CAN assign

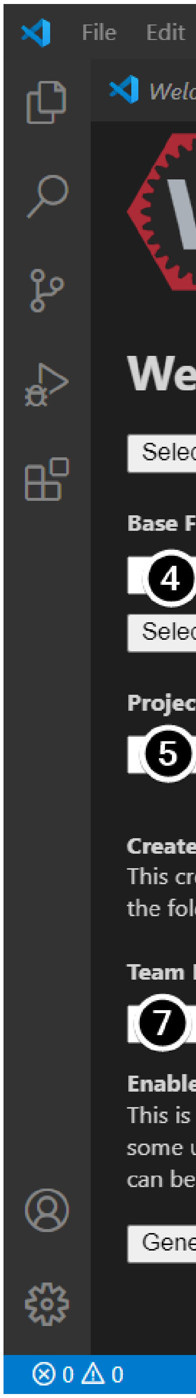
---

### Project WPILib New a Creating 5.2.1

”WPILib“ type Then, .`Ctrl+Shift+P` with palette command Code Studio Visual the up Bring list the up bring will this ”WPILib“, with start commands WPILib all Since prompt. the into command: project“ new a ”Create the select Now, commands. Code VS specificWPILib- of



Window:“ Creator Project ”New the up bring will This



below: explained are Window Creator Project New the of elements The

**Example** select example, this For create. to wish we project of kind The :**Type Project** 1.

project. this for used be will that Java) or (C++ language the is This :**Language** 2.

project the generate to example or class base the select to used is box This :**Base Project** 3.
**Started Getting** select example, this For from.

located. be will project robot the which in folder the determines This :**Folder Base** 4.

the that name the specifies also This project. robot the of name The :**Name Project** 5.

checked. is box Folder New Create the if given be will folder project

6. project the hold to created be will folder new a checked, is this If :**Folder New a Create** located be will project the checked, *not* is it If folder. specifiedpreviously- the within not is folder the if thrown be will error An folder. specifiedpreviously- the in directly box Folder New Create the if given be will folder project checked. not is this and empty checked. is

7. names package for used be will which project, the for number team The :**Number Team** code. deploying when robot the locate to and project the within

8. supports WPILib While simulation. and test unit Enables :**Support Desktop Enable** then desktop, support not do libraries If not. may libraries software party third this, testing unit unless unchecked left be should It crash. may or compile not may code your this check not do example, this For it. support libraries all and needed is simulation or box.

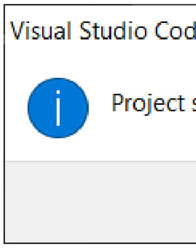
will project robot the and Project“ ”Generate click configured, been have above the all Once created. be

---

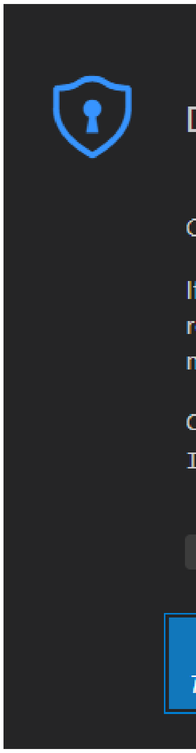
the of corner handright- bottom the in appear will generation project in errors Any **:□□□□** screen.

---

## Project New The Opening 5.2.2

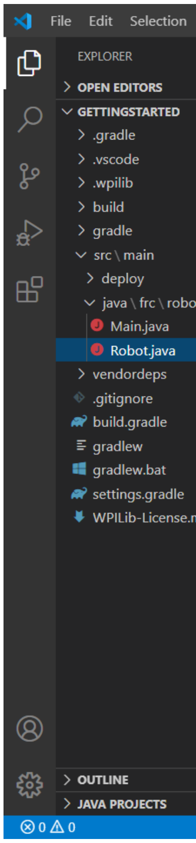

Visual Studio Cod
Project s

project the opening of option the give will Code VS project, your creating successfully After just (or `Ctrl+O` then `Ctrl+K` typing by later or now that do to choose can We above. shown as project. our saved we where folder the select and macOS) on `Command+O`



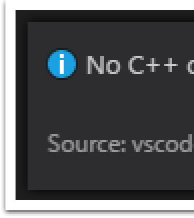
*.authors the trust I Yes* Click

will file the on clicking Double left. the on hierarchy project the see will we opened Once editor. the in file that open



## Only) (C++ Configurations C++ 5.2.3

project, a open we Whenever IntelliSense. up set to step more one is there projects, C++ For Click configurations. C++ refresh to asking corner right bottom the in uppop- a get should we IntelliSense. up set to ”Yes“



No C++ c

Source: vscod

## Imports/Includes 5.2.4

PWM

Java

```
;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.wpilibj.Timer import
;edu.wpi.first.wpilibj.XboxController import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import
```

C++

```
frc/TimedRobot.h>< include#
frc/Timer.h>< include#
frc/XboxController.h>< include#
frc/drive/DifferentialDrive.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#
```

CTRE

Java

```
;edu.wpi.first.wpilibj.Joystick import
;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.wpilibj.Timer import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
;com.ctre.phoenix.motorcontrol.can.WPI_TalonFX import
```

C++

```
frc/Joystick.h>< include#
frc/TimedRobot.h>< include#
frc/Timer.h>< include#
frc/drive/DifferentialDrive.h>< include#
ctre/phoenix/motorcontrol/can/WPI_TalonFX.h>< include#
```

REV

Java

```
;com.revrobotics.CANSparkMax import
;com.revrobotics.CANSparkMaxLowLevel.MotorType import

;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.wpilibj.Timer import
;edu.wpi.first.wpilibj.XboxController import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
```

C++

```
frc/TimedRobot.h>< include#
frc/Timer.h>< include#
frc/XboxController.h>< include#
frc/drive/DifferentialDrive.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#

rev/CANSparkMax.h>< include#
```

this C++ In used. are that WPILib of components the reference to needs code Our
statements. `import` with done is it Java in statements; `#include` using accomplished is
/ `WPI_TalonFX` / `PWMSparkMax` driving), (for `Joystick` for classes references program The
the for used class base (the `TimedRobot`` motors), controlling (for CANSparkMax`
joystick the connecting (for `DifferentialDrive` and autonomous), for (used `Timer` example),
motors). the to control

### robot sample our for variables the Defining 5.2.5

PWM

Java

```
                                              { TimedRobot extends Robot class public
                         );0PWMSparkMax( new = m_leftDrive PWMSparkMax final private
                        );1PWMSparkMax( new = m_rightDrive PWMSparkMax final private
m_ DifferentialDrive(m_leftDrive, new = m_robotDrive DifferentialDrive final private
                                                                       rightDrive); ↪
                  );0XboxController( new = m_controller XboxController final private
                                          Timer(); new = m_timer Timer final private

                                                                                **/
  ␣for used be should and up started first is robot the when run is function This *
                                                                                any ↪
                                                            code. initialization *
                                                                                */
                                                                          @Override
                                                          { ()robotInit void public
         voltages positive that so drivetrain the of side one invert to need We //
             s'robot your how on Depending forward. moving sides both in result //
        instead. side left the invert to have might you constructed, is gearbox //
                                                   );true(setInvertedm_rightDrive.
                                                                                  }
```

C++

```
                                                                             :public
                                                                          { Robot()
         voltages positive that so drivetrain the of side one invert to need We //
             s'robot your how on Depending forward. moving sides both in result //
        instead. side left the invert to have might you constructed, is gearbox //
                                                        );truem_right.SetInverted(
                                              ms);_100m_robotDrive.SetExpiration(
                                                                 m_timer.Start();
                                                                                  }
```

```
                                                                            :private
                                                              system drive Robot //
                                                        ;}0m_left{ PWMSparkMax::frc
                                                        ;}1m_right{ PWMSparkMax::frc
                               m_right}; m_robotDrive{m_left, DifferentialDrive::frc

                                               ;}0m_controller{ XboxController::frc
                                                                m_timer; Timer::frc
                                                                                   ;}
```

CTRE

Java

```
                                              { TimedRobot extends Robot class public
                        );1WPI_TalonFX( new = m_leftDrive WPI_TalonFX final private
                       );2WPI_TalonFX( new = m_rightDrive WPI_TalonFX final private
 ␣DifferentialDrive(m_leftDrive, new = m_robotDrive DifferentialDrive final private
                                                                     m_rightDrive); ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   );0Joystick( new = m_stick Joystick final private
                                          Timer(); new = m_timer Timer final private
```

C++

```
                                                                                :public
                                                                             { Robot()
                                                         );truem_right.SetInverted(
                                                ms);_100m_robotDrive.SetExpiration(
          voltages positive that so drivetrain the of side one invert to need We //
              s'robot your how on Depending forward. moving sides both in result //
         instead. side left the invert to have might you constructed, is gearbox //
                                                                  m_timer.Start();
                                                                                     }
```

```
                                                                               :private
                                                                system drive Robot //
                              ;}1m_left{ WPI_TalonFX::can::motorcontrol::phoenix::ctre
                             ;}2m_right{ WPI_TalonFX::can::motorcontrol::phoenix::ctre
                                 m_right}; m_robotDrive{m_left, DifferentialDrive::frc

                                                            ;}0m_stick{ Joystick::frc
                                                                  m_timer; Timer::frc
```

REV

Java

```
                                                { TimedRobot extends Robot class public
    );kBrushlessMotorType. ,1CANSparkMax( new = m_leftDrive CANSparkMax final private
   );kBrushlessMotorType. ,2CANSparkMax( new = m_rightDrive CANSparkMax final private
 m_ DifferentialDrive(m_leftDrive, new = m_robotDrive DifferentialDrive final private
                                                                         rightDrive); ↪
                   );0XboxController( new = m_controller XboxController final private
                                           Timer(); new = m_timer Timer final private
```

C++

```
                                                                              { Robot()
            voltages positive that so drivetrain the of side one invert to need We //
                s'robot your how on Depending forward. moving sides both in result //
           instead. side left the invert to have might you constructed, is gearbox //
                                                           );truem_right.SetInverted(
                                                  ms);_100m_robotDrive.SetExpiration(
                                                                    m_timer.Start();
                                                                                      }
```

```
                                                                               :private
                                                                system drive Robot //
                  kBrushless};::MotorType::CANSparkMax::rev ,1m_left{ CANSparkMax::rev
                 kBrushless};::MotorType::CANSparkMax::rev ,2m_right{ CANSparkMax::rev
                                 m_right}; m_robotDrive{m_left, DifferentialDrive::frc

                                                 ;}0m_controller{ XboxController::frc
                                                                  m_timer; Timer::frc
```

two and drive arcade for 0 port USB on joystick a have will examples our in robot sample The create we Here 2). and 1 IDs with CAN use examples (Vendor 1 and 0 ports PWM on motors This (m_timer). Timer and (m_stick) Joystick (m_robotDrive), DifferentialDrive type of objects things: three does code the of section

class. Robot our of members as variables the Defines 1.

variables. the Initializes 2.

---

the of bottom the at section `private` the in are C++ for initializations variable The :□□□□ Motor the sets also code C++ The ).`Robot`( class the to private are they means This program. every command a it give don't we if off shut will drive (the seconds 0.1 to expiration Safety autonomous. for used `Timer` the starts and seconds) .1

---

## Initialization Robot 5.2.6

Java

```
                     @Override
}{ ()robotInit void public
```

C++

```
}{ ()RobotInit void
```

constructor. the after but up, starting is program robot the when run is method `RobotInit` The something run to wanted we If anything. do doesn't program sample our for `RobotInit` The default). the override to above code the provide could we here

## Example Autonomous Simple 5.2.7

Java

```
   */ mode. autonomous enters robot the time each once run is function This **/
                                                                    @Override
                                               { ()autonomousInit void public
                                                            ();restartm_timer.
                                                                            }

                    */ autonomous. during periodically called is function This **/
                                                                    @Override
                                           { ()autonomousPeriodic void public
                                                          seconds 2 for Drive //
                                                    { )2.0 < ()get(m_timer. if
           off squaring input turn to sure make speed, half forwards Drive //
                                    );false ,0.0 ,0.5(arcadeDrivem_robotDrive.
                                                                    { else }
                                      robot stop // ();stopMotorm_robotDrive.
                                                                          }
                                                                            }
```

C++

```
               } m_timer.Restart(); { override ()AutonomousInit void

                        { override ()AutonomousPeriodic void
                              seconds 2 for Drive //
                            { s)_2 < (m_timer.Get() if
       off squaring input turn to sure make speed, half forwards Drive //
                   );false ,0.0 ,0.5m_robotDrive.ArcadeDrive(
                                     { else }
                                 robot Stop //
                   );false ,0.0 ,0.0m_robotDrive.ArcadeDrive(
                                        }
                                         }
```

from autonomous to transitions robot the time each once run is method `AutonomousInit` The method. this in `Timer` the restart we program, this In mode. another

In mode. autonomous in is robot the while period every once run is `AutonomousPeriodic` the example, this In 20ms. to defaults which time, fixed a is period the class `TimedRobot` the speed half at forward drives so, if and seconds 2 than less is timer the if checks code periodic has seconds 2 than more If class. `DifferentialDrive` the of method `ArcadeDrive` the using drive. robot the stops code the elapsed,

### Teleoperation for Control Joystick 5.2.8

Java

```
 */ mode. teleoperated enters robot the time each once called is function This **/
                                     @Override
                            }{ ()teleopInit void public

       */ mode. teleoperated during periodically called is function This **/
                                     @Override
                           { ()teleopPeriodic void public
  ());getRightXm_controller.- (),getLeftYm_controller.-(arcadeDrivem_robotDrive.
                                         }
```

C++

```
                           }{ override ()TeleopInit void

                          { override ()TeleopPeriodic void
              steer) to stick right (use style arcade with Drive //
                m_controller.GetLeftY(),-m_robotDrive.ArcadeDrive(
               m_controller.GetRightX());
                                         }
```

this In function. `TeleopPeriodic` and `TeleopInit` a has mode Teleop the Autonomous, in Like purposes illustration for provided is it ,`TeleopInit` in do to anything have don't we example the of axisY- the map to method `ArcadeDrive` the uses code the ,`TeleopPeriodic` In only. motion. turning to axisX- the and motors drive the of motion forward/back to `Joystick`

### Mode Test 5.2.9

Java

```
*/ mode. test enters robot the time each once called is function This **/
                                                                @Override
                                                  }{ ()testInit void public

       */ mode. test during periodically called is function This **/
                                                                @Override
                                              }{ ()testPeriodic void public
```

C++

```
        }{ override ()TestInit void

    }{ override ()TestPeriodic void
```

and `TestInit` the ,`TeleopInit` to Similar functionality. robot testing for used is Mode Test only. purposes illustrative for here provided are methods `TestPeriodic`

### Robot a to Project the Deploying 5.2.10

robot. a onto program the deploying for *here* instructions the see Please

## Program Test your Running 5.3

### Overview 5.3.1

language: programming your for described as Program Test a download and create should You

*C++/Java*

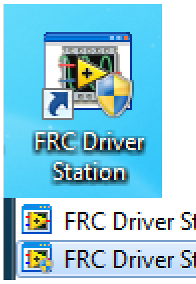
*LabVIEW*

### Operation Tethered 5.3.2

cable USB or ethernet via Station Driver the to tethered while program test your Running roboRIO and station driver the that and deployed successfully was program the confirm will configured. properly are

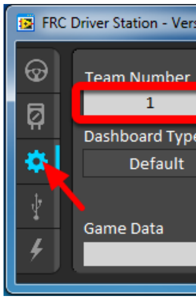
USB. or Ethernet over PC the to connected and on powered be should roboRIO The

### Station Driver FRC the Starting 5.3.3



by or Desktop the on icon the clickingdouble- by launched be can Station Driver FRC® The Station. Driver >FRCPrograms- >AllStart- selecting

### Station Driver the Up Setting 5.3.4

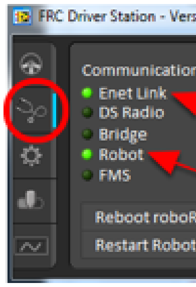


Team Number
1
Dashboard Typ
Default
Game Data

do to order In robot. your to connect to order in number team your to set be must DS The return Press box. number team the in number team your enter then tab Setup the click this effect. take to setting the for box the outside click or

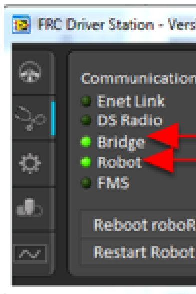
already, robot the to connect to DS the for settings network correct the have typically will PCs DHCP. to set is adapter Network your sure make not, if but

### Connectivity Confirm 5.3.5



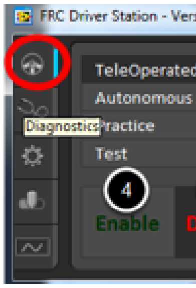
Tethered 1: Fig.

Robot (or Link Enet the that confirm and Diagnostics click software, Station Driver the Using green. are leds Robot and wirelessly) operating if led, Radio



Wireless 2: Fig.

### 5.3.6 Robot the Operate



Tab Operation the Click

1. displayed is voltage battery that Confirm
2. green. are indicators Joysticks and Code, Robot Communications,
3. Mode Teleop in robot the Put
4. responds. robot the how observe and joysticks the Move Enable. Click
5. Disable Click

### 5.3.7 Operation Wireless

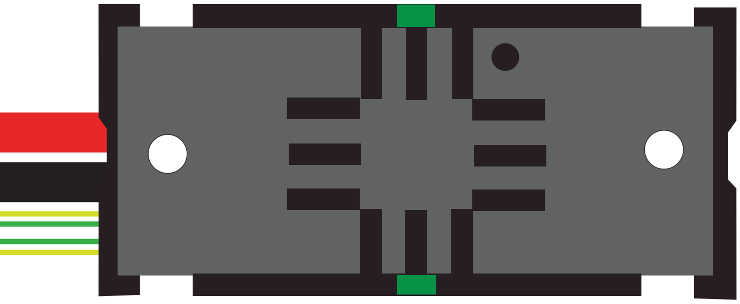
as confirmed been have should operation tethered operation, wireless attempting Before Driver the to connected while program test your Running .*Operation Tethered* in described configured. properly is point access the that confirm will WiFi via Station

#### Point Access the Configuring

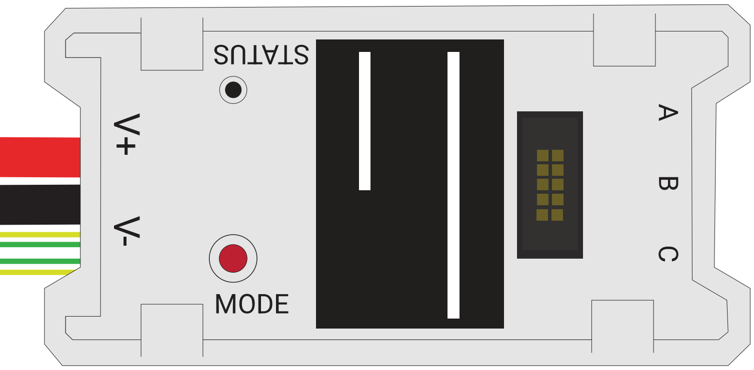
as use for radio robot the configuring on details for *radio your Programming* article the See point. access an

The robot. the to wirelessly station driver the connect point, access the configuring After a set you If Utility). Configuration Bridge the in entered (as number team your be will SSID the to connect to it enter to need will you Utility Configuration Bridge the using when key address IP an (”Obtain DHCP to set is adapter network computer the sure Make network. automatically“).

and **Connectivity Confirm** in steps same the using operation wireless confirm now can You above. **Robot the Operate**



Victor SPX

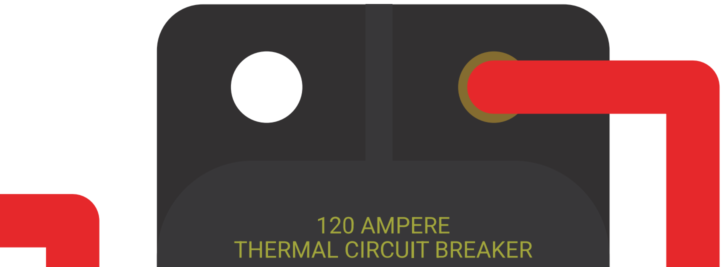


Spark MAX

### DISCRETE
### MOTOR CONTROLLERS
### (CAN/PWM Controlled)

More Information about
the FRC Control System can be found
at **https://docs.wpilib.org/**

120A Breaker



[redacted]

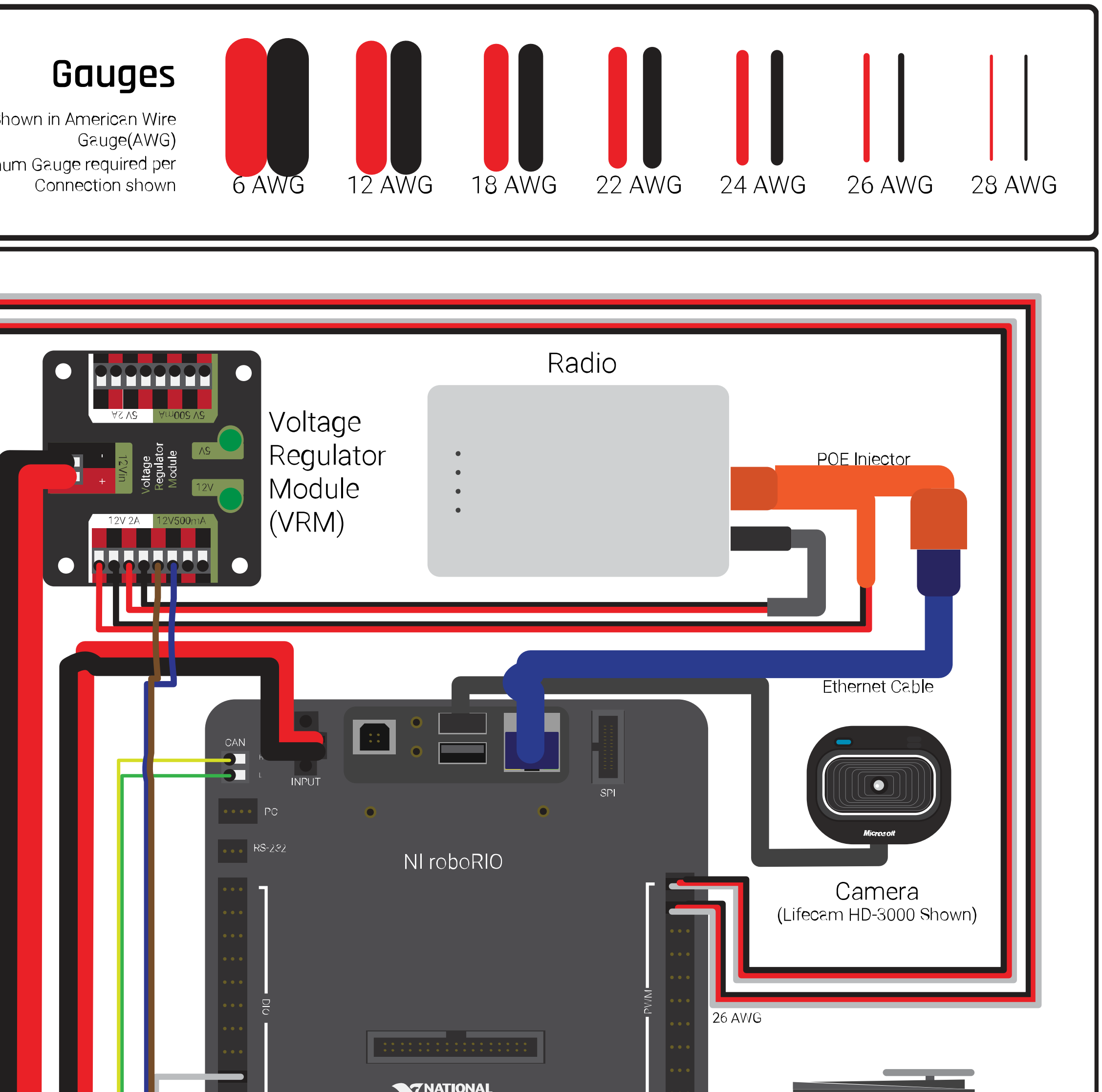
[illegible]

ms, wiring For :[illegible]
document.

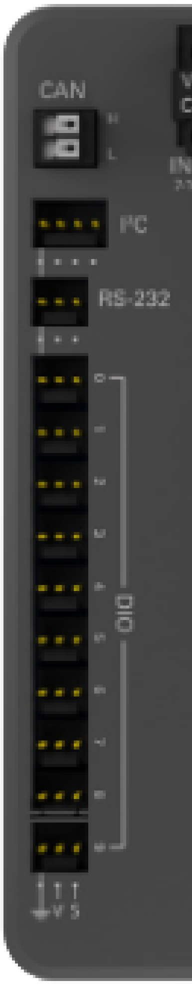
## 6.1 סקירה כללית

REV

CTRE


Gauges
hown in American Wire Gauge(AWG)
um Gauge required per Connection shown
6 AWG
12 AWG
18 AWG
22 AWG
24 AWG
26 AWG
28 AWG
Radio
Voltage Regulator Module (VRM)
POE Injector
Ethernet Cable
Camera
(Lifecam HD-3000 Shown)
NI roboRIO
CAN
INPUT
SPI
I2C
RS-232
DIO
PWM
26 AWG
12Vin
Voltage Regulator Module
5V 2A
5V 500mA
12V 2A
12V500mA
5V
12V

## roboRIO NI 6.2



”brain“ the as serves roboRIO The FRC. for used controller robot main the is *roboRIONI-* The hardware. other the of all commands that code generatedteam- running robot the for

## Panel Distribution Power CTRE 6.3

12VDC a from power distribute to designed is (PDP) *Panel Distribution Power CTRE* The
small a and breakers circuit resettingauto- through components robot various to battery
for rated pairs output 8 provides PDP The connections. fused function special of number
provides PDP The current. continuous 30A for rated pairs 8 and current continuous 40A
Regulator Voltage the for connectors as well as roboRIO, the for connectors 12V dedicated
current, logging for interface CAN a includes also It Module. Control Pneumatics and Module
.Manual User PDP the see information, detailed more For voltage. battery and temperature,

## Hub Distribution Power REV 6.4

battery 12VDC a from power distribute to designed is (PDH) Hub Distribution Power REV The 3 channels, max) (40A currenthigh- 20 features PDH The components. robot various to Hub Distribution Power The channel. currentlow- switchable 1 and max), (15A currentlow- connect to ability the and display, voltage LED an terminals, WAGO latching toolless features telemetry. timereal- for Client Hardware REV the to CUSB- or CAN over

## Module Regulator Voltage CTRE 6.5

by powered is that module independent an is (VRM) Module Regulator Voltage CTRE The multiple has module The PDP. the on connector dedicated a to wired is device The volts. 12 the for power regulated provide to is VRM the of purpose The outputs. 5V and 12V regulated User VRM the see information, more For cameras. vision IP and circuits, custom radio, robot .Manual

## Module Power Radio REV 6.6

components, system critical most the of one keep to designed is Module Power Radio REV The Radio The competition. the of moments toughest the in powered radio, WiFi OpenMesh the power barrel traditional a through radio the powering for need the eliminates Module Power Module Power Radio the connectors, RJ45 socketed two with POE Passive 18V Utilizing jack. radio. the to directly power providing while roboRIO and radio the between signal passes by Module Power Radio the to power add easily roboRIO, and radio the connecting After coded color the utilizing Hub Distribution Power the on channels currentlow- the to it wiring terminals. WAGO button push

## Radio ACOM5P- or ANOM5P- OpenMesh 6.7

robot the as used is radio wireless ACOM5P- OpenMesh or ANOM5P- OpenMesh the Either
be can device The robot. the to functionality communication wireless provide to radio
also can It home. at use for laptop a of connection direct for Point Access an as configured
of one by powered be should radio robot The field. the on use for bridge a as configured be
For Ethernet. over controller roboRIO the to connected and VRM the on outputs 12V/2A the
.*Radio your Programming* see information, more

more has heavier, slightly is ACOM5P- The .purchase for available longer no is ANOM5P- The
AN.OM5P- the to compared texture surface rough a has and grates, cooling

## Breaker Circuit 120A 6.8

switch power robot main the robot: the on roles two serves Breaker Circuit Main 120A The circuit 120A The components. and wiring robot downstream for device protection a and boards. Distribution Power and battery robot the of terminals positive the to wired is breaker 185120F) (PN: Datasheet Series 18X Bussmann Cooper the see please information, more For

## Breakers Circuit Action Snap 6.9

Power the with used are ,Series VB3 and series MX5 breakers, circuit Action Snap The breakers circuit these on ratings The circuits. branch to current limit to Panel Distribution higher. considerably be can values peak temporary current, continuous for are

## Battery Robot 6.10

battery, (SLA) Acid Lead Sealed 18Ah 12V single a is robot FRC an for supply power The the see information, more For robot. FRC an of demands current high the meeting of capable *page. Battery Robot*

**:□□□□** complete a for Manual FRC the consult legal, be may numbers part battery Multiple list.

## Light Signal Robot 6.11

is It B12ME522.855PB- BradleyAllen- the be to required is (RSL) Light Signal Robot The disabled. while solid stay and enabled when flash will and roboRIO the by controlled directly

## Module Control Pneumatics CTRE 6.12

required outputs and inputs the of all contains (PCM) *Module Control Pneumatics CTRE* The
contains PCM The compressor. board on the and solenoids pneumatic 24V or 12V operate to
robot the when automatically compressor the control will and sensor pressure the for input an
PCM the see information more For code. the in created been has solenoid a and enabled is
.Manual User

## Hub Pneumatic REV 6.13

24V and 12V both switching of capable is that module standalone a is Hub Pneumatic REV The
allow which channels solenoid 16 features Hub Pneumatic The valves. solenoid pneumatic
two the of combination a or solenoids, actingdouble- 8 solenoids, actingsingle- 16 to up for
to solenoids 12V even allowing regulated, fully is voltage output selectable user The types.
4.75V. as low as drops battery robot the when active stay

flexibility the increasing device, the into built are ports sensor pressure analog and Digital
works Hub the on connection CUSB- The system. pneumatic the of functionality feedback and
for need a without systems pneumatic test to users allowing Client, Hardware REV the with
controller. robot additional an

## Controllers Motor 6.14

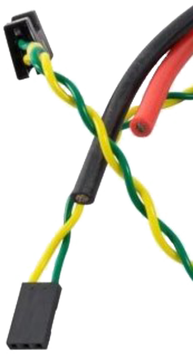
System Control FRC the with work which *controllers motor* different of variety a are There the of control voltage variable provide to used are devices These use. for approved are and .usage of order in here listed are They FRC. in used motors DC brushless and brushed

*PartyThird-* on section this See WPILib. from supported not is control CAN Party 3rd :□□□□ information. more for *Devices CAN*

### SRX Talon 6.14.1

Road The Cross from controller“ motor ”smart a is Controller Motor SRX Talon The PWM or bus CAN the over controlled be can SRX Talon The Robotics. Electronics/VEX switches limit from inputs take can device this control, bus CAN the using When interface. For control. advanced perform to order in sensors similar or encoders, potentiometers, and .Guide User’s SRX Talon the see information more

## 6.14.2 Victor SPX



The Victor SPX Motor Controller is a CAN or PWM controlled motor controller from Cross The Road Electronics/VEX Robotics. The device is connectorized to allow easy connection to the roboRIO PWM connectors or a CAN bus. The case is sealed to prevent debris from entering the controller. For more information, see the Victor SPX User Guide.

### Controller Motor MAX SPARK 6.14.3

controller motor DC brushless and brushed advanced an is Controller Motor MAX SPARK The
from input uses MAX SPARK the control, USB or bus CAN using When Robotics. REV from
NEO REV the of encoder integrated the including sensors, other and encoders, switches, limit
over controlled be can MAX SPARK The modes. control advanced perform to Motor, Brushless
MAX SPARK the see information, more For only). configuration/testing (for USB or CAN PWM,
.Manual User's

## Controller Motor TalonFX 6.14.4

features It motor. brushless 500 Falcon the into integrated is Controller Motor TalonFX The
more For more! and SRX Talon the of features smart the of all and encoder integrated an
.Guide User 500 Falcon the see information

## Controller Motor SPARK 6.14.5

> has manufacturer the use, FRC for legal still is controller motor this While :□□□□□
> product. this discontinued

motor DC brushed inexpensive an is Robotics REV from Controller Motor SPARK The wired be may switches Limit interface. PWM the using controlled is SPARK The controller. information, more For directions. both or one in travel motor limit to SPARK the to directly .Manual User's SPARK the see

### SP Victor 6.14.6

> has manufacturer the use, FRC for legal still is controller motor this While **:[illegible]**
> product. this discontinued

Road The Cross from controller motor PWM a is Controller Motor SP Victor The
heat for housing metal isolated electrically an has SP Victor The Robotics. Electronics/VEX
from debris prevent to sealed is case The optional. fan the of use the making dissipation,
models. previous of size the half approximately is controller The controller. the entering

### Controller Motor Talon 6.14.7

> has manufacturer the use, FRC for legal still is controller motor this While **:□□□□□**
> product. this discontinued

DC brushed controlled PWM a is Electronics Road the Cross from Controller Motor Talon The
cooling. passive with controller motor

## Controller Motor 884 Victor / Controller Motor 888 Victor 6.14.8

has manufacturer the use, FRC for legal still is controller motor this While **:□□□□□**
product. this discontinued

PWM speed variable are Robotics VEX from controllers motor 888 Victor and 884 Victor The usable also is which 884, Victor the replaces 888 Victor The FRC. in use for controllers motor FRC. in

### Controller Motor Jaguar 6.14.9

has manufacturer the use, FRC for legal still is controller motor this While :□□□□□
product. this discontinued

Texas and Micro Luminary by made (formerly Robotics VEX from Controller Motor Jaguar The
may Jaguar the FRC, For FRC. in use for controller motor speed variable a is Instruments)
interface. PWM the using controlled be only

## Controller Motor 60CDMC- and 60DMC- 6.14.10

has manufacturer the use, FRC for legal still is controller motor this While :□□□□□
product. this discontinued

integrated features 60DMC- The Digilent. from controller motor PWM a is 60DMC- The
and overheating prevent to foldbackcurrent- including protection and sensing thermal
easier for status and direction, speed, indicate to LEDs colormulti- four and damage,
manual reference 60DMC- the see information, more For debugging.

the to Due controller. 60DMC- the to capabilities controller smart CAN adds 60CDMC- The
more For PWM. with usable only is 60CDMC- the product, this discontinuing manufacturer
Page Product 60CDMC- the see information

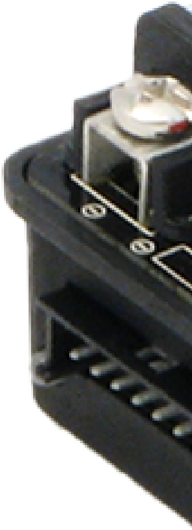
## Controller Motor Venom 6.14.11

the on based motor a into integrated is Fusion With Playing from Controller Motor Venom The enabling onboard, measured all are position and temperature, current, Speed, CIM. original schemes. wiring and sensing complicated without modes control advanced

## Controller with Motor BLDC Dynamo Nidec 6.14.12

controller and motor brushless first the is Controller with Motor BLDC Dynamo Nidec The data motor The motor. the of back the into integrated is controller motor's This FRC. in legal specifics. device more provides sheet

### Controllers Motor SD540C and SD540B 6.14.13



PWM. using controlled are Mindsensors from Controllers Motor SD540C and SD540B The Limit support. manufacturer of lack to due SD540C the for available longer no is control CAN directions. both or one in travel motor limit to SD540 the to directly wired be may switches page FRC Mindsensors the see information more For

## Relay BridgeH- Spike 6.15

□□□□□: While this relay is still legal for FRC use, the manufacturer has discontinued this product.

The Spike H-Bridge Relay from VEX Robotics is a device used for controlling power to motors or other custom robot electronics. When connected to a motor, the Spike provides On/Off control in both the forward and reverse directions. The Spike outputs are independently controlled so it can also be used to provide power to up to 2 custom electronic circuits. The Spike H-Bridge Relay should be connected to a relay output of the roboRIO and powered from the Power Distribution Panel. For more information, see the Spike User's Guide.

## 6.16 Servo Power Module

The Servo Power Module from Rev Robotics is capable of expanding the power available to servos beyond what the roboRIO integrated power supply is capable of. The Servo Power Module provides up to 90W of 6V power across 6 channels. All control signals are passed through directly from the roboRIO. For more information, see the Servo Power Module webpage.

## HD3000 Lifecam Microsoft 6.17

the into directly plugged be can that webcam USB a is HD3000 Lifecam Microsoft The
more For FPS. 30 at video 1280x720 to up capturing of capable is camera The roboRIO.
about information more For .page product Microsoft the see camera, the about information
documentation. this of section *Processing Vision* the see roboRIO, the with camera the using

## Credits Image 6.18

Digilent. of courtesy 60DMC- of Image Instruments. National of courtesy roboRIO of Image
SRX, Talon Controller, Motor Jaguar of Images Mindsensors. of courtesy SD540 of Image
VEX of courtesy Relay BridgeH- Spike and SPX, Victor SP, Victor 888, Victor FX, Talon
and Module, Power Radio Hub, Distribution Power MAX, SPARK of Image Inc. Robotics,
photos VRM and SPARK, PCM, PDP, Lifecam, Robotics. REV of courtesy Hub Pneumatic
Inc. AndyMark of courtesy photos other All ®.*FIRST* of courtesy

# 7

[redacted]

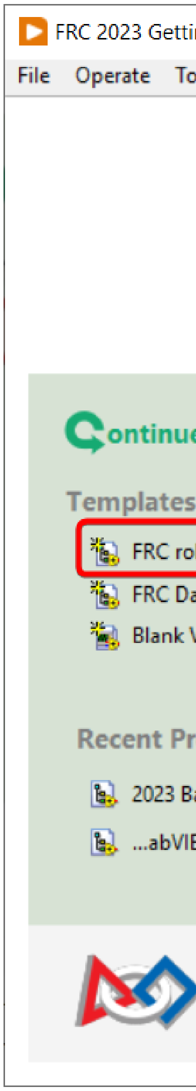
components. optional and mandatory of variety wide a of consists software FRC® The of debugging and development, design, the in you assist to designed are elements These feedback provide to and operation robot control with assist as well as code robot your brief a provide will document this component software each For troubleshooting. when further to link a and appropriate, if download, package the to link a purpose, its of overview available. where documentation

## 7.1 מערכות הפעלה תואמות

software FRC required All Windows. is components FRC for OS supported primary The 11. & 10 Windows on tested been have components

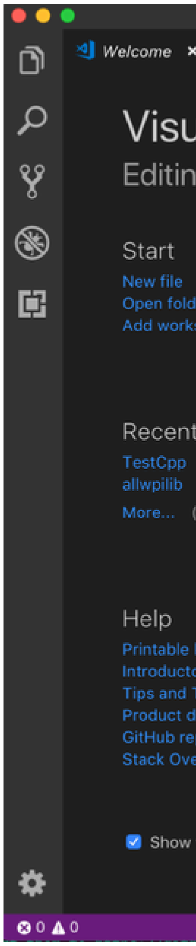
and macOS on tested and supported also are programming C++/Java for tools the of Many systems, these using develop to able be should C++/Java in programming Teams Linux. Radio Station, Driver the as such operations onlyWindows- the for system Windows a using Tool. Imaging roboRIO and Utility, Configuration

## 7.2 (בלבד (Windows FRC LabVIEW



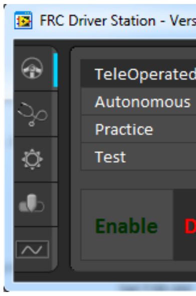
three the of one is Professional, LabVIEW of version recent a on based FRC, LabVIEW
graphical, a is LabVIEW robot. FRC an programming for languages supported officially
VIs, called icons, of collection a of consist programs LabVIEW language. drivendataflow-
is installer FRC LabVIEW The VIs. the between data pass which wires with together wired
A download. for available also is and Parts of Kit Kickoff the in found DVD a on distributed
instructions installation including software, FRC LabVIEW the with started getting to guide
.*here* found be can

## Code Studio Visual 7.3



other (the Java and C++ for environment development supported the is Code Studio Visual A languages. programming based text orientedobject- are Both languages). supported two configuration and installation the including FRC, for Java or C++ with started getting to guide .*here* found be can Code Studio Visual of

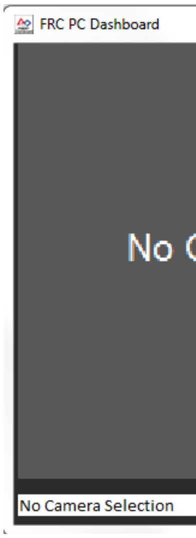
## (Windows LabVIEW NI by Powered Station Driver FRC 7.4
## (בלבד



robot the of state the controlling of purpose the for used be to allowed software only the is This devices. input of variety a from robot your to data sends software This competition. during information More issues. robot troubleshoot help to used tools of number a contains also It .*here* found be can LabVIEW NI by Powered Station Driver FRC the about

## Options Dashboard 7.5

### Only) (Windows Dashboard LabVIEW 7.5.1

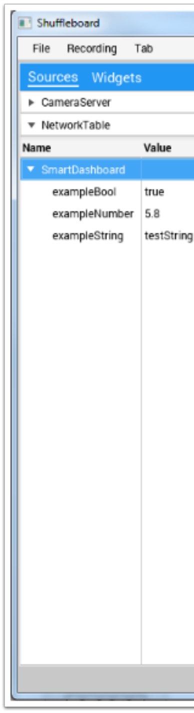


default. by Station Driver FRC the by launched automatically is Dashboard LabVIEW The using robot the of operation the about feedback provide to is Dashboard the of purpose The Default FRC the about information More features. in built of variety a with display tabbed .*here* found be can software Dashboard

## SmartDashboard 7.5.2

customizable creating automatically by data robot your view to you allows SmartDashboard documentation Additional robot. your from sent data of piece each for specifically indicators .*here* found be can SmartDashboard on

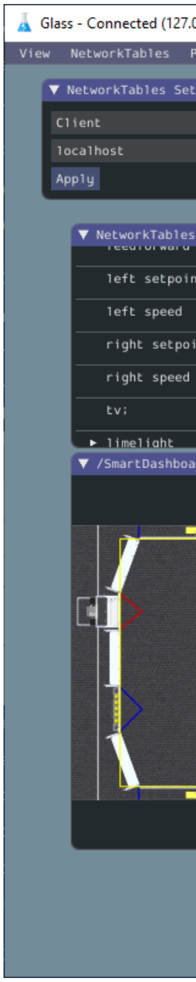
## Shuffleboard 7.5.3



| Name | Value |
|---|---|
| SmartDashboard | |
| exampleBool | true |
| exampleNumber | 5.8 |
| exampleString | testString |

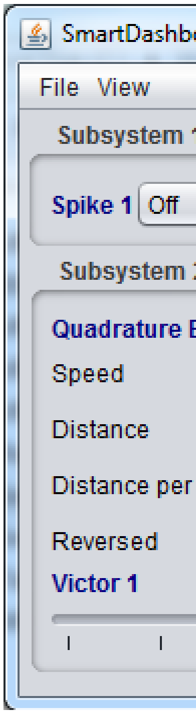
and setup the on improves also It SmartDashboard. as features same the has Shuffleboard less being of cost the at design modern a and features new with data your of visualization .*here* found be can Shuffleboard on documentation Additional efficient. resource

## Glass 7.5.4



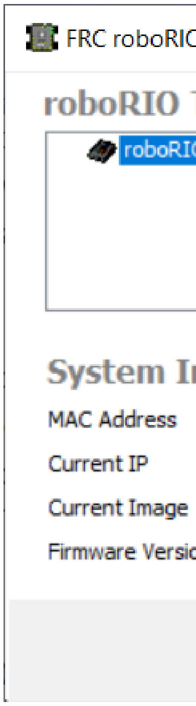
primary The debugging. for tool programmer's a being on focused Dashboard a is *Glass*
tools. plotting signal advanced and visualization pose view, field the are advantages

## LiveWindow 7.6



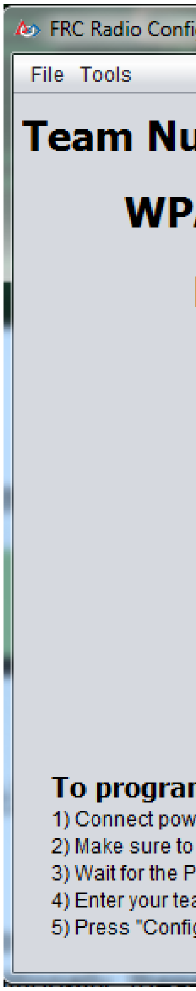
Test the with use for designed Shuffleboard, and SmartDashboard of feature a is LiveWindow the on sensors from feedback see to user the allows LiveWindow Station. Driver the of Mode about information More code. user written the of independent actuators control and robot .*here* found be can LiveWindow

## Only) (Windows Tool Imaging roboRIO FRC 7.7



can instructions Installation FRC. in use for roboRIO a setup and format to used is tool This found be can tool this using roboRIO your imaging on instructions Additional .*here* found be .*here*

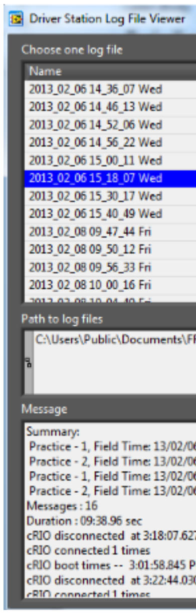
## Only) (Windows Utility Configuration Radio FRC 7.8



To progran
1) Connect pow
2) Make sure to
3) Wait for the P
4) Enter your tea
5) Press "Confi

practice for radio standard the configure to used tool a is Utility Configuration Radio FRC The
the of experience the mimic to settings network appropriate the sets tool This home. at use
installer standalone a by installed is Utility Configuration Radio FRC The field. playing FRC
.*here* found be can that

## Only) (Windows Viewer Log Station Driver FRC 7.9



```
2013_02_06 14_36_07 Wed
2013_02_06 14_46_13 Wed
2013_02_06 14_52_06 Wed
2013_02_06 14_56_22 Wed
2013_02_06 15_00_11 Wed
2013_02_06 15_18_07 Wed
2013_02_06 15_30_17 Wed
2013_02_06 15_40_49 Wed
2013_02_08 09_47_44 Fri
2013_02_08 09_50_12 Fri
2013_02_08 09_56_33 Fri
2013_02_08 10_00_16 Fri
```

```
C:\Users\Public\Documents\F
```

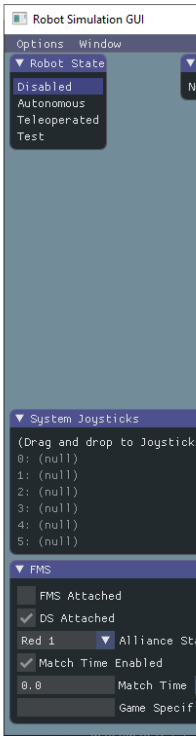
```
Summary:
 Practice - 1, Field Time: 13/02/0
 Practice - 2, Field Time: 13/02/0
 Practice - 1, Field Time: 13/02/0
 Practice - 2, Field Time: 13/02/0
Messages : 16
Duration : 09:38.96 sec
cRIO disconnected  at 3:18:07.62
cRIO connected 1 times
cRIO boot times --  3:01:58.845 P
cRIO disconnected  at 3:22:44.03
```

Station. Driver FRC the by created logs view to used is Viewer Log Station Driver FRC The happened what understanding for important information of variety a contain logs These Station Driver FRC the about information More match. FRC or session practice a during *here* found be can logs the understanding and Viewer Log

## RobotBuilder 7.10

robot Based Command a of structuring and setup in aid to designed tool a is RobotBuilder
of components various the in enter to you allows RobotBuilder Java. or C++ for project
a in are commands your what define and interface operator and subsystems robot your
get to code template structural generate then will RobotBuilder structure. tree graphical
information More .*here* found be can RobotBuilder about information More started. you
.*here* found be can architecture programming Based Command the about

## סימולציית רובוט 7.11

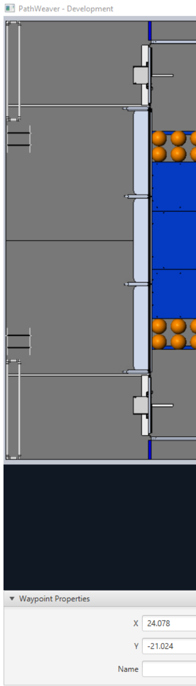


code robot actual their verify to teams C++ and Java for way a offers Simulation Robot
VS from directly launched be can simulation This environment. simulated a in working is
more For on. movement robot's their visualize can users that field 2D a includes and Code
.*section Simulation Robot* the see information

# Only) (Windows Simulator Robot LabVIEW FRC 7.12

that environment programming LabVIEW the of component a is Simulator Robot FRC The and/or code test to environment simulated a in robot predefined a operate to you allows here found be can Simulator Robot FRC the using on Information functions. Station Driver Explorer. Project LabVIEW the in file Readme.html Simulation Robot the opening by or

## PathWeaver 7.13



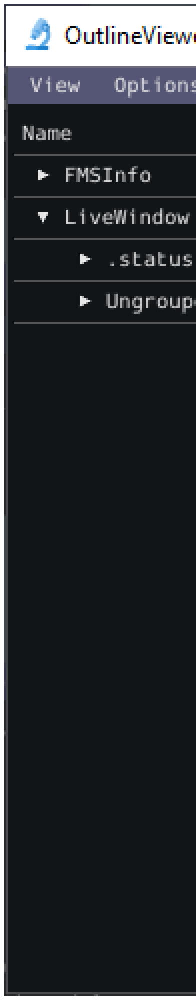
X 24.078
Y -21.024
Name

autonomous advanced for paths configure and generate quickly to teams allows PathWeaver
robot their navigate quickly to team the allowing curves smooth have paths These routines.
.*section PathWeaver* the see information more For field. the on points between

## Identification System 7.14

the describe to used be can that constants calculate automatically teams helps tool This
following, trajectory simulation, robot like features in use for robot your of properties physical
.*section Identification System* the see information more For control. PID and

## OutlineViewer 7.15



the of contents the of all to add and modify view, to used utility a is OutlineViewer the of tab Variables the use can teams LabVIEW purposes. debugging for NetworkTables *Outline* the see information more For functionality. this accomplish to Dashboard LabVIEW *.section Viewer*

# 8

[redacted]

to teams for provided *library software* standard the is (WPILib) Library Robotics WPI The
for subroutines and classes useful of set a contains WPILib robots. FRC® their for code write
controllers, motor sensors, as (such system control FRC the of parts various with interfacing
functions. utility other of assortment an as well as station), driver the and

## 8.1 שפות נתמכות

basedtext- supportedofficially- two the of each for one WPILib, of versions two are There
maintain to made is effort considerable A C++. for WPILibC and Java, for WPILibJ languages:
be can they unless added not are features library - languages two these between parityfeature-
names method and class the possible when and C++, and Java both for supported reasonably
for available is support builtcommunity- unofficial While similar.highly- or identical kept are
C++. and Java cover only will documentation this ,python notably languages, other some
appropriate their to due languages supportedofficially- the for chosen were C++ and Java
classes. science computer schoolhigh- and industry both in ubiquity and abstractionof-level-

effort user increased of cost the at performance, endhigh- better offers C++ general, In
ensure to much do not does compiler C++ the and manually, handled be must (memory
greater much but performance, lesser offers Java runtime). at crash not will code user
Java. use to encouraged strongly are users New/inexperienced convenience.

## documentation and code Source 8.2

the on online available is code source its of entirety the - library sourceopen- an is WPILib
Page: GitHub WPILib

- GitHub WPILib Official

directories: source WPILibC and WPILibJ the in found be can code source C++ and Java The

- code source Java
- code source C++

questions detailed resolve to code source the read to encouraged strongly are users While official the on found be can documentation concisemore- functionality, library about WPILibC: and WPILibJ for pages documentation

documentation Java •

documentation C++ •

# 9

[redacted]

## 9.1 בעיות ידועות

Software. System Control FRC® for workarounds) (and issues known details article This

### 9.1.1 בעיות פתוחות

#### Settings Ethernet 2.0 roboRIO

in work will This only. DHCP to configured is port Ethernet the 2.0, roboRIO the On **Issue:** communicate not will but server, DHCP a as acts radio the where setups networking normal Ethernet. via Station Driver the to directly tethered when

eth0 Adapter Ethernet the change to Dashboard Web roboRIO the Use **Workaround:** .*Local Link or DHCP* to *Address IPv4 Configure*

#### Code No Reporting Station Driver

properly not to roboRIO the causes that 2.0 roboRIO the in occurrence rare a is There **Issue:** but connection successful a report to Station Driver the causes This program. robot the start roboRIO. the on deployed is code though even code, no

been have volunteers FIRST but cause, root the investigating currently are We **Workaround:** occurs. this when roboRIO the reboot to is recommendation the and aware made

> also can seconds 5 for roboRIO the on button *User* physical the Pressing **:□□□□** If code. robot the start not will reboot a but start, not to code robot the cause that Ensure button. *User* the press rebooting, after start not does code robot the button. *User* the with contact in is robot the on nothing

### Communicate to Fails Sometimes Port Second Radio

port Ethernet second the causes that Radios OM5P the in occurrence rare a is There **Issue:** communicate. not to plug) power the from farthest one (the

the with communication restablish will radio the cycling power Generally, **Workaround:** from available switch linktp- the as such switch network a utilize Alternately, port. second switch network the into devices ethernet all plug and 005SW- brainboxes the or Choice FIRST tethering easier allows also This port. Ethernet first radio's the into switch the plug then and competition. at while

### Lockups System Causing I2C Onboard

in result can language, any in 2, or 1 roboRIO the on port I2C onboard the of Use **Issue:** specific the on dependent be to appears lockups these of frequency The lockups. system being is bus the how as well as differently) behave will roboRIOs different (i.e. hardware used.

to device another or port I2C MXP the use to is mitigation surefire only The **Workaround:** may roboRIO different a using and/or frequently less device the Accessing data. I2C the read assess to team each to up be will it lockups, of likelihood/frequency the reduce significantly the on identified definitively be not can lockup This lockup. of risk the of tolerance their occur. to believed is behavior this where match a for called be not will fault field a and field not will and responding stop completely will roboRIO the hang, CPU/kernel a is lockup This these of any via roboRIO your access can you If SSH. or webpage DS, the via accessible be issue. different a experiencing are you methods,

I2C roboRIO the using without sensor color REV the accessing for exist alternatives Several sensors. I2C other for used be could approach similar A port.

- roboRIO the to data sends sensors, color REV 2 to up Supports .Pico Pi Raspberry a Use available. readily and $10) than (less cost low is Pico Pi The serial. via
- via roboRIO the to data sends sensors, color 41- Supports .Pi Raspberry a Use a as Pi Raspberry a using already teams for useful Primarily NetworkTables. coprocessor.

### hang or slow be may 2.0 roboRIO on Properties Updating

Imaging the using reformatting without 2.0 roboRIO a on properties the Updating **Issue:** hang. or slow be may number) team the setting as (such Tool

be to able be should roboRIO the waiting tool the of minutes few a After **Workaround:** set. be should properties new the and rebooted

### WPILib updating after Mac on crashes Simulation

running WPILib, of version newer a use to project the updating after macOS, On **Issue:** appearing. GUI the without crashes immediately simulation

run Alternatively, .`clean` Gradle, in command a Run | WPILib run Code, VS In **Workaround:** directory. build the delete or terminal the in `clean gradlew/.`

### GradleRIO missing to due build Invalid

to similar errors shown get will they and broken get will cache Gradle user's a Rarely, **Issue:** following: the

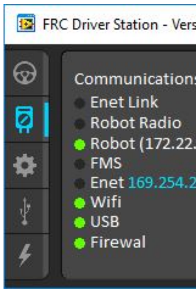
```
␣'2020.3.2'] version: 'edu.wpi.first.GradleRIO', [id: plugin requested apply not Could
                  'edu.wpi.first.GradleRIO' id with plugin a provide not does it as ↪
```

**Workaround:**

need may machines Windows .~`$USER_HOME/.gradle` under located cache Gradle your Delete far. so Windows on up shown only has issue This .files hidden view to ability the enable to OS. alternative an on it get you if issue this report Please

### [illegible] [illegible] Driver Station Log-ב

.[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Station Driver-[illegible] [illegible] Log-[illegible] ,[illegible] [illegible] :[illegible] .[illegible] [illegible] [illegible] [illegible] Windows [illegible] [illegible] [illegible] [illegible] [illegible]



:[illegible] [illegible] [illegible] [illegible] 2 [illegible] :[illegible] [illegible]

1. .[illegible] [illegible] [illegible] Notepad, [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
2. .[illegible] Windows-[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

### Properly Work Don't Launch on Open Files - Intellisense C++

showing Intellisense with issues have will launches Code VS when open files C++, In **Issue:** not or ones appropriate the just not and unit compilation a from options all from suggestions Code. VS in bug a is This files. header finding

**Workaround:**

1. open Code VS leave but Code, VS in files all Close
2. exists it if folder, .vscode the in file c_cpp_properties.json Delete
3. Code. VS in command Intellisense" C++ "Refresh the Run

or (linuxathena platform a like looks that something see should you right bottom the In 4.
(release) linuxathena to it set and it click linuxathena not it’s If etc). 64windowsx86-

min ~1 Wait 5.

working be now should Intellisense file). header a (not file cpp main the Open 6.

#### Editions N Windows on Simulation and Dashboards WPILib with Issues

on issues have will code) robot simulated and (dashboards CSCore using code WPILib **Issue:**
Windows. of editions N Education

cameras load not but run, will Shuffleboard •

upstart- on crash will Smartdashbard •

upstart- on crash will Simulation Robot •

Pack Feature Media the Install **Solution:**

### 2023.1.0 Tools Game in Fixed 9.1.2

#### startup at joysticks detect not does Station Driver

it when joysticks connected already detect not does application Station Driver The **Issue:**
works. running already is it after joysticks Connecting up. starts

or button rescan joystick the use or DS, the starting after joysticks Connect **Workaround:**
joysticks. for rescan to shortcut F1 the

### 2023.2.1 WPILib in Fixed 9.1.3

#### Maxes Spark CAN using when startup on crash program Robot - SysId

to configured was it if startup on crashes program robot deployed 2023.1.1’s SysId **Issue:**
Maxes. Spark CAN use

newer. or 2023.2.1 WPILib Install **Solution:**

#### work not does NetworkTableInstance client a flushing Manually

to flushed be to data the cause not does `NetworkTableInstance` a on `flush()` Calling **Issue:**
release. WPILib upcoming an in fixed be will issue This immediately. subscribers remote

faster a need that publishers NetworkTable the on option `periodic` the Set **Workaround:**
rate: update

Java

```
                 period. 10ms a with it update and myTopic for DoubleEntry a Get //
    PubSubOption. ,0(getEntry)."myTopic"(getDoubleTopictable. = myEntry DoubleEntry
                                                                 ));0.01(periodic ↪
```

C++

```
                 period. 10ms a with it update and myTopic for DoubleEntry a Get //
  0. = periodic. { ,0).GetEntry("myTopic"table.GetDoubleTopic( = entry DoubleEntry::nt
                                                                             );} 01 ↪
```

## 2023 for New 9.2

This 2023. for software System Control FRC® to made been have improvements of number A as well as features and changes new the of overview brief a provide and describe will article the includes only document This changes. WPILib Java/C++ for changelog complete more a various the on viewed be can changes of list full the users, end for changes relevant most repositories. GitHub WPILib

.*issues known* of list the review also to recommended It's

### Years Previous from Projects Importing 9.2.1

years. previous from projects update to necessary is it changes, GradleRIO internal to Due compatible. be to *imported* be must projects 2022 any ,*2023 for WPILib Installing* After

### (Java/C++) Changes Major 9.2.2

the for important it's that library the to changes major the of *some* contain changes These sections other the see changes, breaking the of all include not does This recognize. to user changes. more for document this of

- pub/sub introduces This 4.0. version as rewritten completely been has *NetworkTables* timestamped including features, new of number a adds and NetworkTables to semantics browser by use easier for basedWebSockets- now also is protocol wire Its updates. use don't who users to transparent be should changes the of most While applications. still are clients V3 NetworkTables changes. breaking several are there features, new the dropped. been has support V2 but compatible,
- *logs data into recording telemetry roboton-* for support Added
- consistent a as observed been has This default. by disabled now is telemetry `LiveWindow` previous the restore to `LiveWindow.enableAllTelemetry` Use overruns. loop of source behavior
- added been has library *AprilTag*
- 11 from 17 to bumped been has version Java Bundled
- C++ running for required is 2022 Studio Visual support. 20 C++ with 12.1 GCC Windows on Simulation
- systems operating Mac on cameras USB supports now CameraServer

**Architectures: and Systems Operating Supported**

- supported not are Arm and bit 32 bit. 64 11, & 10 Windows
- but work, may 2.32 >= glibc with distributions Linux Other bit. 64 22.04, Ubuntu unsupported are
- Arm. and Intel later, or 11 macOS

> 20.04, & 18.04 Ubuntu 10.15, macOS supported: longer no are OSes following The :□□□□□ Windows. bit32- any and 8.1, Windows 7, Windows

## WPILib 9.2.3

### הספרייה הכללית

- `repeatedly()/RepeatCommand` use ,`perpetually()/PerpetualCommand` Deprecated instead
- `until()` to `withInterrupt(BooleanSupplier)` Renamed
- `InterpolatedTreeMap` Added
- decorator `repeatedly` matching and `RepeatCommand` Added
- decorator `unless(BooleanSupplier)` Added
- of property `runsWhenDisabled` the set to decorator `ignoringDisable(boolean)` Added command a
- decorators `handleInterrupt(Runnable)` and `finallyDo(BooleanConsumer)` Added
- Commands in factories command static Added
- `ComputerVisionUtil` Added
- framework Trigger existing the of expansion an ,`BooleanEvent` and `EventLoop` Added commandbasednon- encompassing
- classes HID the to methods factory returning-`BooleanEvent` Added
- with etc.) `CommandXboxController`( classes HID of versions basedcommand- Added methods factory returning-`Trigger`
- controllers unicycle LTV Added
- `fromRotations()` radians; and rotations uses that method factory `Rotation2d` Added `fromRadians()` and
- PID heading on input continuous uses now `HolonomicDriveController`
- classes geometry 3d various Added
  - `Pose3d`
  - `Quaternion`
  - `Rotation3d`
  - `Transform3d`
  - `Translation3d`
  - `Twist3d`
  - `CoordinateAxis`
  - `CoordinateSystem`
- classes sim pneumatic various Added
  - `CTREPCMSim`

  - `DoubleSolenoidSim`
  - `REVPHSim`
  - `SolenoidSim`
- `Translation2d` to `getAngle()` Added
- instead `isEnabled` Use .`Compressor.enable()` Deprecated
- methods triangle `PS4Controller` missing Add
- mode test in control actuator LW disable to method Add
- commands of representation `Sendable` Enhanced
- `Commands` to moved been have factories static the ;`CommandGroupBase` Deprecated
- and constructor *Supplier<Command>* SelectCommand's Refactor ProxyCommand into ProxyScheduleCommand
- commands default for check *isFinished* Remove
- commands default remove to method Add
- class `Button` and consistent be to renamed were methods `Button` and `Trigger` deprecated.
  - be should it as terminology, `False`/`True` use to changed are bindings '`sTrigger` brevity, for variants; `False` and `True` both has type binding Each unambiguous. here: listed are variants `True` the only
    - edge. rising on schedule ):`whenPressed` and `whenActive` (replaces `onTrue`
    - on cancel edge, rising on schedule ):`whileActiveOnce` (replaces `whileTrue` edge. falling
    - if schedule edge, rising on ):`toggleWhenActive` (replaces `toggleOnTrue` scheduled. if cancel and unscheduled
  - deprecated: completely are types binding Two
    - as described better is which case use niche fairly a is this :`cancelWhenActive` the for condition end an as )`Trigger.rising()`( edge rising trigger's the having ).`Command.until()` (using command
    - behavior opno- the on relied this common, however :`whileActiveContinuously` to way correct more The command. scheduledalready- an scheduling of `Command.` using is edge falling the before ends it if command the repeat the if is difference only the – `RunCommand` a or `RepeatCommand`/`repeatedly` commands two in result to likely more is that but interrupted, is command Manually behavior. desired the achieve than other each canceling perpetually is `whileActiveContinuously` like binding schedulingblindly- a implementing intuitive. be not might though possible, still
- times. compile C++ improve to instantiations template common Precompile

## Changes Breaking

must Users framework. basedcommand- old the includes longer no release 2023 The :□□□□
*framework basedcommand-* new the use to code existing refactor

axis UpWest-North- use to classes `MecanumDrive` and `DifferentialDrive` Updated :□□□□
inverted be to need will turning) (i.e. axisZ- The WPILib. of rest the match to conventions
behavior. old the restore to

- classes Shuffleboard changes. breaking several introduced (NT4) 4.0 NetworkTables provides `GenericEntry` as ;`NetworkTableEntry` of instead `GenericEntry` return now should name class the of replacement textual simple a methods, same the all nearly for *guide migration NT4* the See removed. been have setters `force` the Also, suffice. information. more
- `StateSpaceUtil` from `MakeMatrix()` deprecated Removed
- class `KilloughDrive` deprecated Removed
- MecanumDrive of detail implementation an was which ,`Vector2d` Removed or )`edu.wpi.first.math.Vector`( `><N2Vector` use Java, In KilloughDrive. and C++, In instead. )`edu.wpi.first.math.geometry.Translation2d`( `Translation2d` `<frc/geometry/` from `Translation2d` or `><Eigen/Core` from `Eigen::Vector2d` use instead. `>Translation2d.h`
- Use classes. `SpeedControllerGroup` and `SpeedController` deprecated Removed instead MotorControllerGroup and MotorController
- class `MatrixUtils` deprecated Removed
- classes mentioned above used that overloads deprecated various Removed
- available are functions Static functions. `getInstance()` deprecated various Removed instead
- `SimDevice` in functions deprecated various Removed
- property enum an be to `interruptible` command Refactored flag boolean a than rather object command the of )`getInterruptionBehavior()`( be can decorator `withInterruptBehavior(InterruptBehavior)` the scheduling; when property this set to used
- overridden be cannot groups command of methods lifecycle Command
- value onlymove- new a – `CommandPtr` return to changed Decorators Command only] [C++ commands holding for type
- distances wheel use now `SwerveDrivePoseEstimator` and `SwerveDriveOdometry` module's swerve a represent to `SwerveModulePosition` Use speeds; wheel of instead driven. distance and angle
- distances wheel the in take now `SwerveDrivePoseEstimator` and `SwerveDriveOdometry` parameter. variadic a as than rather array an in
- distances wheel use now `MecanumDrivePoseEstimator` and `MecanumDriveOdometry` wheel the represent to `MecanumDriveWheelPositions` Use speeds; wheel of instead distances.

- classes estimation pose and odometry all on methods `resetPosition` and Constructors parameters. distance wheel mandatory have now
- rearranged been have arguments function and constructor estimator pose and Odometry documentation API the consult should Users implementations. between consistent be to accordingly. calls method the update and using they’re class particular the for
- methods C++20 of versions wpi Removed
  - )><`numbers` (include `wpi::numbers` of instead `std::numbers` Use
  - )><`span` (include `wpi::span` of instead `std::span` Use
- C++. in `ElevatorFeedforward` from argument template Removed

### סימולציה 9.2.4

- values decimal NetworkTables for setting precision Added
- elements GUI for support docking Added
- plots in axis Y secondary Save

### Shuffleboard 9.2.5

- widget bar number to option orientation vertical Added
- populating auto not widget Field2d Fixed
- channels 24 support to Widget PowerDistribution Update
- image field Up Charged 2023 Added
- and (kF PIDController by supported longer no features remove to widget PID Update enable)

### SmartDashboard 9.2.6

Macs. (Arm64) Silicon Apple on supported not is SmartDashboard **:□□□□**

- channels 24 support to Widget PowerDistribution Update
- plots all clear to option Add
- and (kF PIDController by supported longer no features remove to widget PID Update enable)

### Glass 9.2.7

- values decimal NetworkTables for setting precision Added
- elements GUI for support docking Added
- plots in axis Y secondary Save

### PathWeaver 9.2.8

- image field Up Charged 2023 Added

### GradleRIO 9.2.9

- 7.5.1 Gradle to Upgrade
- during off powered roboRIO if damaged get could scripts upstart- where issue Fixed deploy

### cscore 9.2.10

- 4.6.0 opencv to Update
- module ArUco Added

### OutlineViewer 9.2.11

- values decimal NetworkTables for setting precision Added

### Installer One in All WPILib 9.2.12

- supported now are Macs (Arm64) Silicon Apple
- 1.74 Code VS to Update
- 7 .NET use to Update
- issues known and changelog to links Add

### Code Studio Visual הרחבת 9.2.13

- 5.8.2 JUnit to templates Update
- dialog versions project from button copy Add
- projects Romi importing Allow

### RobotBuilder 9.2.14

---

been has install RobotBuilder legacy the based,command- old of removal the With :□□□□ removed.

---

2022 from files save yaml import not will Robotbuilder changes, file project to Due :□□□□□□ earlier. or

- parameters ><`doublestd::function` and `DoubleSupplier` for support Add
- SmartDashboard to Buttons Joystick to tied commands put to option Add
- Controller PS4 Add
- Number Team Validate

### SysID 9.2.15

- support 2 Pigeon Added
- 0 of delay measurement a specify now can User
- rotations per units overriding not option `Units Override` Fixed

### Romi 9.2.16

- changes major No

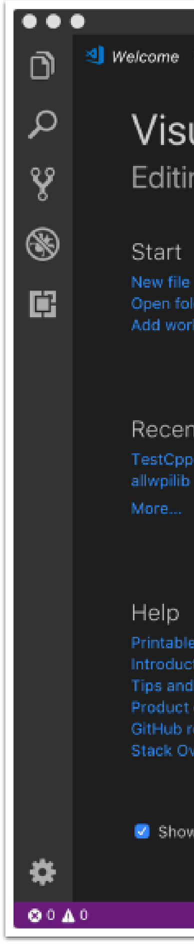
# 01

[redacted]

## WPILib והרחבת Code Studio Visual יסודות 10.1

FRC. in development Java and C++ for IDE supported the is Code Studio Visual Microsoft’s WPILib the and Code Studio Visual using of basics the of some introduces article This extension.

### 10.1.1 מסך הפתיחה



[illegible] Visual Studio Code [illegible], [illegible]. [illegible] [illegible]-Visual Studio Code, [illegible] [illegible]-IDE [illegible].

[illegible] WPILib [illegible]. [illegible] WPILib ([illegible]).

### 10.1.2 ממשק משתמש

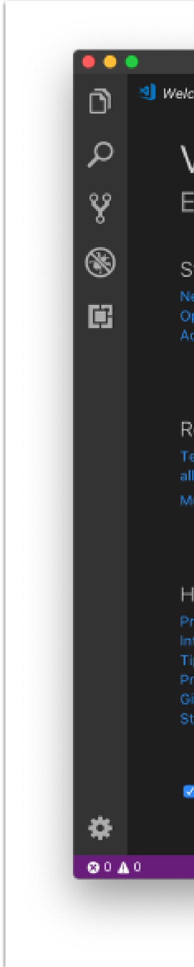
[illegible] .[illegible] Visual-[illegible] FRC. [illegible] Code Studio

### 10.1.3 לוח הפקודות

Studio Visual-[illegible] [illegible] "View" [illegible] WPILib). [illegible] Code [illegible] macOS)-[illegible] `Cmd+Shift+P`( `Ctrl+Shift+P` [illegible] .[illegible]

[illegible] ,[illegible] "wpilib" [illegible] WPILib. [illegible]

### 10.1.4 הרחבת WPILib



[illegible] FRC® [illegible] WPILib [illegible] roboRIO-[illegible] .[illegible] WPILib [illegible] ,[illegible] :[illegible]

- [illegible] [illegible] [illegible]WPILib[illegible] [illegible] [illegible] [illegible]
- [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] WPILib [illegible] [illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] WPILib

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[illegible] Code VS [illegible] [illegible] [illegible] IntelliCode Studio Visual [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] **:[illegible]**
IntelliSense. [illegible] [illegible] [illegible] [illegible] [illegible] FRC

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## 10.2 Code Studio Visual-ב WPILib פקודות

[illegible] [illegible] Code VS [illegible] WPILib [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] .[illegible]

[illegible] [illegible] [illegible] [illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible] Ctrl+Shift+P [illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible]

- GradleRIO [illegible] [illegible] [illegible] [illegible] [illegible] - **Code Robot Build WPILib:**
- [illegible] [illegible] [illegible] [illegible] - **project new a Create WPILib:**
- Intellisense C++ the to update an Force - **Intellisense C++ Refresh C++: WPILib** configuration.
- for use to toolchain the Select - **Toolchain C++ Current Select C++: WPILib** current the clicking as same the is This vs...). roboRIO vs. desktop (i.e. Intellisense bar. status right bottom the in mode
- Intellisense Switch - **Types Binary Intellisense C++ Enabled Select C++: WPILib** executable and shared, static, between
- [illegible] WPILib [illegible] [illegible] [illegible] [illegible] - **tasks running currently Cancel WPILib:** .[illegible]
- [illegible] [illegible] [illegible] [illegible] [illegible] - **Setting Deploy On Save Auto Change WPILib:** .[illegible] [illegible] [illegible] [illegible] Deploy. [illegible] [illegible]
- RioLog whether Change - **Setting Deploy on RioLog Start Auto Change WPILib:** Enabled. to defaults This deploy. on automatically starts
- robot building whether Change - **Setting Enabled Support Desktop Change WPILib:** defaults This purposes. simulation and test for this Enable enabled. is Desktop on code off. Support Desktop to
- Java. [illegible] C++ [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] - **Setting Language Change WPILib:**
- **Setting Mode Offline in Deploy/Debug Except Commands Run Change WPILib:** then other commands for Mode Online in running is GradleRIO whether Change - Defaults online). from dependencies pull automatically to attempt (will deploy/debug mode). (online enabled to
- Change - **Setting Mode Offline in Command Deploy/Debug Run Change WPILib:** to attempt (will deploy/debug for Mode Online in running is GradleRIO whether mode). (offline disabled to Defaults online). from dependencies pull automatically

- whether Change - **Setting Extension Simulate Default Select Change WPILib:** `build.` in defined extensions simulation (all default by enabled are extensions simulation enabled) be will `gradle`
- on tests skip to whether Change - **Setting Deploy On Tests Skip Change WPILib:** deploy) on run are (tests disabled to Defaults deploy.
- robot stop to whether Change - **Setting Entry on Simulation Stop Change WPILib:** entry). on stop (don't disabled to Defaults simulation. running when entry on code
- **Debugger Windows as Store) (From Preview WinDbg Use Change WPILib:** (from Preview WinDbg or debugger Code VS the use to whether Change - **Setting** Store). Windows
- GradleRIO WPILib the to update an for Check - **Updates WPILib for Check WPILib:** or tools, extension, Code Studio Visual the update not does This project. the for version *installer wpilib offline* the use to recommended strongly are Users dependencies. offline
- mode debug in roboRIO to code robot deploy and Build - **Code Robot Debug WPILib:** debugging start and
- roboRIO.-[illegible] [illegible] Deploy [illegible] [illegible] - **Code Robot Deploy WPILib:**
- on project code robot current the builds This - **Code Robot Sim Hardware WPILib:** comupter the to attached hardware using simulation in running it starts and PC your support. vendor Requires simulation. software pure then rather
- to wizard a Open - **Project Gradle 2020/2021/2022 WPILib a Import WPILib:** 2022.2020- from project Gradle Code VS existing a from project new a create you help *project gradle importing* at is documentation Further
- (e.g. tools Java WPILib the Install - **GradleRIO from tools Install WPILib:** offline the by default by done is this that Note etc.). Shuffleboard, SmartDashboard, installer
- [illegible] [illegible] [illegible] [illegible] [illegible]/[illegible] - **Libraries Vendor Manage WPILib:**
- C++ or Javadocs WPILib the either Opens - **Documentation API Open WPILib:** documentation Doxygen
- (Project information project with widget a Opens - **Information Project Open WPILib:** etc.) version, extension version,
- WPILib a open to used is command This - **Palette Command WPILib Open WPILib:** )`WPILib` typing and `Ctrl+Shift+P` hitting of (equivalent Palette Command
- WPILib the to links which page simple a opens This - **Help WPILib Open WPILib:** site) (this documentation
- current the on flag the clear will This - **Flag Updates WPILib for Ask Reset WPILib:** you if version WPILib latest the to project a update to promptre- to you allowing project, update. not to chose previously
- the in command arbitrary an run you lets This - **Gradle in command a Run WPILib:** environment command GradleRIO
- [illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible] [illegible] - **Number Team Set WPILib:** .[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
- variable Home Java Code VS the Set - **Home FRC to Home Java Code VS Set WPILib:** using not if needed is This extension. FRC the by discovered Home Java the to point to WPILib the with sync in are settings intellisense the sure make to installer offline the settings. build

- stores extension WPILib the where folder the Shows - **Folder Log Show WPILib:** the to issue extension an debugging/reporting when useful be may This logs. internal developers WPILib
- PC your on project code robot current the builds This - **Code Robot Simulate WPILib:** Enabled. to set be to Support Desktop requires This simulation. in running it starts and
- from output console view to used display RioLog the starts This - **RioLog Start WPILib:** program robot a
- SmartDashboard, (e.g. tools WPILib launch to you allows This - **Tool Start WPILib:** Code VS inside from etc.) Shuffleboard,
- any runs and project code robot current the builds This - **Code Robot Test WPILib:** Enabled. to set be to Support Desktop requires This tests. created

## Program Robot a Creating 10.3

with comes WPILib program. robot a create to ready we're installed, is everything Once for recommended highly is templates these of Use programs. robot for templates several scratch. from code robot own their write to free are users advanced however, users; new

### Class Base a Choosing 10.3.1

choose first must users templates, program robot WPILib the of one using project a start To `Robot` primary their create to classes base these subclass Users robot. their for class base a available choices three are There program. robot the of flow main the controls which class, class: base the for

#### TimedRobot

C++ - Java Documentation:

C++ - Java Source:

the of control provides It users. most for recommended class base the is class `TimedRobot` The are which methods, `exit()` and ,`periodic()` ,`init()` of collection a through program robot these During teleoperated). or autonomous (e.g. states robot specific during WPILib by called For receives. it data the to according acts and device input each polls typically code your calls, joystick the of state and joystick the of position the determine typically would you instance, of example an provides also class `TimedRobot` The accordingly. act and call each on buttons C++ /Java( SendableChooser through routines autonomous retrieving

---

comments informative some removes that available is template *Skeleton TimedRobot* A :□□□□ .*TimedRobot* with familiar already you're if this use can You example. autonomous the and .*Skeleton TimedRobot* of is below shown example The

---

Java

```java
import edu.wpi.first.wpilibj.TimedRobot;

/**
 * The VM is configured to automatically run this class, and to call the functions corresponding to
 * each mode, as described in the TimedRobot documentation. If you change the name of this class or
 * the package after creating this project, you must also update the build.gradle file in the
 * project.
 */
public class Robot extends TimedRobot {
  /**
   * This function is run when the robot is first started up and should be used for any
   * initialization code.
   */
  @Override
  public void robotInit() {}

  @Override
  public void robotPeriodic() {}

  @Override
  public void autonomousInit() {}

  @Override
  public void autonomousPeriodic() {}

  @Override
  public void teleopInit() {}

  @Override
  public void teleopPeriodic() {}

  @Override
  public void disabledInit() {}

  @Override
  public void disabledPeriodic() {}

  @Override
  public void testInit() {}

  @Override
  public void testPeriodic() {}

  @Override
  public void simulationInit() {}

  @Override
  public void simulationPeriodic() {}
}
```

C++

```cpp
#include "Robot.h"
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                                         }{ ()Robot::RobotInit void
                                     }{ ()Robot::RobotPeriodic void

                                    }{ ()Robot::AutonomousInit void
                                }{ ()Robot::AutonomousPeriodic void

                                        }{ ()Robot::TeleopInit void
                                    }{ ()Robot::TeleopPeriodic void

                                      }{ ()Robot::DisabledInit void
                                  }{ ()Robot::DisabledPeriodic void

                                          }{ ()Robot::TestInit void
                                      }{ ()Robot::TestPeriodic void

                                    }{ ()Robot::SimulationInit void
                                }{ ()Robot::SimulationPeriodic void

                                         RUNNING_FRC_TESTS ifndef#
                                                      { ()main int
                                 ();>Robot<StartRobot::frc return
                                                                 }
                                                            endif#
```

the calling by changed be can This default. by ms 20 every called are methods Periodic rate. update desired new the with constructor superclass

> overruns). (loop behavior unintended some cause can rate robot your Changing :□□□□ rate. custom a at methods schedule to Notifiers use also can Teams

Java

```
                                                   { ()Robot public
        ms. 30 every called be now will methods Periodic // );0.03(super
                                                                  }
```

C++

```
                                     }{ ms)_30TimedRobot(::frc : Robot()
```

### RobotBase

C++ - Java Documentation:

C++ - Java Source:

not generally is and offered, classbase- minimal most the is class `RobotBase` The must everything user; the for handled is flow control robot No use. direct for recommended default by template The method. `startCompetition()` the inside scratch from written be etc). auto, (teleop, modes operation different the process to how showcases

`startCompetition()` blank a offers that available is template `Skeleton RobotBase` A :□□□□

method.

### Robot Command

by `Robot Timed` a of functionality basic the to adds framework `Robot Command` The events These events. into data input raw the converting and inputs polling automatically a when instance, For triggered. is event the when executed is which code, user to tied are is it and called automatically is button that of pressing the to tied code pressed, is button `Robot Command` The directly. button that of state the of track keep or poll to necessary not but behavior, complex with code readto-easy- compact write to easier it makes framework understand to order in programmer a from investment time frontup- additional an requires works. framework Robot Command the how

.*Tutorial Programming BasedCommand-* the see should `Robot Command` using Teams

### Romi

template. `Bot Command - Romi` or `Timed - Romi` the use should *Romi* a using Teams

### Timed - Romi

an exposes that class `RomiDrivetrain` a provides template `Timed - Romi` The to user the to up It’s method. `zaxisRotate) double xaxisSpeed, arcadeDrive(double` function. arcadeDrive this feed

encoders. onboard Romi’s the resetting and retrieving for functions provides also class This

### Bot Command - Romi

an exposes that subsystem `RomiDrivetrain` a provides template `Bot Command - Romi` The feed to user the to up It’s method. `zaxisRotate) double xaxisSpeed, arcadeDrive(double` function. arcadeDrive this

onboard Romi’s the resetting and retrieving for functions provides also subsystem This encoders.

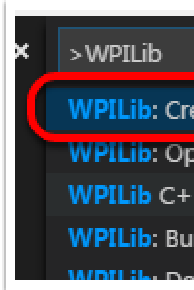
### Class Base a Using Not

`main()` a in program their write simply and entirely class base a omit can users desired, If not should users - discouraged *highly* is This program. other any for would they as method, wish who those for supported is it but - code robot their writing when wheel“ the ”reinvent to have absolute control over their program flow.

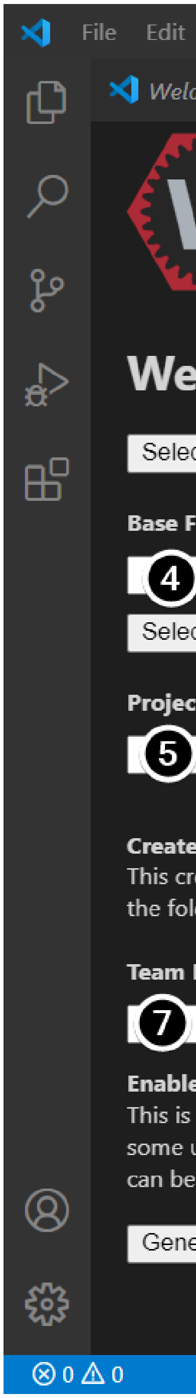
> are they unless program robot a of method `main()` the modify *not* should Users :□□□□□ doing. are they what of sure absolutely

### 10.3.2 יצירת פרויקט WPILib חדש

Visual the up Bring project. robot new our create can we class, base a on decided we've Once prompt. the into ”WPILib“ type Then, .`Ctrl+Shift+P` with palette command Code Studio specificWPILib- of list the up bring will this ”WPILib“, with start commands WPILib all Since command: *project new a Create* the select Now, commands. Code VS



Window:“ Creator Project ”New the up bring will This



below: explained are Window Creator Project New the of elements The

project, example an be can This create. to wish we project of kind The :**Type Project** 1.
the of each for exist Templates WPILib. by provided templates project the of one or
which projects, *basedCommand-* for exists template a Additionally, classes. base robot
this - features additional of number a include but class base `TimedRobot` the on built are
teams. new for recommended highly is program robot of type

project. this for used be will that Java) or (C++ language the is This :**Language** 2.

be will that template of type the specifies this project, template a is this If :**Folder Base** 3.

used.

located. be will project robot the which in folder the determines This :**Location Project** 4.

the that name the specifies also This project. robot the of name The :**Name Project** 5.
checked. is box Folder New Create the if given be will folder project

project the hold to created be will folder new a checked, is this If :**Folder New a Create** 6.
located be will project the checked, *not* is it If folder. specifiedpreviously- the within
not is folder the if thrown be will error An folder. specifiedpreviously- the in directly
checked. not is this and empty

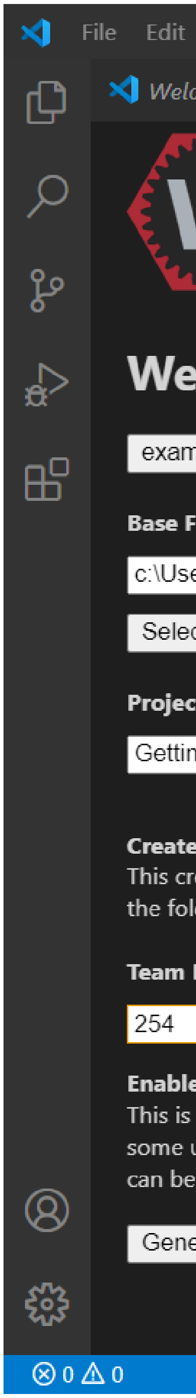
□□□□□□□ □□□□□□□ □□□□□□ □□□□□ □□□□□ ,□□□□□□□ □□□□ □□□□□□ □□□□ :**Number Team** 7.
.□□□□ □□ Deploying □□□□□ □□□ □□□□□□

supports WPILib While simulation. and test unit Enables :**Support Desktop Enable** 8.
then desktop, support not do libraries If not. may libraries software party third this,
testing unit unless unchecked left be should It crash. may or compile not may code your
it. support libraries all and needed is simulation or

will project robot the and Project“ ”Generate click configured, been have above the all Once
created. be

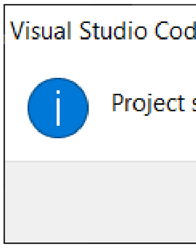
the of corner handright- bottom the in appear will generation project in errors Any **:□□□□**
screen.

below. shown is selected are options all after example An

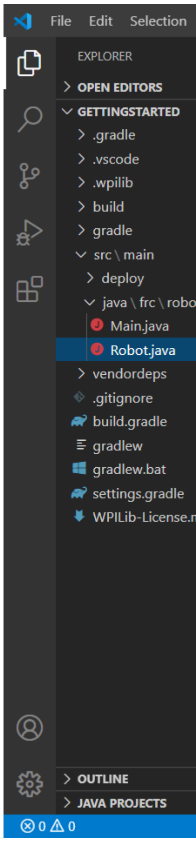

File
Edit
Welc
We
exam
Base F
c:\Use
Selec
Projec
Gettin
Create
This cr
the fol
Team I
254
Enable
This is
some u
can be
Gene
0
0

### פתיחת הפרויקט החדש 10.3.3

project the opening of option the give will Code VS project, your creating successfully After just (or `Ctrl+O` then `Ctrl+K` typing by later or now that do to choose can We below. shown as project. our saved we where folder the select and macOS) on `Command+O`

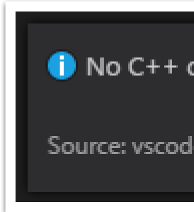


will file the on clicking Double left. the on hierarchy project the see will we opened Once editor. the in file that open



### 10.3.4 קונפיגורציית C++ (עבור C++ בלבד)

project, a open we Whenever IntelliSense. up set to step more one is there projects, C++ For Click configurations. C++ refresh to asking corner right bottom the in uppop- a get should we IntelliSense. up set to ”Yes“



No C++ c

Source: vscod

## 10.4 ספריות צד שלישי

need likely most will sensors advanced or controllers motor PWMnon- using are that Teams dependencies. vendor external install to

### 10.4.1 Dependencies? Vendor Are What

*software* their add to others and REV, CTRE, as such vendors for way a is dependency vendor A devices. other and controllers motor with interface can library This projects. robot to *library* complex more to access have and CAN via devices their with interact can teams way, This control. PWM traditional than features depthin- and

### 10.4.2 Dependencies Vendor Managing

its have can project robot each (so basis projectper- a on installed are dependencies Vendor ”offline“. or ”online“ installed be can dependencies Vendor dependencies). vendor of set own while internet, the over dependencies the downloading by done is functionality ”online“ The installer. specificvendor- a by provided typically is offline

reconnect to sure make mode, ”online“ the via dependency vendor a installing If **:□□□□□** will cache the otherwise days 30 every about rebuild and internet the to computer the install. library downloaded the deleting completely clear,

offline the because available, when installers offline their using recommend Vendors **:□□□□** working when useful extremely are that programs additional with bundled typically is installer devices. their with

## Work? It Does How

### Java/C++ - Work? It Does How

`~/` to system your on installed is library vendor the describing file *JSON* a C++, and Java For Windows). on `Public\Users\C:` is ~ and year the is YYYY (where `wpilib/YYYY/vendordeps` location online an from fetched be can file the or installer offline an by done be either can This the to add to Code VS from used then is file This Code. Studio Visual in item menu the using projectper- a on managed is information library Vendor project. individual each to library vendor given a of version consistent a to pointing always is project a that sure make to basis `\wpilib\Public\Users\C:` at cache Maven the in placed are themselves libraries The library. or (recommended) installer offline an with here copy local a place can Vendors `.maven\YYYY` a from library the fetch to build initial an for internet the to connected be to users require location. Maven remote

C++, (Java, components multiple with libraries complex of specification allows file JSON This choose that Vendors simulation. to related complexities some handle helps also and etc.) JNI, VS within from updates for check to users enable also JSON the in URL remote a provide to Code.

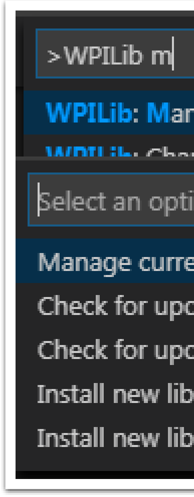
### LabVIEW - Work? It Does How

palettes various on items *Party Third* new few a be might there teams, LabVIEW For and ,*Motor CAN* labeled *Control Motor* >- *Actuators* in one ,*Actuators* in one (specifically, `\Instruments National\Files Program\C:` in folders to correspond These ).*Sensors* in one `Party Third\WPI\Robotics Rock\vi.lib\2020 LabVIEW`

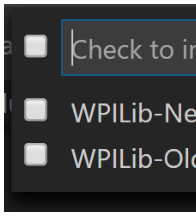
vendor the from VIs the download LabVIEW, for libraries party third install to order In respective the into VIs party third the drop and drag Then installer). of sort some via (typically folder mentioned above just like any other VI.

## Libraries Installing

### Code VS



and `Ctrl+Shift+P` press installer, offline an by installed been has that library vendor a add To Palette Command WPILib the open to right top the in icon WPILib the on click or WPILib type option the Select menu. the from it select then ,*Libraries Vendor Manage* typing begin and .*(offline) libraries new Install* to



click then each, to next box the checking by project the to add to libraries desired the Select library the adding project, the in folder `vendordeps` the to copied be will file JSON The .*OK* project. the to dependency a as

or WPILib type and `Ctrl+Shift+P` press mode, online in library vendor a install to order In begin and Palette Command WPILib the open to right top the in icon WPILib the on click *new Install* on click then and menu, the in it select and *Libraries Vendor Manage* typing URL. JSON vendor the paste + copy and instead *(online) libraries*

### חיפוש עדכונים (Offline)

offline, installed when even basis, projectper- a on managed version are dependencies Since each for *(offline) updates for Check* select and *Libraries Vendor Manage* to need will you update. to wish you project

### חיפוש עדכונים (Online)

a If location. update online an is populate optionally may vendors that file JSON the of Part check will *(online) updates for Check* running specified, location appropriate an has library location. remote the from available is library the of version newer a if

### הסרת תלות בספריה

the from *Libraries Current Manage* select project, a from dependency library a remove To .*OK* click and uninstall to libraries any for box the check menu, *Libraries Vendor Manage* project. the from dependencies as removed be will libraries These

### LineCommand-

the through done be also can URL vendor the from dependency library vendor a Adding enter and root, project the at instance linecommand- a Open task. gradle a via linecommand- the add will This URL. JSON vendor the is `><url` where `><urlurl=-- vendordep gradlew` libraries Vendor project. the of folder `vendordeps` the to file JSON dependency library vendor way. same the updated be can

folder. `wpilib` user the from JSONs vendordep fetch also can task gradle `vendordep` The `vendordep gradlew` example, For URL. file the as `FRCLOCAL/Filename.json` pass so, do To basedcommand- the for JSON the fetch will `url=FRCLOCAL/WPILibNewCommands.json--` framework.

### 10.4.3 ספריות

offline installers, online offer they whether see to site vendor the visit to links these Click *(online) Libraries New Install >- Code VS* the to in plug to are below URLs both. or installers, feature.

**2023 CTRE Phoenix Framework** - **Contains, CANcoder, CANifier, CANdle, Pigeon IMU, Pigeon 2.0, Talon FX, Talon SRX, and Victor SPX Libraries and Phoenix Tuner program for configuring CTRE CAN devices**

electronics.com/release/com/ctre/phoenix/-https://maven.ctr (v5): Phoenix
latest.json-frc2023-Phoenix5

electronics.com/release/com/ctre/-https://maven.ctr (Pro): Phoenix
latest.json-frc2023-phoenixpro/PhoenixPro

electronics.com/release/com/ctre/-https://maven.ctr v5): and (Pro Phoenix
latest.json-frc2023-phoenixpro/PhoenixProAnd5

---

□□□□: the use years, previous as library Phoenix same the of version 2023 the get To Pro. Phoenix using you're if links json other the of one Use v5). (Phoenix above link first

---

□□□□□: you If project. a within links vendordep Phoenix above the of **ONE** use Only option. third the use project, same the in Pro Phoenix and v5 Phoenix both need

**Playing With Fusion Driver** - **Library for all PWF devices including the Venom motor/controller**
https://www.playingwithfusion.com/frc/playingwithfusion2023.json

**Kauai Labs** - **Libraries for NavX- MXP,NavX- Micro,and Sensor Fusion**
https://dev.studica.com/releases/2023/NavX.json

**REV Robotics REVLib** - **Library for all REV devices including SPARK MAX and Color Sensor V3**
2023.json-metadata.revrobotics.com/REVLib-https://software

#### ספריות מהקהילה

**PhotonVision** - **Library for PhotonVision CV software**
https://maven.photonvision.org/repository/internal/org/photonvision/
1.0.json-json-json/1.0/PhotonLib-PhotonLib

**PathPlanner** - **Library for PathPlanner**
https://3015rangerrobotics.github.io/pathplannerlib/PathplannerLib.json

### Libraries Command WPILib

the by installed is It library. vendor a into split been has library command *new* WPILib The link: online following the with installed be also may It installation. offline for installer WPILib

Library Command New

**Vendor Manage**-[illegible] **Libraries Current Manage** [illegible] ,[illegible] **Libraries**, [illegible]. [illegible].

### Library Romi

the of part a are that classes helper several contain to created been has Library Romi A example. `RomiReference`

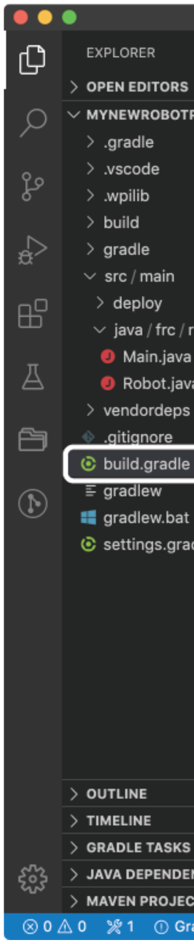
.Vendordep Romi

## 10.5 בנייה והורדה של קוד רובוט

Since roboRIO. the on run to order in deployed and (”built“) compiled be must projects Robot compilation.“”cross- as known is this controller, robot the on natively compiled not is code the

of: one do project, robot a deploy and build To

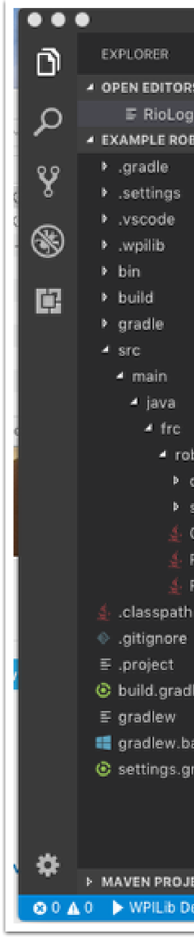
1. Code“ Robot ”Build enter/select and Palette Command the Open
2. Code VS the of corner right top the in ellipses the by indicated menu shortcut the Open Code“ Robot ”Build select and window
3. Code“ Robot ”Build select and hierarchy project the in file build.gradle the on clickRight-



from locations three the of any from Code“ Robot ”Deploy selecting by code robot Deploy the to program robot the deploy and necessary) (if build will That instructions. previous the roboRIO.

> the Interrupting code. robot deploying while robot the off powering Avoid **:□□□□□** from code your prevent and filesystem roboRIO the corrupt can process deployment .*imagedre-* is roboRIO the until working

the with open will RioLog the and (1) message Successful“ ”Build a see will we successful, If (2). runs it as program robot the from output console



## Output Console Viewing 10.6

NetConsole. a implements roboRIO the programs based text of output console the viewing For Console The roboRIO: the from output NetConsole the view to ways main two are There Viewer in the FRC Driver Station and the Riolog plugin in VS Code.

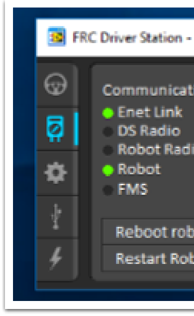
---

interact to want you If output. program for only is NetConsole the roboRIO, the On :▯▯▯▯ with the system console you will need to use SSH or the Serial console.

---

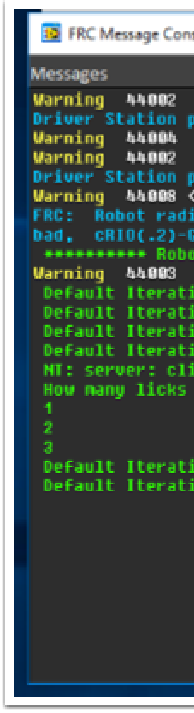
## Viewer Console 10.6.1

### Viewer Console the Opening



the at gear the on click Then, Station. Driver FRC® the open first Viewer, Console open To Console“. ”View select and (1) window viewer message the of top

### Window Viewer Console



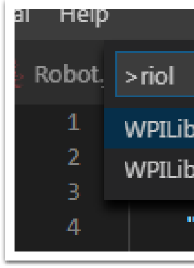
```
Warning  44002
Driver Station
Warning  44004
Warning  44002
Driver Station
Warning  44008 <
FRC:  Robot radi
bad,  cRIO(.2)-
 ********** Robo
Warning  44003
 Default Iterati
 Default Iterati
 Default Iterati
 Default Iterati
 NT: server: cli
 How many licks
 1
 2
 3
 Default Iterati
 Default Iterati
```

gear The green. in program robot our from output the displays window Viewer Console The displayed. messages of level the set and window the clear can right top the in

## Plugin Code VS Riolog 10.6.2

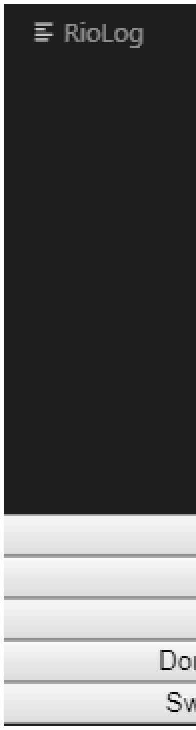
VS in output NetConsole the view to used be can that view Code VS a is plugin Riolog The FRC1511). Stoeckl, Manuel version: Eclipse original the for (credit Code

### View RioLog the Opening



To deploy. roboRIO each of end the at automatically open will view RioLog the default, By start and palette command the open to `Ctrl+Shift+P` press manually, view RioLog the launch option. RioLog Start WPILib: the select then ”RioLog“, typing

### Window Riolog



for controls of number a contains Riolog The pane. top the in appear should view RioLog The console: the manipulating

the background, the In display. the pause/resume will This - **Display Pause/Resume** •
clicked. is button resume the when displayed be will and received be still will packets new

- When packets. new accept to whether toggle will This - **Incoming Discard/Accept** be will received packets all and paused be will display the discarded being are packets packets. receiving resume will again button the Clicking discarded.
- display. the of contents current the clear will This - **Clear**
- print as categorized messages hides or shows This - **Prints Show/Show Don't** statements
- files log saved for viewer to switches This - **Viewer to Switch**
- warnings as categorized messages hides or shows This - **Warnings Show/Show Don't**
- stream console the to reconnects or disconnects This - **Disconnect/Reconnect**
- the in messages on timestamps hides or Shows - **Timestamps Show Show/Don't** window
- with later open or view and save can you file a into contents log the Copies - **Log Save** above) Viewer to Switch (see viewer RioLog the
- console the to connect to roboRIO the of number team the Sets - **Number Team Set** process deploy the by launched is RioLog if automatically set on, stream

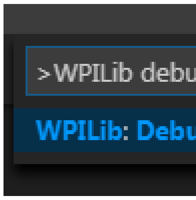
## Program Robot a Debugging 10.7

occurs, this When behave. to it expect we way the in behave not will program a Inevitably, can we that so doing, is it what doing is program the why out figure to necessary becomes it a called is behavior program undesired an Such instead. do, to it want we what do it make ”debugging.“ called is process this and ”bug,“

in assist to order in variables monitor and flow program control to used tool a is debugger A FRC® an for session debug a up set to how describe will section This program. a debugging program. robot

to time know/have not do but programs their debug to need who users beginning For :□□□□ the printing by simply program a debug to possible often is it debugger, a use to how learn students that recommended strongly is it However, console. the to state program relevant debugger. a use to learn eventually

### Debugger the Running 10.7.1



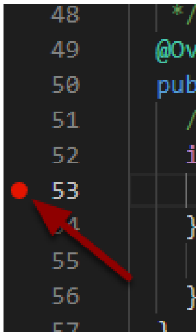
Command the open to *Item Menu WPILib* the on click or `WPILib` type and `Ctrl+Shift+P` Press item menu Code Robot Debug the select and Debug Type populated.pre- WPILib with palette debugging. begin and roboRIO the to download will code The debugging. start to

## Breakpoints 10.7.2

so execution program the pause will debugger the which at code of line a is ”breakpoint“ A as debugging, while useful extremely is This state. program the examine can user the that determine to code problematic in points specific at program the pause to user the allows it behavior. expected the from deviating is program the exactly where

encounters. it breakpoint first the at pause automatically will debugger The

### Breakpoint a Setting



a set to number) line the of left the (to window code source the of margin left the in Click on set been has breakpoint the indicates circle red small A program: user your in breakpoint line. corresponding the

## Statements Print with Debugging 10.7.3

them view and code your in statements print use to is program your debug to way Another be should statements Print Station. Driver the or Code Studio Visual in RioLog the using They quantities. high in used when especially efficient very not are they as care with added overruns. loop cause can they as competition for removed be should

Java

```
);"example"(print.outSystem.
```

C++

```
;"n\example" << outs()::wpi
```

## NetworkTables with Debugging 10.7.4

computer. debugging your with information robot share to used be can *NetworkTables* advantage One .*OutlineViewer* or Dashboard favorite your with viewed be can *NetworkTables* data. the analyze graphically to used be can *Shuffleboard* like tools that is NetworkTables of for interface operator an provide later to data same with used be then can tools same These drivers. your

### More Learn 10.7.5

- .link this see Code VS with debugging about more learn To
- and understand you help will article Code VS this in mentioned features the of Some very be can feature bulb) light (yellow Fix Quick The code. your with problems diagnose import. to what including problems of variety a with helpful
- Testing. Unit do to is issues many so debug to having prevent to ways best the of One
- do to having prevent to way great a also is *Simulation* in works robot your that Verifying robot. actual the on debugging complex

## Project Gradle a Importing 10.8

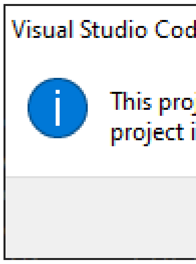
years previous a for files build the update to necessary is it project, the in changes to Due vendor year’s last since again, libraries vendor import to necessary also is It project. Gradle projects. year’s this with compatible be to updated be must libraries

### Import Automatic 10.8.1

year’s current the into projects gradle years previous import to teams for easy it make To Code. VS into projects years previous importing for wizard a includes WPILib framework, In Code. VS into project the load and components gradle necessary the generate will This supported. not are upgrades place

new a to directory current the from files source project your copies process import The :□□□□ the for code the updates it Additionally, files. gradle the regenerates completely and directory you ,`build.gradle` the to updates standardnon- made you If 2022. in made changes package supported. not are upgrades place in reason, this For again. changes those make to need will must libraries vendor year’s last since again, libraries vendor import to necessary also is It projects. year’s this with compatible be to updated be

#### Wizard Import the Launching

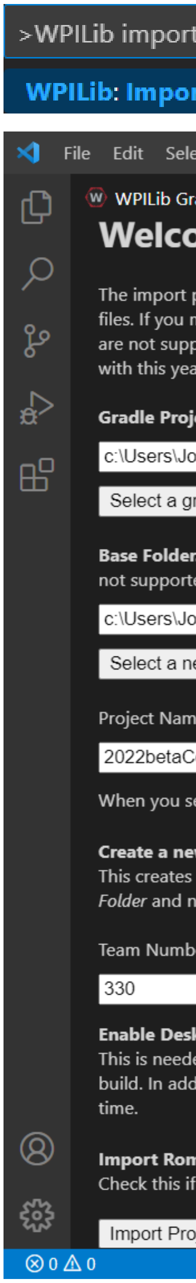


Visual Studio Cod

This proj
project i

Click project. that import to prompted be will you project, year’s previous a open you When *.yes*

”WPILib“ type and `Ctrl+Shift+P` Press menu. the from it import to chose can you Alternately, WPILib a ”Import typing Begin commands. WPILib the locate to icon WPILib the click or below. shown as dropdown the from it select and project“ Gradle 2020/2021/2022



>WPILib import

**WPILib**: Impor

Welco

The import
files. If you r
are not supp
with this yea

**Gradle Proj**

c:\Users\Jo

Select a gr

**Base Folder**
not support

c:\Users\Jo

Select a ne

Project Nam

2022betaC

When you s

**Create a ne**
This creates
*Folder* and n

Team Numb

330

**Enable Des**
This is neede
build. In add
time.

**Import Ro**
Check this if

Import Pro

of process the to similar is This window. Importer Project WPILib the with presented be You'll
contains window This below. shown are steps the and window the and project new a creating
elements: following the

build.gradle the select should Users imported. be to project the Selects :**Project Gradle** 1.
project. gradle the of directory root the in file

located. be will project robot the which in folder the determines This :**Location Project** 2.

the that name the specifies also This project. robot the of name The :**Name Project** 3.
a be must This checked. is box Folder New Create the if given be will folder project
location. original the from directory different

project the hold to created be will folder new a checked, is this If :**Folder New a Create** 4.
located be will project the checked, *not* is it If folder. specifiedpreviously- the within

not is folder the if thrown be will error An folder. specifiedpreviously- the in directly checked. not is this and empty

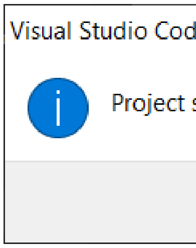
5. **Number Team**: [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] Deploying [illegible] [illegible].

6. **Support Desktop Enable**: If this is checked, simulation and unit test support is enabled. However, there are some cases where this will do some unexpected things. In addition, all vendor libraries need desktop support which not all libraries do.

7. **Project Romi Import**: If this is checked, the project is imported using the Romi gradle template. This should only be checked for Romi projects.

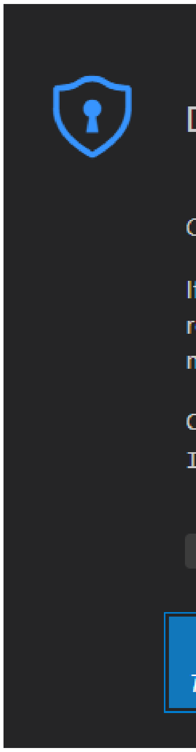
upgrade. the begin to *Project Import* Click

then can You directory. project new the into copied and upgraded be will project gradle The the using later it open or below uppop- the using immediately project new the open either shortcut. macOS) for `Command+O` (or `Ctrl+O`



Visual Studio Cod

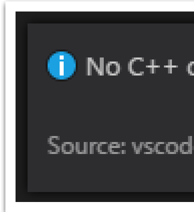
Project s



.*authors the trust I Yes* Click

### קונפיגורצית C++ (עבור C++ בלבד)

project, a open you Whenever IntelliSense. up set to step more one is there projects, C++ For Click configurations. C++ refresh to asking corner right bottom the in uppop- a get should you IntelliSense. up set to *Yes*



No C++ c

Source: vscod

### ספריות צד שלישי

details. for *Libraries Party 3rd* See libraries. party 3rd importre- and update to necessary is It

[redacted]

disadvantages. and advantages its of description a get to below dashboard each on Click

## Shuffleboard 11.1

tables network displays It dashboard. focused driveteam looking modern a is Shuffleboard It code. robot with controlled and positioned be can that widgets of variety a using data widgets. custom advanced and playback, / recording tabs, like: features extra many includes

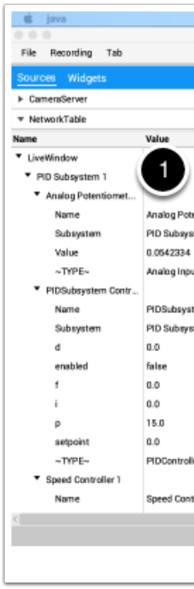
### Started Getting - Shuffleboard 11.1.1

#### Shuffleboard of Tour

are that JavaFX as such technologies newer on based FRC® for dashboard a is Shuffleboard Java and C++ for dashboards creating for used be to designed is It programs. Java to available many with familiar already are you then past the in SmartDashboard used you've If programs. Shuffleboard But way. same the work fundamentally they since Shuffleboard of features the of highlights: the of some are Here SmartDashboard. in aren't that features many has

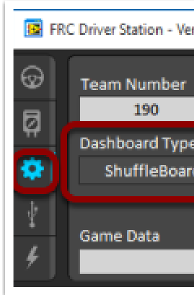
- has components the of Each standard. graphics Java the ,**JavaFX** on based is Graphics "themes" or "skins" different have to possible becomes it so sheet style associated an themes. dark and light default supply We Shuffleboard. for
- can you fact In .**data your of display the for sheets multiple** supports Shuffleboard which and if indicate and window) Shuffleboard the in tab a as (shown sheet new a create SmartDashboard a and tab Test a is there default By it. on autopopulated be should data vs. debugging robot for be might tabs Other arrives. data as autopopulated are that tab driving.
- interface the keep to **grid a on out laid are (widgets) elements display** Graphical in resolution less or more have to size grid the change can You read. to easy and clean and drag using layout your change you help to provided are cues visual and layouts your preserved. is layout grid the although lines grid the off turn to choose can you Or drop.
- run you when default by instantiated is layout previous the and saved are Layouts again. shuffleboard

- robot your by sent data the review you lets that feature **playback and record** a is There if robot the of actions the review carefully can you way That finishes. it after program wrong. goes something
- graph a onto data drag can you and **data numeric for available are widgets Graph** scale. same the on and time same the at points multiple see to
- team’s your to specific are that widgets own your writing by Shuffleboard extend can You .*Widgets Custom* in found be can it extending on Documentation requirements.



1. from values choose can you which from sources data are Here **area: Sources** tabs the of one into value a dragging by display to sources other or NetworkTables
2. this In sources. other or robot the from displayed is data you where is This **panes: Tab** This tab. LiveWindow the in here shown are that subsystems modeTest- is it example of set own it’s has window each and windows, tabbed of number any show can area populate.auto- and size grid like properties
3. the playback can you where controls likemedia- of set **controls: Record/playback** data historical see to session current

## Shuffleboard Starting



ways: four of one in Shuffleboard start can You

1. ”Dashboard the setting by starts Station Driver the when it start automatically can You above. picture the in shown as tab settings the in Shuffleboard to Type“
2. folder *tools WPILib YEAR* the in icon Shuffleboard the clickingdouble- by it run can You Desktop. Windows the on
3. ”WPILib“ type and `Ctrl+Shift+P` pressing by Code Studio Visual with from start can You Select Palette. Command WPILib the launch to right top the in logo WPILib the click or .*Shuffleboard* select then ,*Tool Start*
4. on `vbs.` is XXX (where file shuffleboard.XXX the on clickingdouble- by it run can You the is YYYY (where `~/WPILib/YYYY/tools/` in macOS) or Linux on `py.` and Windows system development a on useful is This Windows). on `Public\Users\C:` is ~ and year system. Linux or macOS a as such installed Station Driver the have not does that
5. on `shuffleboard` command: the typing by line command the from it start can You `~/WPILib/YYYY/tools` from Linux or macOS on `shuffleboard.py python` or Windows often is This Windows). on `Public\Users\C:` is ~ and year the is YYYY (where directory installed. Station Driver the have doesn’t that system development a on easiest

the using tools the launch help scripts (macOS/Linux) `py.` and (Windows) `vbs.` The :□□□□ JDK. correct

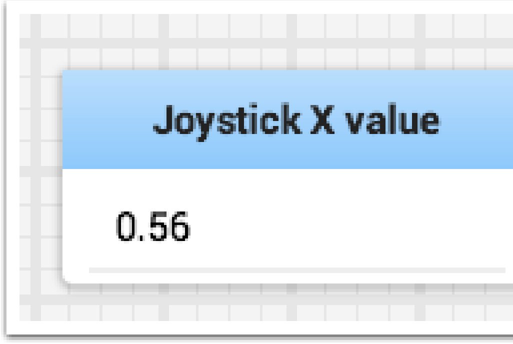
## dashboard the onto data robot Getting

the in methods use to simply is dashboard the on displayed data get to way easiest The write: Shuffleboard to number a write to example For class. SmartDashboard

Java

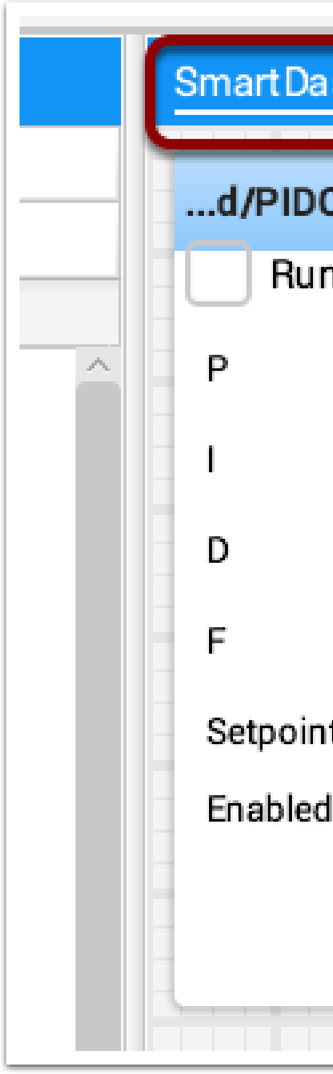
```
());getXjoystick1. ,"value X Joystick"(putNumberSmartDashboard.
```

of value X the of value a and value“ X ”Joystick label the with displayed field a see to to sent be will value joystick new a executed, is code of line this time Each joystick. the an see to want you whenever value joystick the write must you Remember: Shuffleboard. value the display only will program the of start the at once line this Executing value. updated executed. was code of line the time the at once



## robot your from data Displaying

modes Autonomous and Teleop like modes operating regular in data display can robot Your
is robot the when subsystems robot the all operate and status the display also can you but
for one Shuffleboard, start you when tabs two see you'll default By mode. Test to switched
as underlined is tab selected currently The mode. Test for another and Teleop/Autonomous
below. picture the in seen be can

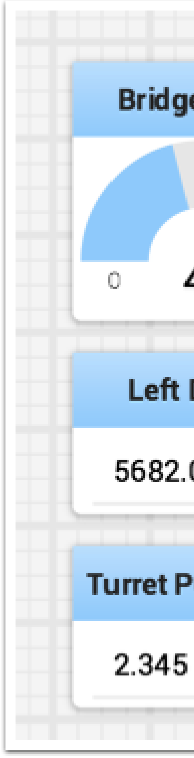


the to values of number a writing involves robot a of status the monitoring or debugging Often
is that GUI a to values put can you Shuffleboard With by. stream them watching and console
corresponding the updated, are values As program. your on based constructed automatically
the on by streaming numbers catch to try to need no is there - value changes element GUI
screen.

### teleop) or (autonomous mode operating normal in values Displaying

Java

```
                                                                { ()execute void protected
                 ());atBridgebridgeTipper. ,"Limit Bridge"(putBooleanSmartDashboard.
               ());getPositionbridgeTipper. ,"Angle Bridge"(putNumberSmartDashboard.
              ());getSwerveAngledrivetrain. ,"Angle Swerve"(putNumberSmartDashboard.
          ());getLeftEncoderdrivetrain. ,"Encoder Drive Left"(putNumberSmartDashboard.
        ());getRightEncoderdrivetrain. ,"Encoder Drive Right"(putNumberSmartDashboard.
                  ());getCurrentAngleturret. ,"Pot Turret"(putNumberSmartDashboard.
            ());getAverageVoltageturret. ,"Voltage Pot Turret"(putNumberSmartDashboard.
                               ());getRPMshooter. ,"RPM"(putNumberSmartDashboard.
                                                                                  }
```

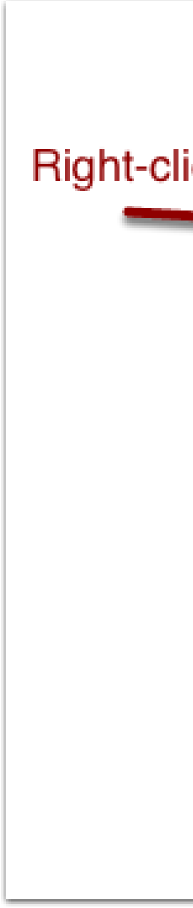


correct the calling simply by Shuffleboard to values String or Numeric, Boolean, write can You is code additional no data, the of value the and name the including and type the for method required.

- call double or float long, int, char, as such types Numeric value). name“,SmartDashboard.putNumber(”dashboard-
- value) name“,SmartDashboard.putString(”dashboard- call types String
- value) name“,SmartDashboard.putBoolean(”dashboard- call types Boolean

### data of type display the Changing

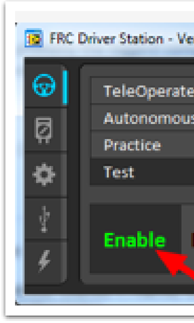
change often can you Shuffleboard to sent being values the of type data the on Depending displayed were values number that see can you example previous the In format. display the the for view voltage a as and angles, represent better to dial a numbers, decimal either as as...“. ”Show select and tile the on clickright- type display the set To potentiometer. turret menu. popup the in list the from types display choose can You



### mode Test in data Displaying

the while actuators and sensors your for values display to program your to code add may You not is robot the whenever Station Driver the from selected be can This mode. Test in is robot or RobotBuilder by generated automatically is values these display to code The field. the on designed is mode Test article. next the in described is and program your to added manually be can it addition In robot. a on actuators and sensors the of operation correct the verify to in loops PID tuning for and potentiometers as such sensors from setpoints obtaining for used code. your

## mode test Setting

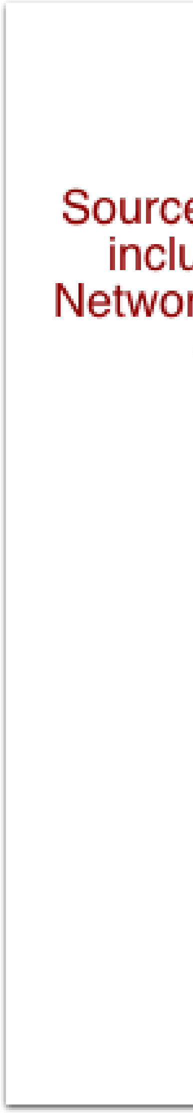


”Enable“ setting and button ”Test“ the on clicking by Station Driver the in Mode Test Enable and actuators any of status the display will Shuffleboard this, doing When robot. the on subsystem. by organized program your by used sensors

## view Sources the from data Getting

rearrange just you and tabs the of one on appears automatically data *NetworkTables* Normally deleted accidentally was that value a recover to want might you Sometimes data. that use and key. NetworkTables / SmartDashboard the of part not is that value a display or tab the from under view NetworkTables from pane a onto dragged be can values these cases these For just and display to want you that value the Choose window. the of side left the on Sources the for widget of type default the with created automatically be will it and pane the to it drag type. data

divider the drag to possible is it - left the on visible not is view Sources the Sometimes **:□□□□** move happens this If visible. not is sources the so Sources the and panes tabbed the between drag and click left then cursor, resizing divider a for look and edge left the over cursor the finished when and drag, and click to where see can you below images two the In view. the out image. second the in shown as is divider the


Source
inclu
Networ

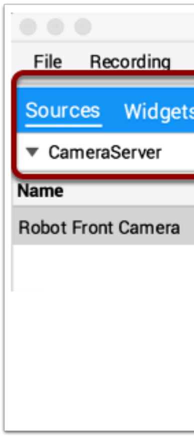

Put the curs
here and dra
to the right
open the
NetworkTabl

## Streams Camera Displaying

for useful is This Shuffleboard. in tab a on viewed be can robot the from streams Camera helping or operators for view obstructed less a give to seeing is robot the what viewing a or computer station driver the on running algorithm vision a from output the visualize be can API CameraServer the using running is that stream Any robot. the on coprocessor widget. stream camera a in viewed

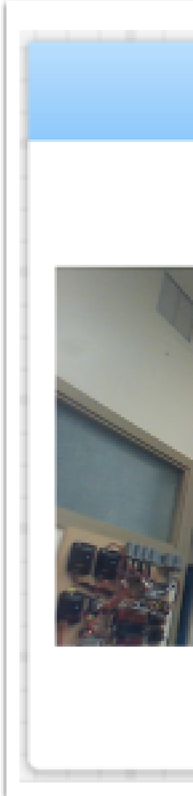
## Stream Camera a Adding

in source ”CameraServer“ the view and ”Sources“ select dashboard your to camera a add To camera of list A below. example the in shown as window Shuffleboard the in panel side left the Camera“. Front ”Robot called camera one only is there case this in shown, be will streams placed be also can stream the Alternatively displayed. be should it where tab the to that Drag as: ”Show selecting and list Sources the in stream the on clickingright- by dashboard the on Stream“. Camera



and resized be can It window. the in displayed be will it added is stream camera the Once it. like would you where moved

frame a high too or resolution a high too from data much too sending that aware Be :□□□□ laptop. the and roboRIO the both on usage CPU high cause will rate

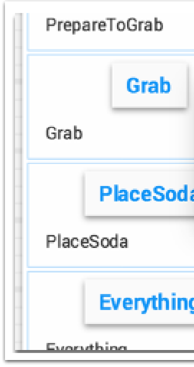


## widgets with Working

widgets. called are Shuffleboard in screen the on manipulate you that displays visual The publishes program robot the that values from displayed automatically generally are Widgets NetworkTables. with

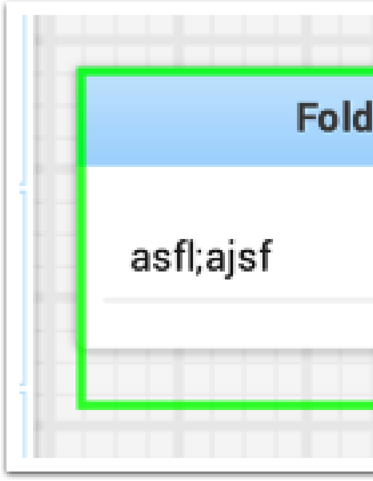
### widgets Moving

widget, the over cursor the move Just drop. and drag with simply moved be can Widgets grid on widgets place only can you dragging When position. new the to it drag and clickleft- a dragging When display. your of resolution the effect will grid the of size the and squares at room enough is there that means generally Green displayed. be will outline green or red too be or overlap will it that means generally red and widget the drop to location current the fit. doesn't it where location a to moved being is widget a below example the In drop. to big



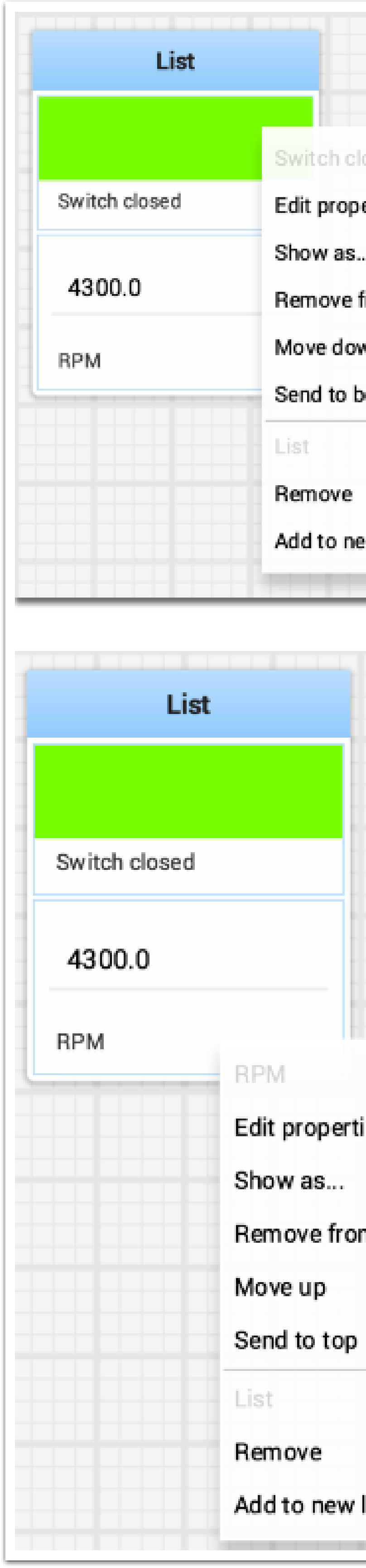
### widgets Resizing

The image. widget the of corner or edge the dragging and clicking by resized be can Widgets
As widget. the resize to position right the in is it when cursorresize- a to change will cursor
be can widget the that indicating drawn be will outline red or green a widgets, moving with
the with area larger a to resized being widget a shows below example The not. or resized
widgets. surrounding with overlap no is there that indicating outline green



### widgets of type display the Changing

It robot. the from published data the on depending types display in rich very is Shuffleboard
depending it change to want might you but type, display default a choose automatically will
the on clickright- widget, any for are displays possible the what see To application. the on
the In type. desired the choose menu, popup the from and as...“ ”Show the select and widget
the see can You boolean. a other the and number a one values, data two are below example
two only has value boolean The each. to available are that options display of types different
or text, or color), red/green (the box boolean a as shown be can it (true/false) values possible
number graph, a as displayed be can value number The. switch. toggle or button toggle a
value. the of context the on depending view voltage a or text, dial, slider, number bar,

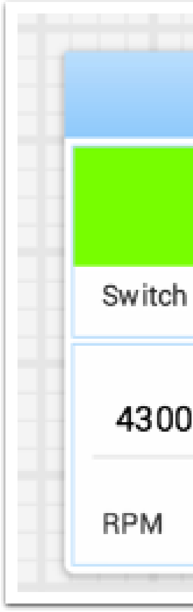

List
Switch closed
4300.0
RPM
Switch clo
Edit prope
Show as..
Remove f
Move dow
Send to b
List
Remove
Add to ne
List
Switch closed
4300.0
RPM
RPM
Edit properti
Show as...
Remove fron
Move up
Send to top
List
Remove
Add to new l

### widgets of title the Changing

to title the editing and bar title their in clickingdouble- by widgets of title the change can You
select and widget the on clickright- then layout, a in contained is widget a If value. new the
displayed. is that title widget the change can you there From properties. the

### properties widget Changing

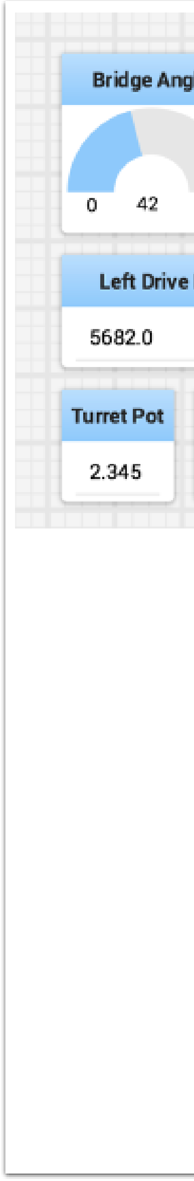
colors represented, values of range the as such widget a of appearance the change can You
and widget the on clickright- possible is this where cases In element. visual other some or
the below, shown widget value boolean this In menu. popup the from properties“ ”Edit select
edited. be all can color false and color true title, widget



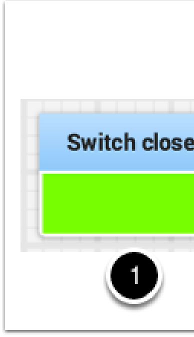
### Lists with Working

visually it making layout, vertical a in together grouped tiles of sets are Shuffleboard in Lists
than space screen less up take lists in tiles addition, In related. are tiles those that obvious
tiles: individual

- within labels smaller have instead they labels; header individual have don’t lists in Tiles
entries. list their
- gaps smaller have lists another; one between gaps create together placed tiles Individual
tiles. between


Bridge Ang
0
42
Left Drive
5682.0
Turret Pot
2.345

### list a Creating



follows: as created be can list A

list. the in first be should that tile the on clickRight- 1.

menu. popup the from Layout“ ”List then layout...“, new to ”Add Select 2.

it. of top the at be will tile the and ”List“, labeled created be will list new A 3.

entry. list their of bottom the at is label their labels; header have not do lists in tiles that Note

### list a from tiles to/removing tiles Adding

follows: as list existing an to **added** be can tile A

added. be to tile the and list the Identify 1.

list. the onto tile new the Drag 2.

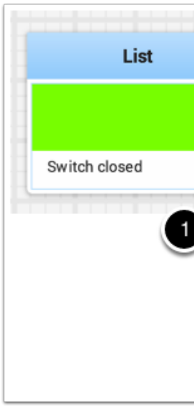
tile the it, show to small too is size list current the If list. the to added be will tile The 3.
already not if added be will scrollbar vertical a and screenoff- list the to added be will
present.

reverse: in process the following by list a from **removed** be can tile A

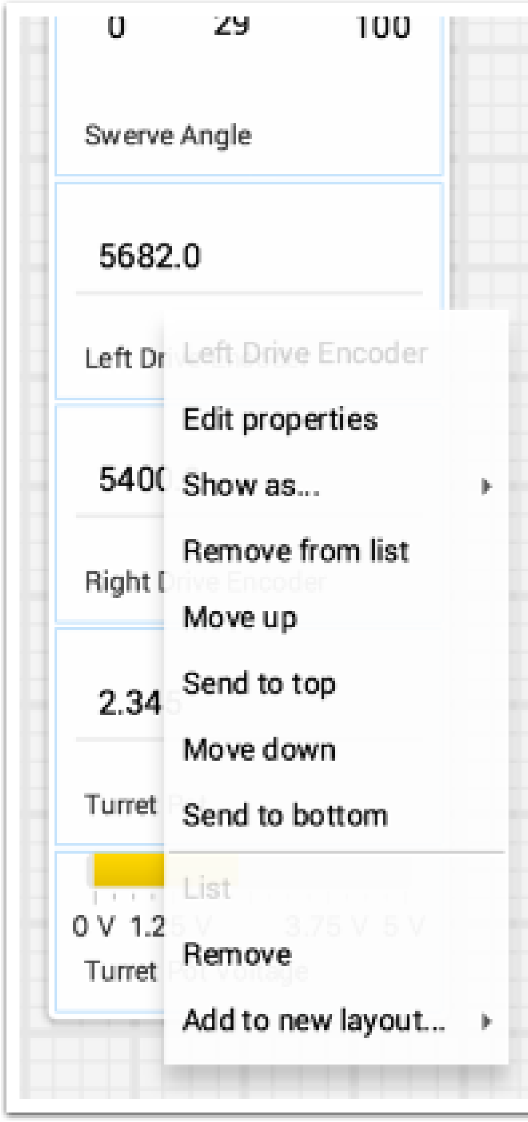
removed. be to it within tile the and list the Identify 1.

space. free with anywhere it place and list the of out tile the Drag 2.

location. that at placed and list the from removed be will tile The 3.



### list a in tiles Rearranging



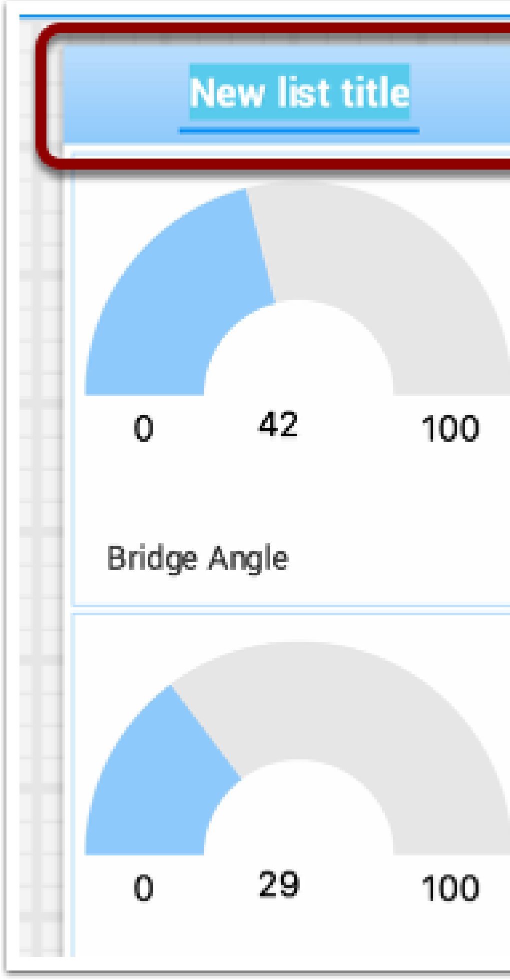
selecting: and tile the on clickingright- by rearranged be can list a in Tiles

- list. the of *top* the **towards** tile the moves *up Move*
- list. the of *bottom* the **towards** tile the moves *down Move*
- list. a of *top* the **to** tile the moves *top to Send*
- list. a of *bottom* the **to** tile the moves *bottom to Send*
- does: button each and ,*Remove* labeled buttons two are There
  - *tile* outgrayed- with dropdown of section pinline; the (above button *Remove* **top** The layout. Shuffleboard the from *tile* the **deletes** label)
  - outgrayed- with dropdown of section pinline; the (below button *Remove* **bottom** The layout. Shuffleboard the from *it inside tiles all and list* the **deletes** label) *list*

*tiles Adding* see it, deleting without list a of out entry an take to want you If –
*.list a from tiles to/removing*

### list a Renaming

outside Click name. the changing and label list the on clickingdouble- by list a rename can You changes. save to label the

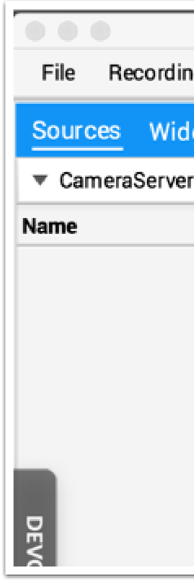


### tabs manipulating and Creating

data robot your of ”views“ different separate help uses Shuffleboard the layout tabbed The helping for display the has the tab a have might You useful. more displays the make and number a are There competitions. in use for tab different a and program robot the debug or NetworkTables from data which control can You powerful. very tabs make that options of in later described options populateauto- the using tabs your of each in appears sources other article. this

## tabs Default

SmartDashboard labeled tabs, two are there time first the for Shuffleboard open you When
on depending had SmartDashboard that views two the to correspond These LiveWindow. and
of both shuffleboard In mode. Test or Autonomous/Teleop in running is robot your whether
time. any available are views these



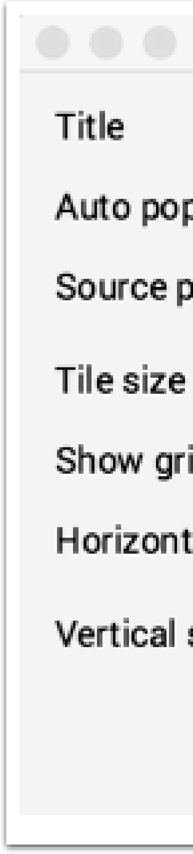
the using written are that values the all tab SmartDashboard the On
autogenerated the all tab LiveWindow the On methods. of set SmartDashboard.putType()
shown. are values debugging

## tabs between Switching

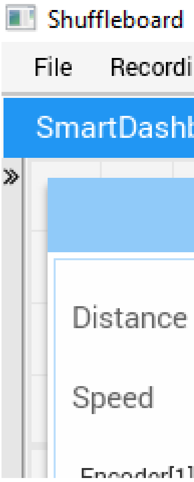
case the In window. the of top the at label tab the on clicking tabs between switch can You
associated are that values the see to LiveWindow or SmartDashboard on click simply above,
tab. each with

## Tabs Hiding and Adding

tab. last the of right the to just symbol plus(+) the on clicking by tabs additional add can You
tab the in label the on clickingdouble- by label the set can you tab new a create you Once
tab the up bring to menu Tab the use or tab the on clickright- also can You it. editing and
field. Title the editing by name the change can you window that from and preferences



Since name. tab selected the of left the to symbol )minus(- the clicking by tabs hide can You
permanently to possible not is it ,*NetworkTable* relevant the on based generated are tabs
table. the deleting without them delete



### populateauto- to tab the Setting

values new populate automatically them have to is tabs with features powerful most the of One
example above the In pane. Preferences tab the in supplied is that prefix source a on based
is populate Auto and ”SmartDashboard/Shooter“ of prefix Source a has pane Preferences the
sub- a specifies that class SmartDashboard the using written are that values Any on. turned
one than more match that keys Note: tab. that on appear automatically will Shooter of key
SmartDashboard/ with start also keys those Because tabs. both in appear will prefix Source
appear will widgets those tab, SmartDashboard default the for prefix Source the that’s and
write to NetworkTables use can you pane, one in appear values have only To panes. both in
Alternatively SmartDashboard. under not is that path different a use and values and labels
have but cluttered, very it making tab SmartDashboard the in appear everything let could you
filtered. better be will that needs your for tabs specific

### spacing and grid tab the Using

might tabs some So square). large per pixels of (number size Tile own it’s have can tab Each
the in size Tile The grid. fine a have might others and layout easier for resolution coarser have
addition, In preferences. Shuffleboard the in settings global any overrides preferences Tab
the of the of edge the and widget the in drawing the between padding the specify can you
horizontal as to referred usually are parameters these interfaces user program you If widget.
vgap). (hgap, gap vertical and

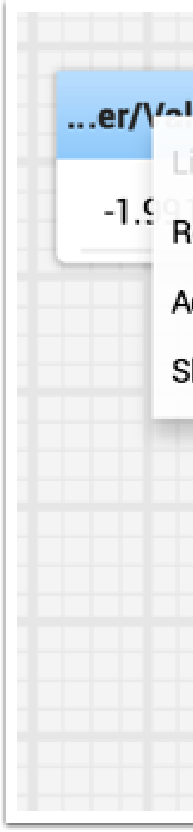
### tabs between widgets Moving

one from it deleting without tabs between widgets move easily to way no is there Currently
hope We pane. new the into left the on hierarchy sources the from field the dragging and tab
soon. update subsequent a in capability that have to

### Graphs with Working

see to useful very are Graphs time. over values numeric graph can you Shuffleboard With
sensor the example For operating. is robot your as changing are values motor or sensor how
tuning. during responding is it how see to loop PID a in graphed be can value

”Show select and heading the in clickright- and value numeric a choose graph, a create To
graph choose then and as…“

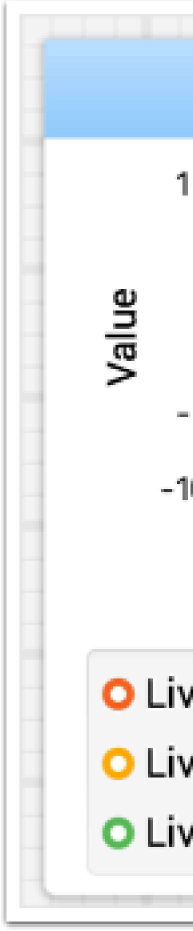


set automatically will It selected. you that value the of plots line shows widget graph The can You seconds. 30 be will show will graph the that interval time default the and scale the below). (see graph the for setting the in that change

## Values Data Additional Adding

do To  graph. same the on values multiple show to desirable often is it values related For
the of side (left view source NetworkTables the from values additional drag simply that,
shown as added be will value that and graph the onto it drop and window) Shuffleboard
graph. the onto values additional drag to continue can You below.

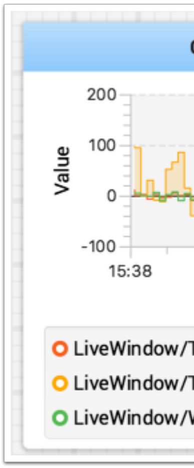
the in shown as displayed not is it if legend the view to vertically graph the resize can You
plot. the in used are that sources the all shows legend The below. image



### Properties Graph Setting

time“ ”Visible the changing by graph the in shown are that seconds of number the set can You select and graph the on clickright- properties, the access To properties. widget graph the in properties“. ”Edit

by off and on sources turn selectively can graph the time visible the setting to addition In (see window properties the in shown sources the of each for off and on switch the turning below).



## Playback and Recording

”played be can file log the Later session. a during updates widget all log can Shuffleboard if useful especially is This run. practice a or match a during happened what see to back“ happened. what see to want you and match a during intended as operate doesn’t something file. recording a in captured is recording Each

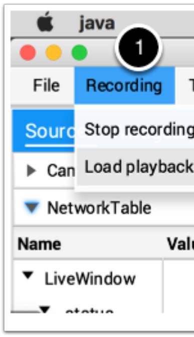
## Recording a Creating

recorded are values NetworkTables the all to recording begins it starts shuffleboard When as controls recorder the in button record/stop the hitting by stopped until continues and mechanical or code of piece new a when as such desired, is recording new a If below. shown button. record the click and running, is it if recording current the stop tested, being is system (as round is button the If file. recording the close and recording stop to again button the Click currently is recoding a then square, a is button the If recording. a start to it click then shown) recording. the stop to it click so running

### Recording a Playing

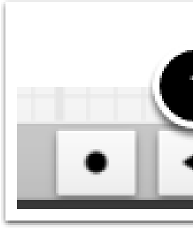
by: back played be can recordings Previous

1. playback“. ”Load click then menu ”Recording“ the Selecting
2. date by grouped are Recordings shown. directory the from the from recording a Choose one. correct the identify help to made was recording the time the are names file the and list. the from recording correct the Select



### Playback the Controlling

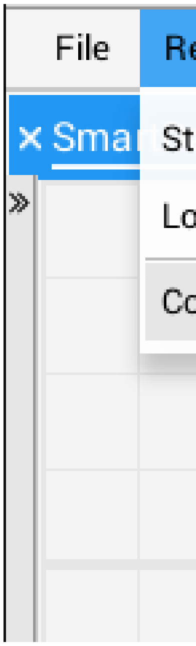
the playing is recording the While file. that of playback begin will file recoding the Selecting to option the as well as recording the within time current the show will controls recording ”transport“ the back played being is recording the When it. watching while recording the loop controlled. be to playback the allow will controls



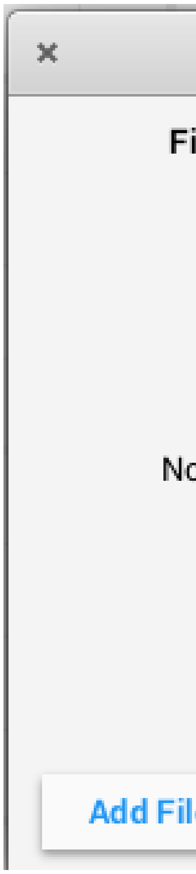
follows: as work controls The

1. point data changed last the to playback the up backs button arrowdouble- left The
2. playback the stops and starts controls play/pause The
3. values robot current showing resumes and playback stops button stop square The
4. value data changed next the to forward skips arrowdouble- right The
5. the of parts different view to time in point any to positioning direct for allows slider The recording
6. over and over run will playback the is, that looping, playback on turns switch loop The stopped until
7. recording the of time total the and recording the within point current the shows time The

## Formats File Different to Converting



data recorded analyze To efficiency. for format binary custom a in are recordings Shuffleboard the convert to converters data supports Shuffleboard app, the through back it playing without but app, the with shipped is converter CSV simple a Only format. arbitrary an to recordings plugins. Shuffleboard in them include and converters custom write can teams



”Add the with selected be can files Individual once. at converted be can recordings Multiple ”Add the with once at selected be can directory a in files recording all or button, Files“ button. Directory“

but directory, `~/Shuffleboard/recordings` the in generated be will recordings Converted button. ”Change“ the with selected manually be can

only default, By right. top the in dropdown the with selected be can converters Different the in options as appear will plugins from converters Custom available. is converter CSV the dropdown.

### Notes Additional

where through playing is it if but timeline the scrubbing while properly display won’t Graphs run. original the in as display will they then graph the by captured be can history graph the

### Shuffleboard for preferences global Setting

are Those behaves. and looks Shuffleboard way the set that settings of number a are There
menu. File the from accessed be can that pane Preferences Shuffleboard the on

#### theme the Setting

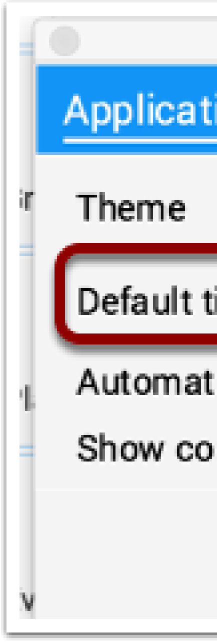
depends setting the and Light Material and Dark Material themes, two supports Shuffleboard
be can and application entire the to apply that styles css uses This preferences. your on
time. any changed

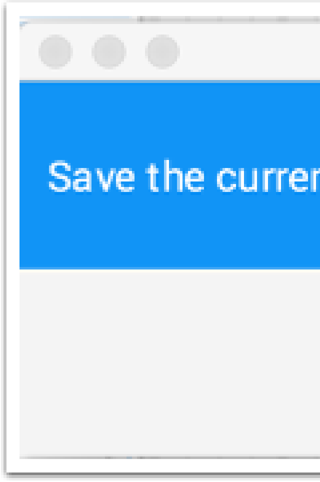
#### size tile default the Setting

when or yourself them moving or adding are you when grid a on tiles positions Shuffleboard
be can it or tab each for when size tile default the set can You populated.auto- are they
in resolution Finer changed. is setting default the after created tabs the all for globally set
Shuffleboard the in set be can This tiles. of placement over control finer in results grid the
below. shown as window Preferences

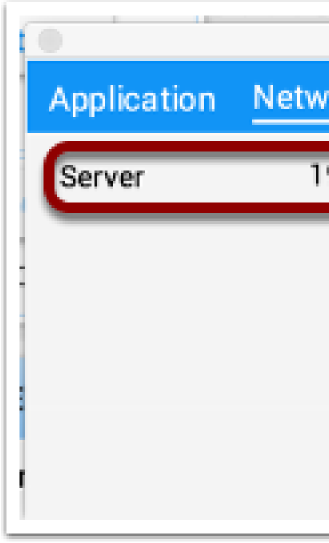
#### files save layout the with Working

The options. menu as... Save / File and Save / File the using layout your save can You
applied automatically be to layout previous the cause to options has window preferences
to window layout" "Save a display will Shuffleboard addition, In starts. Shuffleboard when
off turn to choose can You changed. has layout the if exit, on layout the save to you remind
don't you so case this in manually layout the save to sure be but exit, on prompt automatic the
changes. your loose


Applicati
Theme
Default ti
Automat
Show co


Save the curren

### number team the Setting



specify robot, your on server NetworkTables your find to able be to Shuffleboard for order In
running you’re If pane. Preferences the on tab ”NetworkTables“ the in number team your
the with populatedauto- be will field Server the Station, Driver running a with Shuffleboard
can you Station, Driver the without computer a on running you’re If information. correct
address. network robotRIO the or number team your enter manually

## bugs and issues, FAQ, Shuffleboard

> were components system control other the of most as well as Shuffleboard **:□□□□□**
> problems reporting before sure Be 8. Java with work not will and 11 Java with developed
> Environment. Java default the as set is and installed 11 Java has computer your that

### Questions Asked Frequently

#### Shuffleboard? with requests feature or bugs issues, report I do How

creating by page GitHub Shuffleboard the on added be can requests feature and issues, Bugs,
at look to try Please system. the into entered are they as them address to try will We issue. an
that something duplicating aren’t you sure make to ones new creating before issues existing
Shuffleboard the on issues the find can You planned. is that work or reported been already has
.page GitHub

### Shuffleboard? to extensions other or widgets own my add I can How

custom with program the extending on documentation of amount large a has *Widgets Custom* themes and widgets custom additional for used be can that projects plugin Sample plugins. .page GitHub Shuffleboard the on found be can

### code? source the from Shuffleboard build I can How

GitHub the on repository the forking or cloning, downloading, by code source the get can You is directory current the that sure make source, the from Shuffleboard run and build To site. commands: these of one use and code source level top the

| | |
|---|---|
| the run systems Windows (for Command file) gradlew.bat | Application |
| :app:run ./gradlew | Shuffleboard Running |
| :api:shadowJar ./gradlew | for classes utility and APIs the Building creation plugin |
| :app:shadowJar ./gradlew | file jar application complete the Building |

## Code with Layouts - Shuffleboard 11.1.2

### tabs Using

By grouping. logical a in widgets organizes tab Each interface. tabbed a is Shuffleboard tabs new but - LiveWindow and SmartDashboard legacy the for tabs has Shuffleboard default, organization. better for program robot a from directly Shuffleboard in created be now can

tab new a Creating

Java

```
);"Title Tab"(getTabShuffleboard. = tab ShuffleboardTab
```

C++

```
);"Title Tab"GetTab(::Shuffleboard = tab &ShuffleboardTab
```

which class, Shuffleboard the on method single a calling as simple as is tab new a Creating tab. the to data your adding for handle a return and Shuffleboard on tab new a create will time. each handle same the return will title tab same the with times multiple getTab Calling

### tab a Selecting

Java

```
);"Title Tab"(selectTabShuffleboard.
```

C++

```
);"Title Tab"SelectTab(::Shuffleboard
```

title“ ”Tab and Title“ ”Tab (so sensitivecase- is This title. by selected be tab a lets method This method the time the at exists title that with tab a if works only and tabs), individual two are ”Example“ named tab a if effect an have only will`selectTab("Example")` calling so called, is defined. been previously has

robot the by created ones just not Shuffleboard, in tab any select to used be can method This program.

### חסרונות

created tabs normal from ways important few a in differ program robot a from created Tabs dashboard: the from

- file save Shuffleboard the in saved Not
- autopopulation for support No
- program robot their in contents tab the specify to expected are Users
- tabs normal from differentiate to color special a Have

## data Sending

specifying first without Shuffleboard to directly sent be cannot data SmartDashboard, Unlike in. placed be should data the tab what

### data simple Sending

add calling by done is these) of arrays and booleans, strings, (numbers, data simple Sending an overwrite not will but present, already not if value the set will method This tab. a on value. existing

Java

```
)"Numbers"(getTabShuffleboard.
        );3.14 ,"Pi"(add.
```

C++

```
)"Numbers"GetTab(::Shuffleboard
        );3.14 ,"Pi"Add(.
```

robot), the on done calculation some of output the example, (for updated be to needs data If function `periodic` a in or needed when it update then value, the defining after `getEntry()` call

Java

```
                                     { VisionCalculator class
  );"Vision"(getTabShuffleboard. = tab ShuffleboardTab private
               = distanceEntry NetworkTableEntry private
                   )0 ,"target to Distance"(addtab.
                                          ();getEntry.

                                   { ()calculate void public
                                    ;... = distance double
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
(distance);setDoubledistanceEntry.
                                   }
                                     }
```

### reboots between persist choices Making

between persist to want may settings some dashboard, the from robot a configuring When the configure to forget) (or remember drivers having of instead reboots driverstation or robot match. each before settings

and roboRIO the on saved value the make will *add* of instead *addPersistent* using Simply starts. program robot the when loaded

controllers. motor or choosers as such data sendable to apply not does This :□□□□

Java

```
          )"Drive"(getTabShuffleboard.
);1.0 ,"Speed Max"(addPersistent.
```

### etc motors, sensors, Sending

motor sensors, (most object Sendable any ,`SmartDashboard.putData` to Analogous tab any to added be can SendableChoosers) and controllers,

Java

```
        )"Title Tab"(getTabShuffleboard.
mySendable); ,"Title Sendable"(add.
```

### data Retrieving

also is Shuffleboard from data retrieving friends, and `SmartDashboard.getNumber` Unlike article. previous the in covered we which NetworkTableEntries, the through done

Java

```
                           { Subsystem extends DriveBase class
);"Drive"(getTabShuffleboard. = tab ShuffleboardTab private
                       = maxSpeed NetworkTableEntry private
                                )1 ,"Speed Max"(addtab.
                                        ();getEntry.

                ;... = robotDrive DifferentialDrive private

             { right) double left, double(drive void public
         dashboard the from speed maximum the Retrieve //
                    );1.0(getDoublemaxSpeed. = max double
           max); * right max, * (lefttankDriverobotDrive.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                                              }
                                                                                                 }
```

to dashboard the on set be can speed maximum the flaw: glaring a has example basic This maximum at (always saturated be to inputs the cause could which - 1] [0, outside value a the in covered - problem this avoid to way a is there Fortunately, reversed! even or speed), article. next

## widgets Configuring

how as well as point, data a display to use to widget which exactly specify can programs Robot consult here, listed be to widgets many too are there As configured. be should widget that details. for docs the

### widget a Specifying

chain: call the in add after `withWidget` Call

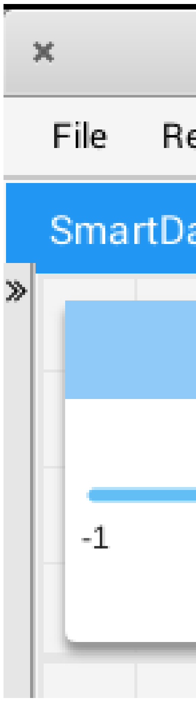
Java

```
                                                   )"Drive"(getTabShuffleboard.
                                                          )1 ,"Speed Max"(add.
           here widget the specify // )kNumberSlider(BuiltInWidgets.withWidget.
                                                                 ();getEntry.
```

C++

```
                                              )"Drive"GetTab(::Shuffleboard::frc
                                                          )1 ,"Speed Max"Add(.
      here widget the specify // kNumberSlider)::BuiltInWidgets::WithWidget(frc.
                                                                 GetEntry();.
```

values the modify to slider a use to widget Speed“ ”Max the configure we example, this In field. text basic a of instead



### properties widget Setting

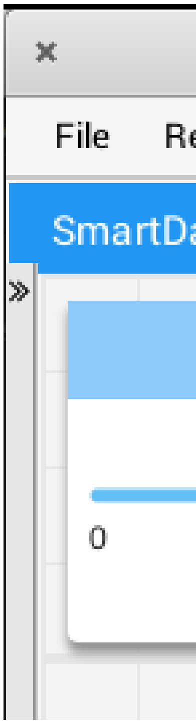
speed), full to stop (full 1 to 0 from value a be to sense makes only speed maximum the Since can we Fortunately, zero. below drops value the if problems cause can 1 to 1- from slider a method `withProperties` the using that modify

Java

```
                                        )"Drive"(getTabShuffleboard.
                                             )1 ,"Speed Max"(add.
                         )kNumberSlider(BuiltInWidgets.withWidget.
   here properties widget specify // ))1 ,"max" ,0 ,"min"(of(Map.withProperties.
                                                     ();getEntry.
```

C++

```
                                 )"Drive"GetTab(::Shuffleboard::frc
                                             )1 ,"Speed Max"Add(.
                        kNumberSlider)::BuiltInWidgets::WithWidget(frc.
                      here properties widget specify // WithProperties({.
                              )},0MakeDouble(::Value::nt ,"min"{
                               )}1MakeDouble(::Value::nt ,"max"{
                                                               )}
                                                     GetEntry();.
```



### Notes

sensitivewhitespace- and case- are names however, name; by specified be can Widgets it reason, this For ”NumberSlider“). and slider“ ”Number from different is Slider“ (”Number name. raw by of instead widget the specify to class widgets in built the use to recommended is `WidgetType` custom a creating by or name by specified be only can widget custom a However, widget. that for

”max“ and (”Max“ sensitivewhitespace- nor sensitivecase- neither are names property Widget details for class BuiltInWidgets the in widget the on documentation the Consult same). the are widget. that of properties the on

## Widgets Organizing

### Position and Size Widget Setting

tab. the in widget the of position and size the set to `withPosition` and `withSize` Call

example, For be. should widget the high rows and wide columns of number the sets `withSize` some that Note grid. the in cell single a occupy widget the makes `1)` `withSize(1,` calling the case which in size, specified the than greater be may that size minimum a have widgets size. supported smallest the use will widget

columns and Rows widget. the of corner lefttop- the of column and row the sets `withPosition` number also is column leftmost the and 0 number is row topmost the so indexed,0- both are position its have also should widget every specified, is tab a in widget any of position the If 0. widgets. overlapping avoid to set

Java

```
                                                       )"Pre-round"(getTabShuffleboard.
                                                   autoModeChooser) ,"Mode Auto"(add.
                                               2x1 widget the make // )1 ,2(withSize.
                              corner top-left the in it place // );0 ,0(withPosition.
```

C++

```
                                                 )"Pre-round"GetTab(::Shuffleboard::frc
                                                   autoModeChooser) ,"Mode Auto"Add(.
                                                                      )1 ,2WithSize(.
                                                                  );0,0WithPosition(.
```

### Layouts to Widgets Adding

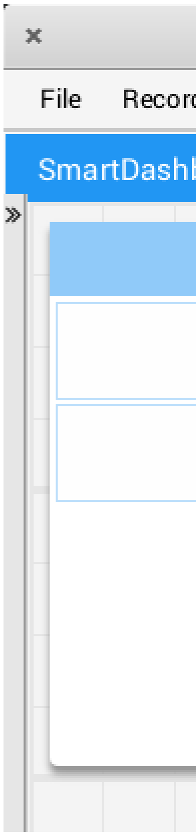
smaller into them place to useful be can it data, related with tab a in widgets many are there If with retrieved is tab a to handle the how like Much tab. the in loose of instead subgroups with retrieved be can layout) another in even (or tab a inside layout a ,`Shuffleboard.getTab` `.ShuffleboardTab.getLayout`

Java

```
                  )"Commands"(getTabShuffleboard. = elevatorCommands ShuffleboardLayout
                                         )kListBuiltInLayouts. ,"Elevator"(getLayout.
                                                                      )2 ,2(withSize.
     commands for labels hide // ));"HIDDEN" ,"position Label"(of(Map.withProperties.

                                       ElevatorDownCommand()); new(addelevatorCommands.
                                         ElevatorUpCommand()); new(addelevatorCommands.
                                                     commands claw the for Similarly //
```

C++

```
                                 properties{ >>Value::nt<shared_ptr::std<StringMap::wpi
                    ))"HIDDEN"MakeString(::Value::nt ,"position Label"make_pair(::std
                                                                                   ;}

        )"Commands"GetTab(::Shuffleboard::frc = elevatorCommands &ShuffleboardLayout::frc
                                   kList)::BuiltInLayouts::frc ,"Elevator"GetLayout(.
                                                                      )2 ,2WithSize(.
                                                         WithProperties(properties);.

                         ElevatorDownCommand(); new = elevatorDown *ElevatorDownCommand
                               ElevatorUpCommand(); new = elevatorUp *ElevatorUpCommand

                                   elevatorDown); ,"Down Elevator"elevatorCommands.Add(
                                       elevatorUp); ,"Up Elevator"elevatorCommands.Add(
```



## Usage Advanced - Shuffleboard 11.1.3

### Subsystems and Commands

what understand to easier it makes Shuffleboard framework basedcommand- the using When time.real- in subsystems and commands various of state the displaying by doing is robot the

### Subsystems Displaying

or autonomous either in operating is robot the while subsystem a of status the see To currently is command what and is command default its what is that modes, teleoperated Shuffleboard: to instance subsystem a send subsystem, that using

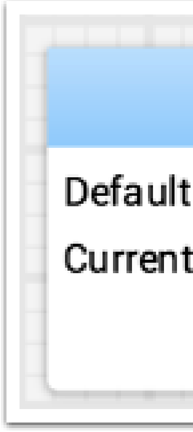
Java

```
reference);-(subsystemputDataSmartDashboard.
```

C++

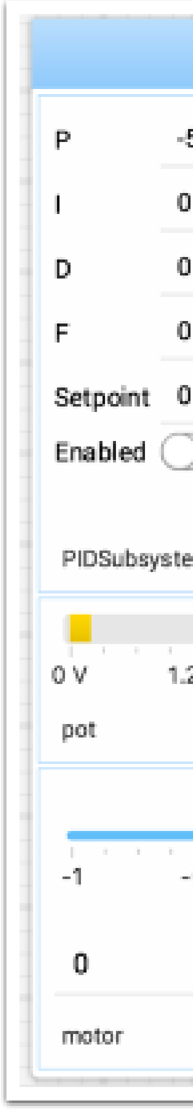
```
pointer);-PutData(subsystem::SmartDashboard
```

this with associated command default the name, subsystem the display will Shuffleboard for command default the example this In command. running currently the and subsystem, that command current the also is it and `AutonomousCommand` called is subsystem Elevator the subsystem. Elevator the using is



### Mode Test in Subsystems

the in displayed be may subsystems station) driver the in (Test/Enabled mode Test In verifying for ideal is This subsystem. the of actuators and sensors the with tab LiveWindow actuators addition, In returning. are they that values the seeing by working are sensors of commanded their set to sliders using operated be can motors example, For operated. be can along displayed are constants F and D, I, P, the PIDSubsystems For direction. and speed adjusting by PIDSubsystems tuning for useful is This control. enable an and setpoint the with the Then PIDController. embedded the enabling and setpoint, a in putting constants, the observe) and enable, parameters, (change cycle This observed. be can response mechanism's found. is parameters of set reasonable a until repeated be can



will RobotBuilder Using .*here* found be can PIDSubsystems tuning on information More that code The mode. Test in displayed subsystem the get to code the generate automatically string a is namesubsystem- where below shown is displayed subsystems have to necessary is subsystem: the of name the containing

```
name);-setName(subsystem
```

### Commands Displaying

easily can that programs robot modular very makes subsystems and commands Using completely written be can commands because is this of Part modified. and tested be To Shuffleboard. from run easily be therefore can and commands other of independently here: shown as method `SmartDashboard.putData` the use Shuffleboard to command a write

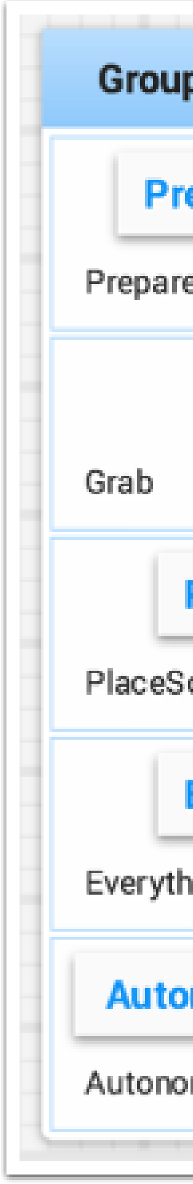
Java

```
));2.7ElevatorMove( new ,"up ElevatorMove:"(putDataSmartDashboard.
```

C++

```
));2.7ElevatorMove( new ,"up ElevatorMove:"PutData(::SmartDashboard
```

this In command. the execute to button a and name command the display will Shuffleboard
special needing without tested be easily can groups command and commands individual way
contained commands of number a are there below image the In program. robot a in code test
stops again it pressing and command the runs once button the Pressing list. Shuffleboard a in
mode. teleop in enabled be must robot the feature this use To command. the



## Loops PID Tuning and Testing

the drive to algorithm good a have to is mechanisms control to sensors using in challenge One called is algorithm control used commonly most The speed. or position proper the to motors explain that playlist) controls robot the for (look videos of set good a is There control. PID motor into values sensor converts algorithm PID The here. described algorithms control the by: speeds

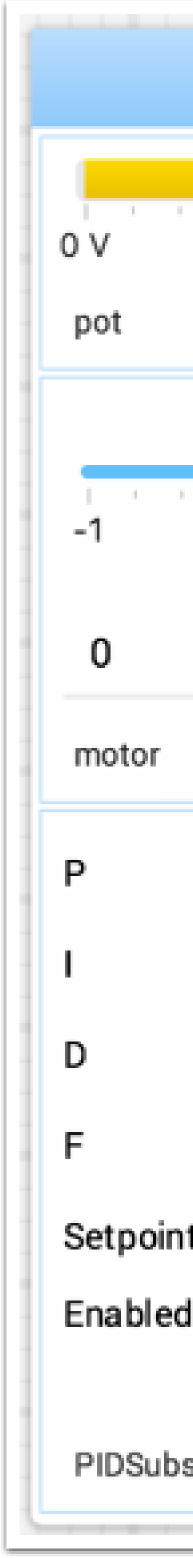
1. desired the from mechanism or robot the far how determine to values sensor Reading For goal. expected the to corresponds that value sensor the is setpoint The setpoint. very angle specified a to move to able be should joint wrist a with arm robot a example, that sensor a is potentiometer A sensor. a by indicated as angle that at stop and quickly get can program the input, analog an to it connecting By angle. rotational measure. can angle. the to proportional directly is that measurement voltage a
2. The value). desired the and value sensor the between difference (the error an Compute example For on. is wrist the setpoint the of side which indicates value error the of sign desired the than larger is angle wrist measured the that indicate might values negative from is angle wrist measured the far how is error the of magnitude The angle. wrist matches exactly angle measured the then zero, is error the If angle. wrist actual the a compute to algorithm PID the to input an as used be can error The angle. desired the speed. motor
3. a and direction correct the in motor the drive to used then is speed motor resultant The overshooting without possible as quickly as setpoint the reach will hopefully that speed setpoint). the past (moving

constants accepts and algorithm PID the implements that class PIDController a has WPILib that components three has algorithm PID The values. Kd and Ki, Kp, the to correspond that error. the from speed motor the computing to contribute

1. a generate will (Kp) constant a by multiplied when that term a is this - (proportional) P speed. and direction correct the in motor the move help will that speed motor
2. the exists error the longer The errors. successive of sum the is term this - (integral) I If time. over errors the all of sum a simply is It be. will contribution integral the larger move, to trying is it load large a of because setpoint the to getting quite isn’t wrist the enough contributes it until errors) the of (sum increase to continue will term integral the multiplied is errors the of sum The setpoint. the to move to it get to speed motor the to system. the for term integral the scale to (Ki) constant a by
3. down slow to used is It errors. the of change of rate the is value this - (differential) D between difference the taking by computed It’s fast. too moving it’s if speed motor the constant a by multiplied also is It value. error previous the and value error current the system. the of rest the match to it scale to (kd)

## Controller PID the Tuning

Shuffleboard results. accurate for constants adjusting of consists controller PID the Tuning setting for interface user a with subsystem PID a of details the displaying by process this helps operating is robot the while displayed is This operates. it well how testing and values constant station). driver the in ”Test“ setting by (done mode test in



(pot) sensor the as potentiometer a has that subsystem wrist a of picture mode test the is This to correspond that areas of number a has It motor. the to connected controller motor a and PIDSubsystem. the

value. input sensor the is This potentiometer. the from value voltage input analog The 1.

positive The stopped. as 0 with direction either in motor wrist the moves that slider A 2.
down. or up moving to correspond values negative and

speed for used is that value feedforward a is (F above described as constants PID The 3.
loops) PID

the reached has wrist the when value pot the to the corresponds that value setpoint The 4.
value desired

below. see working, longer No - controller PID the Enables 5.

to linked video the at look can You performance. motor desired the get to gains PID various Try performance. desired the get to internet the on sources other or article this of beginning the at

---

the as 2020, in introduced `PIDController` the affect not does option enable The :□□□□ this retain to how on below example the See loop. robot every updated is controller functionality.

---

### PIDController New the in Functionality Enable

will that dashboard your on button a create to how demonstrates example following The PIDController. the enable/disable

Java

```
                                  );"Shooter"(getTabShuffleboard. = tab ShuffleboardTab
         ();getEntry).false ,"Enable Shooter"(addtab. = shooterEnable NetworkTableEntry

                                    PIDSubsystem a in be to assumed Example Command //
      InstantCommand(m_shooter::enable)); new(onTrueNetworkButton(shooterEnable). new

                                                               Example Robot Timed //
                                           { ())getBoolean(shooterEnable. if
   reading sensor the on based algorithm PID the of output the Calculates //
                                                    motor a to it sends and //
                      setpoint)); (),getDistance(encoder.calculate(pid.setmotor.
                                                                              }
```

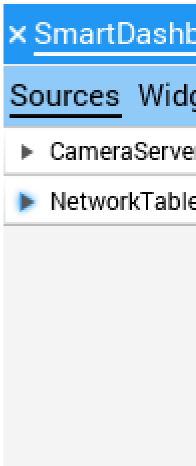
C++

```
                   );"Shooter"GetTab(::Shuffleboard::frc = tab &ShuffleboardTab::frc
     ).GetEntry();false ,"Enable Shooter"tab.Add( = shooterEnable NetworkTableEntry::nt

                                      PIDSubsystem a in be to assumed Command-based //
      m_shooter. { ]&InstantCommand([::NetworkButton(shooterEnable).OnTrue(frc2::frc2
                                                                    ));} Enable(); ↪

                                                               Example Robot Timed //
                                           { (shooterEnable.GetBoolean()) if
   reading sensor the on based algorithm PID the of output the Calculates //
                                                    motor a to it sends and //
                      setpoint)); motor.Set(pid.Calculate(encoder.GetDistance(),
                                                                              }
```

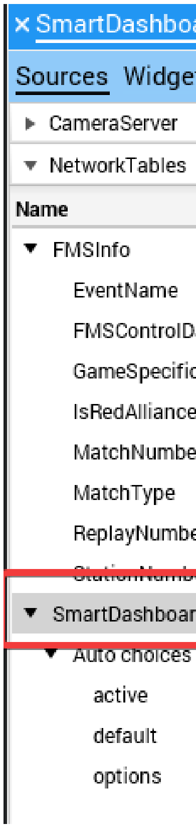
## Data of Hierarchies Viewing

a in hierarchy the displays hierarchy) the in (deeper it below keys other with key a Dragging left. the on sources NetworkTables the to similar tree,

source: data the Select



tab. preferred the into key NetworkTables the drag and Click



## Widgets Custom - Shuffleboard 11.1.4

### Plugins inBuilt-

use, FRC® for tasks common handle that plugins inbuilt- of number a provides Shuffleboard connections. *NetworkTables* and widgets, all streams, camera as such

### Plugin Base

It use. FRC for necessary layouts and widgets, types, data the all defines plugin base The source those for widgets or types data special any or types, source the of any define *not* does This .*Plugin CameraServer* the and *Plugin NetworkTables* the by handled are Those types. or types source custom for plugins create to teams for easier it makes concerns of separation client. NetworkTables a needing without types data FRC the for ZeroMQ) HTTP, (eg protocols

### Plugin CameraServer

the from camerastreams viewing for widgets and sources provides plugin server camera The class. WPILib `CameraServer`

camera available the discover to order in *Plugin NetworkTables* the on depends plugin This streams.

### discovery Stream

`CameraPublisher/` the at looking by discovered automatically are sources CameraServer NetworkTable.

```
                                   CameraPublisher/
                                   >name camera</
                         ]... ,"url2" ,"url1"[=streams
```

would `frc.local-0000-roborio` at server a with ”Camera“ named camera a example, For layout: table this have

```
                                                CameraPublisher/
                                                         Camera/
   ]"mjpeg:http://roborio-0000-frc.local:1181/?action=stream"[=streams
```

the by roboRIO a on hosted streams camera all discover automatically will setup This streams camera have to want that projects WPILibnon- Any WPILib. in class CameraServer server. camera the for entry streams the set to have will shuffleboard in appear

### Plugin NetworkTables

,`LiveWindow` the Since ntcore. by backed sources data provides plugin NetworkTables The data the send to NetworkTables use WPILib in classes `Shuffleboard` and ,`SmartDashboard` classes. those use to order in loaded be to need will plugin this station, driver the to

users automatically, NetworkTables to reconnection and connection the handles plugin This of intricacies the about worry to have not will plugins custom of writers and shuffleboard of protocol. NetworkTables the

## Plugin a Creating

### סקירה כללית

custom and sources/types, data layouts, widgets, custom create to ability the provide Plugins .*plugins inbuilt-* following the provides Shuffleboard themes.

- NetworkTables over published data to connect To Plugin: NetworkTables
- widgets custom in types data FRC® custom display To Plugin: Base
- CameraServer the from streams view To Plugin: CameraServer

---

simple a and type data custom a creates which plugin Shuffleboard custom example An :□□□ .here found be can it displaying for widget

---

### Plugin Custom a Create

of subclass a be must class plugin the plugin, a define to order In plugin a of example An subclasses. its of one or edu.wpi.first.shuffleboard.api.Plugin following. as be would class

Java

```
;edu.wpi.first.shuffleboard.api.plugin.Description import
;edu.wpi.first.shuffleboard.api.plugin.Plugin import

= summary ,"1.2.3" = version ,"MyPlugin" = name ,"com.example" = (group@Description
)"plugin example An" ↪
{ Plugin extends MyPlugin class public

}
```

be can numbers version including used, are attributes these how on explanations Additional .here found

the of properties the loader plugin the tell to needed is annotation `@Description` the Note cannot it but constructor default a have to permitted are classes Plugin class. plugin custom arguments. any take

### plugin Building

shufflebloard the in folder *pluginsexample-* the utlize to is plugins build to way easiest The
`https://github.com/wpilibsuite/` `clone git` with Shuffleboard Clone tree. source
you version WPILib the to corresponds that version the checkout and ,`shuffleboard.git`
`v2023.2.1 checkout git` 2023.2.1). (e.g. installed have

the Copy directory. `NAME-PLUGIN\plugins-example` the in plugin your Put
and `widget-and-data-custom\plugins-example` from `widget.gradle-and-data-custom`
directory root shuffleboard the in `settings.gradle` Edit name. plugin your match to rename
`NAME"-plugins:PLUGIN-"example include` add to

must they however, libraries, and plugins other on dependencies have to allowed are Plugins
other on depends plugin a When file. build gradle or maven the in correctly included be
the when load not does plugin the so dependencies those define to practice good is it plugins,
shown as annotation `@Requires` the using done be can This well. as load not do dependencies
below:

```
        )"1.2.3" = minVersion ,"Plugin Good" = name ,"com.example" = (group@Requires
  )"1.0.0" = minVersion ,"Base" = name ,"edu.wpi.first.shuffleboard" = (group@Requires
   = summary ,"1.2.3" = version ,"MyPlugin" = name ,"com.example" = (group@Description
                                                           )"plugin example An" ↪
                                             { Plugin extends MyPlugin class public

                                                                                 }
```

loaded. be can that plugin the of version allowable minimum the specifies `minVersion` The
it loaded, is 1.4.7 version the with plugin the and 1.4.5, is `minVersion` the if example, For
be not will it loaded, is 1.2.4 version the with plugin the if However, so. do to allowed be will
.`minVersion` the than less is it since to allowed

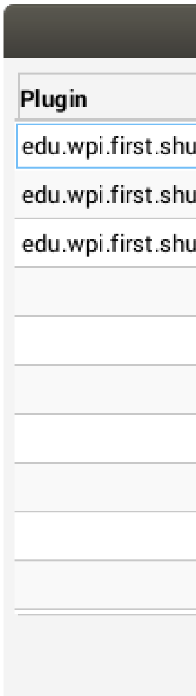
### Shuffleboard To Plugin Deploying

plugin the of file jar a generate to need will you Shuffleboard, in plugin a load to order In
running by automatically done be can This folder. `~/Shuffleboard/plugins` the in it put and
`NAME:installPlugin-plugins:PLUGIN-:example gradlew` root shuffleboard the from

automatically be can it so plugin the of path the cache will Shuffleboard deploying, After
under `Cache Clear` on click to necessary be may It loads. Shuffleboard time next the loaded
Shuffleboard. into plugin a reload or plugin a remove to menu plugins the

### Plugin Adding Manually

from it add and file jar a to it compile to is Shuffleboard to plugin a add to way other The
after `libs\build\NAME-PLUGIN\plugins-example` in located is file jar The Shuffleboard.
in tab file the on click Shuffleboard, Open root shuffleboard the in `build gradlew` running
menu. down drop the from Plugins choose and left, top the



Plugin
edu.wpi.first.shu
edu.wpi.first.shu
edu.wpi.first.shu

select and right, bottom the in button plugin“ ”Load the choose window, plugins the From file. jar your

### Types Data Custom Creating

integers be could data This data. of types different visualize and control to us allow Widgets is it widgets, using data of types these display to order In Objects. Java even or doubles and Class Data own your create to necessary not is It them. for class container a create to helpful strings. or arrays, doubles, as such types data fielded single handle will widget the if

### Class Data The Creating

coordinates. y and x its and Point 2D a for type data custom a create will we example, this In .ComplexData class abstract the extend must it class, type data custom a create to order In represented the returns that method `asMap()` the implement also must class data custom Your annotation: `@Override` the with below noted as map simple a as data

```
                          ;edu.wpi.first.shuffleboard.api.data.ComplexData import

                                                      ;java.util.Map import

                          { >MyPoint2D<ComplexData extends MyPoint2D class public

                                                  x; double final private
                                                  y; double final private

  ␣their them assign and needed fields different the all take should Constructor//
                                               variables. instance corresponding ↪
                                     { y) double x, double(MyPoint2D public
                                                                    x; = x.this
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                               y; = y.this
                                                         }

                                                 @Override
                  { ()asMap >Object String,<Map public
                     y); ,"y" x, ,"x"(ofMap. return
                                                         }
                                                           }
```

that ensure to methods hashcode and equals default the override to practice good also is It `asMap()` The same. the are fields their when equivalent considered are objects different the to mapped be will it as object Map simple a in represented data the return should method and X its as point the represent can we case, this In to. corresponds it entry NetworkTables them. containing Map a return and coordinates Y

```
                    ;edu.wpi.first.shuffleboard.api.data.ComplexData import

                                                     ;java.util.Map import

               { >MyPoint2D<ComplexData extends MyPoint2D class final public

                                             x; double final private
                                             y; double final private

    ␣to them assign and needed fields different the all take should Constructor //
                                  variables. instance corresponding their ↪
                                    { y) double x, double(Point public
                                                      x; = x.this
                                                      y; = y.this
                                                                 }

                                                         @Override
                                  { ()asMap >Object String,<Map public
                        );y.this ,"y" ,x.this ,"x"(ofMap. return
                                                                 }
                                                                   }
```

is it however, variables, instance and fields edit or retrieve to added be can methods Other objects. data source the changing prevent to immutable classes these make to practice good For object. existing the manipulating of instead object copy new a make can you Instead, following the define can we point, our of coordinate y the change to wanted we if example, method:

```
                                 { newY) double(withY MyPoint2D public
                                 newY); ,x.thisMyPoint2D( new return
                                                                   }
```

be can Same coordinate.y- new the with it returns and object `MyPoint2D` new a creates This coordinate. x the changing for done

## Type Data a Creating

one only have that types data Simple made: be can that types data different two are There
fields data multiple have that types data Complex and string), or number single a (ie. field
numbers). multiple strings, multiple (ie.

><`DataTypeSimpleDataType` the extend must class the type, data simple a define to order In
this In method. `getDefaultValue()` the implement and needed type data the with class
type. data simple our as double a use will we example,

```
{ >Double<SimpleDataType extends MyDoubleDataType class final public

;"Double" = NAME String final static private

{ ()MyDataType private
);classDouble. (NAME,super
}

@Override
{ ()getDefaultValue Double public
;0.0 return
}

}
```

type data the of instance single a only that ensure to private to set is constructor class The
exist. will

and class `ComplexDataType` the extend must class the type, data complex a define to order In
class MyPoint2D our use will We methods. `getDefaultValue()` and `fromMap()` the override
like. look would class type data complex a what see to example an as

```
{ >MyPoint2D<ComplexDataType extends PointDataType class final public

;"MyPoint2D" = NAME String final static private
PointDataType(); new = Instance PointDataType final static public

{ ()PointDataType private
);classMyPoint2D. (NAME,super
}

@Override
{ ()fromMap >MyPoint2D ,>Object String,<Map<Function public
{ >- map return
map. )double( ),0.0 ,"x"(getOrDefaultmap. )doubleMyPoint2D(( new return
));0.0 ,"y"(getOrDefault ↪
;}
}

@Override
{ ()getDefaultValue MyPoint2D public
coordinates Y and X for 0 of values default use //
);0 ,0MyPoint2D( new return
}

}
```

noted: as works above code following The

entry NetworkTables the in values the using MyPoint2D new a creates method `fromMap()` The
The values. entry the get cannot it if 0.0 return will method `getOrDefault` The to. bound is it
present. is source no if object `MyPoint2D` new a return will `getDefaultValue`

### Plugin To Type Data Exporting

them export must plugin the Shuffleboard, by recognized be type data the have to order In
example, For method. `getDataTypes` the overriding by

```
{ Plugin extends MyPlugin class public

    @Override
    { ()getDataTypes >DataType<List public
        );Instance(PointDataType.ofList. return
    }

}
```

### Widget A Creating

data different through published data with interact and change, view, to us allow Widgets
control to widgets the provide plugins Base and NetworkTables, CameraServer, The sources.
to us allow widgets custom However, types). data specificFRC- (including types data basic
Objects. Java or sections previous the in made we types data custom our control

`Component` interfaces. `Sourced` and `Component` the from inherits interface `Widget` basic The
is `Sourced` Shuffleboard. in displayed be that components of block building basic most the is
modify or display to sources data with interface and handle can that things for interface an
the use not would nodes child have simply but bindings data support don't that Widgets data.
towards blocks building basic are Both interface. `Component` the simply but interface `Sourced`
data. display and modify to us allows and widgets making

example An needs. their suit to widget the customize to userend- the allows widget good A
maximum its is, that slider, number the of range the control to user the allow to be could
looks it how or widget the of view The itself. slider the of orientation the or minimum and
static the defining for useful is that language based XML an is FXML FXML. using defined is
Controls). and Labels (Panes, widget the of layout

.here found be can FXML about More

### FXML Widget's a Defining

our of coordinates Y and X the control us help to sliders two create will we example, this In
the in file FXML the place to helpful is It sections. previous in created we type data Point2D
class. Java the as package same

is Pane A .`Pane` a create to need we widget, our for window blank empty, an create to order In
different many are There sliders. 2 case, this in nodes, child other contains that node parent a
noted: as are they Pane, of types

- Pane Stack
  - child center default by StackPanes Also, overlaid. be to elements allow Panes Stack
nodes.

Pane Grid •

system coordinate a using elements child defining useful extremely are Panes Grid –
pane. the on columns and rows of grid flexible a creating by

Pane Flow •

vertically flow can nodes Child set. boundary a at nodes child all wrap Panes Flow –
width the at (wrapped horizontally or pane) the for boundary height the at (wrapped
pane). the of boundary

Pane Anchor •

right side, left bottom, top, the in placed be to elements child allow Panes Anchor –
pane. the of center or side,

a using row horizontal one in nodes child placing for useful extremely also are panes Layout
.VBox a using column vertical one or HBox

following: the as be would FXML using Pane a defining for syntax basic The

```
javafx.scene.layout.*?> import?<
␣path/to/widget/class"/"fx:controller= http://javafx.com/fxml/1""xmlns:fx= StackPane<
>root""fx:id= ↪
...
StackPane>/<
```

class this of instance An class. widget the of name the contains attribute `fx:controller` The
a have must class controller the work, to this For loaded. is file FXML the when created is
constructor. argumentno-

## Class Widget A Creating

example, this In pane. that to elements child add now can we Pane, a have we that Now
be can they so element each to `fx:id` an add to Remember objects. slider two add can we
slider our position to `VBox` a use will We on. later make will we class Java our in referenced
other. each of top on

```
javafx.scene.layout.*?> import?<
␣path/to/widget/class"/"fx:controller= http://javafx.com/fxml/1""xmlns:fx= StackPane<
>root""fx:id= ↪

>VBox<
>/xSlider"" = fx:id Slider<
>/ySlider"" = fx:id Slider<
VBox>/<

StackPane>/<
```

The class. widget a create now can we file, FXML our creating finished have we that Now
types data supported the states that annotation `@Description` a include should class widget
the present, not is annotation `@Description` a If widget. the of name the and widget the of
widgets. its return to method `get()` the implement must class plugin

file FXML the to points that annotation `@ParametrizedController` a include must also It
must it source data one supports only that class the If widget. the of layout the containing
must it sources, data multiple supports class the If class. `SimpleAnnotatedWidget` the extend
.*Types Widget* see information, more For class. `ComplexAnnotatedWidget` the extend

```
                          ;edu.wpi.first.shuffleboard.api.widget.Description import
                 ;edu.wpi.first.shuffleboard.api.widget.ParametrizedController import
                  ;edu.wpi.first.shuffleboard.api.widget.SimpleAnnotatedWidget import

                                                                                  */
 ␣is file Java the is that package, same the in are file Java and file FXML the If *
                                                                 the and src/main/java in ↪
       ␣the package, equivalent code your or src/main/resources under is file FXML *
                                                                 work will path relative ↪
      required. be will path absolute an packages, different in are they if However, *
                                                                                  */

                        )classMyPoint2D. = dataTypes ,"MyPoint2D" = (name@Description
                                                 )"Point2DWidget.fxml"(@ParametrizedController
            { >MyPoint2D<SimpleAnnotatedWidget extends Point2DWidget class final public

                                                                                   }
```

Double. (ie. type data Java any reference can you type, data custom a using not are you If .NoneType.class pass can you binding data need not does widget the if or ),class

our in declared we widgets the for fields create can we class our created have we that Now be: would example an sliders, two our For annotation. @FXML the using file FXML

```
                          ;edu.wpi.first.shuffleboard.api.widget.Description import
                 ;edu.wpi.first.shuffleboard.api.widget.ParametrizedController import
                  ;edu.wpi.first.shuffleboard.api.widget.SimpleAnnotatedWidget import
                                                               ;javafx.fxml.FXML import

                        )classMyPoint2D. = dataTypes ,"MyPoint2D" = (name@Description
                                                 )"Point2DWidget.fxml"(@ParametrizedController
            { >MyPoint2D<SimpleAnnotatedWidget extends Point2DWidget class final public

                                                                               @FXML
                                                                 root; Pane private

                                                                               @FXML
                                                            xSlider; Slider private

                                                                               @FXML
                                                            ySlider; Slider private
                                                                                   }
```

method getView() the override to need we widget custom our on pane our display to order In .StackPane our return and

```
                          ;edu.wpi.first.shuffleboard.api.widget.Description import
                 ;edu.wpi.first.shuffleboard.api.widget.ParametrizedController import
                  ;edu.wpi.first.shuffleboard.api.widget.SimpleAnnotatedWidget import
                                                               ;javafx.fxml.FXML import

                        )classMyPoint2D. = dataTypes ,"MyPoint2D" = (name@Description
                                                 )"Point2DWidget.fxml"(@ParametrizedController
            { >MyPoint2D<SimpleAnnotatedWidget extends Point2DWidget class final public

                                                                               @FXML
                                                            root; StackPane private
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                   @FXML
                                                 xSlider; Slider private

                                                                   @FXML
                                                 ySlider; Slider private

                                                               @Override
                                                 { ()getView Pane public
                                                         root; return
                                                                       }

                                                                          }
```

## Listeners Adding and Elements Binding

the with relationships direct express to widgets JavaFX allows that mechanism a is Binding and NetworkTableEntry related its change will widget a changing example, For source. data versa. vice

by point 2D our of coordinate Y and X the changing be would case, this in example, An respectively. ySlider and xSlider of values the changing

`@FXML` the with tagged method `initialize()` the in bindings set to is practice good A .`public` not is method the if FXML from method the call to required is which annotation

```
                 ;edu.wpi.first.shuffleboard.api.widget.Description import
      ;edu.wpi.first.shuffleboard.api.widget.ParametrizedController import
       ;edu.wpi.first.shuffleboard.api.widget.SimpleAnnotatedWidget import
                                                   ;javafx.fxml.FXML import

              )classMyPoint2D. = dataTypes ,"MyPoint2D" = (name@Description
                              )"Point2DWidget.fxml"(@ParametrizedController
{ >MyPoint2D<SimpleAnnotatedWidget extends Point2DWidget class final public

                                                                   @FXML
                                                 root; StackPane private

                                                                   @FXML
                                                 xSlider; Slider private

                                                                   @FXML
                                                 ySlider; Slider private

                                                                   @FXML
                                             { ()initialize void private
    (MyPoint2D::getX));map(dataOrDefault.bind().valuePropertyxSlider.
    (MyPoint2D::getY));map(dataOrDefault.bind().valuePropertyySlider.
                                                                       }

                                                               @Override
                                                 { ()getView Pane public
                                                         root; return
                                                                       }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
}
```

class« data MyPoint2D the to property value slider's the binds method initialize above The
and coordinate the change will slider the changing Meaning, value. Y and X corresponding
source no if or, value, source's data the get will method dataOrDefault.map() The versa. vice
value. default the return will present, is

changed. has source data or slider the when values change to way another is listener a Using
be: would slider our for listener a example For

```
␣>- newValue) oldValue, ((observable,addListener().valuePropertyxSlider.
                                    (newValue));withXsetData(getData(). ↪
```

the to widget the of source data the in value the sets method `setData()` the case, this In
.newValue

### Components Custom Exploring

must plugin defining the plugins; loading when discovered automatically not are Widgets
be to plugins multiple allow to taken is approach This usable. be to it for it export explicitly
JAR. same the in defined

```
                                                             @Override
                                  { ()getComponents >ComponentType<List public
          ));class(Point2DWidget.forAnnotatedWidget(WidgetType.ofList. return
                                                                          }
```

### type Data For Widget Default Set

the override can you type, data custom your for default as widget your set to order In
as widgets default all for Map a stores that class plugin your in `getDefaultComponents()`
below: noted

```
                                                             @Override
                  { ()getDefaultComponents >ComponentType DataType,<Map public
  (Point2DWidget.forAnnotatedWidgetWidgetType. ,Instance(Point2DType.ofMap. return
                                                                 ));class ↪
                                                                          }
```

### Themes Custom

Cascading via themes custom for support has it application, JavaFX a is shuffleboard Since
HTML making for webpages on used commonly are These short). for **CSS**( Stylesheets
for here (see subset language different a for albeit support, has also JavaFX but nice, look
it). use to how on documentation

and Dark, Material Light, Material default: by themes three with comes Shuffleboard
they addition, In stylesheet. design material same the on variations color are These Midnight.
in ,defined components custom the for styles defines that stylesheet `base.css` a from inherit

the to applies only stylesheet design material base the uses; it that libraries or shuffleboard JavaFX. into built components UI

the with directory a in stylesheets the place theme: custom a define to ways two are There theme ”Yellow“ theoretical a example, for ;`~/Shuffleboard/themes` in theme the of name in placed be could

```
css.yellowtheme/Yellow/themes/Shuffleboard/~
```

theme. the of part as treated be will directory the in stylesheets the All

### Plugins via Themes Loading

bundle and share to easier them makes This plugins. by defined be also can themes Custom a need will object theme The define. to difficult more slightly are but widgets, custom with the where determine can loader plugin the that so plugin the in defined class a to reference in, is plugin the that JAR the in present *not* is that passed is class a If located. are stylesheets used. be to able be not will theme the

```
" = summary ,"1.2.3" = version ,"Plugin My" = name ,"com.example" = (group@Description
                                                                                  )" ↪
                                                           { Plugin extends MyPlugin class

  /" ,"Name Theme My" ,classTheme(MyPlugin. new = myTheme Theme final static private
                                  );... ,"path/to/stylesheet/" ,"path/to/stylesheet ↪

                                                                              @Override
                                                          { ()getThemes >Theme<List public
                                                       (myTheme);ofImmutableList. return
                                                                                      }

                                                                                        }
```

### Themes Default Shuffleboard’s Extending or Modifying

framework the of lot a provide themes Dark Material and Light Material Shuffleboard’s shuffleboard, to specific styles many as well as respectively, themes, dark and light for design. stylematerial- the with fit to components UI Medusa and ControlsFX,

these for statements import add to need themes these modify to want that Themes stylesheets:

```
  ␣for CSS design Material */ ;edu/wpi/first/shuffleboard/api/material.css"/" import@
                                                               */ components JavaFX ↪
     ␣for CSS design Material */  ;edu/wpi/first/shuffleboard/api/base.css"/" import@
                                                          */ components shuffleboard ↪
  ␣Light Material the for CSS */ ;edu/wpi/first/shuffleboard/app/light.css"/" import@
                                                                            */ theme ↪
   ␣Dark Material the for CSS */  ;edu/wpi/first/shuffleboard/app/dark.css"/" import@
                                                                            */ theme ↪
    ␣Midnight the for CSS */  ;edu/wpi/first/shuffleboard/app/midnight.css"/" import@
                                                                            */ theme ↪
```

and ,`dark.css` ,`light.css` and ,`material.css` imports internally `base.css` that Note `base.` both import implicitly will `light.css` importing so ,`base.css` import all `midnight.css` well. as `material.css` and `css`

## Files CSS the for Code Source

- https://github.com/wpilibsuite/shuffleboard/blob/main/api/src/main/ _material.css: resources/edu/wpi/first/shuffleboard/api/material.css
- https://github.com/wpilibsuite/shuffleboard/blob/main/api/src/main/ _base.css: resources/edu/wpi/first/shuffleboard/api/base.css
- https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/ _light.css: resources/edu/wpi/first/shuffleboard/app/light.css
- https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/ _dark.css: resources/edu/wpi/first/shuffleboard/app/dark.css
- https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/ _midnight.css: resources/edu/wpi/first/shuffleboard/app/midnight.css

## Swatches Color Design Material

variables These everything. almost for variables swatch color uses CSS design material The needed. code custom of amount the reducing files, CSS custom from set be can

the of shades darker progressively define variables `><100|200|300|400|500-swatch-` The but ,`material.css` in set blue of shades default the uses theme light The color. primary same defines `gray-><|light|dark-swatch-` red. of shades with these overrides theme dark the colors. text or background various for use to gray of levels three

## Colors Swatch the Overriding

### (light) red with blue Replacing

```
                     "edu/wpi/first/shuffleboard/app/light.css/" @import

                                                              { root.
                                   );%98 ,%80 ,0hsb( :100-swatch-
                                   );%88 ,%80 ,0hsb( :200-swatch-
                                   );%78 ,%80 ,0hsb( :300-swatch-
                                   );%68 ,%80 ,0hsb( :400-swatch-
                                   );%58 ,%80 ,0hsb( :500-swatch-
                                                                    }
```

### (dark) blue with red Replacing

```
                    "edu/wpi/first/shuffleboard/app/dark.css/" @import

                                                          { root.
                                          BBDEFB;# :100-swatch-
                                          90CAF9;# :200-swatch-
                                          64BEF6;# :300-swatch-
                                          42A5F5;# :400-swatch-
                                          2196F3;# :500-swatch-
                                                                }
```

### Types Widget

several are there concerned, is interface the as far as straightforward pretty is `Widget` While widget. the define to easier it make to implementations intermediate

| Class | Description |
|---|---|
| `AbstractWidget` | `titleProperty()` and ,`getSources()` ,`getProperties()` Implements |
| `><TSingleTypeWidget` | type data single a support only that widgets for properties Adds |
| `AnnotatedWidget` | for `getDataTypes()` and `getName()` for implementations default Adds annotation `@Description` a with widgets |
| `SingleSourceWidget` | support widgets default, (by source single a only with widgets For sources) multiple |
| `><TSimpleAnnotatedWidget` | and ,`AnnotatedWidget` ,`><TSingleTypeWidget` Combines `SingleSourceWidget` |

widgets: define help to annotations two also are There

| Name | Description |
|---|---|
| `@ParametrizedController` | defined views JavaFX for controllers FXML be to widgets Allows FXML via |
| `@Description` | single a in defined be types data supported and name the Lets line |

### AbstractWidget

and ,`addSource()` ,`getSources()` ,`getProperties()` implements class This so method `>...)<?exportProperties(Property` method a defines also It .`titleProperty()` components JavaFX the for properties or properties, widget custom add easy can subclasses this. use plugin base the in widgets the of Most widget. the in

### SingleTypeWidget

has and parametrized is interface This type. data single a supports only that widget of type A
type data (single) the getting for method a as well as data, the getting or setting for methods
widget. the of

### AnnotatedWidget

`@Description` the at looking by `getName()` and `getDataTypes()` implements interface This
the or present, be to annotation the *requires* This class. implementing the on annotation
used. and loaded be to able be not will widget

```
                                   annotation! @Description No //
{ AnnotatedWidget implements WrongImplementation class public
                                                            ... //
                                                                 }
```

```
                  )... = dataTypes ,... = (name@Description
{ AnnotatedWidget implements CorrectImplementation class public
                                                          ... //
                                                               }
```

### SingleSourceWidget

source. single a uses only that widget of type A

### SimpleAnnotatedWidget

Most .`SingleSourceWidget` and ,`AnnotatedWidget` ,><`TSingleTypeWidget` of combination A
called field `protected` a has also This class. this from extend plugin base the in widgets
a have doesn't widget the if value data default a use subclasses lets that `dataOrDefault`
.`null` providing is source the if or source,

### @ParametrizedController

FXML an it's that know shuffleboard let to class widget a on placed be can annotation This
that parameter single a takes annotation The FXML. via defined view JavaFX a for controller
a example, For .*placed is it which on class the to relation in* file FXML the where defines
file FXML a for controller FXML an is that `src/main/java/com/acme` directory the in widget
either as annotation the use can `src/main/resources/com/acme` in

```
)"MyWidget.fxml"(@ParametrizedController
```

as or

```
)"com/acme/MyWidget.fxml/"(@ParametrizedController
```

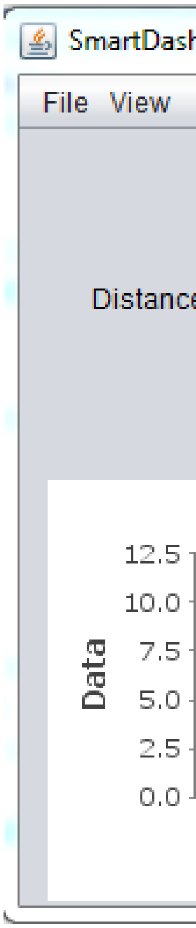
**@Description**

single a by defined types data supported and name their have to widgets allows This .*AnnotatedWidget* alongside used when annotation,

## SmartDashboard 11.2

computer few relatively uses that dashboard efficient and simple a is SmartDashboard but has, Shuffleboard features the of some or look fancy the have not does It resources. driver the down bogging without widgets of variety a with data tables network displays it computer. station

### Introduction SmartDashboard 11.2.1



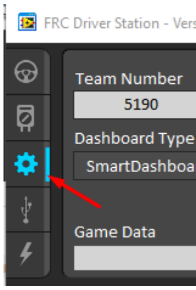
The time. real in data robot display will that program Java a is SmartDashboard The things: these with you helps SmartDashboard

- as displayed be can It running. is program the while choice your of data robot Displays etc. dials, graphs, like types display other many in elaborately more or fields text simple
- and commands executing currently the as such program robot the of state the Displays subsystems any of status the

- robot your on set be to variables cause to press can you that buttons Displays
- robot the by read be can that dashboard the on options startup choose to you Allows program

robot, the from sent is data the as timereal- in formatted automatically is data displayed The screen new the save then and types widget display the or format the change can you but use. to simple extremely still is it options, these all with And later. again used be to layouts with methods SmartDashboard the of one call simply dashboard, the on data some display To the data and its name and the value will automatically appear on the dashboard screen.

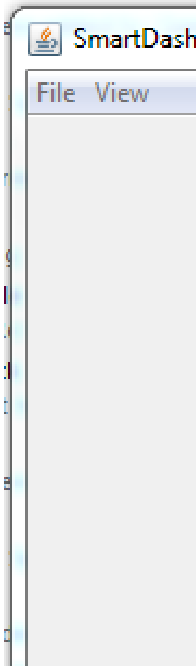
## SmartDashboard the Installing



Team Number
5190
Dashboard Type
SmartDashboa
Game Data

from directly launched be can and Installer WPILib the with packaged is SmartDashboard The tab. Setup the on button **SmartDashboard** the selecting by Station Driver the

### הגדרת מספר הקבוצה



number. team your for prompted be should you SmartDashboard the launch you time first The Preferences the open to **Preferences > File** click this: after number team the change To

Team FRC® your enter and **Number Team** of right the to box the clickDouble- dialog. save. to box the outside click then Number,

---

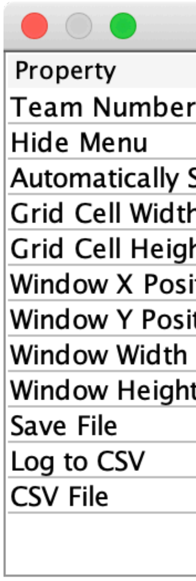
not do number, team the for itself configure to moment a take will SmartDashboard :□□□□ alarmed. be

---

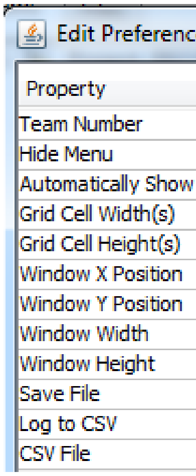
### Location Server NetworkTables Custom a Setting

connected a on running instances NetworkTables for look will SmartDashboard default, By address. IP different a at NetworkTables for look to useful sometimes it's but RoboRIO, SmartDashboard open roboRIO, the than other host a from SmartDashboard to connect To or address IP the enter field, `Number Team` the in and menu `File` the under preferences host. NetworkTables the of hostname

Simply .*simulation WPILib* with SmartDashboard using for useful incredibly is option This hostedlocally- your detect will SmartDashboard and field `Number Team` the to `localhost` add robot!

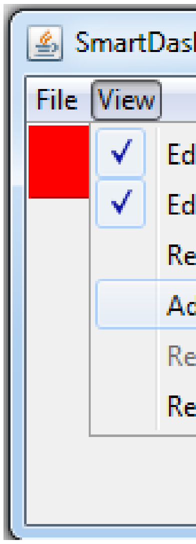


### File Save the Locating



box the click this do To SmartDashboard. the of location save the customize to wish may Users configuration. the save to like would you where folder the to browse then **File Save** to next overwritten be likely will components WPILib the for directories installation the in saved Files tools. the to updates on

### Indicator Connection a Adding



connection a add To robot. the to connected is SmartDashboard the if see to helpful often is It when red be will indicator This .**Indicator Connection > Add > View** select indicator, **> View** select indicator, this resize or move To connected. when green and disconnected the of center the drag then mode, editable into SmartDashboard the toggle to **Editable** place. in it lock to again item **Editable** the Select resize. to edges the or it move to indicator

### SmartDashboard the to Widgets Adding

robot the by sent ”key“ each for SmartDashboard the to added automatically are Widgets *Displaying* see SmartDashboard the to write to code robot adding on instructions For code. *.Program Robot the Within from Expressions*

## Program Robot a from Expressions Displaying 11.2.2

---

of number a writing involves robot a of status the monitoring or debugging Often :□□□□ values put can you SmartDashboard With by. stream them watching and console the to values to a GUI that is automatically constructed based on your program. As values are updated, the corresponding GUI element changes value - there is no need to try to catch numbers streaming by on the screen.

---

### SmartDashboard to Values Writing

Java

```
                                          { ()execute void protected
                    ());atBridgebridgeTipper. ,"Limit Bridge"(putBooleanSmartDashboard.
                   ());getPositionbridgeTipper. ,"Angle Bridge"(putNumberSmartDashboard.
                  ());getSwerveAngledrivetrain. ,"Angle Swerve"(putNumberSmartDashboard.
              ());getLeftEncoderdrivetrain. ,"Encoder Drive Left"(putNumberSmartDashboard.
            ());getRightEncoderdrivetrain. ,"Encoder Drive Right"(putNumberSmartDashboard.
                     ());getCurrentAngleturret. ,"Pot Turret"(putNumberSmartDashboard.
               ());getAverageVoltageturret. ,"Voltage Pot Turret"(putNumberSmartDashboard.
                               ());getRPMshooter. ,"RPM"(putNumberSmartDashboard.
                                                                                 }
```

C++

```
                                               { ()Command::Execute void
          BridgeTipper.AtBridge()); ,"Limit Bridge"PutBoolean(::SmartDashboard::frc
       BridgeTipper.GetPosition()); ,"Angle Bridge"PutNumber(::SmartDashboard::frc
      Drivetrain.GetSwerveAngle()); ,"Angle Swerve"PutNumber(::SmartDashboard::frc
  Drivetrain.GetLeftEncoder()); ,"Encoder Drive Left"PutNumber(::SmartDashboard::frc
 Drivetrain.GetRightEncoder()); ,"Encoder Drive Right"PutNumber(::SmartDashboard::frc
            Turret.GetCurrentAngle()); ,"Pot Turret"PutNumber(::SmartDashboard::frc
   Turret.GetAverageVoltage()); ,"Voltage Pot Turret"PutNumber(::SmartDashboard::frc
                          Shooter.GetRPM()); ,"RPM"PutNumber(::SmartDashboard::frc
                                                                                }
```

the calling simply by SmartDashboard the to values String or Numeric, Boolean, write can You additional no data, the of value the and name the including and type the for method correct same the with value another write you that program your in time Any required. is code development or station driver the on screen the on element UI same the in appears it name, your of status getting and debugging of way great a is this imagine can you As computer. operating. is it as robot

### SmartDashboard on Widgets Creating

is intervention user no automatically, SmartDashboard the on populated are Widgets may you written, first is value the when populated only are widgets the that Note required. an for routine code particular a trigger or mode particular a in robot your enable to need *Changing* sections two next the see widget, the of appearance the alter To appear. to item .*Value a for Type Widget Display the Changing* and *Value a of Properties Display the*

### Data Stale

the and robot the between values communicating for *NetworkTables* uses SmartDashboard pairs. value and name of table distributed a as acts NetworkTables laptop. station driver replicated is it (robot) server or (laptop) client the either to added is pair name/value a If SmartDashboard the but robot the say, from, deleted is pair name/value a If other. the to still will values old the restarted, is robot the when then running, still are OutlineViewer or and running stopped never they because OutlineViewer and SmartDashboard the in appear will values old those restarts, robot the When tables. their in values those have to continue robot. the to replicated be

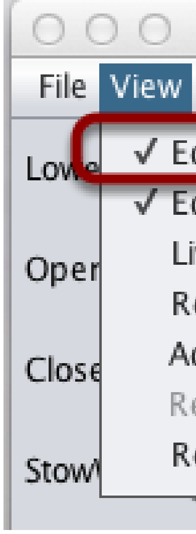
is it values, current showing are OutlineViewer and SmartDashboard the that ensure To old way, That time. same the at robot and clients NetworkTables the restart to necessary others. the to replicated get won't holding is one that values

in is program the if but changing, constantly isn't program the if problem a isn't usually This then changing, constantly is NetworkTables to added being keys of set the and development current. is what see accurately to everything of restart the do to necessary be might it

## value a of properties display the Changing 11.2.3

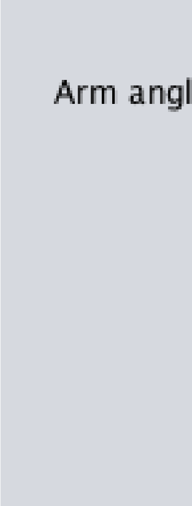
it's way the effect that properties of set a has SmartDashboard with displayed value Each displayed.

### mode editing into display SmartDashboard the Setting



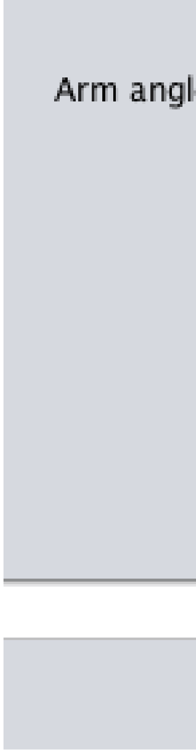
edit In mode. edit and mode display in, operate can it modes two has SmartDashboard The the put To properties. their edit and screen the on widgets around move can you mode on turn to ”Editable“ select then menu, ”View“ the click mode, edit into SmartDashboard mode. edit

### widget a of editor properties the Getting



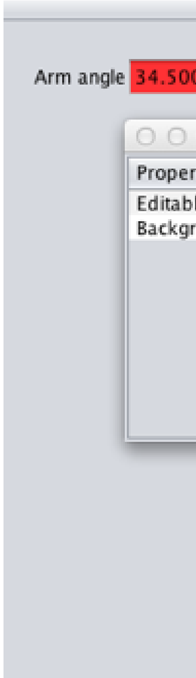
the on clickRight- widget. a for properties the edit and display can you mode, edit in Once ”Properties...“. select and widget

### field a on properties the Editing



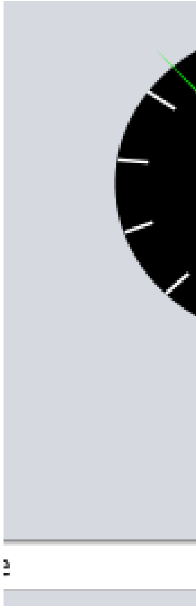
right- widgets the on item menu ”Properties…“ the to response in shown be will box dialog A menu. context click

### color background widgets the Editing



this (in shown color background the click color, Background say, value, property a edit To the as used be will This up. pops that editor color the from color a choose and grey), case color. background widgets

### widgets other of properties Edit

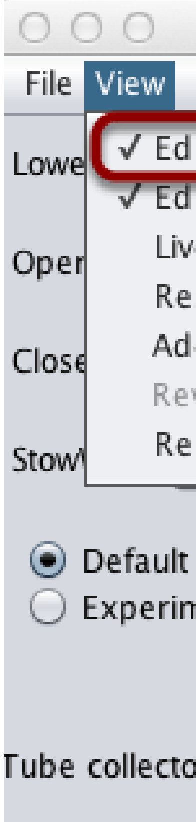


appearance. the change to properties editable of sets different have types widget Different changeable are interval tick the and dial the of limits lower and upper the example, this In parameters.

## Value a for Type Widget Display the Changing 11.2.4

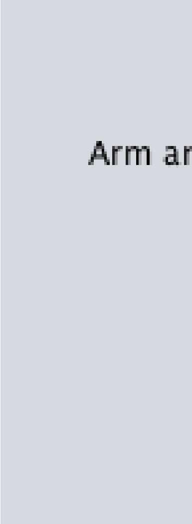
The SmartDashboard. the with values displays that widget of type the change can One displayed. being value the of type the on depend widgets allowable

### Mode Edit Setting



from `Editable` selecting by done is This mode. edit in is SmartDashboard the that sure Make .menu `View` the

### Type Widget Choosing



for use to widget of type the pick Then, `.to... Change` select and widget the on clickRight- .`LinePlot` choose we case this In value. particular the

### Type Widget New Showing

Arm the of values the show will Plot, Line a case, this In displayed. is type widget new The data your fit better it make to graph the of properties the set can You time. over value angle *a of properties display the Changing* See: `.Properties...` selecting and clickingright- by *.value*

### Program Autonomous an Choosing 11.2.5

or reasons competitive for either program, autonomous one than more have teams Often different delays, time like things adding by vary often Programs software. new testing for joystick switches, involves usually run to strategy the choose to methods The etc. strategies, inputs. based hardware other or knobs buttons,

the choose to screen the on widget a display simply can you SmartDashboard the With that programs, based command with And run. to like would you that program autonomous an select to how shows article This commands. several of one in encapsulated is program with interface, user looking nice a and code of lines few a only with program autonomous Robots. BasedCommand- and TimedRobot both for examples

## TimedRobot

):C++ ,Java( template TimedRobot the of part are below shown snippets code The :□□□□

### Object SendableChooser Creating

object. `SendableChooser` a to reference a hold to variable a create ,`Robot.h` / `Robot.java` In
Using chooser. the to send to strings creating by added be can modes auto more or Two
`Auto My` and `Default` example, this In them. between choose can one ,`SendableChooser` the
chosen, been has auto which store to variable a need also will You options. as shown are
.`m_autoSelected`

Java

```
        ;"Default" = kDefaultAuto String final static private
         ;"Auto My" = kCustomAuto String final static private
                            m_autoSelected; String private
();><SendableChooser new = m_chooser >String<SendableChooser final private
```

C++

```
      m_chooser; >string::std<SendableChooser::frc
;"Default" = kAutoNameDefault string::std const
 ;"Auto My" = kAutoNameCustom string::std const
                      m_autoSelected; string::std
```

### Options Up Setting

strings the case this in elements, defined of list a from pick to you allows chooser The
using above strings as created options your add ,`robotInit` In above. defined we
when default by selected one the be will `setDefaultOption` .`addOption` or `setDefaultOption`
station driver your on dashboard the to it push will function `putData` The starts. dashboard the
computer.

Java

```
                           { ()robotInit void public
kDefaultAuto); ,"Auto Default"(setDefaultOptionm_chooser.
         kCustomAuto); ,"Auto My"(addOptionm_chooser.
      m_chooser); ,"choices Auto"(putDataSmartDashboard.
                                                     }
```

C++

```
                                 { ()Robot::RobotInit void
kAutoNameDefault); m_chooser.SetDefaultOption(kAutoNameDefault,
         kAutoNameCustom); m_chooser.AddOption(kAutoNameCustom,
        m_chooser);& ,"Modes Auto"PutData(::SmartDashboard::frc
                                                             }
```

## Code Autonomous Running

variable `m_autoSelected` the use can you ,`autonomousPeriodic` and `autonomousInit` in Now, period. autonomous the during happens what change and chosen, was option which read to

Java

```
                                     @Override
                           { ()autonomousInit void public
                    ();getSelectedm_chooser. = m_autoSelected
              m_autoSelected); + " selected: Auto"(println.outSystem.
                                         }

           */ autonomous. during periodically called is function This **/
                                     @Override
                         { ()autonomousPeriodic void public
                            { (m_autoSelected) switch
                               kCustomAuto: case
                         here code auto custom Put //
                                    ;break
                               kDefaultAuto: case
                                    :default
                         here code auto default Put //
                                    ;break
                                        }
                                         }
```

C++

```
                            { ()Robot::AutonomousInit void
                     m_chooser.GetSelected(); = m_autoSelected
                 m_autoSelected); ,"n\}{ selected: Auto"print(::fmt

                      { kAutoNameCustom) == (m_autoSelected if
                             here goes Auto Custom //
                                      { else }
                            here goes Auto Default //
                                         }
                                          }

                          { ()Robot::AutonomousPeriodic void
                      { kAutoNameCustom) == (m_autoSelected if
                             here goes Auto Custom //
                                      { else }
                            here goes Auto Default //
                                         }
                                          }
```

## BasedCommand-

project example HatchbotTraditional the of part are below shown snippets code The :□□□□
):C++ ,Java(

### Object SendableChooser the Creating

Two object. `SendableChooser` a to reference a hold to variable a create ,`RobotContainer` In ,`SendableChooser` the Using variables. new in stored and created be can commands more or as shown are `ComplexAuto` and `SimpleAuto` example, this In them. between choose can one options.

Java

```
stops. then and distance, specified a forward drives that routine auto simple A //
                                                  = m_simpleAuto Command final private
                                                                    DriveDistance( new
   m_ ,kAutoDriveSpeedAutoConstants. ,kAutoDriveDistanceInchesAutoConstants.
                                                                        robotDrive); ↪

    ␣drives then and hatch, a drops forward, drives that routine auto complex A //
                                                                          backward. ↪
        m_ ComplexAuto(m_robotDrive, new = m_complexAuto Command final private
                                                                    hatchSubsystem); ↪

                                                  commands autonomous for chooser A //
                          ();><SendableChooser new = m_chooser >Command<SendableChooser
```

pointers) raw (using C++

```
                                                            routines autonomous The //
                    kAutoDriveDistanceInches,::m_simpleAuto{AutoConstants DriveDistance
                    m_drive};& kAutoDriveSpeed,::AutoConstants
                                          m_hatch};& m_drive,&m_complexAuto{ ComplexAuto

                                                routines autonomous the for chooser The //
                                              m_chooser; >*Command::frc2<SendableChooser::frc
```

)CommandPtr (using C++

```
                                                            routines autonomous The //
                          m_drive);&SimpleAuto(::autos = m_simpleAuto CommandPtr::frc2
                m_hatch);& m_drive,&ComplexAuto(::autos = m_complexAuto CommandPtr::frc2

                                                routines autonomous the for chooser The //
                                              m_chooser; >*Command::frc2<SendableChooser::frc
```

### SendableChooser up Setting

are they and between choose to programs autonomous two have you that Imagine them: between choose To .ComplexAuto and SimpleAuto commands in encapsulated

two the of instances add and object SendableChooser a create ,RobotContainer In default a as added one the and commands, of number any be can There it. to commands command each that Notice selected. initially is that one the becomes ),setDefaultOption( SendableChooser the on call method addOption() or setDefaultOption() an in included is instance.

Java

```
chooser command autonomous the to commands Add //
m_simpleAuto); ,"Auto Simple"(setDefaultOptionm_chooser.
m_complexAuto); ,"Auto Complex"(addOptionm_chooser.
```

pointers) raw (using C++

```
chooser command autonomous the to commands Add //
m_simpleAuto);& ,"Auto Simple"m_chooser.SetDefaultOption(
m_complexAuto);& ,"Auto Complex"m_chooser.AddOption(
```

)CommandPtr (using C++

```
chooser command autonomous the to commands Add //
chooser the into ownership move *not* do we that Note //
m_simpleAuto.get()); ,"Auto Simple"m_chooser.SetDefaultOption(
m_complexAuto.get()); ,"Auto Complex"m_chooser.AddOption(
```

dashboard: the to chooser the publish Then,

Java

```
dashboard the on chooser the Put //
(m_chooser);putDataSmartDashboard.
```

C++

```
dashboard the on chooser the Put //
m_chooser);&PutData(::SmartDashboard::frc
```

### Command Autonomous an Starting

to polled is object SendableChooser the starts, period autonomous the when ,Robot.java In scheduled. be must command that and command selected the get

Java

```
{ ()getAutonomousCommand Command public
();getSelectedm_chooser. return
}
```

```
{ ()autonomousInit void public
();getAutonomousCommandm_robotContainer. = m_autonomousCommand
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
(example) command autonomous the schedule //
{ )null =! (m_autonomousCommand if
();schedulem_autonomousCommand.
}
}
```

(Source) C++

```
{ ()RobotContainer::GetAutonomousCommand *Command::frc2
autonomous in command chosen the Runs //
m_chooser.GetSelected(); return
}
```

```
{ ()Robot::AutonomousInit void
m_container.GetAutonomousCommand(); = m_autonomousCommand

{ )nullptr =! (m_autonomousCommand if
Schedule();>-m_autonomousCommand
}
}
```

## Autonomous during Scheduler the Running

every (about period update station driver every scheduler the run will this ,`Robot.java` In run. to command autonomous selected the cause and 20ms)

---

or function `autonomousPeriodic()` the in occur can scheduler the Running :□□□□ mode. autonomous in similarly function will both ,`robotPeriodic()`

---

Java

```
@Override
{ ()robotPeriodic void public
();run().getInstanceCommandScheduler.
}
```

(Source) C++

```
{ ()Robot::RobotPeriodic void
GetInstance().Run();::CommandScheduler::frc2
}
```

## Command Autonomous the Canceling

canceled. be will command autonomous the begins, period teleop the when ,`Robot.java` In

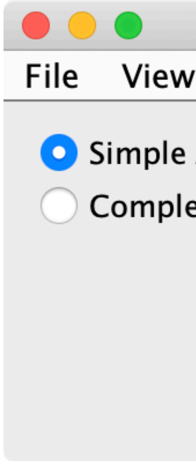
Java

```
                                                  @Override
                                 { ()teleopInit void public
when running stops autonomous the that sure makes This //
  to autonomous the want you If running. starts teleop //
 remove command, another by interrupted until continue //
                          out. it comment or line this //
                       { )null =! (m_autonomousCommand if
                          ();cancelm_autonomousCommand.
                                                        }
                                                          }
```

(Source) C++

```
                                 { ()Robot::TeleopInit void
when running stops autonomous the that sure makes This //
  to autonomous the want you If running. starts teleop //
 remove command, another by interrupted until continue //
                          out. it comment or line this //
                    { )nullptr =! (m_autonomousCommand if
                         Cancel();>-m_autonomousCommand
                         ;nullptr = m_autonomousCommand
                                                        }
                                                          }
```

## Display SmartDashboard



● Simple

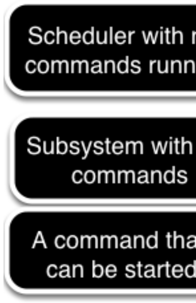
○ Comple

automatically are `SendableChooser` the from choices the run, is SmartDashboard the When the and begins period autonomous the before option an pick simply can You displayed. run. will command corresponding

## Subsystems and Commands of Status the Displaying 11.2.6

they that find will you WPILib, of features programming basedcommand- the using are you If
doing is robot the what diagnose help can It SmartDashboard. with integrated well very are
running. currently what’s of view a and control you gives it and time any at

### Displays Subsystem and Command of Overview



your in subsystems and commands the of status the display can you SmartDashboard With
time debugging the reduce significantly should outputs The ways. various in program robot
possible. are that displays of number a see can you picture this In programs. your for
are: here Displayed

- see can you example next the In `.running commands No` with currently Scheduler The
robot. the of status the showing running commands few a with like looks it what
- commands no currently are there that indicates that `ExampleSubsystem` subsystem, A
name the indicate will it running, are commands When it. ”requiring“ are that running
subsystem. the using are that commands the of
- pressed be can that button `start` a shows that SmartDashboard to written command A
time. a at one commands your testing of way excellent an is This command. the run to
- running. that’s code the debug help to dashboard the to written values data few a And

In the following examples, you’ll see what the screen would look like when there are
display. this produces that code the and running, commands

### Status Scheduler the Displaying

Java

```
());getInstance(CommandScheduler.putDataSmartDashboard.
```

C++

```
GetInstance());::CommandScheduler::PutData(frc2::SmartDashboard::frc
```

run). to commands your schedules that code (the Scheduler the of status the display can You
as RobotProgram your in method `RobotInit` the to line single a adding by done easily is This
to method `putData` the using written is instance Scheduler the example this In here. shown
image. previous the in display the produces code of line This SmartDashboard.

and `ExampleCommand` running, commands two are there when status scheduler the is This screen previous the from message `running.` `commands No` the replaces This `.newCommand` various and runs program the as dashboard the on displayed commands see can You image. triggered. are commands

### Status Subsystem Displaying

Java

```
(exampleSubsystem);putDataSmartDashboard.
```

C++

```
exampleSubsystem);&PutData(::SmartDashboard::frc
```

of instance and `exampleSubsystem` instance, command the writing are we example this In the in shown display the causes This SmartDashboard. the to class `ExampleSubsystem` the no that indicating `---` dashes, few a contain either will field text The image. previous this using currently command the of name the or subsystem, this using current is command subsystem.

the reserving is command the is That subsystems. ”require“ will commands Running will it SmartDashboard, on subsystem a display you If use. exclusive its for subsystem by use in is `ExampleSubsystem` example, this In it. using currently is command which display .`ExampleCommand`

### Button a with Commands Activating

Java

```
exampleCommand); ,"Command Autonomous"(putDataSmartDashboard.
```

C++

```
exampleCommand);& ,"Command Autonomous"PutData(::SmartDashboard::frc
```

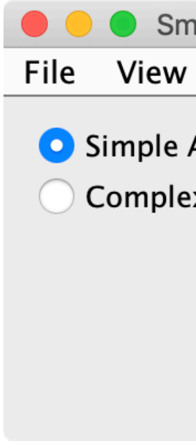
Pressing SmartDashboard. on command the for button a create to required code the is This label button the running, is command the While command. the schedule will button the command. the cancel will button the pressing and `cancel` to `start` from changes

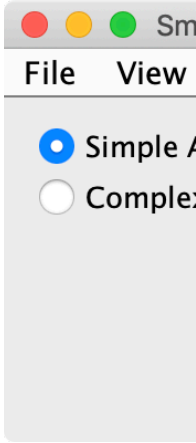
button this Pressing `.Command Autonomous` labeled button a see can you example this In time a at one commands testing of way excellent an is and command associated the run will each for buttons Adding program. robot your to code test awaythrow- add to having without time. a at command one program, the test to simple it makes command

## working is SmartDashboard Verifying 11.2.7

### Indicator Connection

the of address IP and status connection the include automatically will SmartDashboard window. the of title the in source NetworkTables





## Widget Indicator Connection

green or red turn will which widget indicator connection a includes SmartDashboard For roboRIO. the by provided usually NetworkTables, to connection the on depending SmartDashboard the in *Indicator Connection a Adding* at look widget, this add to instructions Intro.

## Example Program Robot

Java

```
                          { TimedRobot extends Robot class public
                                    ;0.0 = counter double

                                { ()teleopPeriodic void public
          );++counter ,"Counter"(putNumberSmartDashboard.
                                                          }
                                                            }
```

C++

```
                                      Robot.h"" include#
                                   ;0.0 = counter float

                              { ()Robot::TeleopPeriodic void
     );++counter ,"Counter"PutNumber(::SmartDashboard::frc
                                                        }
```

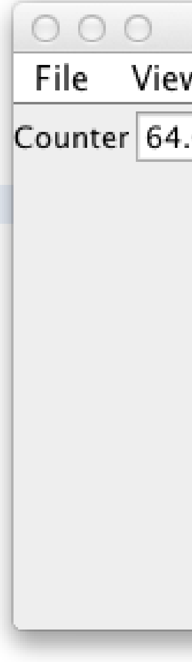
simply It SmartDashboard. the to value a writes that program robot minimal a is This However, working. is connection the that verify to second per times 50 counter a increments times 10 to updates the throttle will default by NetworkTables usage, bandwidth minimize to second. per

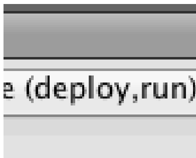
### Program Sample the for Output SmartDashboard

Counter 64

being robot the of seconds 6 about after this like look should display SmartDashboard The correctly is connection the that check to need you then doesn’t, it If mode. Teleop in enabled up. set

### SmartDashboard in address IP the Verifying





set correctly is number team the that verify appearing, not is value the of display the If then ,`File` selecting by viewed be can dialog preferences The picture. this in shown as .`Preferences`

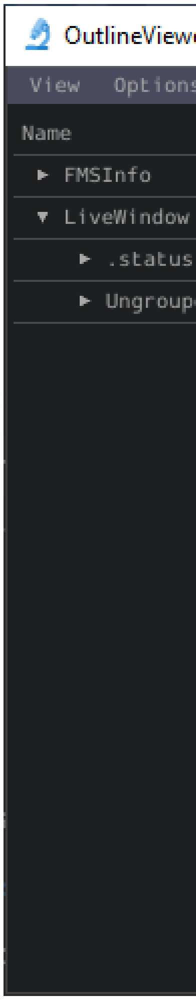
### OutlineViewer using Program Verifying

the using by values SmartDashboard generating is program robot the that verify can You ~/ in located is that ,`OutlineViewer.jar` program, Java a is This program. OutlineViewer Windows). on `C:\Users\Public` is ~ and year the is YYYY (where `wpilib/YYYY/tools`

see information, more For Installer. Offline WPILib the of part as downloaded is OutlineViewer `Ctrl+Shift+P` press Code, Studio Visual In .*guides installation Windows/macOS/Linux* the Command WPILib the launch to right top the in logo WPILib the click or ”WPILib“ type and .*OutlineViewer* select then and ,*Tool Start* Select Palette.

click Then, zeroes. leading no with number team your enter box, Location“ ”Server the In .`Start`

written variable the is `SmartDashboard/Counter` value the table, the in row second the at Look
value the see should you runs program the As NetworkTables. via SmartDashboard the to
for look OutlineViewer, the in variable this see don't you If case). this in `41.0`( increasing
configuration. network the or program robot the with wrong something



### Namespace SmartDashboard 11.2.8

Dashboard the and robot the between data send to NetworkTables uses SmartDashboard
distributed a like pairs, value name, as data sends NetworkTables computer. Station) (Driver
its place, one in changed is value a When computer. the and robot the between hashtable
of set standard a and mechanism This place. other the in updated automatically is value
SmartDashboard. the on displayed is data how is (keys) name

subtables. and tables of set a creating space name the in structure hierarchical a is There
the in is data LiveWindow and subtable SmartDashboard the in is data SmartDashboard
below. shown as subtable LiveWindow

OutlineViewer the using displayed be can values and names the purposes, informational For
all display will It SmartDashboard. the as location same the in installed is that application
updated. are they as values and keys NetworkTables the

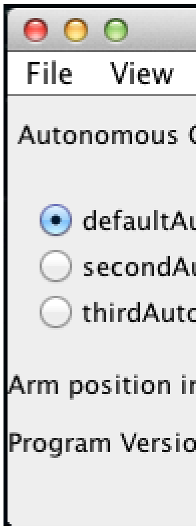
### Values Data SmartDashboard

The `.SmartDashboard/` with begin that names key with created are values SmartDashboard with SmartDashboard the to put data to correspond OutlineViewer with viewed values above statements: following the

```
                                                   SendableChooser(); new = chooser
                AutonomousCommand()); new ,"defaultAuto"(setDefaultOptionchooser.
                        AutonomousCommand()); new ,"secondAuto"(addOptionchooser.
                         AutonomousCommand()); new ,"thirdAuto"(addOptionchooser.
                                      chooser); ,"Chooser"(putDataSmartDashboard.
                          );52.0 ,"degrees in position Arm"(putNumberSmartDashboard.
                                ;"V1.2" ,"Version Program"(putStringSmartDashboard.
```

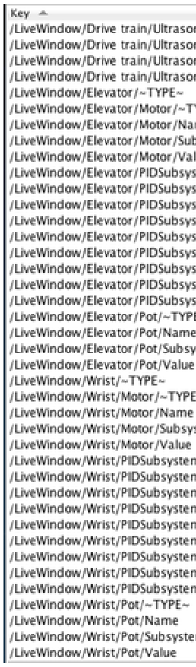
written is `AutonomousCommand` The call. `putNumber()` the with created is `position Arm` The code above the in shown not is that `command) Command", putData("Autonomous` a with `Program` value, string the and object `SendableChooser` a as created is chooser The fragment. call. `putString()` the with created is `Version`

### SmartDashboard of View



SmartDashboard the and shown as values table the generates step previous the from code The the in shown variables NetworkTables the to correspond numbers The here. shown as display step. previous

## Values Data LiveWindow



Key
/LiveWindow/Drive train/Ultrasor
/LiveWindow/Drive train/Ultrasor
/LiveWindow/Drive train/Ultrasor
/LiveWindow/Drive train/Ultrasor
/LiveWindow/Elevator/~TYPE~
/LiveWindow/Elevator/Motor/~T
/LiveWindow/Elevator/Motor/Na
/LiveWindow/Elevator/Motor/Sub
/LiveWindow/Elevator/Motor/Val
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/PIDSubsys
/LiveWindow/Elevator/Pot/~TYP
/LiveWindow/Elevator/Pot/Name
/LiveWindow/Elevator/Pot/Subsy
/LiveWindow/Elevator/Pot/Value
/LiveWindow/Wrist/~TYPE~
/LiveWindow/Wrist/Motor/~TYPE
/LiveWindow/Wrist/Motor/Name
/LiveWindow/Wrist/Motor/Subsys
/LiveWindow/Wrist/Motor/Value
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/PIDSubsysten
/LiveWindow/Wrist/Pot/~TYPE~
/LiveWindow/Wrist/Pot/Name
/LiveWindow/Wrist/Pot/Subsyster
/LiveWindow/Wrist/Pot/Value

the in viewable is data The subsystem. by grouped automatically is data LiveWindow not are you If Station). Driver the on (set mode Test in is robot the when SmartDashboard grouped be to actuators and sensors cause still can you program, based command a writing key the see can you display above the In name. subsystem the specifying by viewing easy for start strings the All SmartDashboard. the on mode Test in output resultant the and names display to used are that values of group a then name, Subsystem the then `LiveWindow/` with below: shown is display LiveWindow this generates that code The element. each

```
                                  );1PWMVictorSPX( new = drivetrainLeft
                         );"Left" ,"train Drive"(setNamedrivetrainLeft.

                                 );1PWMVictorSPX( new = drivetrainRight
                      ;"Right" ,"train Drive"(setNamedrivetrainRight.

        drivetrainRight); DifferentialDrive(drivetrainLeft, new = drivetrainRobotDrive
                            );false(setSafetyEnableddrivetrainRobotDrive.
                                 );0.1(setExpirationdrivetrainRobotDrive.

                              );3AnalogInput( new = drivetrainUltrasonic
                 );"Ultrasonic" ,"train Drive"(setNamedrivetrainUltrasonic.

                                     );6PWMVictorSPX( new = elevatorMotor
                            );"Motor" ,"Elevator"(setNameelevatorMotor.

                                         );4AnalogInput( new = elevatorPot
                                  );"Pot" ,"Elevator"(setNameelevatorPot.

                                            );2AnalogInput( new = wristPot
                                        );"Pot" ,"Wrist"(setNamewristPot.

                                         );3PWMVictorSPX( new = wristMotor
                                    );"Motor" ,"Wrist"(setNamewristMotor.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
);5PWMVictorSPX( new = clawMotor
);"Motor" ,"Claw"(setNameclawMotor.
```

created sliders using set be can but displayed, only not are actuators to correspond that Values
mode. Test in SmartDashboard the in

## Window Live and Mode Test SmartDashboard: 11.2.9

### Values LiveWindow Displaying

to need no is There you. for actuators and sensors your add automatically will LiveWindow and yourself code the writing by displayed be also may values LiveWindow manually. it do them group and names the customize to you allows This program. robot your to it adding command actual are they whether displaying of method convenient a is This subsystems. in program. your in use to decide you that grouping a just or subsystems program based

### Program your to Code Necessary the Adding

by name display and name subsystem the set created, is that actuator or sensor each For mode, LiveWindow into put is SmartDashboard the When C++). in `SetName(` `setName` calling actuators. and sensors the display will it

Java

```
);2 ,1Ultrasonic( new = ultrasonic Ultrasonic
);"Ultrasonic" ,"Arm" (ultrasonic,setNameSendableRegistry.

);1Jaguar( new = elbow Jaguar
);"Elbow" ,"Arm" (elbow,setNameSendableRegistry.

);2Victor( new = wrist Victor
);"Wrist" ,"Arm" (wrist,setNameSendableRegistry.
```

C++

```
;}2 ,1ultrasonic{ Ultrasonic::frc
);"Ultrasonic" ,"Arm" SetName(ultrasonic,::SendableRegistry

;}1elbow{ Jaguar::frc
);"Elbow" ,"Arm" SetName(elbow,::SendableRegistry

;}2wrist{ Victor::frc
);"Wrist" ,"Arm" SetName(wrist,::SendableRegistry
```

of method addChild the using simplified be can this ,`Subsystem` a in are objects your If `SubsystemBase`

Java

```
);2 ,1Ultrasonic( new = ultrasonic Ultrasonic
ultrasonic); ,"Ultrasonic"addChild(
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
);1Jaguar( new = elbow Jaguar
    elbow); ,"Elbow"addChild(

);2Victor( new = wrist Victor
    wrist); ,"Wrist"addChild(
```

C++

```
          ;}2 ,1ultrasonic{ Ultrasonic::frc
ultrasonic); ,"Ultrasonic"AddChild(

                   ;}1elbow{ Jaguar::frc
           elbow); ,"Elbow"AddChild(

                   ;}2wrist{ Victor::frc
           wrist); ,"Wrist"AddChild(
```

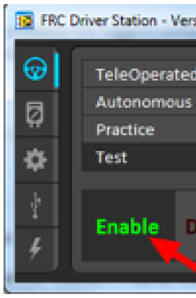
### SmartDashboard in Display the Viewing

subsystem. by grouped displayed be will LiveWindow the to added actuators and sensors The the of display the organize to helping the grouping arbitrary an just is name subsystem The controllers. motor two the for slider the operating by operated be can Actuators sensors.

## (LiveWindow) mode Test Enabling

the while actuators and sensors your for values display to program your to code add may You is robot the whenever Station Driver the from selected be can This mode. Test in is robot RobotBuilder by generated automatically is values these display to code The field. the on not of operation correct the verify to designed is mode Test article. next the in described is and from setpoints obtaining for used be can it addition In robot. a on actuators and sensors the code. your in loops PID tuning for and potentiometers as such sensors

### Station Driver the with mode Test Setting



”Enable“ setting and button ”Test“ the on clicking by Station Driver the in Mode Test Enable mode test to switch will display SmartDashboard the this, doing When robot. the on program. your by used sensors and actuators any of status the display will and (LiveWindow)

### display mode test implicit vs. Explicitly

Java

```
leftDrive; PWMSparkMax
rightDrive; PWMSparkMax
arm; PWMVictorSPX
accel; BuiltInAccelerometer

@Override
{ ()robotInit void public
);0PWMSparkMax( new = leftDrive
);1PWMSparkMax( new = rightDrive
);2PWMVictorSPX( new = arm
BuiltInAccelerometer(); new = accel
);"Arm" ,"SomeSubsystem" (arm,setNameSendableRegistry.
);"Accelerometer" ,"SomeSubsystem" (accel,setNameSendableRegistry.
}
```

C++

```
;}0leftDrive{ PWMSparkMax::frc
;}1rigthDrive{ PWMSparkMax::frc
accel{}; BuiltInAccelerometer::frc
;}3arm{ PWMVictorSPX::frc

{ ()Robot::RobotInit void
);"Arm" ,"SomeSubsystem" arm,&SetName(::SendableRegistry::wpi
```

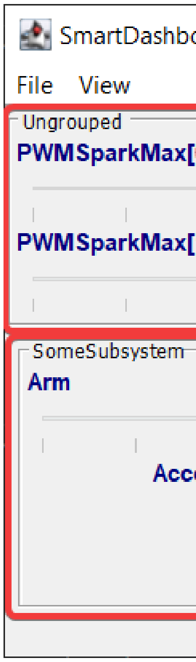
page) next on (continues

(□□□□ □□□□□ □□□□)

```
        );"Accelerometer" ,"SomeSubsystem" accel,&SetName(::SendableRegistry::wpi
                                                                                }
```

test in SmartDashboard the on displayed be automatically will actuators and sensors All PWMVictorSPX, PWMSparkMax, as (such type object the using named be will and mode In created. was object the which with number channel with etc.) BuiltInAccelerometer, in display, mode test the to actuators and sensors add explicitly can program the addition, the making specified be can names object and subsystem definedprogrammer- case which actuators. and sensors those defining explicitly illustrates example This clearer. program

### mode Test in displayed is what Understanding



In mode. test into placed is robot the when display SmartDashboard the in output the is This WPILib by created implicitly were Ungrouped as listed objects the above shown display the subsystem a in contained are objects These created. were objects corresponding the when this in (PWMSparkMax type device the with named are and **(1)** ”Ungrouped“ called group group **(2)** ”SomeSubsystem“ the in shown objects The numbers. channel the and case), section. previous the in example code the from programmer the by created explicitly are sensors created Explicitly `.SendableRegistry.setName()` to calls the in named are These subsystem. specified the by grouped be will actuators and

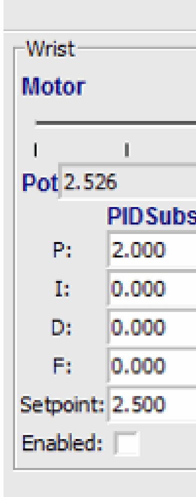
### SmartDashboard with Tuning PID

speed motor the determining for algorithm an is Differential) Integral, (Proportional, PID The with robot a example, For possible. as quickly as setpoint a reach to feedback sensor on based possible as fast as there move should position predetermined a to moves that elevator an to controller PID the Getting oscillation. to leading overshoot excessive without stop then difference the is that value error an compute to is idea The ”tuning“. called is way this behave (setpoint) desired the and element feedback mechanism the of value current the between channel analog an to connected potentiometer a be might there arm, the of case the In value. is value desired The arm. the of position the to proportional is that voltage a provides that current the and to, move should arm the position the for predetermined is that voltage the arm. the of position actual the for voltage the is value

### LiveWindow with values setpoint the Finding

the contain Subsystems PID The feedback. with mechanism each for Subsystem PID a Create mode Test use can You case). this in (potentiometer sensor feedback the and (motor) actuator actuator the adjust manually slider the Using actuators. and sensors subsystem the display to These positions. desired the of each for (2) values sensor the Note position. desired each to controller. PID the for setpoints the become will

### LiveWindow in PIDController the Viewing



Pot 2.526

P: 2.000

I: 0.000

D: 0.000

F: 0.000

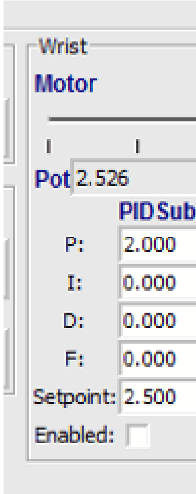
Setpoint: 2.500

Enabled: ☐

code. the in set are that parameters D and I, P, their display Subsystems PID the mode, Test In over errors of sum (P), error computed the to applied weights the are values D and I, P, The weights the by multiplied is terms those of Each (D). errors of change of rate the and (I), time be can values D and I, P, optimal the Choosing value. motor the form to together added and allows robot the on mode Test The experimentation. of amount some requires and difficult observed. response mechanism the and modified, be to values the

the as 2020, in introduced PIDController the affect not does option enable The :□□□□ this retain to how on *here* example the See loop. robot every updated is controller functionality.

## PIDController the Tuning


Wrist
Motor
Pot 2.526
PID Sub
P: 2.000
I: 0.000
D: 0.000
F: 0.000
Setpoint: 2.500
Enabled: ☐

techniques describe that articles many are there and difficult be can controller PID the Tuning low a in fill values different try To first. value P the with start to best is It used. be can that the fast how note and document, this in earlier determined setpoint a enter P, for number increase setpoint, the reaching never perhaps slowly, too responds it If responds. mechanism until process this Repeat value. P the reduce oscillating, perhaps quickly, too responds it If P. P a having that possible It's oscillation. without possible as fast as is that response a get you information Further mechanism. your of control adequate achieve to needed that's all is term document. *Controller Velocity Flywheel a Tuning* the in located is

You'll program. the into inserted be can they values D and I, P, determined have you Once constructor the in or RobotBuilder in PIDSubsystem the for properties the in either them find code. your in Subsystem PID the for

controller. PID a with velocity controlling for used is term (feedforward) F The

.*WPILib □□ PID □□□□* at found be can information More

## Glass 11.3

to similar extremely is GUI Its tool. visualization data robot and dashboard new a is Glass
tool programmer’s a as used be to meant is it state, current its In .*GUI Simulation* the of that
environment. competition a in dashboard proper a than rather

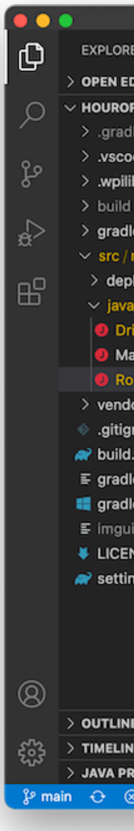
Station. Driver NI the in dashboards of list the within available be not will Glass **:□□□□**

### Glass to Introduction 11.3.1

same the of many supports It tool. visualization data robot and dashboard new a is Glass
advanced and visualization pose robot including supports, GUI Simulation the that *widgets*
and debugging for tool programmer’s a as used be to meant is it state, current its In plotting.
use. competition for dashboard a as not

#### Glass Opening

*Tool Start* on clicking Code, VS in )...( menu ellipsis the selecting by launched be can Glass
.*Glass* choosing then and

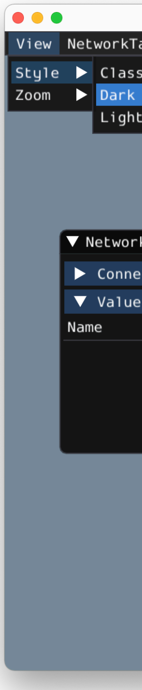


running and `~/wpilib/YYYY/tools` to navigating by directly Glass launch also can You :□□□□
folder desktop Tools WPILib the inside shortcut the using by or macOS) and (Linux `Glass.py`
(Windows).

### Settings View Changing

*Zoom* The customized. be can that settings *Style* and *Zoom* contains item menu *View* The
to you allows option *Style* the whereas application the in text the of size the dictates option
modes. `Dark` and ,`Light` ,`Classic` the between select

below: is setting style `Dark` the of example An



### Data Application Clearing

custom other as well as positions and sizes widget including Glass, for data Application
based varies file this of location The file. `glass.ini` a in stored is widgets for information
system: operating your on

- .`%APPDATA%` in located is file configuration the Windows, On
- .`~/Library/Preferences` in located is file configuration the macOS, On
- the if `~/.config` or `$XDG_CONFIG_HOME` in located is file configuration the Linux, On
exist. not does former

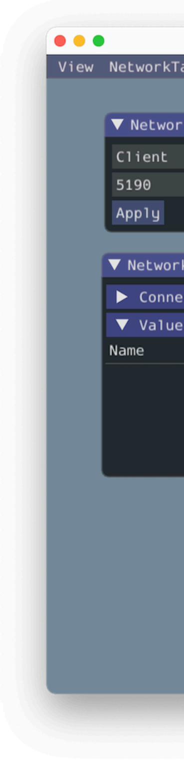
slate“. ”clean a to Glass restore to deleted be simply can file configuration `glass.ini` The

## Connections NetworkTables Establishing 11.3.2

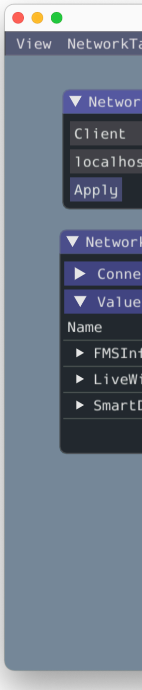
It program. robot your with connection a establish to protocol *NetworkTables* the uses Glass robot. the from and to data receive and transmit to used also is

### Robot a to Connecting

and *Settings NetworkTables* – widgets two see will you launched, first is Glass When *NetworkTables* the in *Mode* under *Client* select robot, a to connect To .*NetworkTables* .*Apply* on click and number team your enter widget, *Settings*



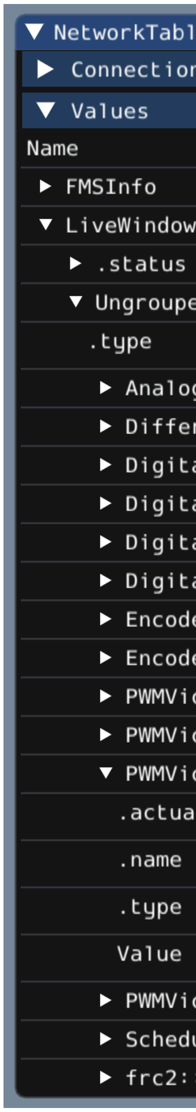
(including computer your on simulation in running is that robot a to connect also can You box. *Team/IP* the into `localhost` in typing by robots) Romi



Glass the of bar title the on visible always is status connection NetworkTables The **:□□□□** application.

## Entries NetworkTables Viewing

over sent being are that entries all view to used be can widget *NetworkTables* The so and table,sub- table, main by arranged hierarchically are entries These NetworkTables. on.



pane *Connections* the under clients NetworkTables connected all view can you Furthermore, widget. the of

### Widgets Glass 11.3.3

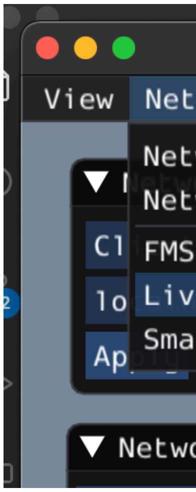
include These code. robot in exist that types certain for available are widgets Specialized or instances, `SendableChooser` as such NetworkTables over sent manually are that objects .*LiveWindow* over sent automatically is that hardware

of handful a only are there therefore, – infancy its in still is Glass in support Widget :□□□□ continues. work development as grow will list This available. widgets

name. new a specifying and header its on clickingright- by renamed be can widget A :□□□□

## Widgets Hardware

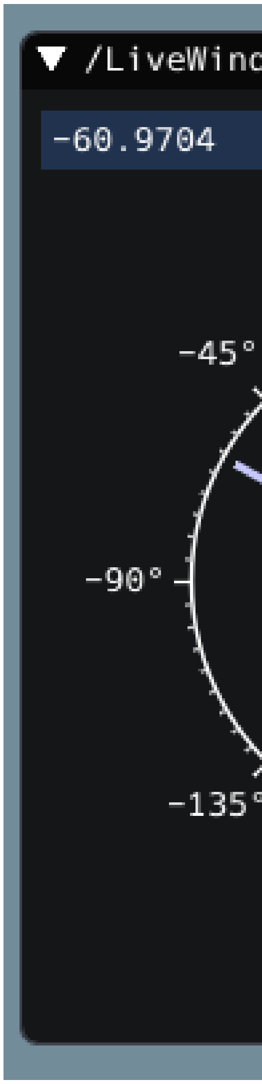
via available usually are controllers) motor as (such hardware specific for Widgets clicking option, menu *NetworkTables* the selecting by accessed be can These LiveWindow. widget. desired the choosing and *LiveWindow* on



below: is widgets has that automatically) LiveWindow over (sent hardware of list The

- `DigitalInput`
- `DigitalOutput`
- `SpeedController`
- `Gyro`

gyroscopes: for widget the of example an is Here



### Widget Chooser Sendable

It code. robot from instance `SendableChooser` a represents widget *Chooser Sendable* The `SendableChooser` your dashboards, other Like modes. autonomous select to used often is something use to is simplest The API. NetworkTables a using sent be to needs simply instance :`SmartDashboard` like

Java

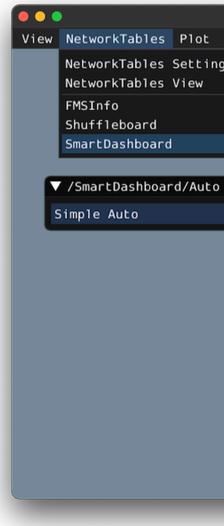
```
m_selector); ,"Selector Auto"(putDataSmartDashboard.
```

C++

```
m_selector);& ,"Selector Auto"PutData(::SmartDashboard::frc
```

.*document this* see please ,`SendableChooser` a creating on information more For :□□□□

the underneath and menu *NetworkTables* the in appear will widget *Chooser Sendable* The table main the above, example the From over. sent was instance the that name table main .*SmartDashboard* be would name



## Widget Controller PID

A controller. certain a for values PID tune quickly to you allows widget *Controller PID* The use to is simplest The API. NetworkTables a using sent be must instance `PIDController` :`SmartDashboard` like something

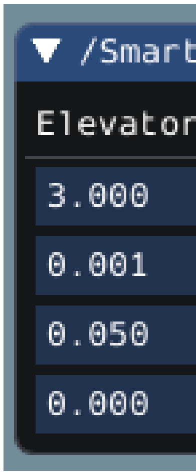
Java

```
m_elevatorPIDController); ,"Controller PID Elevator"(putDataSmartDashboard.
```

C++

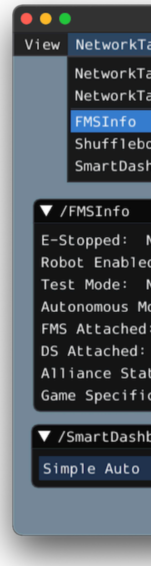
```
m_elevatorPIDController);& ,"Controller PID Elevator"PutData(::SmartDashboard::frc
```

setpoints. various for values D and I, P, tune quickly to you allows This



### Widget FMSInfo

displays widget This robot. a to connects Glass when default by created is widget *FMSInfo* The connected, is Station Driver a whether state, enabled robot's the about information basic the selecting by viewed be can It etc. data, specificgame- the connected, is FMS an whether .*FMSInfo* on clicking and item menu *NetworkTables*



## Framework BasedCommand- the for Widgets 11.3.4

These .*framework basedcommand-* the to specific are that widgets several has also Glass specific a on commands running actively view commands, schedule to widgets include .*scheduler command* the of state the view or subsystem,

### Widget Selector Command

command a of instance specific a cancel and start to you allows widget *Selector Command* The `MyCommand` of instance an create can you example, For Glass. from NetworkTables) over (sent SmartDashboard: to it send and

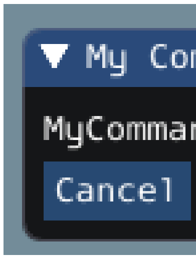
Java

```
MyCommand(...); new = command MyCommand
command); ,"Command My"(putDataSmartDashboard.
```

C++

```
frc/smartdashboard/SmartDashboard.h>< include#

...

command{...}; MyCommand
command);& ,"Command My"PutData(::SmartDashboard::frc
```

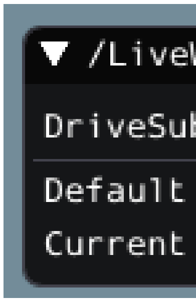
or API NetworkTables levellower- a using sent be also can instance `MyCommand` The :□□□□ the that meaning used, was API `SmartDashboard` the case, this In .*API Shuffleboard* the using name. table `SmartDashboard` the under appear will widget *Selector Command*



appear will button *Run* a running, not is command the When states. two has widget The button, *Cancel* a running, is command the When command. the schedule will it clicking – command. the cancel will This above). shown (as appear will text, *Running...* by accompanied

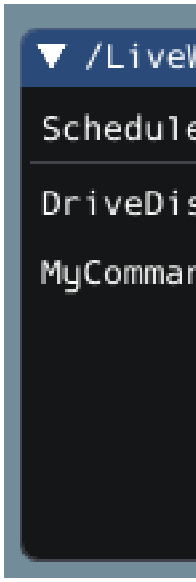
### Widget Subsystem

scheduled currently the and command default the see to used be can widget *Subsystem* The your class, base `SubsystemBase` the using are you If subsystem. specific a on command widget, this view To LiveWindow. over NetworkTables to sent automatically be will subsystem menu. *NetworkTables* the in name table main *LiveWindow* the under look



### Widget Scheduler Command

In commands. scheduled currently all see to you allows widget *Scheduler Command* The GUI. the from canceled be can commands these of any addition,



To LiveWindow. over NetworkTables to sent automatically is instance `CommandScheduler` The menu. *NetworkTables* the in name table main *LiveWindow* the under look widget, this view

## Widget Field2d The 11.3.5

An widget. *Field2d* the using field the on position robot's your displaying supports Glass updated and NetworkTables, over sent created, be should class `Field2d` the of instance code. robot your in pose robot latest the with periodically

### Code User from Pose Robot Sending

`Field2d` a estimator), pose a or *odometry* by obtained (usually position robot's your send To then must instance The NetworkTables. over sent and code robot in created be must instance pose. robot latest the with periodically updated be

Java

```
Field2d(); new = m_field Field2d final private

{ ()Drivetrain public
...
m_field); ,"Field"(putDataSmartDashboard.
}

...

{ ()periodic void public
...
());getPoseMeters(m_odometry.setRobotPosem_field.
}
```

C++

```
frc/smartdashboard/Field2d.h>< include#
frc/smartdashboard/SmartDashboard.h>< include#

m_field; Field2d::frc

{ Drivetrain()
 ...
m_field);& ,"Field"PutData(::SmartDashboard::frc
}

...

{ Periodic() void
 ...
m_field.SetRobotPose(m_odometry.GetPose());
}
```

---

or API NetworkTables levellower- a using sent be also can instance `Field2d` The :□□□□ the that meaning used, was API `SmartDashboard` the case, this In .*API Shuffleboard* the using name. table `SmartDashboard` the under appear will widget *Field2d*

---

## Field2d to Trajectories Sending

trajectories your that verifying for step debugging great a is trajectory your Visualizing the using *Field2d* in visualized easily be can Trajectories intended. as created are functions. `SetTrajectory()/setTrajectory()`

Java

```
{ ()robotInit void public
initialize to best is It autonomous. in follow to trajectory the Create //
autonomous. in time wasting avoid to here trajectories //
= m_trajectory
(generateTrajectoryTrajectoryGenerator.
)),0(fromDegreesRotation2d. ,0 ,0Pose2d( new
)),1- ,2Translation2d( new ),1 ,1Translation2d( new(ofList.
)),0(fromDegreesRotation2d. ,0 ,3Pose2d( new
)));3.0(feetToMetersUnits. ),3.0(feetToMetersTrajectoryConfig(Units. new

SmartDashboard. to Field2d push and Create //
Field2d(); new = m_field
(m_field);putDataSmartDashboard.

Field2d. to trajectory the Push //
(m_trajectory);setTrajectory)."traj"(getObjectm_field.
}
```

C++

```
{ override ()AutonomousInit void
timer. the Start //
m_timer.Start();
```

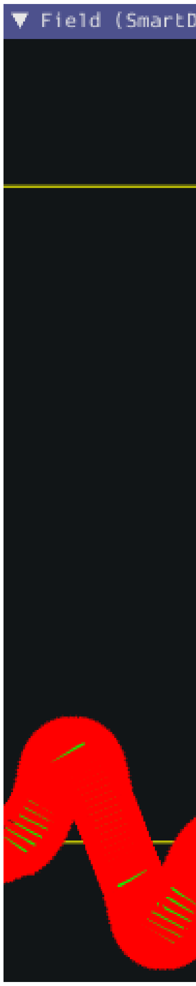
page) next on (continues

(□□□□ □□□□□ □□□□)

```
                               SmartDashboard. to Field2d Send //
                          m_field);&PutData(::SmartDashboard::frc

 trajectory. the of pose starting the to odometry s'drivetrain the Reset //
                 m_drive.ResetOdometry(m_trajectory.InitialPose());

                        Field2d. to trajectory generated our Send //
            SetTrajectory(m_trajectory);>-)"traj"m_field.GetObject(
                                                                    }
```

### Glass with Trajectories Viewing

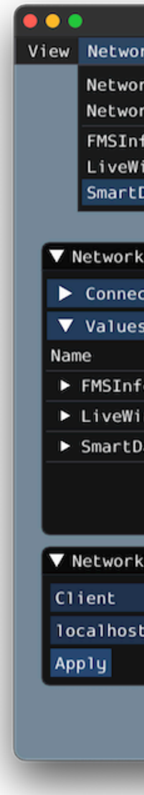
>- *NetworkTables* dropdown the through *Glass* with viewed be can trajectory sent The *.Field2d >- SmartDashboard*



RamseteController/(Java) RamseteController the uses which example above The :□□□□ once. least at enabled is autonomous until trajectory sent the show not will (C++)

### Glass in Pose Robot the Viewing

to added be can widget *Field2d* the NetworkTables, over instance `Field2d` the sending After instance the that name table the choosing bar, menu the in *NetworkTables* selecting by Glass button. *Field* the on clicking then and over, sent was



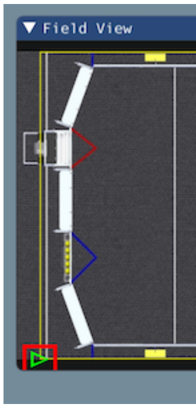
desire. you as workspace Glass the on it place and resize can you appears, widget the Once select widget, the of name the customize to you allow will widget the of top the clickingRight- and field the of dimensions the choose and image, robot custom a select image, field custom a robot.

PathWeaver a or file image an select either to choose can you *image… Choose* selecting When will file JSON the Choosing directory. same the in is file image the as long as file JSON the of size correct the and image the in field the of location correct the import automatically field.

---

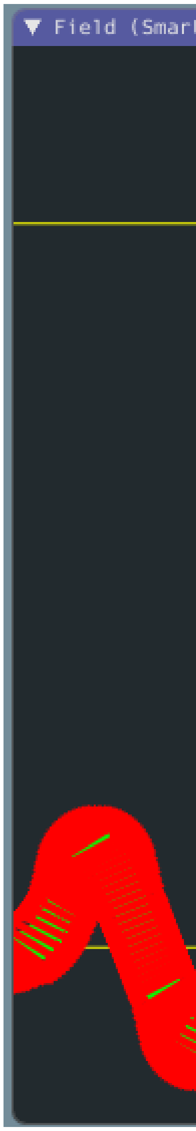
same the is This .here from files JSON and image field latest the retrieve can You :□□□□ .*PathWeaver* using paths generating when used are that JSON and image

---

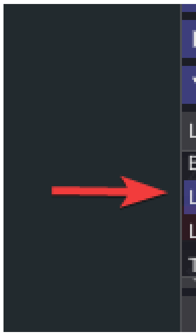


### Style Pose Modifying

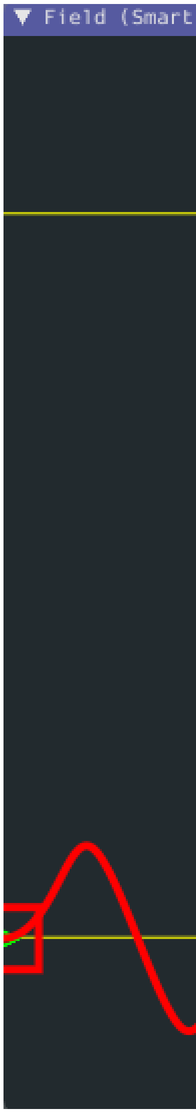
bar. menu Field2d the on clicking right by ways of plethora a in customized be can Poses weight, arrow width, arrow style, weight, line width, line are: customization of Examples etc. color,



object pose `traj` shown previously the converting is style pose the customizing of usage One
You .*Line* select and box dropdown *Style* the on Click poses. of list a than rather line, a to
looks. trajectory the how in change immediate an notice should



fluid and nice a like look to trajectory our cause will This checkbox. *Arrows* the uncheck Now,
line!



### Widget Mechanism2d The 11.3.6

the using mechanisms robot’s your of representations figurestick- displaying supports Glass extend or / and rotate can that ligaments of combinations supports It widget. *Mechanism2d* complicated more for combined be can they and elevators and arms as such retract, or sent populated, and created be should class `Mechanism2d` the of instance An mechanisms. robot your in states mechanism latest the with periodically updated and NetworkTables, over robot’s your program and visualize to *Simulation Physics* the with used be also can It code. built. is robot the before mechanisms

### Instance Mechanism2d the Configuring and Creating

is node root The  drawn. is mechanism the where ”canvas“ the is object Mechanism2d The the would this arm jointed single a For  .Mechanism2d to anchored is mechanism the where get To  base. robot’s the to attached it’s where be would this elevator, an For  point. pivot the on y)  x, getRoot(name, call object), MechanismRoot2d a by (represented node root a and NetworkTables, within root the name to used is name The object. Mechanism2d container the follows system coordinate y / x The  important. isn’t otherwise but unique, be should left. bottom is (0,0) - Field2d as orientation same

elevator. the of top on wrist rotational a with drawn, is elevator an below, examples the In C++ / Java in available is example Mechanism2d full The

Java

```
                              object mechanism main the //
                   );3 ,3Mechanism2d( new = mech Mechanism2d
                              node root mechanism the //
      );0 ,2 ,"climber"(getRootmech. = root MechanismRoot2d
```

C++

```
                              object mechanism main the //
                               ;}3 ,3m_mech{ Mechanism2d::frc
                                 node root mechanism the //
  );0 ,2 ,"climber"m_mech.GetRoot( = m_root *MechanismRoot2d::frc
```

three a has It  mechanism. the of stage a represents object MechanismLigament2d Each Mechanism2d the of size the to (relative draw to length initial an name, a parameters, required to relative are angles Ligament degrees. in ligament the draw to angle initial an and object), (counterclockwise- *Rotation2d* as same the - notation math follow and ligament, parent the optional Two  right. point will zero of angle an with root the on based ligament A  positive). and object) Mechanism2d the of size the to relative (also width the change you let parameters to node another add to node ligament or node root a on Append()/append() Call  color. the pass C++, In  it. add to object MechanismLigament2d constructed a pass Java, In  figure. the ligament. a add and construct to order in parameters construction the

Java

```
␣mechanism, the of section"/"stage"" each represent objects MechanismLigament2d //
                                                               based are and ↪
                           object ligament another or node root the off //
                 ␣,"elevator"MechanismLigament2d( new(appendroot. = m_elevator
                                           ));90 kElevatorMinimumLength, ↪
                                                                = m_wrist
                                                     (appendm_elevator.
      Color8Bit(Color. new ,6 ,90 ,0.5 ,"wrist"MechanismLigament2d( new
                                                            )));kPurple ↪
```

C++

```
           the of section"/"stage"" each represent objects MechanismLigament2d //
          object ligament another or node root the off based are and mechanism, //
                                           = m_elevator *MechanismLigament2d::frc
         deg);_90 ,1 ,"elevator"(>MechanismLigament2d::frc<Append>-m_root
                                               = m_wrist *MechanismLigament2d::frc
                                  (>MechanismLigament2d::frc<Append>-m_elevator
           kPurple});::Color::Color8Bit{frc::frc ,6 deg,_90 ,0.5 ,"wrist"
```

NetworkTables: to object Mechanism2d the publish Then,

Java

```
                                        dashboard the to mechanism the post //
                                       mech); ,"Mech2d"(putDataSmartDashboard.
```

C++

```
                                                       dashboard to publish //
                                 m_mech);& ,"Mech2d"PutData(::SmartDashboard::frc
```

---

or API NetworkTables levellower- a using sent be also can instance `Mechanism2d` The **:□□□□**
the that meaning used, was API `SmartDashboard` the case, this In .*API Shuffleboard* the using name. table `SmartDashboard` the under appear will widget *Mechanism2d*

---

the on `setAngle()` or `setLength()` call length, or angle ligament a manipulate To sensor of off based length ligament manipulating When object. `MechanismLigament2d` therefore (and length0- prevent to length minimum the add to sure make measurements, ligaments. invisible)

Java

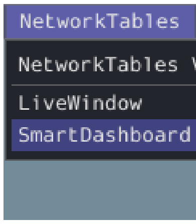
```
                                                                     @Override
                                                  { ()robotPeriodic void public
                                             state s'mechanism dashboard the update //
  ());getDistancem_elevatorEncoder. + (kElevatorMinimumLengthsetLengthm_elevator.
                                            ());get(m_wristPot.setAnglem_wrist.
                                                                            }
```

C++

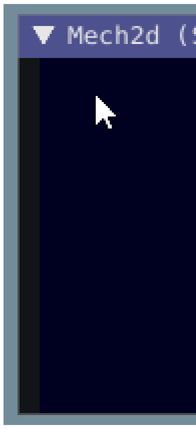
```
                                                  { override ()RobotPeriodic void
                                             state s'mechanism dashboard the update //
                                        + SetLength(kElevatorMinimumLength>-m_elevator
                          m_elevatorEncoder.GetDistance());
                      degree_t{m_wristPotentiometer.Get()});::SetAngle(units>-m_wrist
                                                                            }
```

## Glass in Mechanism2d the Viewing

can widget *Mechanism2d* the NetworkTables, over instance `Mechanism2d` the sending After that name table the choosing bar, menu the in *NetworkTables* selecting by Glass to added be button. *Field* the on clicking then and over, sent was instance the



workspace Glass the on it place and resize can you below, shown as appears widget the Once of name the customize to you allow will widget the of top the clickingRight- desire. you as will mechanism the changes, encoder elevator and potentiometer wrist the As widget. the widget. the in update



### שלבים הבאים

*Simulation Physics* with combined be can visualization Mechanism2d the above, mentioned As )C++ / Java( ArmSimulation The built. is robot your before mechanisms program you help to Mechanism2d and simulation physics combine examples )C++ / Java( ElevatorSimulation and without elevator and arm jointed single a programming practice can you that so visualization robot. a

## Plots 11.3.7

Some NetworkTables. from data of plotting comprehensive performance,high- at excels Glass examine, pause, to ability the and axes y multiple with plots plots, resizable include features plots. resume and

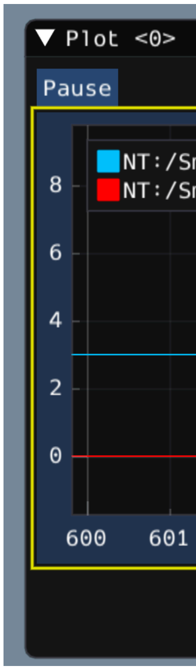
## Plot a Creating

then and bar menu main the on button *Plot* the selecting by created be can widget plot new A
To window. plot each to added be can plots individual Several .*Window Plot New* on clicking
can you Then widget. the inside button *plot Add* the click window, plot a within plot a add
plot: the into widget *NetworkTables* the from sources various drag

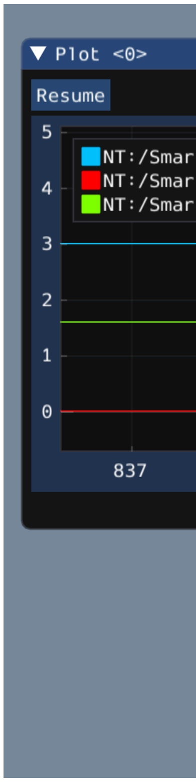
## Plots Manipulating

y the zoom to plot the of top on scroll and around move to plot the on drag and click can You limits axis and zoom the that so it autoscale will graph the on clicking Double out. and in axes with you present will plot the on clickingright- Furthermore, plotting. is it data the of all fit if axes, y tertiary and secondary display to want you whether including options, of plethora a etc. axes, certain lock to wish you

onto sources data drag can you available, axes y tertiary and secondary make to choose you If axis: desired your with correspond lines their make to axes those



of regardless constant, remains always range their that so axes certain lock can you Then,
was entry) `SmartDashboard/Kp/` the (with range axis secondary the example, this In panning.
12. and 9 between locked



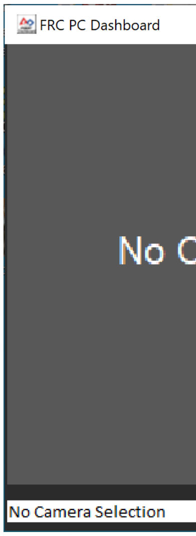
# Dashboard LabVIEW 11.4

box the of out straight features of lot a provides and use to easy is Dashboard LabVIEW The customized be can It feedback. joystick and selection, autonomous streams, camera like: C++ or Java by *used be can* it While project. Dashboard new a creating by LabVIEW using in customized be can which Shuffleboard or SmartDashboard prefer generally they teams, language. respective their

## Dashboard LabVIEW FRC 11.4.1

LabVIEW a is Station Driver FRC® the by launched and installed application Dashboard The to ability the with robot, their from feedback basic with teams provide to designed program uses application Dashboard This needs. their suit to information the customize and expand useful. find may teams that tools of variety a contains and *NetworkTables*

### Dashboard LabVIEW



camera a displaying for is pane left The sections. main two into broken is Dashboard The contains: pane right The image.

- by up (hooked values motor drive and joystick for indicators contains that tab Drive selection Autonomous an indicator, gyro a code), robot LabVIEW with used when default camera the for indicators and controls some and indicator connection a box, text
- indicators and controls default some contains that tab Basic
- left the in viewer the to similar viewer, camera secondary a contains that tab Camera pane
- LabVIEW using dashboard the customizing for tab Custom
- framework LabVIEW the in Mode Test with use for tab Test
- Framework C&C LabVIEW new the with use for tab Commands
- between and/or before complete to lists task create to used be can that tab Checklist matches

format view tree a in variables NetworkTables raw the displays that tab Variables •

bottom the in located functionality, Record/Playback includes also Dashboard LabVIEW The .*Record/Playback* under below included is feature this about detail More right.

### Controls and Image Camera

are There robot. the on located acamera from feed video a display to used is pane left The area: tab the below camera the to related indicators and controls some also

Display Image Camera 1.

use. to display camera of type the select to you allows downdrop- This - Selector Mode 2. HW Camera USB compression), (software SW Camera USB Off, Camera are choices The setting Camera IP the that Note camera). (Axis Camera IP and compression) (hardware USB. over roboRIO the to connected is PC your when work not will

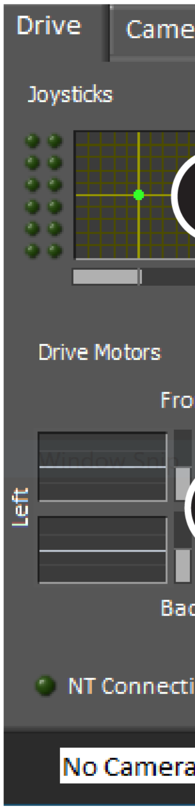
and framerate resolution, the change to you allows control This - Settings Camera 3. the uppop- to control the click dashboard, the to stream image the of compression configuration.

stream. image the of usage bandwidth approximate Indicates - Indicator Bandwidth 4. should teams when yellow usage, bandwidth "safe" for green display will indicator The the on work will that levels beyond is bandwidth stream the if red and caution use field. competition

stream. image the of framerate received approximate the Indicates - Framerate 5.

streams camera all for bandwidth combined the indicates indicator bandwidth The :□□□ open.

## Drive



drive and joysticks the on feedback provides that section a contains pane center The the displays that section a and framework LabVIEW the with used when commands selector: autonomous and status NetworkTables

using when joysticks 2 to up for values button and information Throttle and X,Y Displays 1. framework LabVIEW the

framework LabVIEW using when controllers motor to sent being values Displays 2.

robot the from data NetworkTables the for indicator connection a Displays 3.

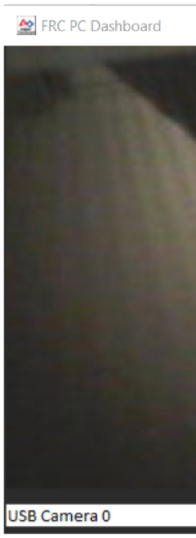
value Gyro a Displays 4.

code language's Each modes. Autonomous select to used be can that box text a Displays 5. programs. autonomous multiple from select to box this using of examples have templates

when default by values appropriate to up hooked are Gyro) the than (other indicators These *Using* see code C++/Java with them using on information For framework. LabVIEW the using *.Code C++/Java with Dashboard LabVIEW the*

## Camera

:□□□ the on tab camera the use so output, camera single a display only can pane left The
needed. if output camera second a display to pane right

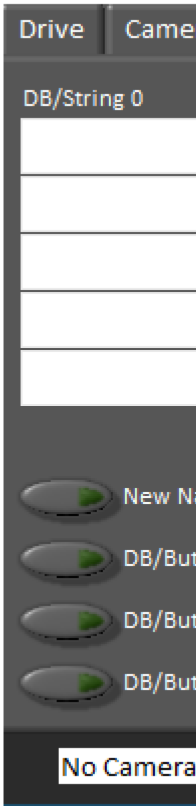


are There robot. the on located camera a from feed video a display to used is tab camera The
area: tab the below camera the to related indicators and controls some also

1. Display Image Camera
2. use. to display camera of type the select to you allows downdrop- This - Selector Mode
HW Camera USB compression), (software SW Camera USB Off, Camera are choices The
setting Camera IP the that Note camera). (Axis Camera IP and compression) (hardware
USB. over roboRIO the to connected is PC your when work not will
3. and framerate resolution, the change to you allows control This - Settings Camera
the uppop- to control the click dashboard, the to stream image the of compression
configuration.
4. stream. image the of usage bandwidth approximate Indicates - Indicator Bandwidth
should teams when yellow usage, bandwidth ”safe“ for green display will indicator The
the on work will that levels beyond is bandwidth stream the if red and caution use
field. competition
5. stream. image the of framerate received approximate the Indicates - Framerate

:□□□ streams camera all for bandwidth combined the indicates indicator bandwidth The
open.

## Basic

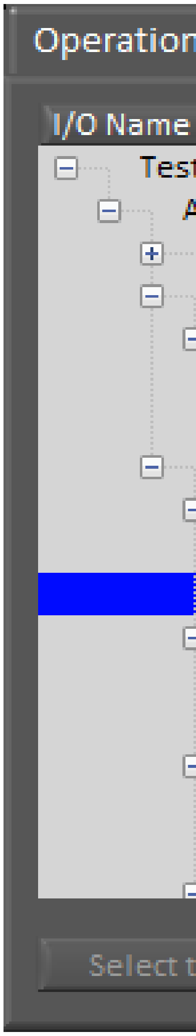


can which controls/indicators directionalbi- populatedpre- of variety a contains tab Basic The key SmartDashboard The robot. the from information display or robot the control to used be the of exception the with indicator the to next labeled are item each with associated names DB/String to 0 DB/String from increment and pattern naming same the follow which Strings contains framework LabVIEW The right. the on 9 DB/String to 5 DB/String and left the on 4 example an contains also It Teleop. in Sliders and Buttons the from reading of example an see code, C++Java with tab this using on detail more For Begin. in labels the customizing of .*Code C++/Java with Dashboard LabVIEW the Using*

## Custom

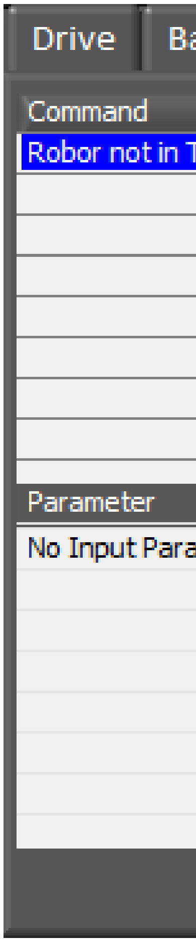
using dashboard the to controls/indicators additional add to you allows tab Custom The
need will you tab this customize To functionality. existing any removing without LabVIEW
LabVIEW. in project Dashboard a create to

### Test



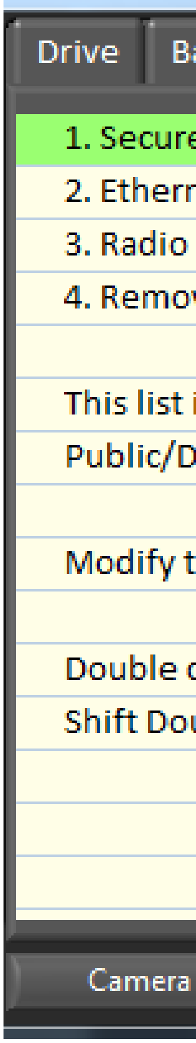
should teams C++ and (Java LabVIEW using teams for mode Test with use for is tab Test The libraries, the in items many For Mode). Test using when Shuffleboard or SmartDashboard use them to next ** have which items All automatically. here populated be will info Input/Output select to it on click output, an control To dashboard. the by controlled be can that outputs are output. the enable to button green the hold and press then value the set to slider the drag it, used be also can tab This disabled. be will output the released, is button green the as soon As framework. LabVIEW the in provided is test example An robot. the on tests monitor and run to slider the of place in test the of status the show will box dropdown the from test this Selecting controls. enable and

## Commands



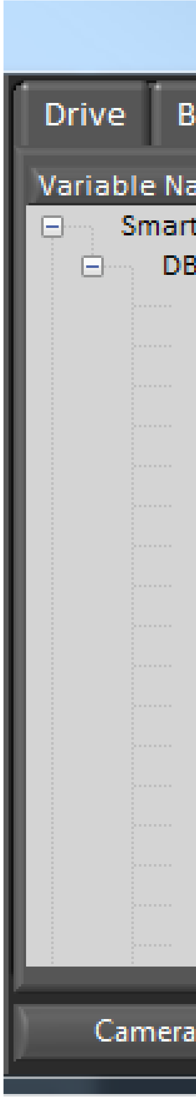
are commands which see to mode Test in Robot the with used be can tab Commands The
purposes. test for commands run manually to and running

## Checklist



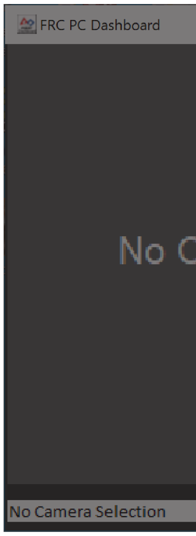
between or before perform to tasks of list a create to teams by used be can tab Checklist The checklist default the in populatedpre- are tab Checklist the using for Instructions matches. file.

## Variables



The display. tree a in variables NetworkTables all shows pane left the of tab Variables The about Information variable. each for shown are type data and Value (Key), Name Variable with shown be will Entries tab. this in displayed also is usage bandwidth NetworkTables the robot. the with synced currently not are they if diamonds black

### Record/Playback



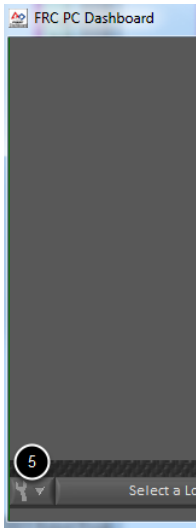
video record to you allows that feature Record/Playback a includes Dashboard LabVIEW The back it play and indicators) Dashboard your of state the as (such data NetworkTables and later.

### Recording

This tab is a
Place contr
Dashboard

pane right the of background The button. Record circular red the click recording, begin To Stop square red the press recording, stop To recording. are you indicate to red turn will button.

### Playback



right the of background The button. Play triangle green the click back, recording a play To camera the of bottom the at appear will controls playback and green pulsing begin will pane pane.

files log The back. play to file log a select to you allows dropdown The - Selector File 1.
the of length the indicate also will dropdown the and time and date the using named are file. that playing begin immediately will logfile a Selecting file.

file. log the of playback resume and pause to you allows button This - button Play/Pause 2.

to speed 1/10 from speed playback adjust to you allows dropdown This - Speed Playback 3.
(1x) timereal- is default the speed, 10x

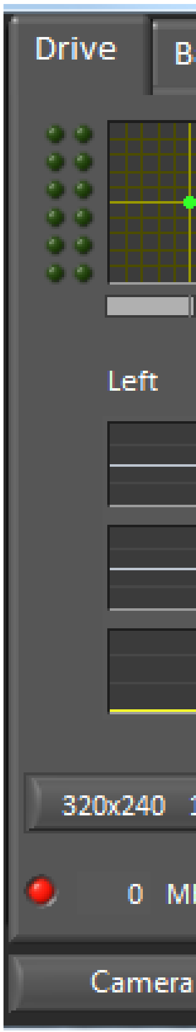
logfile the through rewind or forwardfast- to you allows slider This - Slider Control Time 4.
slider. the dragging or location desired the on clicking by

or file a delete or rename to you allows dropdown this selected, file log a With - Settings 5.
`\Public\Users\C:` (Typically Explorer Windows in logs the containing folder the open `)Dashboard\Files Log\FRC\Documents`

### Code C++/Java with Dashboard LabVIEW the Using 11.4.2

therefore is and values pass to *NetworkTables* utilizes Dashboard LabVIEW default The ranges value and keys the covers article This programs. robot Java and C++ with compatible Dashboard. the with work to use to

#### Tab Drive



routines autonomous available the show so used be can dropdown *Autonomous... Select* The match. the for run to one choose and

Java

```
      ,"Backwards Drive" ,"Forwards Drive"{ ,"List Auto"(putStringArraySmartDashboard.
                                                                           );}"Shoot" ↪

                                                          auto of beginning the At //
␣This // )"Forwards Drive" ,"Selector Auto"(getStringSmartDashboard. = autoName String
                                             auto default the Forwards Drive" make would ↪
                                                                     { (autoName)switch
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
:"Forwards Drive" case
here auto //
:"Backwards Drive" case
here auto //
:"Shoot" case
here auto //
}
```

C++

```
,"Backwards Drive" ,"Forwards Drive"{ ,"List Auto"PutStringArray(::SmartDashboard::frc
);}"Shoot" ↪

auto of beginning the At //
␣This // )"Forwards Drive" ,"Selector Auto"SmartDashboard.GetString( = autoName String
auto default the Forwards Drive" make would ↪
{ (autoName)switch
:"Forwards Drive" case
here auto //
:"Backwards Drive" case
here auto //
:"Shoot" case
here auto //
}
```

here. gyro the populate will entry NetworkTables ”Gyro“ the to Sending

Java

```
());getHeadingdrivetrain. ,"Gyro"(putNumberSmartDashboard.
```

C++

```
Drivetrain.GetHeading()); ,"Gyro"PutNumber(::SmartDashboard::frc
```

2 for configured is This drivetrain. the to power motor the show that outputs four are There like Motors“ ”RobotDrive setting by done is This drivetrain. style tank a and side per motors below. example the

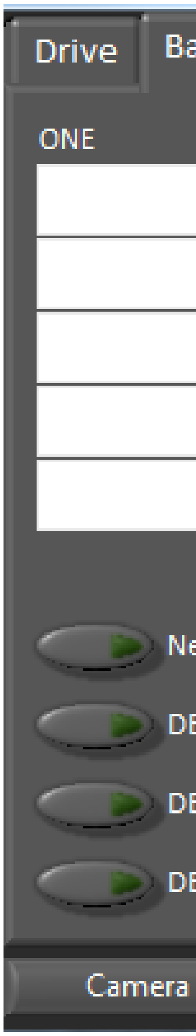
Java

```
␣(),getLeftFrontdrivetrain.{ ,"Motors RobotDrive"(putNumberArraySmartDashboard.
()});getRightBackdrivetrain. (),getLeftBackdrivetrain. (),getRightFrontdrivetrain. ↪
```

C++

```
drivetrain. drivetrain.GetLeftFront(),{ ,"Gyro"PutNumberArray(::SmartDashboard::frc
drivetrain.GetRightBack()}); drivetrain.GetLeftBack(), GetRightFront(), ↪
```

### Tab Basic



data. Dashboard send/receive to tablesub- ”DB“ a the in keys of number a uses tab Basic The receive). or (send directionalbi- all are fields other the only, output are LED’s The

### Strings

Each 9“. ”DB/String to 0“ ”DB/String from rightto-left- bottom,to-top- labeled are strings The characters). what on depends number (exact characters 21 least at display can field String strings: these to write To

Java

```
);"TestString Char 21 My" ,"0 DB/String"(putStringSmartDashboard.
```

C++

```
);"TestString Char 21 My" ,"0 DB/String"PutString(::SmartDashboard::frc
```

Dashboard: the on entered data string read To

Java

```
);"myDefaultData" ,"0 DB/String"(getStringSmartDashboard. = dashData String
```

C++

```
);"myDefaultData" ,"0 DB/String"GetString(::SmartDashboard::frc = dashData string::std
```

### LEDs and Buttons

0“ ”DB/Button from bottomto-top- labeled are and values boolean are LEDs and Buttons The LEDs the directional,bi- are Buttons The 3“. ”DB/LED to 0“ ”DB/LED and 3“ ”DB/Button to Buttons the to write To Dashboard. the on read and Robot the from written be to able only are LEDs: or

Java

```
);true ,"0 DB/Button"(putBooleanSmartDashboard.
```

C++

```
);true ,"0 DB/Button"PutBoolean(::SmartDashboard::frc
```

false) is value (default Buttons: the from read To

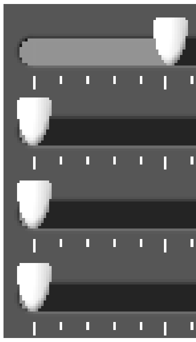
Java

```
);false ,"0 DB/Button"(getBooleanSmartDashboard. = buttonValue boolean
```

C++

```
);false ,"0 DB/Button"GetBoolean(::SmartDashboard::frc = buttonValue bool
```

## Sliders



To 5. to 0 from range a with controls/indicators (double) analog directionalbi- are Sliders The indicators: these to write

Java

```
);2.58 ,"0 DB/Slider"(putNumberSmartDashboard.
```

C++

```
);2.58 ,"0 DB/Slider"PutNumber(::SmartDashboard::frc
```

0.0) of value (default program: robot the into Dashboard the from values read To

Java

```
);0.0 ,"0 DB/Slider"(getNumberSmartDashboard. = dashData double
```

C++

```
);0.0 ,"0 DB/Slider"GetNumber(::SmartDashboard::frc = dashData double
```

## Connectivity Dashboard Troubleshooting 11.4.3

This  events. from issues connectivity Dashboard of reports of number a received have We robot, your to connected not is Dashboard the if recognize to how explain help will document make. can you modification code a and condition this troubleshoot to steps

### Dashboard LabVIEW

dashboard LabVIEW and robot the between connectivity discusses section This

#### Connectivity Dashboard LabVIEW Recognizing

fairly be may it changing be to expect you that dashboard your on indicator an have you If without check to way a is there not, If  connected. is Dashboard the if recognize to trivial variables the Dashboard, the of tab Variables the On code. robot your to changes any making Dashboard the Once robot. the with synced not are they when diamond black a with shown are connects to the robot and these variables are synced, the diamond will disappear.

#### Connectivity Dashboard LabVIEW Troubleshooting

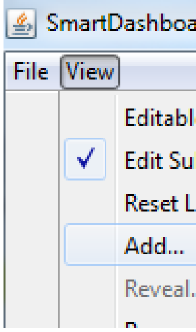
the to connected has Station Driver the (after Robot the to connect not does Dashboard the If are: steps troubleshooting recommended the robot)

1. should (which Station Driver the openre- then Dashboard, and Station Driver the Close Dashboard). the launch
2. the on button Code Robot Restart the using Code Robot the restart work, doesn't that If Station Driver the of tab Diagnostics

## Connectivity Recognizing

SmartDashboard and robot the between connectivity discusses section This

### Connectivity SmartDashboard Recognizing

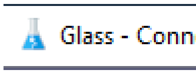


Connection a add to is SmartDashboard the with connectivity recognize to way typical The initialization during key one least at writing is code your sure make to and widget Indicator or moved be can indicator connection The indicator. connection the trigger to disabled or checked. is checkbox Editable the if sizedre-

### Connectivity Shuffleboard Recognizing

application the of corner right bottom the in not or connected is it if indicates Shuffleboard above. image the in shown as

### Connectivity Glass Recognizing



on more for *page* this See top. the across bar the in not or connected is it if displays Glass connection. the configuring

### Connectivity Troubleshooting

the to connected has Station Driver the (after Robot the to connect not does Dashboard the If are: steps troubleshooting recommended the robot)

software) Station Driver the restart to need no is (there Dashboard the Restart 1.

the on button Code Robot Restart the using Code Robot the restart work, doesn't that If 2. Station Driver the of tab Diagnostics

the in properly set is Server / Number Team the that verify connect, doesn't still it If 3. disabled or initialization during value a writes Code Robot your that and Dashboard

[redacted]

## Data TimeReal- Sending and Recording Telemetry: 12.1

accurate - process engineering the of part crucial a is data *telemetry* viewing and Recording for indispensable is and optimally, perform to robot your tune you helps data telemetry expected. as perform to fails it when robot your debugging

data recording However, robot. the on (saved) recorded is data telemetry no default, By data more that namely dashboard, a on recording over benefits provide can robot the on very be can data recorded the all and limitations), bandwidth no are (there recorded be can telemetry of recording roboton- for support integrated has WPILib timestamped. accurately data downloading for tool a provides and classes `DataLog` and `DataLogManager` the via data CSV. to them converting and files log

---

telemetry their record can teams data, telemetry of recording roboton- to addition In :□□□□ .*recordings Shuffleboard* with computer station driver their on data

---

### Code Robot to Telemetry Adding 12.1.1

code. robot from data telemetry send and record to ways different several supports WPILib

robot from statements print viewing for support provides *Riolog* the level, basic most the At console as scale not does but code, problematic of debugging flythe-on- for useful is This code. streams. data rich for suitable not are interfaces

data telemetry rich send easily more to users allow that *dashboards* several supports WPILib *NetworkTables* the with communicate dashboards WPILib All computer. stationdriver- the to dashboard one with logged (telemetry interoperable *degree some to* are they so and protocol, be not generally will widgets/formatting specific the but others, the on visible be will following the support currently dashboards) all WPILib thus (and NetworkTables compatible). types: data

- `boolean`
- `boolean[]`
- `double`

- `double[]`
- `string`
- `string[]`
- `byte[]`

(for method WPILib associated an using dashboard WPILib a to sent be can data Telemetry *directly* by or question), in dashboard individual the for documentation the see details, more *.NetworkTables to publishing*

is (this types data complex of serialization support yet not does NetworkTables While extended easily be can code user from types *mutable* 2023), for scheduled tentatively is usage whose interface, `Sendable` the via dashboards WPILib with directly interface to article. next the in described

## Sendable with Telemetry Robot 12.2

their from data of pieces small send easily to users allow APIs dashboard WPILib the While telemetry publishing for code write manually to tedious often is it dashboard, the to code robot logic. operational code's robot the from values

mark to code user of structure orientedobject- existing the leverage to is approach cleaner A WPILib The style. *programming declarative* a in logging telemetry for fields data important potentially, (and, from reading correctly of part tedious/tricky the handle then can framework write to has user the code of amount total the reducing greatly you, for fields those *)to writing* readability. improving and

implement that Classes interface. `Sendable` the with functionality this provides WPILib dashboard the to data send automatically that listeners value register to able are `Sendable` of any to sent declaratively be can classes These back. values receive cases, some in and, - to teams for need the removing field), data ordinary an would one (as dashboards WPILib the updates. for send/poll to code own their write

### Sendable? is What 12.2.1

Classes telemetry. robot facilitate to WPILib by provided interface an is )C++ ,Java( `Sendable` declared, once - dashboard the to state their send declaratively can `Sendable` implement that need the removes This loop. robot every values telemetry the send automatically will WPILib the from values receiving and sending of logic iterationto-iteration- the handle to teams for logic. robot their from code telemetry their separate to teams allows also and dashboard,

sent be can so and ,`Sendable` implement already *)Commands* as (such classes WPILib Many their extend easily to able also are Users modification. user any without dashboard the to .`Sendable` implement to classes own

classes Implementing .`initSendable` method: one only contains interface `Sendable` The data, *JSON* structured to values data codein- of binding the perform to method this override Implementation NetworkTables. via dashboard robot the to sent automatically then is which .*article next* the in discussed is interface `Sendable` the of

### Dashboard the to Sendable a Sending 12.2.2

---

the on dateto-up- kept automatically are Sendables types, data simple Unlike :□□□□ Accordingly, it“. forget and it ”set - code user further any without WPILib, by dashboard a in *not* constructor, or block initialization an in dashboard the to sent be usually should they function. periodic

---

method. `putData` dashboard’s the use simply dashboard, the to object `Sendable` a send To from telemetry log automatically can *Controller PID* a uses that class ”arm“ an example, For constructor: its in following the calling by controller the

Java

```
armPIDController); ,"PID Arm"(putDataSmartDashboard.
```

C++

```
armPIDController);& ,"PID Arm"PutData(::SmartDashboard::frc
```

*dashboard the from* sent values data the to setters bind classes `Sendable` some Additionally, parameters. robot of tuning remote allowing ,*robot the to*

## Logs Data Into Recording Telemetry RobotOn- 12.3

class `DataLogManager` The robot. the on (saved) recorded is data telemetry no default, By recording roboton- for class `DataLog` levellower- the around wrapper convenient a provides reasons. speed and size for binary are logs data WPILib The logs. data into data telemetry of code, robot to overhead minimal have WPILib by provided facilities log data the general, In mutex a mainly of consists operation log thread–the separate a on performed is I/O file all as data. the copying and acquisition

### Logs Data of Structure 12.3.1

(keys) identifiers string with entries of concept the have logs data NetworkTables, to Similar after changed be cannot type data the NetworkTables, Unlike type. data specified a with string JSON) typically (but arbitrary metadata–an have also entries and created, is entry the or source data the as such entry the about information additional convey to used be can that `DataLog` unidirectional–the is operation log data NetworkTables, unlike Also schema. data the and values) written of backread- support not does (it logs data write only can class the in values changing support not does (it logs data read only can class `DataLogReader` log). data

finishing, starting, allow records Control records. timestamped of series a of consist logs Data Timestamps changes. value data record records data and entries, of metadata the changing or is timestamp FPGA the RoboRIO, the on running when microseconds; integer in stored are ).`Timer.getFPGATimestamp()` by returned timestamp same (the used

## DataLogManager using Logging Data Standard 12.3.2

automatic provides that log data centralized a provides )C++ ,Java( class `DataLogManager` The and low is space disk when files old up cleans automatically It management. file log data number. match competition available) (if or date/time current on either based file the renames `home/lvuser/` to or attached, is one if drive flash USB a to saved be will file data The otherwise.

DS the After connects. DS the until `FRC_TBD_{random}.wpilog` named initially are files Log is date/time the (where `FRC_yyyyMMdd_HHmmss.wpilog` to renamed is file log the connects, to renamed is file log the number, match a provides and connected is FMS the If UTC). .`FRC_yyyyMMdd_HHmmss_{event}_{match}.wpilog`

there If deleted. be will connected been not has DS a where files log existing all startup, On to (oldest deleted are files log `FRC_` storage, target the on space free of MB 50 than less is remaining. files 10 are there OR free MB 50 is there until newest)

this (typically code of line single a requires only DataLogManager of usage basic most The log. data the to changes NetworkTables all record will This ).`robotInit` from called be would

Java

```
;edu.wpi.first.wpilibj.DataLogManager import

log data to recording Starts //
();startDataLogManager.
```

C++

```
frc/DataLogManager.h"" include#

log data to recording Starts //
Start();::DataLogManager::frc
```

of logging for )`DataLogManager.log()`( function convenience a provides DataLogManager standard to printed also is message The log. data the in entry `messages` the to messages text output, so this can be a replacement for `System.out.println()`.

every log data the to UTC) (in time system roboRIO current the records also DataLogManager synchronize (roughly) to used be can This log. data the in entry `systemTime` the to seconds ~5 video. match or logs DS as such records other with log data the

.`DataLogManager.getLog()` via accessed be can `DataLog` managed the logging, custom For

### Data Joystick Logging

provides class `DriverStation` The data. joystick record not does default by DataLogManager function: `startDataLog()` the via data joystick and control DS of logging for support

Java

```
;edu.wpi.first.wpilibj.DataLogManager import
;edu.wpi.first.wpilibj.DriverStation import

log data to recording Starts //
();startDataLogManager.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
data joystick and control DS both Record //
());getLog(DataLogManager.startDataLogDriverStation.

data control DS only Record (alternatively) //
);false (),getLog(DataLogManager.startDataLogDriverStation.
```

C++

```
frc/DataLogManager.h"" include#
frc/DriverStation.h"" include#

log data to recording Starts //
Start();::DataLogManager::frc

data joystick and control DS both Record //
GetLog());::StartDataLog(DataLogManager::DriverStation

data control DS only Record (alternatively) //
);false GetLog(),::StartDataLog(DataLogManager::DriverStation
```

### DataLog using Logging Data Custom 12.3.3

,`BooleanLogEntry` (e.g. classes LogEntry associated its and )C++ ,Java( class `DataLog` The logs. data writing for access levellow- provides etc) ,`DoubleLogEntry`

only values record to DataLogManager with conjunction in used be can classes LogEntry The NetworkTables: to not and log data a to

Java

```
;edu.wpi.first.util.datalog.BooleanLogEntry import
;edu.wpi.first.util.datalog.DataLog import
;edu.wpi.first.util.datalog.DoubleLogEntry import
;edu.wpi.first.util.datalog.StringLogEntry import
;edu.wpi.first.wpilibj.DataLogManager import

myBooleanLog; BooleanLogEntry
myDoubleLog; DoubleLogEntry
myStringLog; StringLogEntry

{ ()robotInit void public
log data to recording Starts //
();startDataLogManager.

entries log custom up Set //
();getLogDataLogManager. = log DataLog
);"my/boolean/" BooleanLogEntry(log, new = myBooleanLog
);"my/double/" DoubleLogEntry(log, new = myDoubleLog
);"my/string/" StringLogEntry(log, new = myStringLog
}

{ ()teleopPeriodic void public
{ (...) if
necessary when log Only //
);true(appendmyBooleanLog.
```

page) next on (continues

(□□□□ □□□□□□ □□□□)

```
                                        );3.5(appendmyDoubleLog.
                                      );"wow!"(appendmyStringLog.
                                                                }
                                                                  }
```

C++

```
                                    frc/DataLogManager.h"" include#
                                           wpi/DataLog.h"" include#

                           myBooleanLog; BooleanLogEntry::log::wpi
                             myDoubleLog; DoubleLogEntry::log::wpi
                             myStringLog; StringLogEntry::log::wpi

                                             { ()RobotInit void
                                    log data to recording Starts //
                                      Start();::DataLogManager::frc

                                           entries log custom up Set //
               GetLog();::DataLogManager::frc = log &DataLog::log::wpi
         );"my/boolean/" BooleanLogEntry(log,::Log::wpi = myBooleanLog
            );"my/double/" DoubleLogEntry(log,::log::wpi = myDoubleLog
            );"my/string/" StringLogEntry(log,::log::wpi = myStringLog
                                                                  }

                                           { ()TeleopPeriodic void
                                                        { (...) if
                                        necessary when log Only //
                                        );truemyBooleanLog.Append(
                                          );3.5myDoubleLog.Append(
                                       );"wow!"myStringLog.Append(
                                                                }
                                                                  }
```

### Robot the from Logs Data Downloading 12.3.4

a of instead memory flash integrated roboRIO the to stored being are files log data If to logs data delete and download periodically to important it's drive, flash USB removable up. filling from storage the avoid

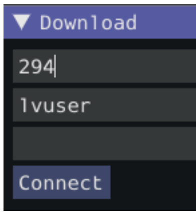
for client SFTP a integrates application desktop DataLogTool the this, facilitate To local the to coprocessor) or roboRIO (e.g. device network a from files log data downloading computer.

steps: four of consists process This

1. coprocessor or roboRIO to Connect
2. download to files what select and directory remote to Navigate
3. folder download Select
4. downloading after files remote delete optionally and files Download

## RoboRIO to Connecting

radio the if wirelessly connect to able be not will it so SSH, uses downloader The **:□□□□**
field). competition the on is robot the when (e.g. enabled is firewall



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lvuser

/ *Number Team* the into entered be can hostname or address, IP number, team a Either
entered, is number team a If to. connect to host remote the specifies field This field. *Address*
address. connection the as used is `frc.local-TEAM-roborio`

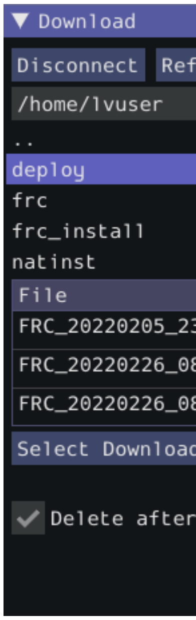
username the roboRIO, the For here. entered also are password and username remote The
password. blank a with `lvuser` be should

as such roboRIO, the than other devices network to connecting supports also tool The
authentication. basedpassword- SFTP supports device the as long as coprocessors,

device. the to connect to attempt will This device. remote the to connect to *Connect* Click
application the If .*Disconnect* clicking by time any at aborted be can attempt connection The
*Number Team* the above displayed be will error an device, remote the to connect to unable is
attempted. be can connection new a and field *Address* /

## Files Downloading

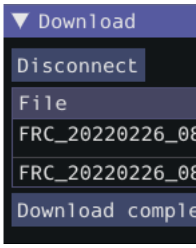
displayed. be will browser file simplified a established, successfully is connection the After
first The download. to files which select and filesystem remote the navigate to used is This
it typing by to navigated be can directory specific A directory. current the shows box text
by performed be can navigation directory Alternatively, Enter. pressing and box text this in
the Following textbox. dir remote the below listed are that directories the of one on clicking
table the so shown, are extension `wpilog.` a with files Only files. of table a is directories of list
data each to next checkbox The directory. current the in files log no are there if empty be will
downloaded. be should file the whether indicates file log



computer. local the for browser file a up bring to *Folder... Download Select* Click

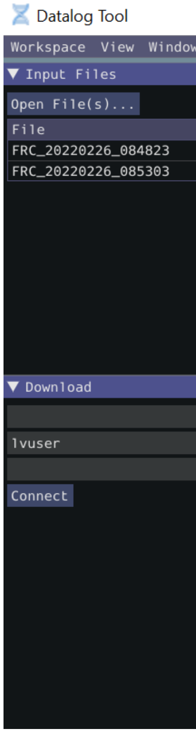
the check downloaded, are they after device remote the from files the delete to want you If checkbox. *download after Delete*

the button, this clicking After appear. will *Download* selected, is folder download a Once each to next shown be will errors Any display. progress download a to change will display browser. file the to return to *complete! Download* Click file.



## CSV to Logs Data Converting 12.3.5

to functionality provides application desktop DataLogTool the files, binary are logs data As may logs data Multiple analysis. or processing further for files CSV into logs data convert be can exports data partial and processing, batch for tool the into loaded simultaneously be output. be to desired is that data the only selecting by performed



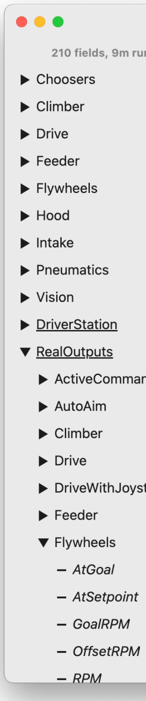
Files window. Files“ ”Input the in files log data opening by started is process conversion The records of number (e.g. file each on status Summary .*File(s)... Open* clicking by opened are file. the closes row table the in *X* Clicking displayed. is entries) and

entries the of view tree a displays window ”Entries“ the loaded, is file one least at After and bar title window ”Entries“ the on clicking right by view flat a to changed be can (this to unchecked or checked be can subtrees entire or entries Individual ).*View Tree* unchecking initial and information type data The export. the in included be should they whether indicate merged a shows view ”Entries“ the As table. the in shown also is entry each for metadata an over hovering open, is file input one than more if files, input all across entries all of view entry. that contain files input what highlight will name entry’s

well as )*Folder... Output Select* (via folder output the specify to used is window output The columns 3 with file CSV a outputs style output list The table). or (list style output the as exported every (for change value every for row a and value) and name, entry (timestamp, for column a and column timestamp a with file CSV a outputs style output table The entry). but entry), exported every (for change value every for output is row a entry; exported every a create will *CSV Export* Clicking entry. that for column correct the in placed is value the file. input each to corresponding folder output the in file `csv`.

## Visualization Log Data 12.3.6

stored data visualize and back play to users allowing tool partythird- a is AdvantageScope etc. synchronization, video displays, field graphs, line for support with logs, data WPILib in offers WPILib that Note .documentation AdvantageScope the in available are details More projects. partythird- for support no



### Logs Data of Processing Custom 12.3.7

can’t that values binary of processing for (e.g. logs data of processing advanced more For ,Java in logs data reading for class `DataLogReader` a provides WPILib CSV), to converted be documented. also is format log data the languages, other For .Python or ,C++

data a over iterating supports it that in log, data a of view levellow- a provides DataLogReader any provide not does but types, data common of decoding and records data and control log’s example printlog The entries. of map likeNetworkTables- a as such abstractions level higher usage. basic demonstrates )`datalog.py` Python the (and C++ and Java in

## Classes Sendable Own Your Writing 12.4

implement that classes own your writing method, one has only interface `Sendable` the Since dashboard) the from values consume and/or to values log automatically thus (and `Sendable` method, `initSendable` overridable the for implementation an provide just easy: extremely is (their values key to bound declaratively are fields class’s your for getters and setters which in dashboard). the on names display

WPILib’s from `initSendable` of implementation the is here example, For :`BangBangController`

Java

```
@Override
{ builder) (SendableBuilderinitSendable void public
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                  );"BangBangController"(setSmartDashboardTypebuilder.
    ::setTolerance);this ::getTolerance,this ,"tolerance"(addDoublePropertybuilder.
       ::setSetpoint);this ::getSetpoint,this ,"setpoint"(addDoublePropertybuilder.
              );null ::getMeasurement,this ,"measurement"(addDoublePropertybuilder.
                          );null ::getError,this ,"error"(addDoublePropertybuilder.
                  );null ::atSetpoint,this ,"atSetpoint"(addBooleanPropertybuilder.
                                                                                   }
```

C++

```
                  { builder) &SendableBuilder::(wpiBangBangController::InitSendable void
                                    );"BangBangController"builder.SetSmartDashboardType(
                                                                builder.AddDoubleProperty(
                                     ,} GetTolerance(); return { ]this[ ,"tolerance"
                             );} SetTolerance(tolerance); { tolerance) double](this[
                                                                builder.AddDoubleProperty(
                                       ,} GetSetpoint(); return { ]this[ ,"setpoint"
                                );} SetSetpoint(setpoint); { setpoint) double](this[
                                                                builder.AddDoubleProperty(
                    );nullptr ,} GetMeasurement(); return { ]this[ ,"measurement"
                                                                builder.AddDoubleProperty(
                                 );nullptr ,} GetError(); return { ]this[ ,"error"
                                                               builder.AddBooleanProperty(
                         );nullptr ,} AtSetpoint(); return { ]this[ ,"atSetpoint"
                                                                                         }
```

data Sendable background“, the ”in WPILib by values of updating automatic the enable To that field a If values. data specific than rather functions setter and getter to bound are names lambda a with inline defined be can they getters, and setters defined no has log to wish you expression.

### Class SendableBuilder The 12.4.1

type of ,`builder` parameter, single a takes method `initSendable` the above, seen As getters of binding allow that methods exposes builder This ).C++ ,Java( `SendableBuilder` consumed values that ensuring safely for methods as well as names, dashboard to setters and behavior. robot unsafe cause not do dashboard the *from*

#### Methods addProperty with Databinding

over transmitted ultimately are fields Sendable code, dashboard WPILib all Like the match `SendableBuilder` by provided methods databinding the thus and ,*NetworkTables* types: data NetworkTables supported

- `addBooleanProperty` :`boolean`
- `addBooleanArrayProperty` :`boolean[]`
- `addDoubleProperty` :`double`
- `addDoubleArrayProperty` :`double[]`
- `addStringProperty` :`string`
- `addStringArrayProperty` :`string[]`

addRawProperty :byte[] •

### setActuator and setSafeState with Safety Ensuring

possible is it dashboard, the from values arbitrary consume to users allows `Sendable` Since unsafe extremely is This actuations. robot to directly controls dashboard pipe to users for robot controlling for interface good particularly a not are dashboards care; with done not if on change a to response in move to robot the expect not do generally users and movement, dashboard. the

`SendableBuilder` values, dashboard with interfacing when safety ensure users help To mechanism `Sendable` any place to called is which method, `setSafeState` a exposes hazardous potentially Any state. safe a into input dashboard on based actuates that safe suitable a with `setSafeState` call should implementation `Sendable` writtenuser- WPILib the from implementation the is here example, For implementation. state class: `PWMMotorController`

Java

```
                                              @Override
           { builder) (SendableBuilderinitSendable void public
         );"Controller Motor"(setSmartDashboardTypebuilder.
                                  );true(setActuatorbuilder.
                     ::disable);this(setSafeStatebuilder.
  ::set);this ::get,this ,"Value"(addDoublePropertybuilder.
```

C++

```
                                                             }

   { builder) &SendableBuilder::InitSendable(wpi::PWMMotorController void
                    );"Controller Motor"builder.SetSmartDashboardType(
                                          );truebuilder.SetActuator(
                         );} Disable(); { ]this ,=builder.SetSafeState([
                                          builder.AddDoubleProperty(
```

might that mechanism any mark to `builder.setActuator(true)` call may users Additionally, to *Shuffleboard* by used is this Currently, actuator. an as input `Sendable` of result a as move mode. *LiveWindow* in not when widgets actuator disable

## Libraries Telemetry PartyThird- 12.5

it! add to request pull a Open be? should it when here listed not library your Is :□□□

beyond functionality provide that exist frameworks and utilities logging partythird- Several WPILib: by provided currently is what

- and ,*logs data WPILib* ,*NetworkTables* for tool visualization Data :AdvantageScope .*logs Station Driver*
- for hooks with framework logging basedeverything"- "Log only): (Java AdvantageKit .*simulation* in data logged replaying

- Oblog (Java only): Minimalistic annotation-based API for `Shuffleboard` (or plain `NetworkTables`) telemetry.

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[redacted]

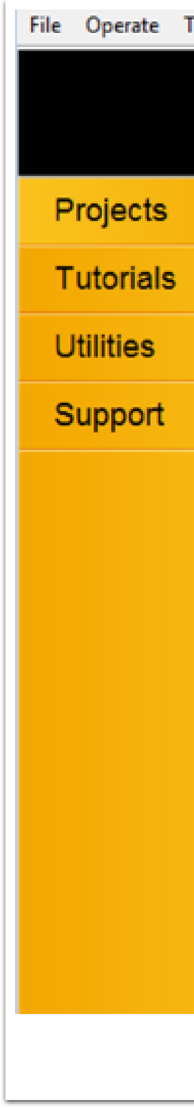
## 13.1 Creating Robot Programs

### 13.1.1 Tank Drive Tutorial

**Question:** How do I get my robot to drive with two joysticks using tank drive?

**Solution:** There are four components to consider when setting up tank drive for your robot. The first thing you will want to do is make sure the tank drive.vi is used instead of the arcade drive.vi or whichever drive VI you were utilizing previously. The second item to consider is how you want your joysticks to map to the direction you want to drive. In tank drive, the left joystick is used to control the left motors and the right joystick is used to control the right motors. For example, if you want to make your robot turn right by pushing up on the left joystick and down on the right joystick you will need to set your joystick's accordingly in LabVIEW (this is shown in more detail below). Next, you will want to confirm the PWM lines that you are wired into, are the same ones your joysticks will be controlling. Lastly, make sure your motor controllers match the motor controllers specified in LabVIEW. The steps below will discuss these ideas in more detail:

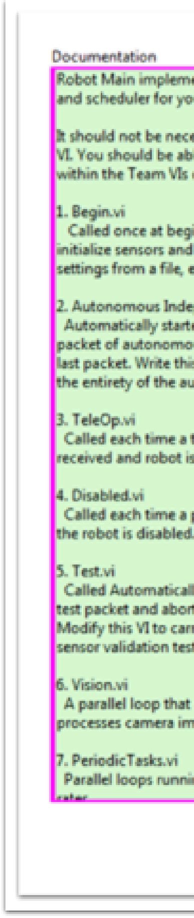
1. Open LabVIEW and double click `FRC roboRIO Project`.



`Robot Drive Arcade` select and number, team your add name, a project your Give 2.
setup to how discuss will tutorial this however, option, another select can You `.roboRIO`
project. this for drive tank

`.Main.vi Robot` the up open window, Explorer Project the In 3.

image: following the like look should It diagram. block the see to `Ctrl+E` Push 4.



Documentation

Robot Main impleme
and scheduler for yo

It should not be nece
VI. You should be ab
within the Team VIs

1. Begin.vi
Called once at beg
initialize sensors and
settings from a file, e

2. Autonomous Inde
Automatically start
packet of autonomo
last packet. Write thi
the entirety of the au

3. TeleOp.vi
Called each time a
received and robot is

4. Disabled.vi
Called each time a
the robot is disabled.

5. Test.vi
Called Automaticall
test packet and abor
Modify this VI to car
sensor validation tes

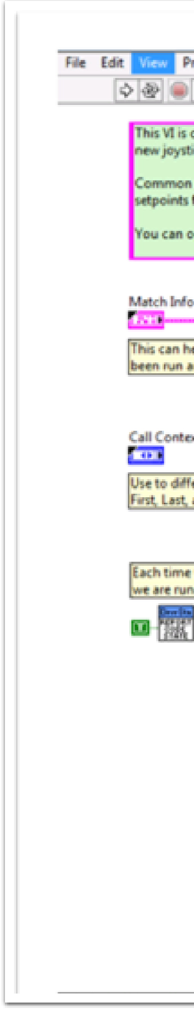
6. Vision.vi
A parallel loop that
processes camera im

7. PeriodicTasks.vi
Parallel loops runni

5. block its at Look structure. case Enabled Teleop the of inside vi ”Teleop“ the click Double here: changes two make to want will You diagram.

- the on clicking right by found be can This drive.vi. tank the with Drive Arcade Replace Drive Tank the clicking and >> Drive Robot >> Library Robotics WPI >> diagram block VI.

- two create to need will You Values.vi. Get the after is that function Array Index the Find what determine can You inputs. index the of one into each wire and constants numeric Driver FRC® the in tab Devices USB the at looking by be should index each of values the You to. tied are they (index) number which determine to joysticks two the Move Station. to intuitive is it because is This joystick. each for index axisY- the use to want likely will you when down and forward, go to motors the want you when joystick the on up push have will you then each, for index axisX- the select you If reverse. in go to them when In move. to motors robot the get to directions) axis(x- right or left joystick the move to right the as 5 index and control axisY- motors left my for 1 index selected I’ve setup, my image: following the in LabVIEW in adjustments the see can You control. axisY- motors

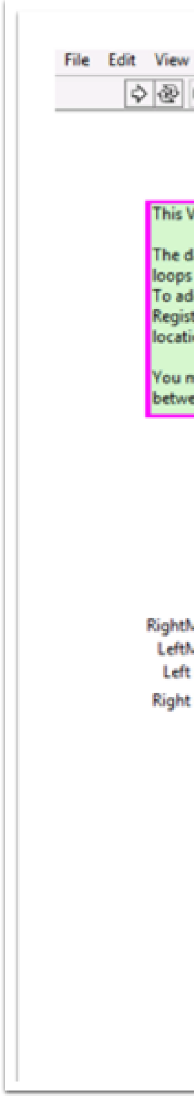


”Begin.vi.“ the on click double and Main.vi“ ”Robot your to back go to want will you Next 6.

to connected are motors right and left your that is VI this in confirm to thing first The 7.
Panel). Distribution (Power PDP your on are they as LabVIEW in lines PWM same the

motor correct the has Motor.vi“ 2 ”Open the that is VI this in confirm to thing second The 8.
etc.). Victor, Jaguar, (Talon, selected controller

into wired are motors my and controllers motor Jaguar using am I example, For
make: to need I changes the shows below image The 9. and 8 PWM



a drive to able now are you and to adjustments made have you that Vis the of all Save 9.
drive! tank with robot

## Tutorial Control and Command 13.1.2

### מבוא

organizes which season 2016 the for added template LabVIEW new a is Control and Command
Each subsystems. specificrobot- of collection a for controllers and commands into code robot
rate appropriate the at running machine state or loop control independent an has subsystem
points. set and operations desired update that commands levelhigh- and mechanism the for
commands. of sequences synchronous build to code autonomous for easy very it makes This
wait to needing without commands same the use can it because benefits TeleOp Meanwhile,
to according commands new of initiation and cancellation easy for allowing completion, for
values control and sensor its displaying panel a has subsystem Each input. team drive the
debugging. in aid to tracing command and time, over

### Control? and Command is What

relatively of up built be to tend robots FRC® that recognizes Control and Command as to referred is these of Each etc. Arm, Shooter, Drive, as such mechanisms independent the of actuators and sensors various the coordinate will that code needs and subsystem a Gripper“ ”Close as such actions, or commands, requested complete to order in subsystem each will subsystems that is framework this of principles key the of One Arm“. ”Lower or other and motors updating for responsible solely is that loop controller independent an have change may which commands issue can controller subsystem the of outside Code actuators. subtle very is difference The outputs. any change directly not should but output, robot’s the This project. the in location one from updated be possibly only can outputs that means this but through look to ability the you giving by unexpectedly behaving robot a debugging up speeds an where for project your searching than rather subsystem the to sent commands of list a change sensor, additional an add to easier becomes also It modified. been have may output controller. the of outside code modify to needing without mechanism a disable or gearing,

set update to need typically will TeleOp, and Autonomous of consisting primarily code, Game to common very is it Autonomous, For mechanisms. certain of state the to react and points it carry up, that pick here, drive – operations of sequence a as operation robot’s the define build quickly to logic additional with sequentially wired be can Commands etc. it, shoot there, the allowing asynchronously, execute can commands same the teleOp, For routines. complex commands new properly, implemented if and inputs, driver latest the process always to robot taking also while conditions field to respond quickly to team drive the allowing interrupt, will sequences. command and commands automated of advantage

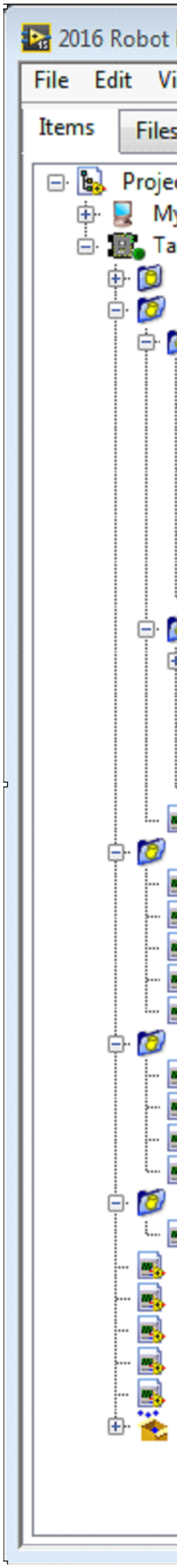
### Control? and Command use I should Why

allowing templates, project LabVIEW existing the to functionality adds Control and Command used are Subsystems code. robot and robots sophisticated more with better scale to code of sequences from built is code game and implementation, the of details the abstract to points, set update can that VIs are themselves commands The VIs. command level high and units, mechanism and units engineering between scaling/mapping numerical perform a changing as such robot, the to made are changes physical If options. synchronization offer across change this reflect to Vis command few a just to made be can changes ratio, gearing base. code entire the

when debugging quicker and operation predictable more for makes encapsulation I/O step single to able are you VI, a is command each Because occur. do conflicts resource commands all of list a view to functionality Trace in built the use or commands through data consistent and notification asynchronous uses framework subsystem.The each to sent to logic simple in add or commands of sequence a program to easy it making propagation run. to command correct the determine

### Explorer Project :1 Part

your for use will you files and Vis the of all for organization provides Explorer Project The help to Explorer Project the in components major the of description a is Below system. robot bold. in marked been have items used frequently most The system. our of expansion the with


2016 Robot
File
Edit
Vi
Items
Files
Projec
My
Ta

**Computer My**
a For on. loaded was project the that computer the on operation define that items The
files. simulation with populated is and target simulation a as used is this project, robot

**Files Support Sim**
robot. simulated the for files description and models CAD 3D containing folder The

**Readme.html Simulation Robot**
code robot write to order in need will you info robot and channels PWM the Documents
robot. simulated the of wiring the matches that

**Dependencies**
you when populate will This code. robot's simulated the by used files the Shows
target. robot simulated the for code the designate

**Specifications Build**
simulated the for code deploy and build to how define that files the contain will This
target. robot

**FRC.local)TEAM-(roboRIO- Target**
(address). at located roboRIO the on operation define that items The

**Drive**
as serves This base. drive robot the for commands and implementation subsystem The
VIs. RobotDrive WPILib the for replacement custom a

**Framework**
often. very used not are that subsystem a of part not is that code robot for used VIs

**Begin**
that code initialization for useful is This starts. first code robot when once Called
subsystem. particular a to belong doesn't

**Disabled**
you when sensors debug to used be can and packet disabled each for once Called
move. to robot the want don't

**Finish**
on called Not finishes. code robot when called be may this development, During
off. turned is power when or abort

**Tasks Periodic**
monitoring or debugging for loops periodic hoc ad for place good A

**Data Global Robot**
subsystem. a to belong doesn't that information robot sharing for Useful

**Code Support**
aids. development code and Debugging

**Vision**
processing. image and camera the for commands and Subsystem

**Main.vi Robot**
code. developing while run will you that VI level Top

**Autonomous.vi**
period. autonomous during runs that VI

**Teleop.vi**
packet. TeleOp each for called is that VI

**Test.vi**

mode. test in is station driver when runs that VI

**SubSystems.vi**

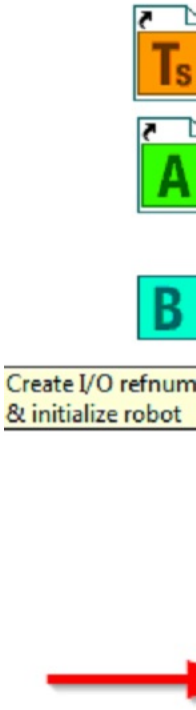
subsystems. all starts and contains that VI

**Dependencies**

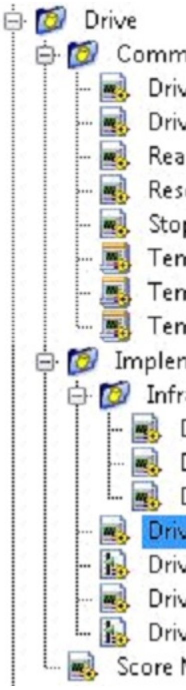
code. robot the by used files the Shows

**Specifications Build**

correctly. works code once application startup a as code the run and build to Used



### Explorer Project Subsystem Drive



**Commands:**

operation. an out carry controller the request that VIs command the contains folder This commands. drive additional creating for templates contains also It

---

or add to `Setpoints.ctl Drive` edit to need may you command, new a creating After :□□□□ the into go to need also You operation. new the define to uses controller that fields update value. every for case a add to structure case the modify and Controller.vi Drive

---

### Implementation

subsystem. the build to used Controls and VIs the are These

**VIs Infrastructure**

- loop. controller the of iteration each called is It Command: New for Check Drive a notifies completion upon and data, timing updates commands, new for checks It command. waiting
- new a that controller the notify to VI this call Commands Helper.vi: Command Drive issued. been has command
- timing, the combines and notifier the allocates It Initialization.vi: Controller Drive wire. data single a into information other and command, default
- also may panel The loop. machine control/state the contains VI This Controller.vi: Drive debugging. for useful displays contain
- Many controller. the of modes operational the defines typedef This Operation.ctl: Drive operation. an share can commands

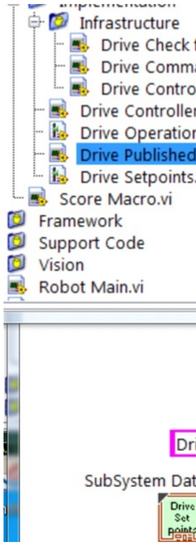
Drive the of modes operating all by used fields data the contains It Setpoint.ctl: Drive • subsystem.

the about information global publishing for place useful A Globals.vi: Published Drive • subsystem. drive

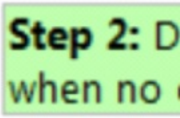
## Subsystem Drive the Initializing :2 Part

that areas key out point that diagram block controller's the on comments green are There edit. to how know to want will you

This up. starts subsystem the when once execute will loop control the of left the to area The the publish may You data. state and I/O all initialize and allocate typically will you where is other that so private them keep to Only Mode Test for them register may you or refnums, I/O command. a using without motors update cannot code

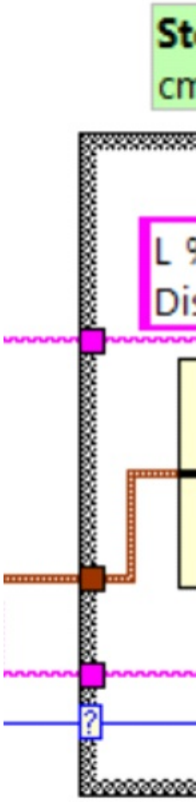


rather Controller.vi respective their in subsystem each for resources the Initializing **:□□□□** and conflicts resource potential reducing encapsulation, I/O improves Begin.vi in than debugging. simplifies


**Step 2:** D
when no

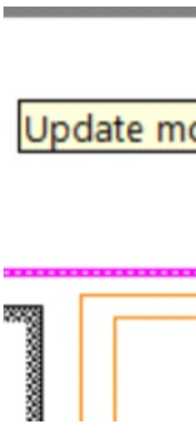
other no when values point set and operation default the select to is initialization the of Part processed. being is operation

Set implemented. actually are operations where statement case a is loop control the Inside the how on influence have all can sensors and count, iteration delay, iteration values, point subsystem. the of state operation each for value a has structure case This operates. subsystem



framework The VI. Trace the update optionally will loop controller the of iteration Each it find may you and description, and operation, name, subsystem the incorporates already VI Trace the Open information. trace the into values point set additional format to helpful to sent commands and setpoints current to running is code robot the while Enable click and subsystem. each

occur can This subsystem. the for actuators update to is controller the of goal primary The structure the of downstream it do to beneficial is it times, many but structure, case the within in location one only in and value correct the with updated always are values that ensure to code. the



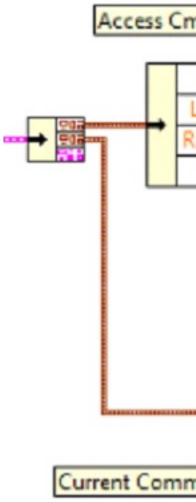
## Commands Shipped Subsystem Drive :3 Part

subsystem: new each for commands example shipped 3 are There

### Time.vi For Drive

with synchronizes optionally It seconds. of number given a for run to motors the sets VI This
command. the of completion the

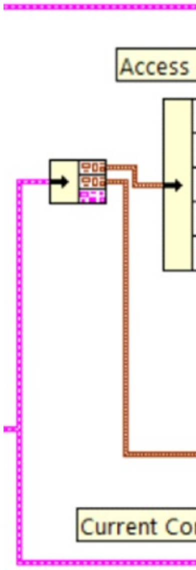
or elapses timer the until point set the at motors the operate will case Time for Drive The
to necessary is it enabled, timeout safety the have motors the If issued. is command new a
of smaller the for waits code the why is This 100ms. every once least at motors the update
50ms. and time remaining the



### Immediate.vi Drive

to immediately motors the set will and motors the for speeds right and left desired the Gets
points. set those

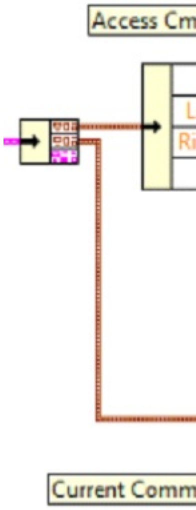
The command. the by defined point set the to motors the updates case Immediate The
a until value this maintain to motors the want you since finished considered not is command
command a anytime useful is timeout The value. timeout a until or in comes command new
and band, dead the than smaller if requested be not will values Small band. dead a includes
out. times command the unless creeping or growling in result will



### Driving.vi Stop

stationary. robot the making motors, drive the Zero

a with used When command. new a for waits and motors the off turns command Reserve The sequence, a of part is subsystem drive the that identifies reserve sequence, command named between resource subsystem arbitrate to helps This robot. the moving currently not if even commands. running simultaneously

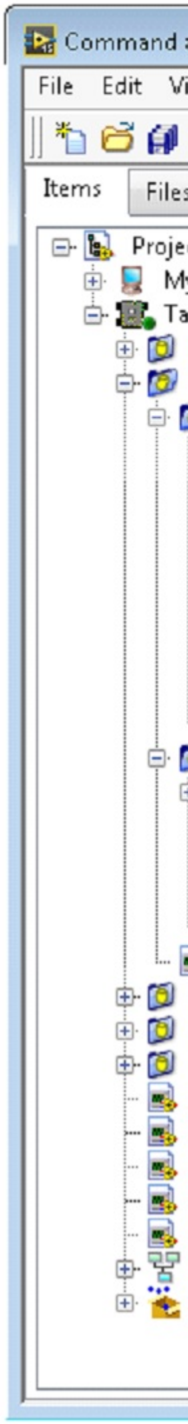


### Commands New Creating :4 Part

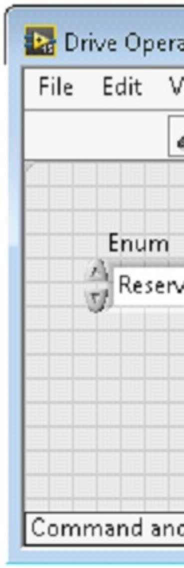
a for commands new create easily to users allows framework Control and Command The project the In folder/Commands subsystem the open command new a Create To subsystem. new your of point starting the as use to Templates VI the of one choose window, explorer Template. From New select and click, right command,

- setpoint. new the about subsystem the notifies VI This :**Immediate**
- and deadband the to value input the compares VI This :**deadband with Immediate** when useful very is This setpoint. new the about subsystem the notifies optionally used. being are values continuous joystick
- given the for command this perform to subsystem the notifies VI This :**duration With** whether determines Synchronization state. default the to return then and duration, to operation the for waits or immediately, returns and operation the Starts VI this Autonomous for second the and TeleOp, for used commonly is option first The complete. sequencing.

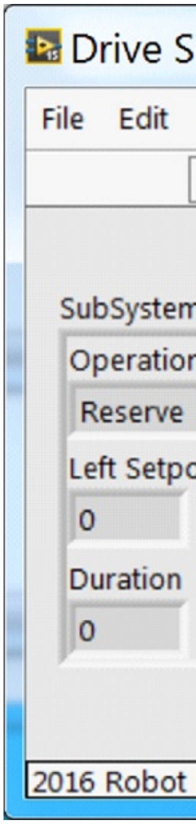
Distance“. for ”Drive command new the add will we example this In



determine Next, Distance“. for ”Drive as such name descriptive a with VI new the save First, The typedef. enum Operations Drive the added value new a needs command new the whether image following the but Distance, for Drive of value enum an has already code project initial needed. if one add would you how shows



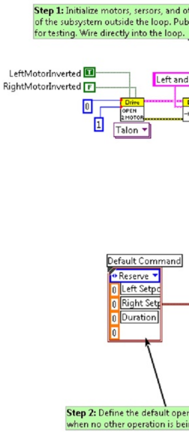
By  control. setpoints the to it add execute, to information additional needs command a If Duration and Setpoint, Right Setpoint, Left the for fields has subsystem Drive the default, reuse could command Distance for Drive The  executed. be to operation the with along Setpoints.ctl Drive the to control numeric a add and ahead go let's but distance, as Duration (feet). Distance called



Operation
Reserve
Left Setpo
0
Duration
0

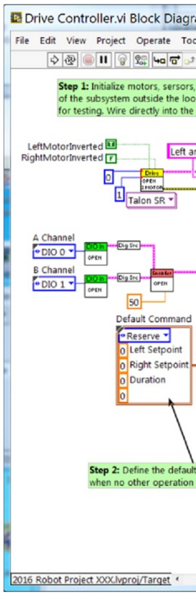
newly the modify can we command, our specify to needed fields the of all have we that Once enum's the from Distance for Drive select below, shown As Distance.vi. for Drive created not do units the If etc. speeds, distance, specify to parameters VI a add and menu down drop units. between map to place great a is VI command the match,

Distance for Drive the when happens what define to Controller Drive the to code add Next, Every for Case Add or Duplicate and Structure Case the on click Right executes. command case. Distance“ for ”Drive new a create will This Value.



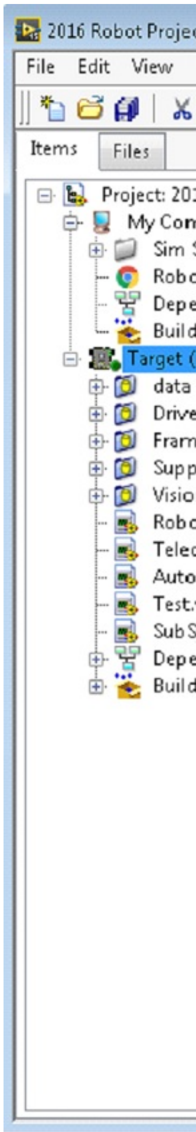
Open node. unbundle setpoints“ Cmd ”Access the grow fields, setpoint new access to order In

structure, case the of diagram new the In loop. the of left the to outside, the on encoder(s) your
There otherwise. it read and iteration loop first the on encoder the reset to call a added we
new If power. motor the updates and values encoder compares that code simple some also is
Trace. the to them adding consider also should you cluster, setpoints the to added are controls
below. image the in shown are changes necessary The

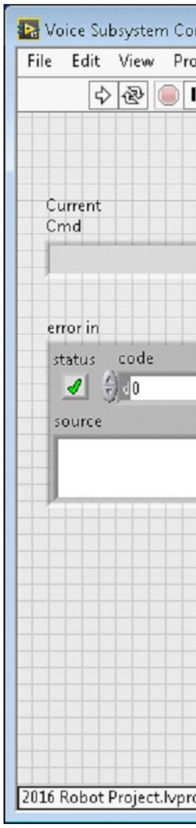


## Subsystem a Creating :5 Part

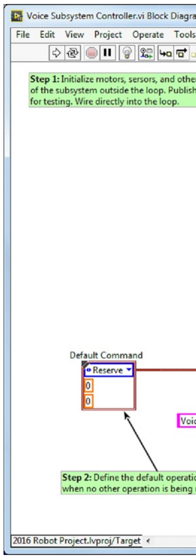
New» select and target roboRIO the on click right subsystem, new a create to order In
operational the list subsystem, the of name the enter box, dialog up pop the In Subsystem.
icon. the of color the specify and modes,



disk project the to added and generated be will folder subsystem the OK, click you When make that controls and VIs the of implementation base a contain will It tree. and folder The VI. Subsystems the into inserted be will controller new the to call A subsystem. a up control or machine state implement and I/O add to you for ready open, will VI controller generated The dialog. the in provided name and color the use will icons VI Generated code. operations. and fields point set for typedefs use will code



generated be will code This  subsystem. created newly the of diagram block the is Below subsystem. the create you when automatically



# Resources LabVIEW 13.2

## Resources LabVIEW 13.2.1

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FRC® programming specifically and LabVIEW in programming about more learn To :□□□□ resources. following the out check LabVIEW, in robots

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### Basics LabVIEW

acquainted get you help can tutorials These .LabVIEW of basics the on tutorials provides NI model programming dataflow graphical, the of basics the and environment LabVIEW the with LabVIEW. in used

### Tutorials FRC NI

.advanced to basic from ranging presentations and tutorials specific FRC many hosts also NI linked Classes Training Advanced and Basic FRC the out check resource single depthin- an For page. the of bottom the near

### Examples and Tutorials Installed

part as provided components and tasks of sorts all for examples and tutorials also are There (the screen Splash LabVIEW the from tutorials, the access To installation. LabVIEW your of the on tab `Tutorials` the on click launched) first is program the when appears that screen to free are you open is it once so document, one in all are tutorials the that Note side. left screen. splash the to returning without tutorials other to browse

anytime or `Examples FRC Find` then tab, `Support` the click either examples the access To FRC the open and `Examples Find` select menu, `Help` the open program a on working you're folder. `Robotics`

### Resources Party Third

- Library Trajectory and Control FRC
- 2 LabVIEW FRC Of Book Secret

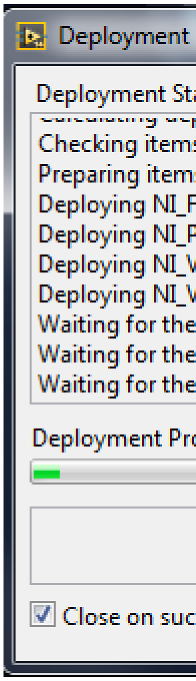
## loops bad from Recovering - Respond to Target for Waiting 13.2.2

---

no with loop (a loop unconstrained an contains which code LabVIEW download you If :□□□□ to connect to unable is LabVIEW where state a into roboRIO the get to possible is it delay) to code fixed, new, load to required process the explains document This code. new download state. this from recover

---

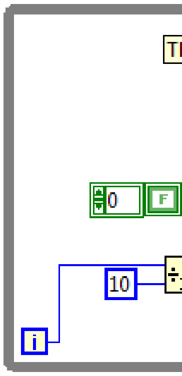
### Symptom The



the at hang code robot new download to attempts is issue this of symptom primary The other are there that Note above. shown as step respond" to (Target) target the for "Waiting LabVIEW to program C++Java a from switching as (such symptom this of causes possible them. of all or most resolve should here described steps the but program)

dialog. download the close to `Cancel` Click

### Problem The



An code. LabVIEW your in loops unconstrained is issue this of source common One on one the as (such element delay any contain not does which loop a is loop unconstrained Vision and Tasks.VI Periodic Disabled.VI, looking, begin to where unsure are you If left). the code, the with issue the fix To loop. of type this for locations common the are Processing.VI loop. right the in found palette, Timing the from VI (ms) Wait the as such element delay a add

### App No Set

*Settings Startup Dashboard Web roboRIO* the on article the (see webserver roboRIO the Using
App“. Startup RT ”Disable to box the **Check** details). more for

### Reboot

top the in Restart click by or device the on button Reset the using either roboRIO, the Reboot
webpage. the of corner right

### App No Clear

*Settings Startup Dashboard Web roboRIO* the on article the (see webserver roboRIO the Using
App“. Startup RT ”Disable to box the **Uncheck** details). more for

### Code LabVIEW Load

set to sure Make Startup). as Run or button Run the using (either code LabVIEW Load follow to need will you or roboRIO the rebooting before Startup as Run to code LabVIEW again. above instructions the

## Modes Camera Two Between Toggle To How 13.2.3

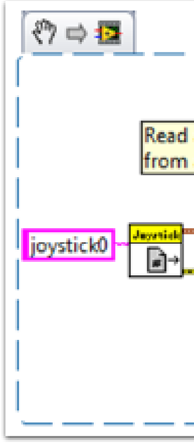
code The modes. camera distinct two between toggle to button a use to how shows code This stages. four of consists

read. is joystick the on button a of value the stage, first the In

and **Node Feedback** a using reading previous the to compared is reading current the Next, when toggled only is mode camera the that ensure these Together, arithmetic. Boolean some the while times multiple forth and back toggling than rather pressed initially is button the down. held is button

the over stage second the of result the masking by toggled is mode camera the that, After function **XOR** the with it doing by and masking bit called is This value. mode camera current nothing do and true returns stage second the when mode camera the toggle will code the otherwise.

Each end. the at structure case the in mode camera each for code the insert can you Finally, mode. camera current the for code the run will section this run, is code the time



## Tutorials and Examples LabVIEW 13.2.4

### Tutorials Popular

Tutorial Movement Timed Autonomous

- intervals time different on based autonomously robot your Move
- Movement Autonomous on more See

Tutorial Control Motor Basic

- software and hardware motor roboRIO your Setup
- Project Robot FRC and System Control FRC® the setup to Learn

Control Motor on more See •
Tutorial Processing Image
Assistant Vision NI use to how and techniques Processing Image basic Learn •
Processing Image and Cameras on more See •
Tutorial Control PID
it? implement I can how and Control PID is What •
Tutorial Control and Command
Control? and Command is What •
it? implement I do How •
Tutorial Station Driver
Station Driver FRC the know to Get •
Tutorial Mode Test
Mode Test use and setup to Learn •

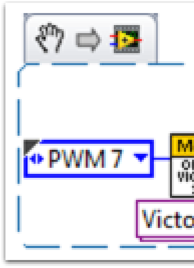
your post or documents more through Search discussions? and examples more for Looking posts your mark to forget Don’t here! clicking by tutorial or code, example discussion, own tag! a with

## Project a to Motor Independent an Add 13.2.5

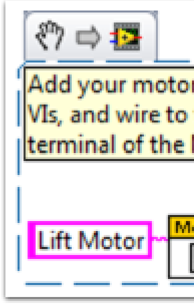
motor additional an add to need might you set, all is wheels the controls that drive your Once motor this Since arm. an as such wheels, the of independent completely something control to independent want definitely you’ll drive, mecanum or arcade, tank, your of part be not will it. of control

contain already may that project a in motor single a up set to how show Snippets VI These image the drag just symbol, HAND>ARROW>LABVIEW the see you If drive. motormulti- a it. do you how here’s Ok, code! voila: and diagram, block your into

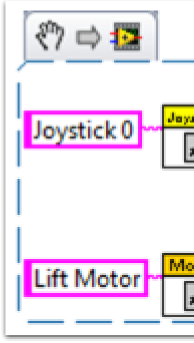
**Open Control Motor** the using ,**Begin.vi** the in reference motor a create FIRST, in clickingright- by found be can These .**VI Set Registry Refnum Control Motor** and **VI** .**Control Library>>RobotDrive>>Motor Robotics WPI** to going and diagram block the to it connected and Motor“ ”Lift mine named I motor. your name and line PWM your Choose automatically which VI, Config Safety Control Motor the enabled and included also (I 7. PWM connection.) loses it if motor the off turns



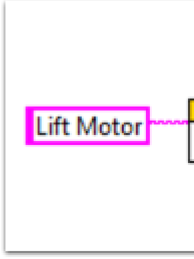
**Motor** the using **Teleop.vi** the in exact) be to has name (the motor your reference Now, **Output Set Control Motor** the with do to what it tell and **VI Get Registry Refnum Control** .**VI** These are in the same place as the above VIs.


Add your motor
VIs, and wire to
terminal of the

on pressed is 4 button if forward move to Motor Lift the tells snippet next the example, For my on bumper left the is 4 button me, For otherwise. motionless remain to and 0 Joystick check options, button joystick depthin- more much For 0“). (”Joystick controller style Xbox .*Solenoids or Motors Control to Buttons Joystick Use to How* out



and drive the with do we like (just **Finish.vi** the in references the close to need we Finally, .**VI Close Control Motor** and **VI Get Registry Refnum Control Motor** the using joystick), all want really we itself, by structure sequence flat a in VI Close the shows picture this While VIs Get other the below VIs two these put just can You frame. same the in VIs Close the of drive). and joystick the (for VIs Close and

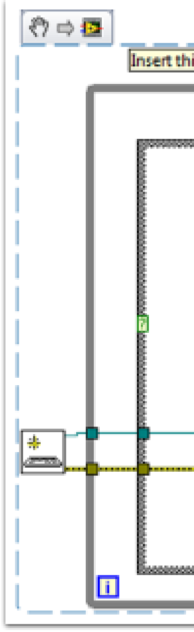


luck! Good ever! robot best the program you helps this hope I

### roboRIO the with Navigation Keyboard 13.2.6

navigation keyboard using robot the controlling for suggestions some provides example This control to keys D and S, W, A, the use we case, this In controller. other or joystick a of place in two drive motors in a tank drive configuration. drive tank a in motors drive two

can You VI. Main Dashboard the in included be to need will that code the is Snippet VI first The keyboard the to connection a opens code The 1. Loop of case True the into code this insert is information This key. pressed the reads it iteration each on and begins, loop the before Loop When project. robot the in VI Teleop the to passed then is which string, a to converted closed. is keyboard the to connection the running, stops 1

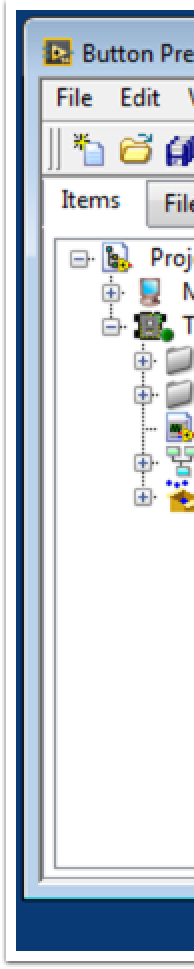


string the reads This VI. Teleop the in included be should that code is Snippet VI second The then Structure Case A pressed. was key which indicates that Dashboard the from value the on depending motors, right and left the to written be should values which determines this in case Each reverse. is S and right, is D left, is A forward, is W case, this In key. the change code, your in same the this keep can You speed. half at motors the runs example or fast drive can you so speed, the adjust to driver the allow to code additional add or values, motors, drive the to written are they selected, are values motor the Once necessary. as slow dashboard. the to published are values motor and

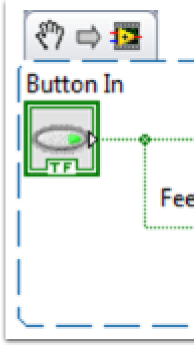
### Press Button ShotOne- a Making 13.2.7

button the cause will button joystick a pushing function, Values Get Joystick the using When multiple read likely most will you that means This released. is button the until TRUE read to the time each value TRUE one only read to want you if What press. each for values TRUE show will tutorial following The Button“. Shot”One- a called often is This pressed? is button this. do to Teleop.vi your into drop can you that subVI a create to how you

project. your of folder Code Support the in VI new a create First,



snippet. code following the in drop VI, new the of diagram block the on Now

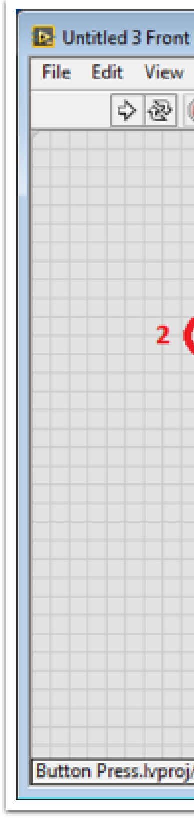


of value current the wired have We  Node. Feedback the called function a uses code This the of arrow the of out coming wire The  node. feedback the of side left the into button the feedback your on arrow the If  button. the of value previous the represents node feedback reverse to option the find to click right here, shown as direction opposite the going is node direction. the

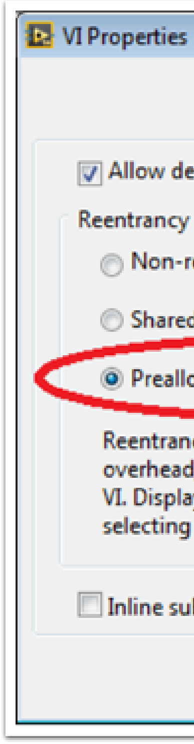
the want We TRUE. to FALSE from goes button the of value the pressed, is button a When the and TRUE, is button the of value current the when only TRUE be to VI this of output FALSE. is button the of value previous

the of outputs and inputs the to indicator and control boolean the connect to need we Next

the connect to button the click then pane, connector the on block the click first this, do To VI.
indicator. the for this Repeat below). diagram the (see two



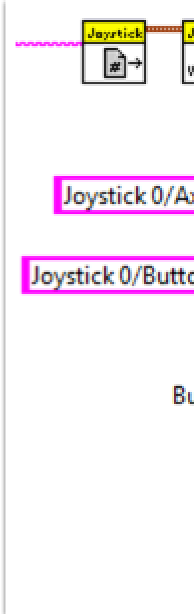
VI this of multiples use can we that so VI this of properties the change to need we Next,
category the select Then Properties. VI to go and Icon VI the click Right TeleOp.vi. our in
execution“. reentrant clone ”Preallocated select and ”Execution“



click Right function. VI's the of descriptive more be to Icon VI the change should we Lastly,
Icon. new a Create Icon. Edit to go and Icon the

the from VI this drop and drag now can You name. descriptive a with VI the save Finally, `Button_Press.` VI: completed the of copy a is Here TeleOp.vi. your into folder Files Support `vi`

VI. this use could you how of example an Here's



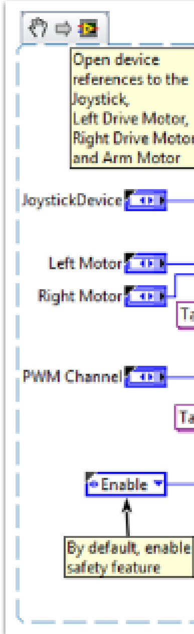
## Code Robot Your to Features Safety Adding 13.2.8

executing is code your of all that sure making is projects complex with problem common A execution long priority, high with tasks when arise can Problems to. it expect you when known is what to leads This roboRIO. the on power processing hog calls frequent or times, In busy. being processor the to due execute to able not are that tasks the for ”starvation“ as other and joysticks the from input your to time reaction the slow simply will this cases most after long on stay to robot your of motors drive the cause also can this However, devices. safety implement can you this, from catastrophes robotic any avoid To them. stop to try you harmful potentially down shut automatically and starvation input task for check that features operations.

checks. safety of implementation easy allow that motors the for functions inbuilt- are There are: functions These

- Configuration Safety Drive Robot
- Configuration Safety Drive Motor
- Configuration Safety Relay
- Configuration Safety PWM
- Configuration Safety Solenoid
- Safety Update and Delay Drive Robot

checks safety the disable and enable can you functions, Configuration Safety the of all In The appropriate. is think you timeout what configure and running is programming your while of any if check will and enabled safety the have that devices all of cache a keep functions and disabled be will cache the in devices all has, any If limit. time their exceeded have them off. turned outputs relay/PWM/solenoid its have or stop immediate an to come will robot the a set to functions Configuration Safety Drive the use to how demonstrates below code The off. shut being before input no receive will motors the that limit time maximum


Open device references to the Joystick, Left Drive Motor, Right Drive Moto and Arm Motor
By default, enable safety feature

your than longer is that loop the to function Wait a adding try off,shut- safety the test To timeout!

Update and Delay Drive checks–Robot safety implementing to relates that function final The limit. time the exceeding without Mode Autonomous in roboRIO the put to you Safety–allows Output Drive the to calls costly making without output motor current the maintain will It the that so updated regularly are checks safety the that sure make also will and functions, stop. suddenly not will motors

your in implemented is check safety of sort some that recommended highly is it Overall, state! dangerous a in left unintentionally not is robot your that sure make to project

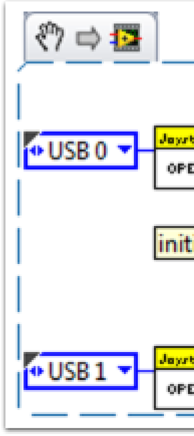
## Solenoids or Motors Control to Buttons Joystick Use to How 13.2.9

devices auxiliary our connecting to on moving are we working, systems drive our get all we As these control to buttons joystick use generally will we this, With solenoids. and motors as such joystick with devices control to ways several through go we'll this, with started get To devices. buttons.

into right this like document a from Snippet VI a drag and click can you that know you Did document. this in snippets the with it Try code? LabVIEW your

### Setup:

excited) really you're (if more or two, one, add to need you'll configuration, the what matter No one. use only others the and joysticks 2 uses example first The ”Begin.vi“. the to joysticks named I below. snippet the like places, other in it use can we so name unique a one each Give If desk. my of sides right and left the on are they because ”RightStick“ and ”LeftStick“ them step. this skip can You great! configured, already are joysticks your

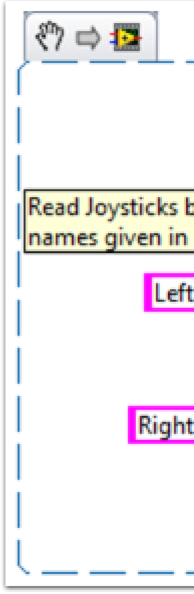


will we where is This ”Teleop.VI“ the in placed be will document this in code the of rest The solenoids. or motors our of aspects different control to buttons joystick our programming be

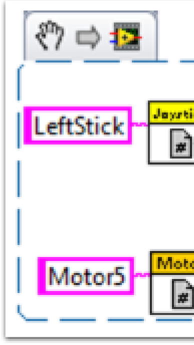
### 1 Scenario

**I when way other the and button one press I when way one move to motor a want ”I button.“ different a press**

on 0 button If motor. same the control to joysticks different two on 0 button uses code This the pressed, is RightStick on 0 button if and backward, moves motor the pressed, is LeftStick motor the pressed, is button neither or pressed are buttons both If forward. moves motor motor your name can you but ”Motor5“, reference motor my named I Here move. doesn’t ”Begin.vi“ the in want you whatever



of example an For control. for joystick same the from buttons multiple use to want may You 2. Scenario in snippet VI the or snippet VI following the at look this,



need. you buttons whatever use to free feel but 2, and 0 buttons joystick used I Here

## 2 Scenario

### speeds.“ various at move buttons joystick different want ”I

the on based things different do motor one have to need you if helpful be could example This buttons 4 and 0) (button trigger a has joystick my say let’s instance, For press. you buttons following the have should buttons following the case, this In 4). through 1 (buttons top on functions:

- speed half at backward move - 1 button
- speed half at forward move - 2 button
- speed 1/4 at backward move - 3 button
- speed 1/4 at forward move - 4 button
- speed) full at (forward ahead! speed full - trigger

”Boolean a to it wire and ”JoystickGetValues.vi“ the from array boolean the take then would We boolean the converts This Palette). ConversionPalette- (Numeric node Number“ to Array structure. case a to numeric this Wire use. can we that number a to array

example, this In array. the in values the of representation binary a to corresponds case Each off), buttons (all 0 cases: six added We combination. buttonone- a to corresponds case each Notice on). 4 (button 16 and on), 3 (button 8 on), 2 (button 4 on), 1 (button 2 on), 0 (button 1 did We time. same the at pressed 1 and 0 buttons to correspond would 3 3. value skipped we it. handle case default the let we’ll so requirements our in this define not

here: document Help Structure Case 2014 LabVIEW the review to helpful be might It

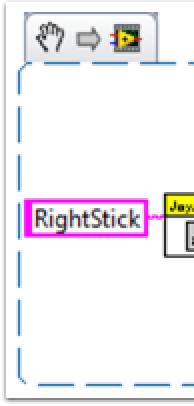
https://zone.ni.com/reference/en-XX/help/371361L-01/glang/case_structure/

here: structures case on Tutorials Community 3 also are There

https://forums.ni.com/t5/Curriculum-and-Labs-for/Unit-3-Case-Structures-Lesson-1/ta-p/3505945?profile.language=en

https://forums.ni.com/t5/Curriculum-and-Labs-for/Unit-3-Case-Structures-Lesson-2/ta-p/3505933?profile.language=en

https://forums.ni.com/t5/Curriculum-and-Labs-for/Unit-3-Case-Structures-Lesson-3/ta-p/3505979?profile.language=en

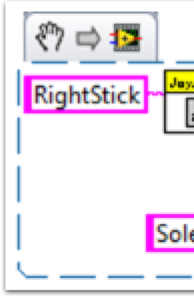


case For case. each in constant single a need only we simple, were requirements our Since constant any use can We etc. 0.5,- a use we back) (half 2 case for 1, a use we ahead) (full 1 (any pressed are buttons multiple if so default the as 0 case left I 1.- and 1 between value these customize to free are course of You stop. will motor the reached) was state undefined want. you however states

### 3 Scenario

#### buttons.“ joystick my with solenoid a control to want ”I

booleans. of array an in buttons the outputs joystick the how with familiar are we now, By to boolean this wire and in, interested are we button the get to array this index to need We to way easiest the input, an as Enum a requires Set.vi“ ”Solenoid the Since node. select a ”Create select and Set.vi“ ”Solenoid the of input ”Value“ the click right to is enum the get the to one and terminal True the to copy one wire and constant this Duplicate Constant“. input ”Value“ the to node select the of output the wire Then node. select the of terminal False VI. solenoid the of



Roboting! Happy

## FRC for LabVIEW in Variables Global and Local 13.2.10

in used are they how variables, global and local to introduction an as serves example This your in them use to want might you how and Project, Robot FRC® for LabVIEW default the project.

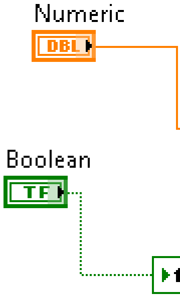
the within locations between data transfer to used be may variables global and variables Local conventional the breaking variables), (global VI’s different within or variables) (local VI same for when, useful be may they Thus, famous. is LabVIEW which for Paradigm Flow Data another. to node the to directly value the wire cannot you reason, whatever

loop consecutive between data pass to need you that be may reason possible One Note: node feedback the that noted be also should It .post this in this covered Miro_T iterations; topic a be may that although register, shift the to equivalent an as used be may LabVIEW in day! another for

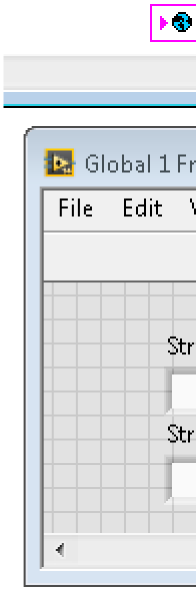
### Variables Global and Local to Introduction

a clickingright- by variable local a Create VI. same the within used be may variables Local Panel: Front your on indicator or control

well. as diagram block the on palette Structures the from variable local a create may You
variable which choose to clickleft- can you VI, one in variables local multiple have you When
is: it



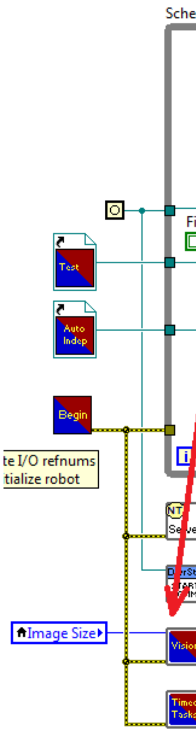
the from diagram block the to one Add  differently. slightly created are variables Global
panel. front separate a opens it it, clickdouble- you when that notice and palette, Structures
front the to entities many as add you but diagram, block a have not does panel front This
file: *.vi a as it save and wish you as panel



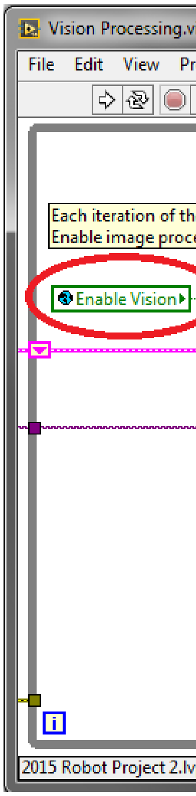
variables! global and local using when conditions race avoid to careful very Be :□□□□ multiple in variable same the to writing accidentally not are you that sure make Essentially, thorough more a For written. last was it location which to know to way a without locations document help this see explanation,

### Project Robot FRC for LabVIEW Default the in Used are They How

of iteration each during to written are Size“ ”Image and Vision“ ”Enable for variables Global VI… Main Robot the



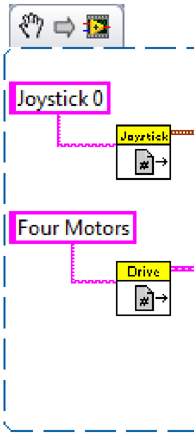
VI: Processing Vision the of iteration each in read then And …



Development LabVIEW the from VI Main Robot to deploying when user, the allows This Front Main’s Robot from size image the change and vision enable/disable to Environment, Panel.

### Project? Your in Them Use You Can How

as such value, some is there Perhaps VI. Tasks Periodic the for diagram block the out Check the in from read then and VI, Teleop the in variable global a to written be may that boolean, a VI, Tasks Periodic the in use to values or code what decide then can You VI. Tasks Periodic variable: global boolean the on depending



## LabVIEW in Compressor the Using 13.2.11

Module Control Pneumatic the use to project roboRIO your up set to how shows snippet This are pressures specific when compressor the stops and starts automatically PCM The (PCM). VIs. following the add to need will you program, roboRIO your In tank. the in measured

links: following the out check information, more For

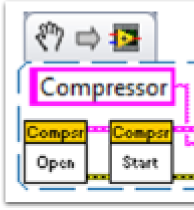
`Manual Pneumatics FRC`

Guide User's PCM

roboRIO the for Step by Step Pneumatics

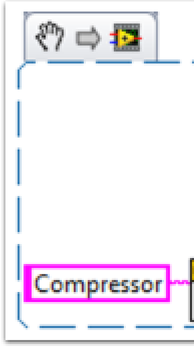
### VI Begin

Begin.vi. the in snippet this Place



## VI Teleop

outputs the using are you if required only is portion This Teleop.vi. the in snippet this Place processes. other for



## VI Finish

Finish.vi. the of frame etc. data, save Refs, Close in snippet this Place

# 41

[redacted]

controllers, motor through pneumatics and motors of control the discusses section This
WPILib. C++ and Java with interface their and pneumatics, and solenoids

## APIs Motors 14.1

showcases section This robot! moving a to essential absolutely are motors your Programming
moving! and up robot your getting for examples and classes helpful some

### Code in Controllers Motor Using 14.1.1

more send can controller CAN A PWM. and CAN flavors: main two in come controllers Motor
set be only can controller PWM a whereas roboRIO, the to back information status detailed
*Using* see classes, drivetrain WPI the with motors these using on information For value. a to
*.Robot your Drive to Classes WPILib the*

#### Controllers Motor PWM Using

a For controller. motor CAN a as way same the in controlled be can controllers motor PWM
use To *.Depth in Controllers Motor PWM* see work, they *how* on background detailed more
WPI by provided class controller motor appropriate the use simply controller, motor PWM a
approved All roboRIO. the on into plugged are controller(s) motor the port the it supply and
them. for provided classes WPI have controllers motor

---

motor PWM other example; an as here used are classes `VictorSP` and `Spark` The :□□□□
API. same the exactly have classes controller

---

Java

```
to connected is this port PWM RIO the is 0 // );0Spark( new = spark Spark

1 and 1- between motor, the of output % the // );0.75-(setspark.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
to connected is this port PWM RIO the is 0 // );0VictorSP( new = victor VictorSP
 1 and 1- between motor, the of output % the // );0.6(setvictor.
```

C++

```
to connected is this port PWM RIO the is 0 // ;}0spark{ Spark::frc
 1 and 1- between motor, the of output % the // );0.75-spark.Set(
to connected is this port PWM RIO the is 0 // ;}0victor{ VictorSP::frc
 1 and 1- between motor, the of output % the // );0.6victor.Set(
```

Python

```
to connected is this port PWM RIO the is 0 # )0Spark(.wpilib = spark
 1 and 1- between motor, the of output % the # )0.75-set(.spark
to connected is this port PWM RIO the is 0 # )0VictorSP(.wpilib = victor
 1 and 1- between motor, the of output % the # )0.6set(.victor
```

### Controllers Motor CAN

Electronics CTR as such vendors through available are controllers motor CAN of handful A
Robotics. REV and

#### MAX SPARK

either in used be can which Controller, Motor CAN MAX SPARK the regarding information For
code. example and resources software MAX SPARK the to refer please mode, PWM or CAN

#### Controllers Motor CAN CTRE

detailed more for software Phoenix the on documentation CTRE party third the to refer Please
here. available is documentation The information.

## Depth in Controllers Motor PWM 14.1.2

that classes of number a are There control. motor for support extensive has WPILib **:□□□**
of classes two currently are There servos. and controllers motor of types different represent
WPILib controllers. motor based CAN and controllers motor based PWM controllers, motor
multiple control to you allow which DifferentialDrive) (like classes composite contains also
CAN controllers; motor PWM of details the cover will article This object. single a with motors
articles. separate in covered be will classes composite and controllers

## operation of theory brief Controllers, PWM

refer can PWM controllers, motor For Modulation. Width Pulse for stands PWM acronym The control To speed. motor control to uses controller the method the and signal input the both to motor. the of voltage input perceived the vary must controller the motor the of speed the the varying quickly, very off and on voltage input full the switches controller the this do To electrical and mechanical the of Because signal. control the on based on is it time of amount effect an produces switching rapid this FRC® in used motors of types the of constants time effect same the produces switching (50% voltage lower fixed a applying of that to equivalent ~6V). applying as

bounds the at Even different. bit little a is input an for use controllers the signal PWM The of cycle duty a approaches never signal the reverse) max or forward (max range signal the of a and 10ms or 5ms either of period a with signal a use controllers the Instead 100%. or 0% controller RC hobby typical the use controllers the of Many 1.5ms. of width pulse midpoint 2ms. to 1ms of timing

## values output Scaled vs Raw

the as value 1.0 to 1.0- scaled a take WPILib in classes controller motor the of all general, In generating of capable is roboRIO the on FPGA the in module PWM The actuator. an to output of steps 2000 in width pulse the vary can and 20ms or 10, 5, of periods with signals PWM The midpoint). the around direction each in steps (1000 midpoint the around each ~.001ms holds which case special a being 0 with range 20000- this in are module this to sent values raw what about information contains controller motor each for class The (disabled). low signal the typical the as well as are deadband) the of side each and max (min, values bound typical the for range proper the into value scaled the map to values these use then can WPILib midpoint. of types different between seamlessly switch to code the for allows This controller. motor the signaling. specific the of details the out abstracts and controllers

## Controllers Motor Calibrating

motor your calibrate to need ever you would why scaling, this all handles WPILib if So of measurement on based approximate are scaling for uses WPILib values The controller? an of timing the factors, of variety a to Due type. controller each of samples of number a ”humming“ eliminate definitively to order In slightly. vary may controller motor individual controller the drive and direction) one in movement slight as interpreted signal (midpoint the general, In recommended. still is controllers the calibrating extreme, each to way the all mode calibration into controller the putting involves controller each for procedure calibration on examples For midpoint. the to back then extreme, each to signal input the driving then *Code/Using in Controllers Motor Using* see code, your in controllers motor these use to how *Controllers Motor PWM*

## Robot your Drive to Classes WPILib the Using 14.1.3

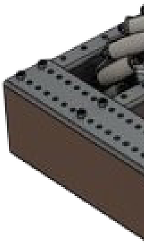
faster. driving get robot your make help to classes many includes WPILib

### drivetrains Standard

### Robots Drive Differential

(e.g., side per wheels omni or traction linein- more or two have typically bases drive These
The Drive“. Coast ”West or drive“, ”tank steer“,”skid- as known be also may and 8WD) or 6WD
of capable are drivetrains These drive. differential a of example an is drivetrain Parts of Kit
causing directions opposite in sides two the driving by turn can and forward/backward driving
translational sideways of capable not are drivetrains These sideways. skid to wheels the
movement.

## Drive Mecanum



robot the allow that wheels designed specially using driving of method a is drive Mecanum
a with robot A robot. the of orientation the changing without direction any in drive to
direction the in turn must direction) same the in pointing wheels (all drivetrain conventional
is and turning first without direction any in move can robot mecanum A drive. to needs it
forces the cause that rollers have robot) this on (shown wheels The drive. holonomic a called
of case the in as forward straight than rather angle degree 45 a at applied be to driving from
drive. conventional a

pattern. »X« an form should drivetrain mecanum a on rollers the top, the from viewed When
wheels two front the on forward) wheel the driving (when vectors force the in results This
By outward. and forward pointing wheels two rear the and inward and forward pointing
cancel vectors force the of components various directions, different in wheels the spinning
has movements different of chart quick A movement. robot desired the in resulting out,
in help may motions these of each for vectors force the out drawing below, provided been
addition in wheels the of speeds the varying By work. drivetrains these how understanding
and direction any in translation in resulting combined be can movements direction, the to
simultaneously. rotation,

## Conventions Class Drive

### Inversion Motor

the is It default. by inverted **longer no** is drivetrain the of side right the 2022, of As
invert can Users drivetrain. their for inversions proper manage to user the of responsibility
objects. motor their on `SetInverted()/setInverted()` calling by motors

Java

```
);0PWMSparkMax( new = m_motorRight PWMSparkMax

@Override
{ ()robotInit void public
);true(setInvertedm_motorRight.
}
```

C++

```
;}0m_motorLeft{ PWMSparkMax::frc

:public
{ override RobotInit() void
);truem_motorRight.SetInverted(
}
```

Python

```
):self(robotInit def
)0PWMSparkMax(.wpilib = motorRight.self
)TruesetInverted(.motorRight.self
```

### Inputs Squaring

robot the that such inputs joystick the manipulate to desirable often is it robots, driving When
accomplish to way One range. output full the using still while speeds low at control finer has
Differential the default By sign. the reapplying then input, joystick the squaring by is this
a from in values passing if (e.g. desired not is this If inputs. the square will class Drive
to it set and parameter squaredInputs the with methods drive the of one use PIDController),
false.

### Deadband Input

that means This 0.02. of deadband input an applies class Drive Differential the default, By
be will above) described as squaring any (after 0.02 below magnitude a with values input
are and centering joystick imperfect from result inputs small these cases most In 0. to set
motor unnecessary reduce helps deadband the movement, drivetrain cause to sufficient not
the change To drivetrain. the to values small these applying from result may that heating
method. *setDeadband()* the use deadband,

### Output Maximum

output. the limit to want and fast too driving is drivetrain their that feel drivers Sometimes is output maximum This method. *setMaxOutput()* the with accomplished be can This inputs. squared and deadband like functions drive previous the of result by multiplied

### Safety Motor

breaks and watchdog a of concept the takes that WPILib in mechanism a is Safety Motor this that Note actuator. individual each for timer) Safety (Motor watchdog one into out it the by controlled is which Watchdog System the to addition in is mechanism protection does it if outputs actuator all disable will and FPGA the and code Communications Network 125ms. for packet data valid a receive not

timer, watchdog a of purpose the as same the is mechanism Safety Motor the of purpose The code the if property or people themselves, to harm cause may which mechanisms disable to concept this breaks Safety Motor output. actuator the update properly not does and up locks necessary is it where determine appropriately can you that so basis actuator per a on out are enabled safety motor have should that mechanisms of Examples not. is it where and they value particular a on latched get systems these If arms. and trains drive like systems that mechanism a of example An themselves. or environment their to damage cause could latched gets mechanism this If shooter. a for flywheel spinning a is safety motor need not may default By disabled. is robot the until spinning continue simply will it value particular a on all for disabled and objects MecanumDrive and DifferentialDrive for enabled is Safety Motor servos. and controllers motor other

been has it long how tracks that timer a maintaining by operates feature Safety Motor The Station Driver the in Code actuator. that for called been has method feed() the since with actuator any for values timeout the to timers these of comparison a initiates class motor each of methods set() The nominal). (100ms packets received 5 every enabled safety indicate to feed() call class servo the of methods setAngle() and set() the and class controller updated. been has actuator the of output the that

the using user the by with interacted be can controllers motor of interface Safety Motor The methods: following

Java

```
);true(setSafetyEnabledexampleJaguar.
);false(setSafetyEnabledexampleJaguar.
);1.(setExpirationexampleJaguar.
()feedexampleJaguar.
```

C++

```
);trueSetSafetyEnabled(>-exampleJaguar
);falseSetSafetyEnabled(>-exampleJaguar
);1.SetExpiration(>-exampleJaguar
Feed();>-exampleJaguar
```

Python

```
)TruesetSafetyEnabled(.exampleJaguar
)FalsesetSafetyEnabled(.exampleJaguar
)1.setExpiration(.exampleJaguar
feed().exampleJaguar
```

the and mechanism the on Depending Safety. Motor enable objects Drive all default By safety motor the of length timeout the configure to wish may you program, your of structure global a not is and basis actuator per a on configured is length timeout The seconds). (in 100ms. is value useful) minimum (and default The setting.

## Conventions Axis

the in reference external as UpWest-(North- convention axes NWU the use classes drive The positive the and left, points axis Y positive the ahead, points axis X positive The frame). world use general, in math and library, the of rest the because here NWU use We up. points axis Z convention. axes NWU

ahead, points axis X positive the where convention, Down)East-(North- NED follow Joysticks important it's However, down. points axis Z positive the and right, points axis Y positive the When translations. not axes, respective the around rotations are values axes that note to negative a is CW and value positive a is CCW you, toward pointing axis each with viewed a get you so axis, Y the around rotation CW a is joystick the on forward Pushing value. positive a get you so axis, X the around rotation CCW a is right the to Pushing value. negative value.

## robots Drive Differential control to class DifferentialDrive the Using

---

drive common most the for classes Drive Robot separate provides WPILib :□□□□ the handles class DifferentialDrive The mecanum). and (differential configurations train linein- more or two have typically bases drive These configuration. drivetrain differential steer“,”skid- as known be also may and 8WD) or 6WD (e.g., side per wheels omni or traction a of example an is drivetrain Parts of Kit The (WCD). Drive“ Coast ”West or drive“, ”tank (”Tank“, styles different 3 with drive the control to methods are There drive. differential below. article the in explained ”Curvature“), or ”Arcade“,

---

Coast“ ”West or steer“”skid- of control the for provided method a is DifferentialDrive simple as is DifferentialDrive a Instantiating chassis. Parts of Kit the as such drivetrains, so: as

Java

```
                                                     { Robot class public
                                              );1Spark( new = m_left Spark
                                             );2Spark( new = m_right Spark
         m_right); DifferentialDrive(m_left, new = m_drive DifferentialDrive

                                                  { ()robotInit void public
␣do must you outputs, motor invert to want you if // );true(setInvertedm_left.
                                                                 here so ↪
                                                                        }
```

(Header) C++

```
                                                               { Robot class
                                                                   :private
                                                     ;}1m_left{ Spark::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
;}2m_right{ Spark::frc
m_right}; m_drive{m_left, DifferentialDrive::frc
```

(Source) C++

```
{ ()Robot::RobotInit void
␣so do must you outputs, motor invert to want you if // );truem_left.SetInverted(
here ↩
}
```

Python

```
):self(robotInit def
)1Spark(.wpilib = left
here so do can you outputs, motor invert to want you if # )TruesetInverted(.left
)2Spark(.wpilib = right
right) DifferentialDrive(left,.drive.wpilib = drive.self
```

## MotorControllerGroups with DifferentialDrive MotorMulti-

with these use to order In side. each on motor 1 than more have drivetrains FRC® Many MotorController, single a into collected be to have side each on motors the DifferentialDrive, side) per (2 motor 4 a show below examples The class. MotorControllerGroup the using them pass and controllers additional the create simply motors, more to extend To drivetrain. inputs). of number arbitrary an takes (it constructor group MotorController the into all

Java

```
{ Robot class public
);1Spark( new = m_frontLeft Spark
);2Spark( new = m_rearLeft Spark
m_rearLeft); MotorControllerGroup(m_frontLeft, new = m_left MotorControllerGroup

);3Spark( new = m_frontRight Spark
);4Spark( new = m_rearRight Spark
m_ MotorControllerGroup(m_frontRight, new = m_right MotorControllerGroup
rearRight); ↩
m_right); DifferentialDrive(m_left, new = m_drive DifferentialDrive

{ ()robotInit void public
␣do can you side entire the invert to want you if // );true(setInvertedm_left.
here so ↩
}
```

(Header) C++

```
{ Robot class
:public
;}1m_frontLeft{ Spark::frc
;}2m_rearLeft{ Spark::frc
m_rearLeft}; m_left{m_frontLeft, MotorControllerGroup::frc

;}3m_frontRight{ Spark::frc
;}4m_rearRight{ Spark::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                    m_rearRight}; m_right{m_frontRight, MotorControllerGroup::frc

                                 m_right}; m_drive{m_left, DifferentialDrive::frc
```

(Source) C++

```
                                                         { ()Robot::RobotInit void
␣so do can you side entire the invert to want you if // );truem_left.SetInverted(
                                                                          here ↪
                                                                              }
```

Python

```
                                                           ):self(robotInit def
                                                  )1Spark(.wpilib = frontLeft
                                                   )2Spark(.wpilib = rearLeft
                              rearLeft) MotorControllerGroup(frontLeft,.wpilib = left
here so do can you side entire the invert to want you if # )TruesetInverted(.left

                                                 )3Spark(.wpilib = frontRight
                                                  )4Spark(.wpilib = rearRight
                             rearLeft) MotorControllerGroup(frontLeft,.wpilib = right

                             right) DifferentialDrive(left,.drive.wpilib = drive.self
```

## Modes Drive

---

your driving of modes default different three contains class DifferentialDrive The :□□□□ motors. robot's

- independently side right and left the controls which Drive, Tank
- speed turn and forward a controls which Drive, Arcade
- car a like handle robot your makes which Drive, Arcade of subset a Drive, Curvature turns. curvatureconstant- with

---

WCD or steerskid- controlling for methods default three contains class DifferentialDrive The and driving robot's the controlling of methods own your create can you that Note robots. motors. right and left for inputs derived the with tankDrive() call them have

with (usually independently drivetrain the of side each control to used is mode Drive Tank The two of axisY- the use to how shows example This each). controlling axis joystick individual an been has objects the of Construction mode. Tank in drivetrain the run to joysticks separate construction. Joystick for here and construction drivetrain for above for omitted,

rotation and speed/throttle using drivetrain the control to used is mode Drive Arcade The joysticks across split or joystick, single a from axes two with either used typically is This rate. from rotation the and stick one from coming throttle the with gamepad) single a on (often Construction mode. Arcade the with joystick single a use to how shows example This another. Joystick for here and construction drivetrain for above for omitted, been has objects the of construction.

using drivetrain the control to used is mode Drive Curvature the Drive, Arcade Like controls input control rotation the that is difference The rate. rotation and speed/throttle of wheel steering the like much change, heading of rate of instead curvature of radius the `boolean` third the when enabled is which place, in turning supports also mode This car. a true. is parameter

Java

```
                                           { ()teleopPeriodic void public
                              rates right and left given a with drive Tank //
                     ());getYrightStick.- (),getYleftStick.-(tankDrivemyDrive.

                            rate turn and forward given a with drive Arcade //
                   ());getXdriveStick.- (),getYdriveStick.-(arcadeDrivemyDrive.

  ␣for button a as well as rate, turn and forward given a with drive Curvature //
                                                            in-place. turning ↪
     driveStick. (),getXdriveStick.- (),getYdriveStick.-(curvatureDrivemyDrive.
                                                                 ));1(getButton ↪
                                                                              }
```

C++

```
                                         { override ()TeleopPeriodic void
                              rates right and left given a with drive Tank //
                     rightStick.GetY());- leftStick.GetY(),-myDrive.TankDrive(

                            rate turn and forward given a with drive Arcade //
                   driveStick.GetX());- driveStick.GetY(),-myDrive.ArcadeDrive(

  ␣quick-turn a as well as rate, turn and forward given a with drive Curvature //
                                                                       button ↪
     driveStick. driveStick.GetX(),- driveStick.GetY(),-myDrive.CurvatureDrive(
                                                                 ));1GetButton( ↪
                                                                              }
```

Python

```
                                               ):self(teleopPeriodic def
                               rates right and left given a with drive Tank #
           getY()).rightStick.self- getY(),.leftStick.self-tankDrive(.myDrive.self

                             rate turn and forward given a with drive Arcade #
        getX()).driveStick.self- getY(),.driveStick.self-arcadeDrive(.myDrive.self

   ␣for button a as well as rate, turn and forward given a with drive Curvature #
                                                            in-place. turning ↪
   ␣getX(),.driveStick.self- getY(),.driveStick.self-curvatureDrive(.myDrive.self
                                              ))1getButton(.driveStick.self ↪
```

### robots Drive Mecanum control to class MecanumDrive the Using

Mecanum with drivetrains holonomic of control the for provided method a is MecanumDrive above. shown as kit, upgrade drive mecanum the with chassis Parts of Kit the as such wheels, so: as simple as is MecanumDrive a Instantiating

Java

```
@Override
{ ()robotInit void public
PWMSparkMax(kFrontLeftChannel); new = frontLeft PWMSparkMax
PWMSparkMax(kRearLeftChannel); new = rearLeft PWMSparkMax
PWMSparkMax(kFrontRightChannel); new = frontRight PWMSparkMax
PWMSparkMax(kRearRightChannel); new = rearRight PWMSparkMax

motors. side right the Invert //
robot. your match to this remove or change to need may You //
);true(setInvertedfrontRight.
);true(setInvertedrearRight.

rearRight); frontRight, rearLeft, MecanumDrive(frontLeft, new = m_robotDrive

Joystick(kJoystickChannel); new = m_stick
}
```

C++

```
:private
;0 = kFrontLeftChannel int constexpr static
;1 = kRearLeftChannel int constexpr static
;2 = kFrontRightChannel int constexpr static
;3 = kRearRightChannel int constexpr static

;0 = kJoystickChannel int constexpr static

m_frontLeft{kFrontLeftChannel}; PWMSparkMax::frc
m_rearLeft{kRearLeftChannel}; PWMSparkMax::frc
m_frontRight{kFrontRightChannel}; PWMSparkMax::frc
m_rearRight{kRearRightChannel}; PWMSparkMax::frc
m_frontRight, m_rearLeft, m_robotDrive{m_frontLeft, MecanumDrive::frc
m_rearRight};
```

Python

```
):self(robotInit def
kFrontLeftChannel).selfPWMSparkMax(.wpilib = frontLeft.self
kRearLeftChannel).selfPWMSparkMax(.wpilib = rearLeft.self
kFrontRightChannel).selfPWMSparkMax(.wpilib = frontRight.self
kRearRightChannel).selfPWMSparkMax(.wpilib = rearRight.self

motors side right the invert #
robot your match to this remove or change to need may you #
)TruesetInverted(.frontRight.self
)TruesetInverted(.rearRight.self

MecanumDrive(.drive.wpilib = robotDrive.self
rearRight.self frontRight,.self rearLeft,.self frontLeft,.self
)
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                          kJoystickChannel).selfJoystick(.wpilib = stick.self
```

## Modes Drive Mecanum

See conventions. axis joystick common from different are conventions axis drive The :□□□□ information. more for above *Conventions Axis* the

motors. robot's your driving of modes default different two contains class MecanumDrive The

- robot's The axis. X positive the from clockwise measured are Angles driveCartesian: rate. rotation or angle its from independent is speed
- at speed The ahead. straight from clockwisecounter- measured are Angles drivePolar: rate. rotation or angle its from independent is (translation) drives robot the which

Java

```
                                               { ()teleopPeriodic void public
                               joystick. the of axes Z and Y, X, the using Drive //
   ());getZm_stick.- (),getXm_stick.- (),getYm_stick.-(driveCartesianm_robotDrive.
␣of axis Y the by given speed the at robot, the to relative degrees 45 at Drive //
                                                     rotation. no with joystick, the ↪
          );0 ),45(fromDegreesRotation2d. (),getYm_stick.-(drivePolarm_robotDrive.
                                                                                   }
```

C++

```
                                               { override ()TeleopPeriodic void
                               joystick. the of axes Z and Y, X, the using Drive //
   m_stick.GetZ());- m_stick.GetX(),- m_stick.GetY(),-m_robotDrive.driveCartesian(
␣of axis Y the by given speed the at robot, the to relative degrees 45 at Drive //
                                                     rotation. no with joystick, the ↪
                          );0 deg,_45 m_stick.GetY(),-m_robotDrive.drivePolar(
                                                                                   }
```

Python

```
                                                         ):self(teleopPeriodic def
                              .joystick the of axes Z and Y, X, the using Drive //
     .self- getX(),.stick.self- getY(),.stick.self-driveCartesian(.robotDrive.self
                                                                     getZ()).stick ↪
␣of axis Y the by given speed the at robot, the to relative degrees 45 at Drive //
                                                     .rotation no with joystick, the ↪
     )0 ),45fromDegrees(.Rotation2d getY(),.stick.self-drivePolar(.robotDrive.self
```

### Driving OrientedField-

`xSpeed, double ySpeed, driveCartesian(double` the to supplied be can parameter 4th A
sensor. Gyro a from returned angle the method, `gyroAngle) double zRotation, double`
drive mecanum with useful particularly is This supplied. value rotation the adjust will This
in go can It sides. or back front, no has really robot the steering, of purposes the for since,
move to robot the cause will object gyro a from degrees in angle the Adding direction. any
it when drivers the towards and forwards, pushed is joystick the when drivers the from away
facing. is robot the direction what of regardless them, towards pulled is

especially drive, to easier much robot the makes often makes driving orientedfield- of use The
robot the when reversed are controls the where system drive oriented“”robot- a to compared
drivers. the facing is

called. is `driveCartesian()` time each angle gyro the get to remember Just

---

smooth a promote to time over inputs joysticks the ramp to like also teams Many :□□□□
.*Limiter Rate Slew* a with accomplished be can This jerk. reduce and acceleration

---

## with Servos Controlling - Movement Power Low Repeatable 14.1.4 WPILib

order in motor the into feedback positional integrates which motor of type a are motors Servo
the as position taking movement, controllable repeatable, perform to motor single a allow to
hobby common the match which servos control to capability the provides WPILib signal. input
width) pulse ms 2.4 - ms 0.6 signal, (PWM) Modulation Width (Pulse specification input

### object Servo a Constructing

Java

```
);1Servo( new = exampleServo Servo
```

C++

```
;}1{ exampleServo Servo::frc
```

Python

```
)1Servo(.wpilib = exampleServo
```

channel. a passing by constructed is object servo A

#### Values Servo Setting

Java

```
);5.(setexampleServo.
);75(setAngleexampleServo.
```

C++

```
);5.exampleServo.Set(
);75exampleServo.SetAngle(
```

Python

```
)5.set(.exampleServo
)75setAngle(.exampleServo
```

WPILib: in values servo setting of methods two are There

- one to corresponds 0 value. 1.0 to 0 scaled a using position servo the Sets - Value Scaled other the to corresponds 1.0 and servo the of extreme
- This 180. to 0 from degrees in angle, the specifying by position servo the Set - Angle Any . servo 322HDHS- Hitec the as range same the with servos for work will method boundary. the to coerced be will range specified the outside method this to passed values

## APIs Pneumatics 14.2

### הפעלת בוכנות פנאומטיות 14.2.1

#### Pneumatics control to System Control FRC the Using

CTRE the cylinders, pneumatic control to solenoids operating for options two are There Hub. Pneumatics Robotics REV the and Module Control Pneumatics

control provides that device basedCAN- a is (PCM) Module Control Pneumatics CTRE The module. per solenoids 8 to up and compressor the over

the over control provides that device basedCAN- a is (PH) Hub Pneumatic REV The module. per solenoids 16 to up and compressor

simple them make that classes of series a through WPILib into integrated are devices These PCM the by handled is switch Pressure and Compressor the of control loop closed The use. to

solenoid the controls that class `Solenoid` the by handled are Solenoids the and hardware
pressure a using pressure robot’s the regulating for responsible are modules These channels.
the with communicate They off. and on solenoids switching and compressor a and switch
□□□□□ □□□□□ □□□□□ see information, more For CAN. over roboRIO

### Numbers Module

default The 0. is PCMs for ID Node default The ID. Node their by identified are Devices CAN
the at it leave to recommended is it bus the on module single a using If 1. is PHs for ID Node
solenoids corresponding modules the where used be can modules Additional ID. Node default
`Compressor` and `Solenoid` the of constructors the in number module the by differentiated are
classes.

### Pressure Storing and Generating

The tanks. pneumatic in stored and compressor pneumatic a using created is Pressure
robot’s the by powered be must but robot, the on be to have necessarily doesn’t compressor
and default, by enabled is Compressor the on mode Loop“ ”Closed The module. pneumatics
enabled is control loop closed When setting. this change teams that recommended *not* is it
pressure digital the when on compressor the turn automatically will module pneumatic the
is switch pressure the when off it turn and threshold) pressure the (below closed is switch
on. turned be not will compressor the disabled is control loop closed When (~120PSI). open
The compressor. the of status the query can users class, )C++ / Java( `Compressor` the Using
queried be all can current compressor and state, switch pressure off), or on (currently state
object. Compressor the from

compressor, the off turn to ability the want you if needed only is object Compressor The :□□□□
status. compressor query or only), (PH sensor pressure the change

Java

```
            );CTREPCMPneumaticsModuleType. ,0Compressor( new = pcmCompressor Compressor
              );REVPHPneumaticsModuleType. ,1Compressor( new = phCompressor Compressor

                                                        ();enableDigitalpcmCompressor.
                                                             ();disablepcmCompressor.

                                          ();enabledpcmCompressor. = enabled boolean
                      ();getPressureSwitchValuepcmCompressor. = pressureSwitch boolean
                              ();getCompressorCurrentpcmCompressor. = current double
```

C++

```
               CTREPCM};::PneumaticsModuleType::frc ,0pcmCompressor{ Compressor::frc
                  REVPH};::PneumaticsModuleType::frc ,1phCompressor{ Compressor::frc

                                                        pcmCompressor.EnableDigital();
                                                             pcmCompressor.Disable();

                                                 pcmCompressor.Enabled(); = enabled bool
                          pcmCompressor.GetPressureSwitchValue(); = pressureSwitch bool
                                pcmCompressor.GetCompressorCurrent(); = current double
```

Analog REV the using control compressor enabling for methods has also Hub Pneumatic The method). `enableAnalog(` Sensor Pressure

### Control Solenoid

shifting including tasks, of variety a performing of part as *valve solenoid* a use can teams FRC a switch electronically to used is valve solenoid A mechanisms. robot moving and gearboxes Control Pneumatics robot's a by controlled are Solenoids ”off“. or ”on“ line air pressurized The CAN. via roboRIO robot's the to connected turn in is which Hub, Pneumatic or Module, the if indicates (which PH or PCM the on LEDs the via is state solenoid's a see to way easiest small the with actuated manually be can solenoids powered,un- When not). or ”on“ is valve body. valve the on button

typically are They port. output single a from pressure vent or apply solenoids acting Single (spring, cylinder the of action return the provide will force external an when either used solenoid double A solenoid. double a as act to pairs in or mechanism) separate gravity, neither where position center a have also (many ports output two between flow air switches when used commonly are valves solenoid Double input). the to connected or vented is output Double pressure. air using cylinder a of actions retract and extend the both control to wish you on channels separate two to back connect which inputs electrical two have valves solenoid breakout. solenoid the

### WPILib in Solenoids Single

construct To ).C++ / Java( class `Solenoid` the using controlled are WPILib in solenoids Single and ID) CAN default (assumes number port desired the pass simply object, Solenoid a the to number port and type, module pneumatics ID, CAN or type module pneumatics disable to set(false) or enable to set(true) call solenoid the of value the set To constructor. output. solenoid the

Java

```
        );1 ,CTREPCMSolenoid(PneumaticsModuleType. new = exampleSolenoidPCM Solenoid
           );1 ,REVPHSolenoid(PneumaticsModuleType. new = exampleSolenoidPH Solenoid

                                                       );true(setexampleSolenoidPCM.
                                                      );false(setexampleSolenoidPCM.
```

C++

```
             ;}1 CTREPCM,::PneumaticsModuleType::exampleSolenoidPCM{frc Solenoid::frc
                ;}1 REVPH,::PneumaticsModuleType::exampleSolenoidPH{frc Solenoid::frc

                                                         );trueexampleSolenoidPCM.Set(
                                                        );falseexampleSolenoidPCM.Set(
```

### WPILib in Solenoids Double

These ).C++ / Java( WPILib in class `DoubleSolenoid` the by controlled are solenoids Double
pass to numbers port two now are there but solenoid single the to similarly constructed are
of state The (second). channel reverse a and (first) channel forward a constructor, the to
channel (forward *kForward* activated), output (neither *kOff* to set be then can valve the
passed be can ID CAN the Additionally, enabled). channel (reverse *kReverse* or enabled)
ID. CAN standardnon- a have teams if DoubleSolenoid the to

Java

```
       verbosity reduce helps an.enum.or.constants.inner.class.*;" static import" Using //
                 kForward just with DoubleSolenoid.Value.kForward"" replaces this //
   https://www.geeksforgeeks.org/static-import-java/ at available is reading further //
                            ;edu.wpi.first.wpilibj.DoubleSolenoid.Value.* static import

␣,1 ,CTREPCMDoubleSolenoid(PneumaticsModuleType. new = exampleDoublePCM DoubleSolenoid
                                                                                 );2 ↪
␣,4 ,REVPHPneumaticsModuleType. ,9DoubleSolenoid( new = exampleDoublePH DoubleSolenoid
                                                                                 );5 ↪


                                                       (kOff);setexampleDoublePCM.
                                                   (kForward);setexampleDoublePCM.
                                                   (kReverse);setexampleDoublePCM.
```

C++

```
      ;}2 ,1 CTREPCM,::PneumaticsModuleType::exampleDoublePCM{frc DoubleSolenoid::frc
      ;}5 ,4 REVPH,::PneumaticsModuleType::frc ,9exampleDoublePH{ DoubleSolenoid::frc

                      kOff);::Value::DoubleSolenoid::exampleDoublePCM.Set(frc
                  kForward);::Value::DoubleSolenoid::exampleDoublePCM.Set(frc
                  kReverse);::Value::DoubleSolenoid::exampleDoublePCM.Set(frc
```

### Solenoids Toggling

the using by toggling) as (known other the to output one from switched be can Solenoids
method. *.toggle()*

---

toggled. be can it before it set to have will you off, to defaults DoubleSolenoid a Since :□□□□

---

Java

```
               );0 ,CTREPCMSolenoid(PneumaticsModuleType. new = exampleSingle Solenoid
);2 ,1 ,CTREPCMDoubleSolenoid(PneumaticsModuleType. new = exampleDouble DoubleSolenoid

␣single for required Not  start. to where knows it so DoubleSolenoid the Initialize //
                                                                       solenoids. ↪
                                                      (kReverse);setexampleDouble.

                                           { ())getYButtonPressed(m_controller. if
                                                        ();toggleexampleSingle.
                                                        ();toggleexampleDouble.
                                                                               }
```

C++

```
;}0 CTREPCM,::PneumaticsModuleType::exampleSingle{frc Solenoid::frc
;}2 ,1 CTREPCM,::PneumaticsModuleType::exampleDouble{frc DoubleSolenoid::frc

␣single for required Not  start. to where knows it so DoubleSolenoid the Initialize //
solenoids. ↪
kReverse);::Value::DoubleSolenoid::exampleDouble.Set(frc

{ (m_controller.GetYButtonPressed()) if
    exampleSingle.Toggle();
    exampleDouble.Toggle();
}
```

### Transducers Pressure

measured the to proportial is voltage analog where sensor a is transducer pressure A pressure.

#### Hub Pneumatic

using transducer pressure a read to used be may that inputs analog has Hub Pneumatic The class. Compressor the

Java

```
);REVPHPneumaticsModuleType. ,1Compressor( new = phCompressor Compressor

();getPressurephCompressor. = current double
```

C++

```
units/pressure.h>< include#

REVPH};::PneumaticsModuleType::frc ,1phCompressor{ Compressor::frc

phCompressor.GetPressure(); = current pounds_per_square_inch_t::units
```

#### roboRIO

can and roboRIO, the on ports Input Analog the to connected be can transducer pressure A WPILib. in classes `AnalogPotentiometer` or `AnalogInput` the by read be

Java

```
;edu.wpi.first.wpilibj.AnalogInput import
;edu.wpi.first.wpilibj.AnalogPotentiometer import

manual product see conversion, voltage->pressure product-specific //
250(V/5)-25 case, this in //
␣1 from scaled is constructor AnalogPotentiometer the in parameter scale the //
5, of instead ↪
250r-25 is pressure the output, AnalogPotentiometer raw the is r if so //
```

page) next on (continues

(□□□□ □□□□□□ □□□□)

```
;25- = offset ,250 = scale double
␣AnalogIn the */AnalogPotentiometer( new = pressureTransducer AnalogPotentiometer
offset); scale, ,2 port*/ ↪

units psi in values scaled //
();getpressureTransducer. = psi double
```

C++

```
manual product see conversion, voltage->pressure product-specific //
250(V/5)-25 case, this in //
␣1 from scaled is constructor AnalogPotentiometer the in parameter scale the //
5, of instead ↪
250r-25 is pressure the output, AnalogPotentiometer raw the is r if so //
;25- = offset ,250 = scale double
offset}; scale, ,2 port*/ AnalogIn the */pressureTransducer{ AnalogPotentiometer::frc

units psi in values scaled //
pressureTransducer.Get(); = psi double
```

## 14.3 חיישנים

with communicate software and hardware robot your having of way integral an are Sensors level. software a at sensors those with interfacing highlights section This other. each

### 14.3.1 סקירת חיישנים - תוכנה

---

see hardware, sensor to guide a For software. in sensors using covers section This :□□□□ .*Hardware - Overview Sensor*

---

a is processing vision ”sensors“, considered be definitely may cameras While :□□□□ here. than rather ,*section own its* in covered is it that subject complicatedsufficiently-

---

their about information gather to able be to robots for vital often is it effective, be to order In are environment its of state the on robot the to feedback provide that Devices surroundings. included classes through sensors of variety large a supports innately WPILib ”sensors.“ called through types sensor common using both to guide a provide will section This library. the in support. official without sensors for code writing as well as WPILib,

### support? WPILIB does sensors What

of variety a of measuring timereal- accurate allows which *FPGA* an includes roboRIO The functionality. this accessing for classes of number a provides turn, in WPILib, input. sensor

for: support native provides WPILib

- *Accelerometers*
- *Gyroscopes*
- *rangefinders Ultrasonic*
- *Potentiometers*
- *Counters*
- *encoders Quadrature*
- *switches Limit*

FPGA's the with directly interfacing for classes levellower- includes WPILib Additionally, outputs. and inputs analog and digital

## Software - Accelerometers 14.3.2

---

to guide hardware a For software. in accelerometers covers section This :□□□□ .*Hardware - Accelerometers* see accelerometers,

---

acceleration. measures that device a is accelerometer An

axissingle- A axis.3- and axissingle- types: two in come generally Accelerometers accelerometer axis3- a dimension; spatial one along acceleration measures accelerometer once. at dimensions spatial three all along acceleration measures

class. *AnalogAccelerometer* the through accelerometers axissingle- supports WPILib

(such protocols communications complicated more require often accelerometers axisThree- the for support native has WPILib data. dimensionalmulti- send to order in I2C) or SPI as accelerometers: axis3- following

- *ADXL345_I2C*
- *ADXL345_SPI*
- *ADXL362*
- *BuiltInAccelerometer*

## AnalogAccelerometer

axissingle- a from values read to users allows )C++ ,Java( class `AnalogAccelerometer` The inputs. analog roboRIO’s the of one to connected is that accelerometer

Java

```
0 input analog on accelerometer analog an Creates //
);0AnalogAccelerometer( new = accelerometer AnalogAccelerometer

G per volt 1 to accelerometer the of sensitivity the Sets //
);1(setSensitivityaccelerometer.

volts 3 to accelerometer the of voltage zero the Sets //
);3(setZeroaccelerometer.

acceleration current the Gets //
();getAccelerationaccelerometer. = accel double
```

C++

```
0 input analog on accelerometer analog an Creates //
;}0accelerometer{ AnalogAccelerometer::frc

G per volt 1 to accelerometer the of sensitivity the Sets //
);1accelerometer.SetSensitivity(

volts 3 to accelerometer the of voltage zero the Sets //
);3accelerometer.SetZero(

acceleration current the Gets //
accelerometer.GetAcceleration(); = accel double
```

for one class, this of instances three use can they accelerometer, analog axis3- a have users If axis. each

## interface Accelerometer The

This ).C++ ,Java( interface `Accelerometer` the implement WPILib in accelerometers axis3- All accelerometers. axis3- supported all to common settings and functionality defines interface

cardinal each along acceleration the for getters contains interface `Accelerometer` The accelerometer the accelerations of range the for setter a as well as z), and y, (x, direction measure. will

> ranges. all measuring of capable are accelerometers all Not **:□□□□□**

Java

```
s'G 8 and 8- between measure to accelerometer the Sets //
);k8G.Range(Accelerometer.setRangeaccelerometer.
```

C++

```
s'G 8 and 8- between measure to accelerometer the Sets //
kRange_8G);::Range::accelerometer.SetRange(Accelerometer
```

### ADXL345_I2C

over accelerometer ADXL345 the for support provides )C++ ,Java( class ADXL345_I2C The bus. communications I2C the

Java

```
port I2C MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
);k8G.RangeAccelerometer. ,kMXP.PortADXL345_I2C(I2C. new = accelerometer Accelerometer
```

C++

```
port I2C MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
kRange_8G};::Range::Accelerometer kMXP,::Port::accelerometer{I2C ADXL345_I2C::frc
```

### ADXL345_SPI

over accelerometer ADXL345 the for support provides )C++ ,Java( class ADXL345_SPI The bus. communications SPI the

Java

```
port SPI MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
);k8G.RangeAccelerometer. ,kMXP.PortADXL345_SPI(SPI. new = accelerometer Accelerometer
```

C++

```
port SPI MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
kRange_8G};::Range::Accelerometer kMXP,::Port::accelerometer{SPI ADXL345_SPI::frc
```

### ADXL362

SPI the over accelerometer ADXL362 the for support provides )C++ ,Java( class ADXL362 The bus. communications

Java

```
port SPI MXP the on object accelerometer ADXL362 an Creates //
s'G 8 to 8- from range measurement a with //
);k8G.RangeAccelerometer. ,kMXP.PortADXL362(SPI. new = accelerometer Accelerometer
```

C++

```
                port SPI MXP the on object accelerometer ADXL362 an Creates //
                                   s'G 8 to 8- from range measurement a with //
     kRange_8G};::Range::Accelerometer kMXP,::Port::accelerometer{SPI ADXL362::frc
```

### BuiltInAccelerometer

inbuilt- own roboRIO’s the to access provides )C++ ,Java( class `BuiltInAccelerometer` The accelerometer:

Java

```
                    accelerometer built-in the for object an Creates //
                                            s'G 8 +- to defaults Range //
            BuiltInAccelerometer(); new = accelerometer Accelerometer
```

C++

```
                    accelerometer built-in the for object an Creates //
                                            s'G 8 +- to defaults Range //
                            accelerometer{}; BuiltInAccelerometer::frc
```

### accelerometers partyThird-

in available are that accelerometers of number a for support native provides WPILib While Heading and (Attitude AHRS popular few a are there Choice, FIRST through or parts of kit the are These accelerometers. include that FRC in used commonly devices System) Reference they output analog simple a have they if though libraries, vendor through controlled generally class. *AnalogAccelerometer* the with used be can

### code in accelerometers Using

---

Precise acceleration. measure suggests, name their as Accelerometers, :□□□□ (since integrationdouble- through position determine to used be can accelerometers used are gyroscopes that way the in much position), of derivative second the is acceleration nearly not are FRC in use for available accelerometers the However, heading. determine to way. this used be to quality enoughhigh-

---

rough a needs which application any for FRC® in accelerometers use to recommended is It other with collisions detecting include can This acceleration. current the of measurement They retracted. automatically be can mechanisms vulnerable that so elements, field or robots autonomous an for terrain rough over passing is robot the when determine to used be also may Stronghold). FIRST in defenses the traversing as (such routine

acceleration. the than jerk the measure to robust more often is it collisions, detecting For the rapidly how indicates and acceleration, of change) of rate (or derivative the is jerk The in spike sharp a causes collision a from impulse sudden the - changing are robot the on forces acceleration subsequent of difference the taking simply by determined be can Jerk jerk. the them: between time the by dividing and measurements,

Java

```
double prevXAccel = 0;
double prevYAccel = 0;

Accelerometer accelerometer = new BuiltInAccelerometer();

@Override
public void robotPeriodic() {
    // Gets the current accelerations in the X and Y directions
    double xAccel = accelerometer.getX();
    double yAccel = accelerometer.getY();

    // Calculates the jerk in the X and Y directions
    // Divides by .02 because default loop timing is 20ms
    double xJerk = (xAccel - prevXAccel)/.02;
    double yJerk = (yAccel - prevYAccel)/.02;

    prevXAccel = xAccel;
    prevYAccel = yAccel;
}
```

C++

```
double prevXAccel = 0;
double prevYAccel = 0;

frc::BuiltInAccelerometer accelerometer{};

void Robot::RobotPeriodic() {
    // Gets the current accelerations in the X and Y directions
    double xAccel = accelerometer.GetX();
    double yAccel = accelerometer.GetY();

    // Calculates the jerk in the X and Y directions
    // Divides by .02 because default loop timing is 20ms
    double xJerk = (xAccel - prevXAccel)/.02;
    double yJerk = (yAccel - prevYAccel)/.02;

    prevXAccel = xAccel;
    prevYAccel = yAccel;
}
```

Most accelerometers legal for FRC use are quite noisy, and it is often a good idea to combine them with the `LinearFilter` class (Java, C++) to reduce the noise:

Java

```
Accelerometer accelerometer = new BuiltInAccelerometer();

// Create a LinearFilter that will calculate a moving average of the measured X␣
↪acceleration over the past 10 iterations of the main loop

LinearFilter xAccelFilter = LinearFilter.movingAverage(10);

@Override
public void robotPeriodic() {
    // Get the filtered X acceleration
    double filteredXAccel = xAccelFilter.calculate(accelerometer.getX());
}
```

C++

```
                                      accelerometer; BuiltInAccelerometer::frc

     ␣X measured the of average moving a calculate will that LinearFilter a Create //
                          loop main the of iterations 10 past the over acceleration ↩
                            );10MovingAverage(::LinearFilter::frc = xAccelFilter auto

                                                        { ()Robot::RobotPeriodic void
                                                 acceleration X filtered the Get //
            xAccelFilter.Calculate(accelerometer.GetX()); = filteredXAccel double
                                                                                  }
```

## Software - Gyroscopes 14.3.3

*Gyroscopes* see gyros, to guide hardware a For software. in gyros covers section This :□□□□
.*Hardware -*

and/or measure to robotics in used typically sensor rate angular an is ”gyro,“ or gyroscope, A gyro ADXRS450 the for support specific provides natively WPILib headings. robot stabilize analog of variety wider a for support general more as well as parts, of kit the in available `Gyro` the from inherit gyros party 3rd common Most class. *AnalogGyro* the through gyros too! usable easily them making interface

### interface Gyro The

This ).C++ ,Java( interface `Gyro` the implement WPILib in objects gyro supportednatively- All the zeroing heading, and rate angular current the getting for methods provides interface gyro. the calibrating and heading, current

gyro. a calibrating while stationary remain robot the that crucial is It :□□□□

### ADIS16448

Devices Analog the See ).C++ ,Java( class `ADIS16448_IMU` the uses ADIS16448 The examples. and information additional for documentation ADIS16448

instructions outdated contains above linked documentation Devices Analog The :□□□□□
WPILib. into built now is ADIS16448 the as installation software for

Java

```
                                        port MXP the into plugged ADIS16448 //
                                        ADIS16448_IMU(); new = gyro ADIS16448_IMU
```

C++

```
port MXP the into plugged ADIS16448 //
gyro; ADIS16448_IMU
```

### ADIS16470

Devices Analog the See ).C++ ,Java( class `ADIS16470_IMU` the uses ADIS16470 The
examples. and information additional for documentation ADIS16470

> instructions outdated contains above linked documentation Devices Analog The :□□□□□
> WPILib. into built now is ADIS16470 the as installation software for

Java

```
port MXP the into plugged ADIS16470 //
ADIS16470_IMU(); new = gyro ADIS16470_IMU
```

C++

```
port MXP the into plugged ADIS16470 //
gyro; ADIS16470_IMU
```

### ADXRS450_Gyro

ADXRS450 Devices Analog the for support provides )C++ ,Java( class `ADXRS450_Gyro` The
bus. SPI the over connects which parts, of kit the in available gyro

FPGA; the in circuitry special through handled is accumulation Gyro ADXRS450 :□□□□
used. be may `ADXRS450_Gyro` of instance single a only accordingly

Java

```
port SPI onboard the on object ADXRS450_Gyro an Creates //
ADXRS450_Gyro(); new = gyro ADXRS450_Gyro
```

C++

```
port SPI onboard the on object ADXRS450_Gyro an Creates //
gyro; ADXRS450_Gyro::frc
```

## AnalogGyro

analog an with gyro axissingle- any for support provides )C++ ,Java( class `AnalogGyro` The output.

---

accordingly, FPGA; the in circuitry special through handled is accumulation Gyro :□□□□
1. and 0 ports analog on used be only may `sAnalogGyro`

---

Java

```
0 port on object AnalogGyro an Creates //
);0AnalogGyro( new = gyro AnalogGyro
```

C++

```
0 port on object AnalogGyro an Creates //
;}0gyro{ AnalogGyro::frc
```

## navX

documentation navX the See interface. `Gyro` the implements and class `AHRS` the uses navX The for additional connection types.

Java

```
SPI using MXP navX //
);kMXP.PortAHRS(SPI. new = gyro AHRS
```

C++

```
SPI using MXP navX //
kMXP};::Port::gyro{SPI AHRS
```

## Pigeon

either can Pigeon The .`Gyro` implements that class `WPI_PigeonIMU` the use should Pigeon The contains Guide User's IMU Pigeon The TalonSRX. a to cable data by or CAN with connected be Pigeon. the using on details full

Java

```
0 ID device with Bus CAN on is Pigeon // );0WPI_PigeonIMU( new = gyro WPI_PigeonIMU
connection) your on based other the or one (choose OR //
0 ID device with Bus CAN on is TalonSRX // );0TalonSRX( new = talon TalonSRX
above created talon the uses Pigeon // WPI_PigeonIMU(talon); new = gyro WPI_PigeonIMU
```

C++

```
0 ID device with Bus CAN on is Pigeon // ;}0gyro{ WPI_PigeonIMU
connection) your on based other the or one (choose OR //
0 ID device with Bus CAN on is TalonSRX // ;}0talon{ TalonSRX
above created talon the uses Pigeon // gyro{talon}; WPI_PigeonIMU
```

### code in gyros Using

---

(adding integrating by inferred is position position, than rather rate measure gyros As **:□□□□** always are measurements angle gyro Thus, angle. in change total the get to signal rate the up) the either when gyro the of angle the by (determined angle zero arbitrary some to relative accumulated to subject also are and called), was method zeroing a or on turned was robot of amount The used. is gyro the longer the magnitude in increase that ”drift“) (called errors gyro. of type the with varies drift

---

Since heading. robot controlling and measuring both for FRC in useful extremely are Gyros to tends match FRC an of course the over drift gyro total short, generally are matches FRC Moreover, gyro). qualitygood- a for degrees of couple a of order the (on small manageably be accurate remain to measurement heading absolute the require applications gyro useful all not match. entire the of course the over

### dashboard the on heading robot the Displaying

a of form the in `Gyro` a from data heading displaying for widget a includes *Shuffleboard* robot the to lines sight when heading robot the viewing for helpful be can This compass. obscured: are

Java

```
                                        here above from declaration gyro Use //

                                                       { ()robotInit void public
                   dashboard the on heading gyro the for indicator compass a Places //
                                   (gyro);add)."tab Example"(getTabShuffleboard.
                                                                               }
```

C++

```
                                        here above from declaration gyro Use //

                                                       { ()Robot::RobotInit void
                   dashboard the on heading gyro the for indicator compass a Places //
                               ).Add(gyro);"tab Example"Shuffleboard.GetTab(::frc
                                                                               }
```

### driving while heading Stabilizing

robot the that so driving, while heading robot stabilize to is gyro a for use common very A and mecanum as such drives holonomic for important especially is This straight. drives well. as drives tank for useful extremely is but swerve,

heading, the or rate turn the either on controller PID a closing by achieved typically is This a be would this drive, tank a (for control turning one’s to loop the of output the piping and drive). the of sides two the between differential speed

sensor the that ensure to careful be should users loops, control all with Like :□□□□□
unstable be will loop the not, are they If consistent. are direction turning the and direction
wildly. turn will robot the and

### rate turn using stabilization drive Tank Example:

the on closed loop P simple a using heading stabilize to how shows example following The
for setpoint the zero, of rate turn a have should turning not is that robot a Since rate. turn
simple. very method this making zero, implicitly is loop the

Java

```
                                                here above from declaration gyro Use //

                                                        loop P simple a for gain The //
                                                                         ;1 = kP double

                                              drive and controllers motor Initialize //
                                                            );0Spark( new = left1 Spark
                                                            );1Spark( new = left2 Spark

                                                           );2Spark( new = right1 Spark
                                                           );3Spark( new = right2 Spark

              left2); MotorControllerGroup(left1, new = leftMotors MotorControllerGroup
           right2); MotorControllerGroup(right1, new = rightMotors MotorControllerGroup

              rightMotors); DifferentialDrive(leftMotors, new = drive DifferentialDrive

                                                                              @Override
                                                             { ()robotInit void public
                                                        );true(setInvertedrightMotors.
                                                                                      }

                                                                              @Override
                                                    { ()autonomousPeriodic void public
                 change to heading the want t'don we since 0, implicitly is Setpoint //
                                                    ();getRategyro.- = error double

     ␣the stabilize to gyro the using speed, half at continuously forward Drives //
                                                                              heading ↪
                                error); * kP - 5. error, * kP + 5.(tankDrivedrive.
                                                                                      }
```

C++

```
                                                here above from declaration gyro Use //

                                                        loop P simple a for gain The //
                                                                         ;1 = kP double

                                              drive and controllers motor Initialize //
                                                                   ;}0left1{ Spark::frc
                                                                   ;}1left2{ Spark::frc
                                                                  ;}2right1{ Spark::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                          ;}3right2{ Spark::frc

                left2}; leftMotors{left1, MotorControllerGroup::frc
              right2}; rightMotors{right1, MotorControllerGroup::frc

              rightMotors}; drive{leftMotors, DifferentialDrive::frc

                                        { ()Robot::RobotInit void
                                    );truerightMotors.SetInverted(
                                                                }

                                   { ()Robot::AutonomousPeriodic void
      change to heading the want t'don we since 0, implicitly is Setpoint //
                                  gyro.GetRate();- = error double

 ␣the stabilize to gyro the using speed, half at continuously forward Drives //
                                                            heading ↪
              error); * kP - 5. error, * kP + 5.drive.TankDrive(
                                                                }
```

the closing When loop. control complicatedmore- a use can implementations advancedMore- effective. particularly are loops PI stabilization, heading for rate turn the on loop

### heading using stabilization drive Tank Example:

the on closed loop P simple a using heading stabilize to how shows example following The current the to setpoint the set to need will we example, rate turn the in Unlike heading. complicated.more- slightly method this making motion, starting before heading

Java

```
                               here above from declaration gyro Use //

                                   loop P simple a for gain The //
                                                  ;1 = kP double

                  motion the starting when robot the of heading The //
                                                 heading; double

                           drive and controllers motor Initialize //
                                      );0Spark( new = left1 Spark
                                      );1Spark( new = left2 Spark

                                     );2Spark( new = right1 Spark
                                     );3Spark( new = right2 Spark

     left2); MotorControllerGroup(left1, new = leftMotors MotorControllerGroup
   right2); MotorControllerGroup(right1, new = rightMotors MotorControllerGroup

     rightMotors); DifferentialDrive(leftMotors, new = drive DifferentialDrive

                                                             @Override
                                         { ()robotInit void public
                                   );true(setInvertedrightMotors.
                                                                 }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                        @Override
                                                    { ()autonomousInit void public
                           auto of start at heading current to setpoint Set //
                                                    ();getAnglegyro. = heading
                                                                                }

                                                                        @Override
                                                { ()autonomousPeriodic void public
                                     ();getAnglegyro. - heading = error double

␣the stabilize to gyro the using speed, half at continuously forward Drives //
                                                                        heading ↪
                            error); * kP - 5. error, * kP + 5.(tankDrivedrive.
                                                                                }
```

C++

```
                                           here above from declaration gyro Use //

                                                   loop P simple a for gain The //
                                                                    ;1 = kP double

                              motion the starting when robot the of heading The //
                                                                   heading; double

                                         drive and controllers motor Initialize //
                                                              ;}0left1{ Spark::frc
                                                              ;}1left2{ Spark::frc
                                                             ;}2right1{ Spark::frc
                                                             ;}3right2{ Spark::frc

                               left2}; leftMotors{left1, MotorControllerGroup::frc
                            right2}; rightMotors{right1, MotorControllerGroup::frc

                            rightMotors}; drive{leftMotors, DifferentialDrive::frc

                                                         { ()Robot::RobotInit void
                                                  );truerightMotors.SetInverted(
                                                                                }

                                                    { ()Robot::AutonomousInit void
                           auto of start at heading current to setpoint Set //
                                                    gyro.GetAngle(); = heading
                                                                                }

                                                { ()Robot::AutonomousPeriodic void
                                     gyro.GetAngle(); - heading = error double

␣the stabilize to gyro the using speed, half at continuously forward Drives //
                                                                        heading ↪
                            error); * kP - 5. error, * kP + 5.drive.TankDrive(
                                                                                }
```

the closing When loop. control complicatedmore- a use can implementations advancedMore-
effective. particularly are loops PD stabilization, heading for heading the on loop

## heading set a to Turning

specified a face to robot a turning is gyro a for application usefulhighly- and common Another during used be can or routine, driving autonomous an of component a be can This direction. elements. field with robot a align help to control teleoperated

with unlike - loop PID a with accomplished often is this stabilization, heading with like Much example following The heading. the on closed be only can loop the however, stabilization, loop: P simple a with degrees 90 face to robot the turn will code

Java

```
                                               here above from declaration gyro Use //

                                                       loop P simple a for gain The //
                                                                     ;0.05 = kP double

                                             drive and controllers motor Initialize //
                                                           );0Spark( new = left1 Spark
                                                           );1Spark( new = left2 Spark

                                                          );2Spark( new = right1 Spark
                                                          );3Spark( new = right2 Spark

             left2); MotorControllerGroup(left1, new = leftMotors MotorControllerGroup
          right2); MotorControllerGroup(right1, new = rightMotors MotorControllerGroup

             rightMotors); DifferentialDrive(leftMotors, new = drive DifferentialDrive

                                                                             @Override
                                                             { ()robotInit void public
                                                    );true(setInvertedrightMotors.
                                                                                     }

                                                                             @Override
                                                    { ()autonomousPeriodic void public
                                         90 is setpoint error; heading the Find //
                                              ();getAnglegyro. - 90 = error double

                                  direction desired the face to robot the Turns //
                                         error); * kP- error, * (kPtankDrivedrive.
                                                                                     }
```

C++

```
                                               here above from declaration gyro Use //

                                                       loop P simple a for gain The //
                                                                     ;0.05 = kP double

                                             drive and controllers motor Initialize //
                                                                  ;}0left1{ Spark::frc
                                                                  ;}1left2{ Spark::frc
                                                                 ;}2right1{ Spark::frc
                                                                 ;}3right2{ Spark::frc

                                   left2}; leftMotors{left1, MotorControllerGroup::frc
                                right2}; rightMotors{right1, MotorControllerGroup::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                    rightMotors}; drive{leftMotors, DifferentialDrive::frc

                                                   { ()Robot::RobotInit void
                                          );truerightMotors.SetInverted(
                                                                        }

                                          { ()Robot::AutonomousPeriodic void
                                    90 is setpoint error; heading the Find //
                                       gyro.GetAngle(); - 90 = error double

                             direction desired the face to robot the Turns //
                                   error); * kP- error, * drive.TankDrive(kP
                                                                        }
```

loops. control complicatedmore- use can implementations advancedmore- before, As

---

the in friction static to due correctly tune to tricky be can loops angleto-Turn- :□□□□
account to ways of number a are There used. is loop P simple a if especially drivetrain,
the of output the to output“ ”minimum a add to is common/effective most the of one this; for
on controllers velocity tunedwell- to cascade to is strategy effective Another loop. control
drive. the of side each

---

## Software - Ultrasonics 14.3.4

---

see ultrasonics, to guide hardware a For software. in ultrasonics covers section This :□□□□
.*Hardware - Ultrasonics*

---

frequencyhigh- using object an to distance measure to used commonly is sensor ultrasonic An
of ”field their within object closest the to distance the measure ultrasonics Generally, sound.
view.“

WPILib: by natively supported ultrasonics of types primary two are There

- *ultrasonics responsePing-*
- *ultrasonics Analog*

### ultrasonics responsePing-

ping- As ultrasonics. responseping- for support provides )C++ ,Java( class `Ultrasonic` The
and ping the sending both for pins separate require name) the (per ultrasonics response
when input and output both for numbers pin DIO specify must users response, the measuring
instance: `Ultrasonic` an constructing

Java

```
             2. and 1 DIO on object Ultrasonic ping-response a Creates //
                       );2 ,1Ultrasonic( new = m_rangeFinder Ultrasonic
```

C++

```
2. and 1 DIO on object Ultrasonic ping-response a Creates //
;}2 ,1m_rangeFinder{ Ultrasonic::frc
```

the C++ in Java; in millimeters or inches either in retrieved be then can measurement The unit: length desired any to convert automatically to used is *library units*

Java

```
millimeters in distance the read can We //
();getRangeMMm_rangeFinder. = distanceMillimeters double
inches in or ... //
();getRangeInchesm_rangeFinder. = distanceInches double
```

C++

```
distance the read can We //
m_rangeFinder.GetRange(); = distance meter_t::units
auto-convert units //
distance; = distanceMillimeters millimeter_t::units
distance; = distanceInches inch_t::units
```

### ultrasonics Analog

measured the to corresponding voltage analog an return simply sensors ultrasonic Some class. *AnalogPotentiometer* the with used be simply may can sensors These distance.

### ultrasonics partyThird-

communications complicated more use may partiesthird- by offered sensors ultrasonic Other such any for support native provide not does WPILib SPI). or I2C as (such protocols libraries. vendor with controlled be typically will they ultrasonics;

### code in ultrasonics Using

For routines. autonomous during spacing determining for useful very are sensors Ultrasonic move )willC++ ,Java( project example UltrasonicPID the from code following the example, detects: sensor the object nearest the from away meter 1 to robot the

Java

```
{ TimedRobot extends Robot class public
object an from stay to wants robot the distance //
meter) (one //
;1.0e3 = kHoldDistanceMillimeters double final static

constant speed proportional //
target the to closer us bring will voltage positive applying because negative //
;0.001- = kP double final static private
constant speed integral //
;0.0 = kI double final static private
constant speed derivative //
;0.0 = kD double final static private
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
;0 = kLeftMotorPort int final static
;1 = kRightMotorPort int final static

;0 = kUltrasonicPingPort int final static
;1 = kUltrasonicEchoPort int final static

outliers, sudden to susceptible and noisy quite be to tend sensors Ultrasonic //
filter median 5-sample a with filtered are measurements so //
);5MedianFilter( new = m_filter MedianFilter final private

␣Ultrasonic(kUltrasonicPingPort, new = m_ultrasonic Ultrasonic final private
kUltrasonicEchoPort); ↪
PWMSparkMax(kLeftMotorPort); new = m_leftMotor PWMSparkMax final private
PWMSparkMax(kRightMotorPort); new = m_rightMotor PWMSparkMax final private
m_ DifferentialDrive(m_leftMotor, new = m_robotDrive DifferentialDrive final private
rightMotor); ↪
kD); kI, PIDController(kP, new = m_pidController PIDController final private

@Override
{ ()autonomousInit void public
controller pid the of setpoint Set //
(kHoldDistanceMillimeters);setSetpointm_pidController.
}

@Override
{ ()autonomousPeriodic void public
();getRangeMMm_ultrasonic. = measurement double
(measurement);calculatem_filter. = filteredMeasurement double
(filteredMeasurement);calculatem_pidController. = pidOutput double

linear is output PID -- squaring input disable //
);false ,0 (pidOutput,arcadeDrivem_robotDrive.
}
}
```

(Header) C++

```
{ TimedRobot::frc public : Robot class
:public
;override AutonomousInit() void
;override ()AutonomousPeriodic void

object an from stay to wants robot the distance //
m;_1 = kHoldDistance millimeter_t::units constexpr static

;0 = kLeftMotorPort int constexpr static
;1 = kRightMotorPort int constexpr static
;0 = kUltrasonicPingPort int constexpr static
;1 = kUltrasonicEchoPort int constexpr static

:private
constant speed proportional //
the to closer us bring will voltage positive applying because negative //
target //
;0.001- = kP double constexpr static
```

page) next on (continues

(□□□□□ □□□□□□ □□□□)

```
                                      constant speed integral //
                                 ;0.0 = kI double constexpr static
                                    constant speed derivative //
                                 ;0.0 = kD double constexpr static

  sudden to susceptible and noisy quite be to tend sensors Ultrasonic //
filter median 5-sample a with filtered are measurements so outliers, //
                     ;}5m_filter{ >millimeter_t::units<MedianFilter::frc

kUltrasonicEchoPort}; m_ultrasonic{kUltrasonicPingPort, Ultrasonic::frc
                                 m_left{kLeftMotorPort}; PWMSparkMax::frc
                               m_right{kRightMotorPort}; PWMSparkMax::frc
                   m_right}; m_robotDrive{m_left, DifferentialDrive::frc
                        kD}; kI, m_pidController{kP, PIDController::frc2
                                                                        ;}
```

(Source) C++

```
                                     { ()Robot::AutonomousInit void
                              controller pid the of setpoint Set //
                       m_pidController.SetSetpoint(kHoldDistance.value());
                                                                  }

                                 { ()Robot::AutonomousPeriodic void
              m_ultrasonic.GetRange(); = measurement millimeter_t::units
m_filter.Calculate(measurement); = filteredMeasurement millimeter_t::units
m_pidController.Calculate(filteredMeasurement.value()); = pidOutput double

                       linear is output PID -- squaring input disable //
                            );false ,0 m_robotDrive.ArcadeDrive(pidOutput,
                                                                  }
```

be will they where ,*Shuffleboard* to sent be can ultrasonics responseping- Additionally, widgets: own their with displayed

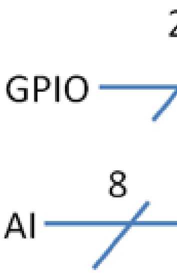
Java

```
  dashboard the of tab Sensors"" the on ultrasonic the Add //
                                 automatically update will Data //
          (m_rangeFinder);add)."Sensors"(getTabShuffleboard.
```

C++

```
  dashboard the of tab Sensors"" the on ultrasonic the Add //
                                 automatically update will Data //
      ).Add(m_rangeFinder);"Sensors"GetTab(::Shuffleboard::frc
```

## Counters 14.3.5



on edges pulse of counting the allows that class versatile a is )C++ ,Java( class `Counter` The classes WPILib complicatedmore- several in component a as used is `Counter` input. digital a own. its on useful quite also is but ),*Ultrasonic* and *Encoder* as (such

---

8 than more no meaning FPGA, roboRIO the in units counter 8 of total a are There :□□□□ resources as contained those including time, one any at instantiated be may objects `Counter` another by used be may `Counter` a when on information detailed For objects. WPILib other in documentation. API official the to refer object,

---

### counter a Configuring

functionalities. differing provide to ways of number a in configured be can class `Counter` The

#### Modes Counter

modes: different four of one in operate to configured be may object `Counter` The

1. channels. different two of edges the on based down and up Counts :*mode pulseTwo-*
2. channel. single a on pulse a of duration the Measures :*mode periodSemi-*
3. the with channel, one of edges the on based down and up Counts :*mode lengthPulse-* channel. that on pulse the of duration the by determined direction
4. with channel, one of edges the on based down and up Counts :*mode direction External* direction. the specifying channel separate a

---

increment to configured be can counter the mode, periodsemi- except modes all In :□□□□ counters default, By decoding). (1X pulse per once or decoding), (2X edge per once either count only will counter the specified is channel one only if though mode, pulsetwo- to set are up.

---

### mode pulseTwo-

”up specified the on edge/pulse every for up count will `Counter` the mode, pulsetwo- In can counter A channel.“ ”down specified the on edge/pulse every for down and channel,“ code: following the with pulsetwo- in initialized be

Java

```
                              mode two-pulse in object Counter new a Create //
                          );k2Pulse.ModeCounter(Counter. new = counter Counter

                                                                    @Override
                                                  { ()robotInit void public
                              counter the for channels input the up Set //
                                                    );1(setUpSourcecounter.
                                                  );2(setDownSourcecounter.

                                               2X to type decoding the Set //
                                     );true ,true(setUpSourceEdgecounter.
                                   );true ,true(setDownSourceEdgecounter.
                                                                          }
```

C++

```
                              mode two-pulse in object Counter new a Create //
                            k2Pulse};::Mode::Counter::counter{frc Counter::frc

                                                  { ()Robot::RobotInit void
                              counter the for channels input the up Set //
                                                    );1counter.SetUpSource(
                                                  );2counter.SetDownSource(

                                               2X to type decoding the Set //
                                     );true ,truecounter.SetUpSourceEdge(
                                   );true ,truecounter.SetDownSourceEdge(
```

### mode periodSemi-

either channel, a on pulses the of duration the count will `Counter` the mode, periodsemi- In A edge. rising next the to edge falling a from or edge, falling next the to edge rising a from code: following the with mode periodsemi- in initialized be can counter

Java

```
                              mode two-pulse in object Counter new a Create //
                      );kSemiperiod.ModeCounter(Counter. new = counter Counter

                                                                    @Override
                                                  { ()robotInit void public
                               counter the for channel input the up Set //
                                                    );1(setUpSourcecounter.

   edge falling to edge rising from duration pulse count to encoder the Set //
                                         );true(setSemiPeriodModecounter.
                                                                          }
```

C++

```
                        mode two-pulse in object Counter new a Create //
             kSemiperiod};::Mode::Counter::counter{frc Counter::frc

                                                         { ()Robot void
                         counter the for channel input the up Set //
                                                  );1counter.SetUpSource(

     edge falling to edge rising from duration pulse count to encoder the Set //
                                            );truecounter.SetSemiPeriodMode(
```

method: getPeriod() the call width, pulse the get To

Java

```
                      seconds in width pulse measured the Return //
                                               ();getPeriodcounter.
```

C++

```
                      seconds in width pulse measured the Return //
                                                  counter.GetPeriod();
```

### mode lengthPulse-

of length the on depending down or up either count will counter the mode, lengthpulse- In count forward a as interpreted be will time threshold specified the below pulse A pulse. the sensors tooth gear some for useful is This count. reverse a is threshold the above pulse a and follows: as mode this in initialized be can counter A manner. this in direction encode which

Java

```
                        mode two-pulse in object Counter new a Create //
           );kPulseLength.ModeCounter(Counter. new = counter Counter

                                                              @Override
                                                { ()robotInit void public
                         counter the for channel input the up Set //
                                                  );1(setUpSourcecounter.

                                             2X to type decoding the Set //
                                   );true ,true(setUpSourceEdgecounter.

      seconds 05. than longer are pulses the if down count to counter the Set //
                                         )05.(setPulseLengthModecounter.
                                                                      }
```

C++

```
                        mode two-pulse in object Counter new a Create //
            kPulseLength};::Mode::Counter::counter{frc Counter::frc

                                               { ()Robot::RobotInit void
                         counter the for channel input the up Set //
                                                  );1counter.SetUpSource(
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                        2X to type decoding the Set //
                              );true ,truecounter.SetUpSourceEdge(

      seconds 05. than longer are pulses the if down count to counter the Set //
                                       )05.counter.SetPulseLengthMode(
```

### mode direction External

on level the on depending down or up either counts counter the mode, direction external In direction the if increase; will counter the low, is source direction the If channel. second the can counter A section). next the see this, reverse (to decrease will counter the high, is source follows: as mode this in initialized be

Java

```
                            mode two-pulse in object Counter new a Create //
                 );kExternalDirection.ModeCounter(Counter. new = counter Counter

                                                                    @Override
                                                { ()robotInit void public
                            counter the for channels input the up Set //
                                                  );1(setUpSourcecounter.
                                                );2(setDownSourcecounter.

                                            2X to type decoding the Set //
                                  );true ,true(setUpSourceEdgecounter.
                                                                            }
```

C++

```
                            mode two-pulse in object Counter new a Create //
                   kExternalDirection};::Mode::Counter::counter{frc Counter::frc

                                                        { ()RobotInit void
                            counter the for channels input the up Set //
                                                  );1counter.SetUpSource(
                                                );2counter.SetDownSource(

                                            2X to type decoding the Set //
                                  );true ,truecounter.SetUpSourceEdge(
```

### parameters counter Configuring

---

will it distance; of units about assumptions any make not does class `Counter` The :□□□□ Users value. pulseper-distance- the calculate to used were units whatever in values return thus have complete control over the distance units used. However, units of time are *always* in seconds.

---

on depend *not* does calculation pulseper-distance- the in used pulses of number The :□□□□ and (rising cycle full a be to considered be always should ”pulse“ each - type decoding the falling).

---

additional of number a offers class `Counter` the configurations, specificmode- the from Apart methods: configuration

Java

```
pulses 256 every for 4 of distance a return to counter the Configures //
getRate of units the changes Also //
);256./4.(setDistancePerPulsecounter.

seconds 1. after stopped itself consider to counter the Configures //
);1.(setMaxPeriodcounter.

10 below is rate its when stopped itself consider to counter the Configures //
);10(setMinRatecounter.

counter the of direction the Reverses //
);true(setReverseDirectioncounter.

samples 5 over measurement period its average to counter an Configures //
samples 127 and 1 between be Can //
);5(setSamplesToAveragecounter.
```

C++

```
pulses 256 every for 4 of distance a return to counter the Configures //
getRate of units the changes Also //
);256./4.counter.SetDistancePerPulse(

seconds 1. after stopped itself consider to counter the Configures //
);1.counter.SetMaxPeriod(

10 below is rate its when stopped itself consider to counter the Configures //
);10counter.SetMinRate(

counter the of direction the Reverses //
);truecounter.SetReverseDirection(

samples 5 over measurement period its average to counter an Configures //
samples 127 and 1 between be Can //
);5counter.SetSamplesToAverage(
```

### counters from information Reading

users: to exposes always class `Counter` the that information some is there mode, of Regardless

#### Count

method: `get()` the with count current the obtain can Users

Java

```
count current the returns //
();getcounter.
```

C++

```
count current the returns //
counter.Get();
```

#### Distance

---

will returned value distance the absolute; not distance, *relative* measure Counters **:□□□□** value encoder the or on turned was robot the when encoder the of position the on depend .*reset* last was

---

by traveled distance total the obtain can users configured, been has *pulse per distance* the If method: `getDistance()` the with sensor counted the

Java

```
distance current the returns //
();getDistancecounter.
```

C++

```
distance current the returns //
counter.GetDistance();
```

#### Rate

---

seconds. in *always* are class `Counter` the for time of Units **:□□□□**

---

method: `getRate()` the with counter the of change of rate current the obtain can Users

Java

```
counter the of rate current the Gets //
();getRatecounter.
```

C++

```
counter the of rate current the Gets //
counter.GetRate();
```

### Stopped

method: `getStopped()` the with stationary is counter the whether obtain can Users

Java

```
stopped is counter the whether Gets //
();getStoppedcounter.
```

C++

```
stopped is counter the whether Gets //
counter.GetStopped();
```

### כיוון

`getDirection()` the with moved last counter the which in direction the obtain can Users method:

Java

```
moved counter the which in direction last the Gets //
();getDirectioncounter.
```

C++

```
moved counter the which in direction last the Gets //
counter.GetDirection();
```

### Period

period. the of not pulse, the of duration the returns method this ,*mode periodsemi-* In :□□□□

`getPeriod()` the with period recentmost- the of seconds) (in duration the obtain can Users method:

Java

```
seconds in period current the returns //
();getPeriodcounter.
```

C++

```
seconds in period current the returns //
counter.GetPeriod();
```

### counter a Resetting

is This method. `reset()` the call zero, of reading distance a to counter a reset To
physical desired actual the to corresponds distance measured the that ensuring for useful
measurement.

Java

```
zero of distance a read to encoder the Resets //
();resetcounter.
```

C++

```
zero of distance a read to encoder the Resets //
counter.Reset();
```

### code in counters Using

is class `Counter` the since but - applications robot of variety wide a for useful are Counters
applications these of Many here. them of summary good a provide to difficult is it varied, so
quadrature a to alternative cheaper a often is counter simple a - class `Encoder` the with overlap
.*Software - Encoders* see code, in encoders for uses potential of summary a For encoder.

## Software - Encoders 14.3.6

:□□□□ This section covers encoders in software. For a hardware guide to encoders, see
.□□□□□ - □□□□□□□□

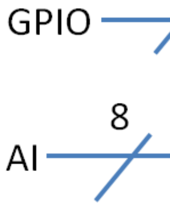
shaft). a of rotation the (usually, motion measure to used devices are Encoders

:□□□□ The classes in this document are only used for encoders that are plugged directly into
encoders using for documentation vendors« appropriate the reference Please roboRIO! the
controllers. motor into plugged

### Class `Encoder` The - Encoders Quadrature

).C++ ,Java( class `Encoder` the through encoders quadrature for support provides WPILib
encoders. from data reading and configuring for API simple a provides class This

out- periodquarter- a are that channels two on signals wavesquare- produce encoders These
and rotation, the measure to used are pulses The ”quadrature“). term, the (hence phaseof-
other. the ”leads“ channel which from determined be can motion of direction the



encoder an or module counter a through either encoders quadrature handles FPGA The
WPILib. by automatically handled is choice the - *type decoding* the on depending module,
modules. encoder 8 contains FPGA The

encoders: quadrature of Examples

- Choice FIRST through available VAMT103-
- Encoder Mag CTRE
- 63r Grayhill
- Encoder Bore Through REV
- E4T Digital US

### Encoder Quadrature a Initializing

follows: as instantiated be can encoder quadrature A

Java

```
1 and 0 pins DIO on encoder an Initializes //
  non-inverted and decoding 4X to Defaults //
         );1 ,0Encoder( new = encoder Encoder
```

C++

```
1 and 0 pins DIO on encoder an Initializes //
  non-inverted and decoding 4X to Defaults //
                  ;}1 ,0encoder{ Encoder::frc
```

### Type Decoding

modes: different three in signals encoder decode can class `Encoder` WPILib The

- signal encoder the of period complete every for distance the Increments :**Decoding 1X** edges). four per (once
- (once signal encoder the of periodhalf- every for distance the Increments :**Decoding 2X** edges). two per
- times (four signal encoder the of edge every for distance the Increments :**Decoding 4X** period). per

rate in ”jitter“ increased of cost potential the at but precision, greatest the offers decoding 4X constructor: following the use type, decoding different a use To measurements.

Java

```
                        1 and 0 pins DIO on encoder an Initializes //
                                      non-inverted and encoding 2X //
);k2X.EncodingTypeEncoder. ,false ,1 ,0Encoder( new = encoder Encoder
```

C++

```
                      1 and 0 pins DIO on encoder an Initializes //
                                    non-inverted and encoding 2X //
k2X};::EncodingType::Encoder::frc ,false ,1 ,0encoder{ Encoder::frc
```

### Parameters Encoder Quadrature Configuring

---

will it distance; of units about assumptions any make not does class `Encoder` The **:□□□□** Users value. pulseper-distance- the calculate to used were units whatever in values return *always* are time of units However, used. units distance the over control complete have thus seconds. in

---

on depend *not* does calculation pulseper-distance- the in used pulses of number The :□□□□
edges). (four cycle full a be to considered be always should ”pulse“ each - *type decoding* the

methods: configuration of number a offers class `Encoder` The

Java

```
pulses 256 every for 4 of distance a return to encoder the Configures //
getRate of units the changes Also //
);256.0/4.0(setDistancePerPulseencoder.

seconds 1. after stopped itself consider to encoder the Configures //
);0.1(setMaxPeriodencoder.

10 below is rate its when stopped itself consider to encoder the Configures //
);10(setMinRateencoder.

encoder the of direction the Reverses //
);true(setReverseDirectionencoder.

samples 5 over measurement period its average to encoder an Configures //
samples 127 and 1 between be Can //
);5(setSamplesToAverageencoder.
```

C++

```
pulses 256 every for 4 of distance a return to encoder the Configures //
getRate of units the changes Also //
);256.0/4.0encoder.SetDistancePerPulse(

seconds 1. after stopped itself consider to encoder the Configures //
);0.1encoder.SetMaxPeriod(

10 below is rate its when stopped itself consider to encoder the Configures //
);10encoder.SetMinRate(

encoder the of direction the Reverses //
);trueencoder.SetReverseDirection(

samples 5 over measurement period its average to encoder an Configures //
samples 127 and 1 between be Can //
);5encoder.SetSamplesToAverage(
```

## Encoders Quadrature from information Reading

the of motion the about user the to information of wealth a provides class `Encoder` The encoder.

### Distance

---

value distance the absolute; not distance, *relative* measure encoders Quadrature **:□□□□** the or on turned was robot the when encoder the of position the on depend will returned .*reset* last was value encoder

---

method: `getDistance()` the with encoder the by traveled distance total the obtain can Users

Java

```
traveled distance the Gets //
();getDistanceencoder.
```

C++

```
traveled distance the Gets //
encoder.GetDistance();
```

### Rate

---

seconds. in *always* are class `Encoder` the for time of Units **:□□□□**

---

method: `getRate()` the with encoder the of change of rate current the obtain can Users

Java

```
encoder the of rate current the Gets //
();getRateencoder.
```

C++

```
encoder the of rate current the Gets //
encoder.GetRate();
```

### Stopped

method: `getStopped()` the with stationary is encoder the whether obtain can Users

Java

```
stopped is encoder the whether Gets //
();getStoppedencoder.
```

C++

```
stopped is encoder the whether Gets //
encoder.GetStopped();
```

### כיוון

getDirection() the with moved last encoder the which in direction the obtain can Users method:

Java

```
moved encoder the which in direction last the Gets //
();getDirectionencoder.
```

C++

```
moved encoder the which in direction last the Gets //
encoder.GetDirection();
```

### Period

method: getPeriod() the with seconds) (in pulses encoder the of period the obtain can Users

Java

```
encoder the of period current the Gets //
();getPeriodencoder.
```

C++

```
encoder the of period current the Gets //
encoder.GetPeriod();
```

### Encoder Quadrature a Resetting

This method. reset() the call zero, of reading distance a to encoder quadrature a reset To physical desired actual the to corresponds distance measured the that ensuring for useful is routine: *homing* a during called often is and measurement,

Java

```
zero of distance a read to encoder the Resets //
();resetencoder.
```

C++

```
zero of distance a read to encoder the Resets //
encoder.Reset();
```

## class `DutyCycleEncoder` The - Encoders Cycle Duty

the through encoders PWM) as marketed (also cycle duty for support provides WPILib and configuring for API simple a provides class This ).C++ ,Java( class `DutyCycleEncoder` encoders. cycle duty from data reading

automatically. encoders cycle duty handles FPGA roboRIO's The

encoders: cycle duty of Examples

- Encoder Mag AndyMark
- Encoder Mag CTRE
- Encoder Bore Through REV
- Lamprey2 221 Team
- MA3 Digital US

### Encoder Cycle Duty a Initializing

follows: as instantiated be can encoder cycle duty A

Java

```
0 pins DIO on encoder cycle duty a Initializes //
);0DutyCycleEncoder( new = encoder DutyCycleEncoder
```

C++

```
0 pins DIO on encoder cycle duty a Initializes //
;}0encoder{ DutyCycleEncoder::frc
```

### Parameters Encoder Cycle Duty Configuring

---

distance; of units about assumptions any make not does class `DutyCycleEncoder` The :□□□□ value. rotationper-distance- the calculate to used were units whatever in values return will it used. units distance the over control complete have thus Users

---

methods: configuration of number a offers class `DutyCycleEncoder` The

Java

```
rotation every for 4 of distance a return to encoder the Configures //
);4.0(setDistancePerRotationencoder.
```

C++

```
rotation every for 4 of distance a return to encoder the Configures //
);4.0encoder.SetDistancePerRotation(
```

### Encoders Cycle Duty from Distance Reading

starting the on depend not does It distance. absolute measure encoders Cycle Duty :□□□□
encoder. the of position

method: `getDistance()` the with encoder the by measured distance the obtain can Users

Java

```
traveled distance the Gets //
();getDistanceencoder.
```

C++

```
traveled distance the Gets //
encoder.GetDistance();
```

### Connected is Encoder Cycle Duty a Detecting

the that detect to possible is it pulses, of set continuous a output encoders cycle duty As
unplugged. been has encoder

Java

```
connected is encoder the if Gets //
();isConnectedencoder.
```

C++

```
connected is encoder the if Gets //
encoder.IsConnected();
```

### Encoder Cycle Duty a Resetting

is This method. `reset()` the call 0, is distance current the so encoder an reset To
physical desired actual the to corresponds distance measured the that ensuring for useful
homed. be to need don’t encoders cycle duty encoders, quadrature Unlike measurement.
so starts program the when set be to stored be can offset position the reset, after However,
method a provides *class Preferences* The again. performed be to have doesn’t reset the that
roboRIO. the on values the retrieve and save to

Java

```
position current the at zero of distance a read to encoder the Resets //
();resetencoder.

reset was encoder the when from offset position the get //
();getPositionOffsetencoder.

rotation a half to offset position the set //
);0.5(setPositionOffsetencoder.
```

C++

```
position current the at zero of distance a read to encoder the Resets //
                                                         encoder.Reset();

          reset was encoder the when from offset position the get //
                                              encoder.GetPositionOffset();

                    rotation a half to offset position the set //
                                         );0.5encoder.SetPositionOffset(
```

### Class `AnalogEncoder` The - Encoders Analog

class `AnalogEncoder` the through encoders absolute analog for support provides WPILib duty from data reading and configuring for API simple a provides class This ).C++ ,Java( encoders. cycle

encoders: analog of Examples

- Lamprey2 221 Team
- Encoder Magnetic Absolute Thrifty
- MA3 Digital US

### Encoder Analog an Initializing

follows: as instantiated be can encoder analog An

Java

```
0 pins Input Analog on encoder cycle duty a Initializes //
                    );0AnalogEncoder( new = encoder AnalogEncoder
```

C++

```
0 pins DIO on encoder cycle duty a Initializes //
                         ;}0encoder{ AnalogEncoder::frc
```

### Parameters Encoder Analog Configuring

---

it distance; of units about assumptions any make not does class `AnalogEncoder` The :□□□□ value. rotationper-distance- the calculate to used were units whatever in values return will used. units distance the over control complete have thus Users

---

methods: configuration of number a offers class `AnalogEncoder` The

Java

```
rotation every for 4 of distance a return to encoder the Configures //
                           );4.0(setDistancePerRotationencoder.
```

C++

```
rotation every for 4 of distance a return to encoder the Configures //
);4.0encoder.SetDistancePerRotation(
```

### Encoders Analog from Distance Reading

---

starting the on depend not does It distance. absolute measure encoders Analog **:□□□□**
encoder. the of position

---

method: `getDistance()` the with encoder the by measured distance the obtain can Users

Java

```
measured distance the Gets //
();getDistanceencoder.
```

C++

```
measured distance the Gets //
encoder.GetDistance();
```

### Encoder Analog an Resetting

is This method. `reset()` the call 0, is distance current the so encoder analog an reset To physical desired actual the to corresponds distance measured the that ensuring for useful homed. be to need don't encoders cycle duty encoders, quadrature Unlike measurement. so starts program the when set be to stored be can offset position the reset, after However, method a provides *class Preferences* The again. performed be to have doesn't reset the that roboRIO. the on values the retrieve and save to

Java

```
position current the at zero of distance a read to encoder the Resets //
();resetencoder.

reset was encoder the when from offset position the get //
();getPositionOffsetencoder.

rotation a half to offset position the set //
);0.5(setPositionOffsetencoder.
```

C++

```
position current the at zero of distance a read to encoder the Resets //
encoder.Reset();

reset was encoder the when from offset position the get //
encoder.GetPositionOffset();

rotation a half to offset position the set //
);0.5encoder.SetPositionOffset(
```

### Code in Encoders Using

requirement a nearly very are they FRC®; in sensors useful most the of some are Encoders
potential The movement. and actuations automatednontrivially- of capable robot a make to
an but here, fully summarize to numerous too are code robot in encoders of applications
below: provided is example

#### Distance a to Driving

is This routine. distance“ to ”drive simple a create to drive robot a on used be can Encoders
cause will momentum robot’s the that disadvantage the has but mode, autonomous in useful
using or *Controller PID* a using include methods Better distance. intended the overshoot to it
*Planning Path*

---

*DutyCycleEncoder* other if similar is but class, *Encoder* the uses example following The **:□□□□**
for suited better typically are encoders quadrature However, used. is *AnalogEncoder* or
position. absolute an have don’t and times many over roll they since drivetrains

---

Java

```
                                            1 and 0 ports DIO on encoder an Creates //
                                                  );1 ,0Encoder( new = encoder Encoder

                                             drive and controllers motor Initialize //
                                                           );0Spark( new = left1 Spark
                                                           );1Spark( new = left2 Spark

                                                          );2Spark( new = right1 Spark
                                                          );3Spark( new = right2 Spark

             left2); MotorControllerGroup(left1, new = leftMotors MotorControllerGroup
          right2); MotorControllerGroup(right1, new = rightMotors MotorControllerGroup

            rightMotors); DifferentialDrive(leftMotors, new = drive DifferentialDrive

                                                                             @Override
                                                             { ()robotInit void public
                                    distance-per-pulse s'encoder the Configures //
                            rotation encoder per foot 1 forward moves robot The //
                                      rotation encoder per pulses 256 are There //
                                             );256./1.(setDistancePerPulseencoder.
                                                                                     }

                                                                             @Override
                                                    { ()autonomousPeriodic void public
     stops: then feet, 5 moved has robot the until speed half at forward Drives //
                                                   { )5 < ()getDistance(encoder.if
                                                    );0.5 ,0.5(tankDrivedrive.
                                                                          { else }
                                                        );0 ,0(tankDrivedrive.
                                                                                 }
                                                                                     }
```

C++

```
1. and 0 ports DIO on encoder an Creates //
;}1 ,0encoder{ Encoder::frc

drive and controllers motor Initialize //
;}0left1{ Spark::frc
;}1left2{ Spark::frc

;}2right1{ Spark::frc
;}3right2{ Spark::frc

left2}; leftMotors{left1, MotorControllerGroup::frc
right2}; rightMotors{right1, MotorControllerGroup::frc

rightMotors}; drive{leftMotors, DifferentialDrive::frc

{ ()Robot::RobotInit void
distance-per-pulse s'encoder the Configures //
rotation encoder per foot 1 forward moves robot The //
rotation encoder per pulses 256 are There //
);256.0/1.0encoder.SetDistancePerPulse(
}

{ AutonomousPeriodic():Robot void
stops: then feet, 5 moved has robot the until speed half at forward Drives //
{ )5 < (encoder.GetDistance()if
);0.5 ,0.5drive.TankDrive(
{ else }
);0 ,0drive.TankDrive(
}
}
```

### Mechanism a Homing

their that ensure to important often is it distance, *relative* measure encoders quadrature Since a which in routine,“ ”homing a is this do to way typical A place. right the in is point“”zero-switch), limit a with accomplished (usually position known a hits it until moved is mechanism example: basic a provides code following The reset. is encoder the then and ”home,“ or

---

analog and encoders cycle duty like encoders absolute for necessary not is Homing :□□□□ encoders.

---

Java

```
);1 ,0Encoder( new = encoder Encoder

);0Spark( new = spark Spark

2 DIO on switch Limit //
);2DigitalInput( new = limit DigitalInput

{ ()autonomousPeriodic void public
pressed is switch limit the until speed half at backwards motor the Runs //
encoder the reset and motor the off turn then //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                        { ())getlimit.!(if
                        );0.5-(setspark.
                                  { else }
                           );0(setspark.
                        ();resetencoder.
                                        }
                                            }
```

C++

```
                  ;}1,0encoder{ Encoder::frc

                      ;}0spark{ Spark::frc

                      2 DIO on switch Limit //
                ;}2limit{ DigitalInput::frc

                  { ()AutonomousPeriodic void
pressed is switch limit the until speed half at backwards motor the Runs //
                  encoder the reset and motor the off turn then //
                        { limit.Get())!(if
                        );0.5-spark.Set(
                                  { else }
                           );0spark.Set(
                        encoder.Reset();
                                        }
                                            }
```

## Software - Inputs Analog 14.3.7

inputs, analog to guide hardware a For software. in inputs analog covers section This :□□□□
.□□□□□ - □□□□□□ □□□ see

value the read to used be can that channels input analog 8 to up supports FPGA roboRIO's The a outputs that sensor any for used be may inputs Analog sensor. a from voltage analog an of voltage. simple

voltage, the to proportional integer bit12- a return default by FPGA the from inputs Analog volts. 5 to 0 from

### class AnalogInput The

to than class wrapper *Potentiometers Analog* the use to convenient more often is It :□□□□
units. meaningful to scaling supports it as directly, `AnalogInput` use

the through provided is inputs analog FPGA the on voltages the reading for Support ).C++ ,Java( class `AnalogInput`

### AnalogInput an Initializing

follows: as initialized be may `AnalogInput` An

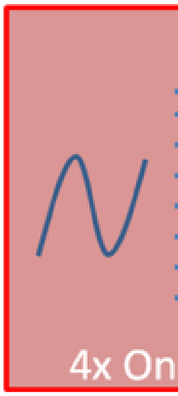
Java

```
                              0 port on AnalogInput an Initializes //
                             );0AnalogInput( new = analog AnalogInput
```

C++

```
                              0 port on AnalogInput an Initializes //
                                          ;}0analog{ AnalogInput::frc
```

### Averaging and Oversampling



These  averaging. and oversampling both supports modules input analog FPGA's The the at used be may Both  ways. important few a in differ but similar, highly are behaviors time. same

### Oversampling

and together, samples consecutive multiple add will FPGA the enabled, is oversampling When $n$ for - oversampling of number the specify may Users  value. accumulated the return bits of oversampling, the number of samples added together is $2^n$:

Java

```
     together. added be will samples 16  oversampling. 4-bit to AnalogInput the Sets //
     update the and 16, of factor a about by increase will values reported the Thus, //
                                         amount. similar a by decrease will rate //
                                                         );4(setOversampleBitsanalog.
```

C++

```
     together. added be will samples 16  oversampling. 4-bit to AnalogInput the Sets //
     update the and 16, of factor a about by increase will values reported the Thus, //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
amount. similar a by decrease will rate //
);4analog.SetOversampleBits(
```

### Averaging

the by divided are values accumulated the except oversampling, like much behaves Averaging often is This change. not does values returned the of scaling the that so samples of number rounding the by introduced error roundoff additional the occasionally but convenient,more- undesirable. is

Java

```
together. averaged be will samples 16  averaging. 4-bit to AnalogInput the Sets //
16. of factor a by decrease will rate update The //
);4(setAverageBitsanalog.
```

C++

```
together. averaged be will samples 16  averaging. 4-bit to AnalogInput the Sets //
16. of factor a by decrease will rate update The //
);4analog.SetAverageBits(
```

---

oversampling the time, same the at used are averaging and oversampling When **:□□□□** oversampling bit2- Thus, averaged. are values oversampled the then and *first,* applied is by values returned the of scale the increase will time same the at used averaging bit2- and 4. of factor a approximately by rate update the decrease and 2, of factor a approximately

---

### AnalogInput an from values Reading

methods: different four of one with AnalogInput an from read be can Values

### getValue

input, analog the from value measured instantaneous raw the returns method `getValue` The The settings. averaging and oversampling ignoring and calibration any applying without integer. an is value returned

Java

```
();getValueanalog.
```

C++

```
analog.GetValue();
```

### getVoltage

input. analog the from voltage measured instantaneous the returns method `getVoltage` The a represent to rescaled is value the but ignored, are settings averaging and Oversampling double. a is value returned The voltage.

Java

```
();getVoltageanalog.
```

C++

```
analog.GetVoltage();
```

### getAverageValue

value The input. analog the from value averaged the returns method `getAverageValue` The an is value returned The applied. both are averaging and oversampling but rescaled, not is integer.

Java

```
();getAverageValueanalog.
```

C++

```
analog.GetAverageValue();
```

### getAverageVoltage

input. analog the from voltage averaged the returns method `getAverageVoltage` The double. a is value returned The applied. all are averaging and oversampling, Rescaling,

Java

```
();getAverageVoltageanalog.
```

C++

```
analog.GetAverageVoltage();
```

### Accumulator

volts of units in value a returning support currently not do methods accumulator The :□□□□ ).`long` a (specifically, integer an be always will value returned the -

(adds integrates which accumulator, an support additionally 1 and 0 channels input Analog values. measured past all of sum the is value returned the that so indefinitely, signal the up) accumulation. to prior applied are averaging and Oversampling

Java

```
0 to accumulator the of value initial the Sets //
time over change will value the which from point" starting" the is This //
);0(setAccumulatorInitialValueanalog.

from subtracted is value This  0. to accumulator the of center"" the Sets //
accumulation. to prior values measured all //
);0(setAccumulatorCenteranalog.

started/ last was accumulator the since samples accumulated of number the Returns //
reset ↪
();getAccumulatorCountanalog.

long. is type Return  accumulator. the of value the Returns //
();getAccumulatorValueanalog.

value initial the to accumulator the Resets //
();resetAccumulatoranalog.
```

C++

```
0 to accumulator the of value initial the Sets //
time over change will value the which from point" starting" the is This //
);0analog.SetAccumulatorInitialValue(

from subtracted is value This  0. to accumulator the of center"" the Sets //
accumulation. to prior values measured all //
);0analog.SetAccumulatorCenter(

started/ last was accumulator the since samples accumulated of number the Returns //
reset ↪
analog.GetAccumulatorCount();

long. is type Return  accumulator. the of value the Returns //
analog.GetAccumulatorValue();

value initial the to accumulator the Resets //
analog.ResetAccumulator();
```

### value and count synchronized Obtaining

This value. the and count the of measurements matched obtain to necessarily is it Sometimes, method: `getAccumulatorOutput` the using done be can

Java

```
measurements matched the hold to object AccumulatorResult an Instantiate //
AccumulatorResult(); new = result AccumulatorResult

measurements matched the with AccumulatorResult the Fill //
(result);getAccumulatorOutputanalog.

AccumulatorResult the from values the Read //
;countresult. = count long
;valueresult. = value long
```

C++

```
fill to variables value and count The //
                        count; int_64t
                        value; int_64t

measurements matched the with variables value and count the Fill //
             value); analog.GetAccumulatorOutput(count,
```

### code in inputs analog Using

(including sensors of variety wide a for code write to used be can class `AnalogInput` The as data their return that more) and ultrasonics, gyroscopes, accelerometers, potentiometers, the of one use to convenient more always almost is it possible if However, voltage. analog an voltages analog the (reading code levellower- the handles that classes WPILib existing other `AnalogInput` use directly only should Users you. for units) meaningful to them converting and resort.“ ”last a as

refer should users code, in sensors analog use effectively to how of examples for Accordingly, classes. specificmore- with deal that chapter this of pages other the to

## Software - Potentiometers Analog 14.3.8

---

analog to guide hardware a For software. in potentiometers analog covers section This :□□□□ .*Hardware - Potentiometers Analog* see potentiometers,

---

converted be to position about information allow that resistors variable are Potentiometers whatever control to roboRIO the by read be can signal This signal. voltage analog an into potentiometer. the to attached is device

*Inputs Analog* an with directly potentiometer a from information read to possible is it While re- handles that )C++ ,Java( class `AnalogPotentiometer` an provides WPILib ,*Software* - this use to encouraged strongly is It user. the for units meaningful into values the scaling class.

be should class this - misnomer a of something is name `AnalogPotentiometer` the fact, In analog scaledlinearly- simple, a as signal their return that sensors of majority vast the for used voltage.

### class AnalogPotentiometer The

---

are constructor `AnalogPotentiometer` the in parameters ”scale“ or range“ ”full The :□□□□ a represent they is, That 5.0- from *not* range, actual the to 10- of range a from factors scale scale. voltage a than rather scale, fractional native

---

follows: as initialized be can AnalogPotentiometer An

Java

```
                         0 port analog on AnalogPotentiometer an Initializes //
␣be could (this 0-180 is units) external meaningful (in motion of range full The //
                                                          instance) for degrees, ↪
␣the when located is mechanism the where i.e. motion, the of point" starting" The //
                                                   30. is 0v, reads potentiometer ↪

                );30 ,180 ,0AnalogPotentiometer( new = pot AnalogPotentiometer
```

C++

```
                         0 port analog on AnalogPotentiometer an Initializes //
␣be could (this 0-180 is units) external meaningful (in motion of range full The //
                                                          instance) for degrees, ↪
␣the when located is mechanism the where i.e. motion, the of point" starting" The //
                                                   30. is 0v, reads potentiometer ↪

                                   ;}30 ,180 ,0pot{ AnalogPotentiometer::frc
```

### AnalogInput underlying the Customizing

---

be must this oversampling, with `AnalogInput` the of scaling the changes user the If :□□□□
.`AnalogPotentiometer` the to passed setting scale the in reflected

---

the by used `AnalogInput` underlying the to settings custom apply to like would user the If is `AnalogInput` the which in used be may constructor alternative an ,`AnalogPotentiometer` injected:

Java

```
           averaging 2-bit enables and 0, port on AnalogInput an Initializes //
                                   );0AnalogInput( new = input AnalogInput
                                                  );2(setAverageBitsinput.

               AnalogInput given the with AnalogPotentiometer an Initializes //
␣be could (this 0-180 is units) external meaningful (in motion of range full The //
                                                          instance) for degrees, ↪
␣the when located is mechanism the where i.e. motion, the of point" starting" The //
                                                   30. is 0v, reads potentiometer ↪

          );30 ,180 AnalogPotentiometer(input, new = pot AnalogPotentiometer
```

C++

```
           averaging 2-bit enables and 0, port on AnalogInput an Initializes //
                                              ;}0input{ AnalogInput::frc
                                                   );2input.SetAverageBits(

               AnalogInput given the with AnalogPotentiometer an Initializes //
␣be could (this 0-180 is units) external meaningful (in motion of range full The //
                                                          instance) for degrees, ↪
␣the when located is mechanism the where i.e. motion, the of point" starting" The //
                                                   30. is 0v, reads potentiometer ↪

                         ;}30 ,180 pot{input, AnalogPotentiometer::frc
```

### Reading values from the AnalogPotentiometer

The scaled value can be read by simply calling the `get` method:

Java

```java
pot.get();
```

C++

```cpp
pot.Get();
```

### Using AnalogPotentiometers in code

Analog sensors can be used in code much in the way other sensors that measure the same thing can be. If the analog sensor is a potentiometer measuring an arm angle, it can be used similarly to an *encoder*. If it is an ultrasonic sensor, it can be used similarly to other *ultrasonics*.

It is very important to keep in mind that actual, physical potentiometers generally have a limited range of motion. Safeguards should be present in both the physical mechanism and the code to ensure that the mechanism does not break the sensor by traveling past its maximum throw.

## 14.3.9 Digital Inputs - Software

---

□□□□: This section covers digital inputs in software. For a hardware guide to digital inputs, see *Digital Inputs - Hardware*.

---

The roboRIO's FPGA supports up to 26 digital inputs. 10 of these are made available through the built-in DIO ports on the RIO itself, while the other 16 are available through the MXP breakout port.

Digital inputs read one of two states - "high" or "low." By default, the built-in ports on the RIO will read "high" due to internal pull-up resistors (for more information, see *Digital Inputs - Hardware*). Accordingly, digital inputs are most-commonly used with switches of some sort. Support for this usage is provided through the `DigitalInput` class (Java, C++).

### The DigitalInput class

A `DigitalInput` can be initialized as follows:

Java

```java
// Initializes a DigitalInput on DIO 0
DigitalInput input = new DigitalInput(0);
```

C++

```cpp
// Initializes a DigitalInput on DIO 0
frc::DigitalInput input{0};
```

### DigitalInput the of value the Reading

method: get the with polled be can DigitalInput the of state The

Java

```
open. is circuit the if true Returns  input. digital the of value the Gets //
();getinput.
```

C++

```
open. is circuit the if true Returns  input. digital the of value the Gets //
input.Get();
```

### AnalogInput an from DigitalInput a Creating

---

analog that share can argument number port a with constructed `AnalogTrigger` An :□□□□ port. same the share not may objects *AnalogInput* two but ,`AnalogInput` separate a with port

---

achieved easily be can This input. digital a as input analog an use to desirable is it Sometimes, ).C++ ,Java( class `AnalogTrigger` the using

an ,`AnalogPotentiometer` with As follows. as initialized be may `AnalogTrigger` An settings: sampling the customize to wishes user the if explicitly passed be may `AnalogInput`

Java

```
0 port on AnalogTrigger an Initializes //
);0AnalogTrigger( new = trigger0 AnalogTrigger

oversampling 2-bit enables and 1 port on AnalogInput an Initializes //
);1AnalogInput( new = input AnalogInput
);2(setAverageBitsinput.

input above the using AnalogTrigger an Initializes //
AnalogTrigger(input); new = trigger1 AnalogTrigger
```

C++

```
0 port on AnalogTrigger an Initializes //
;}0trigger0{ AnalogTrigger::frc

oversampling 2-bit enables and 1 port on AnalogInput an Initializes //
;}1input{ AnalogInput::frc
);2input.SetAverageBits(

input above the using AnalogTrigger an Initializes //
trigger1{input}; AnalogTrigger::frc
```

### points trigger the Setting

.*Software - Inputs Analog* see values, `AnalogInput` ”raw“ of scaling the on details For :□□□□

the values what at specify to necessary is it one, digital a to signal analog the convert To around ”dithering“ avoid to different be may values These disable. and enable will trigger point: transition the

Java

```
1000 of value a at disable and 3500, of value raw a at enable to trigger the Sets //
                                                    );3500 ,1000(setLimitsRawtrigger.

␣1.5 of value a at disable and volts, 4 of voltage a at enable to trigger the Sets //
                                                                              volts ↪
                                                  );4 ,1.5(setLimitsVoltagetrigger.
```

C++

```
1000 of value a at disable and 3500, of value raw a at enable to trigger the Sets //
                                                    );3500 ,1000trigger.SetLimitsRaw(

␣1.5 of value a at disable and volts, 4 of voltage a at enable to trigger the Sets //
                                                                              volts ↪
                                                  );4 ,1.5trigger.SetLimitsVoltage(
```

### code in DigitalInputs Using

is class This `.DigitalInput` a through used be will robot the on switches all almost As control. robot effective for important extremely

### mechanism a of motion the Limiting

some given be should FRC® in elevators) and arms as (such mechanisms motorized all Nearly of range their of end the at themselves damaging from them prevent to switch“ ”limit of form below: given is example short A motions.

Java

```
                                             );0Spark( new = spark Spark

                                                   2 DIO on switch Limit //
                                    );2DigitalInput( new = limit DigitalInput

                                     { ()autonomousPeriodic void public
        pressed is limit the unless speed, half at forwards motor the Runs //
                                                     { ())getlimit.!(if
                                                     );5.(setspark.
                                                            { else }
                                                      );0(setspark.
                                                                   }
                                                                      }
```

C++

```
// Motor for the mechanism
frc::Spark spark{0};

// Limit switch on DIO 2
frc::DigitalInput limit{2};

void AutonomousPeriodic() {
    // Runs the motor forwards at half speed, unless the limit is pressed
    if(!limit.Get()) {
        spark.Set(.5);
    } else {
        spark.Set(0);
    }
}
```

**Homing a mechanism**

Limit switches are very important for being able to "home" a mechanism with an encoder. For an example of this, see *Homing a Mechanism*.

## 14.3.10 Programming Limit Switches

Limit switches are often used to control mechanisms on robots. While limit switches are simple to use, they only can sense a single position of a moving part. This makes them ideal for ensuring that movement doesn't exceed some limit but not so good at controlling the speed of the movement as it approaches the limit. For example, a rotational shoulder joint on a robot arm would be best controlled using a potentiometer or an absolute encoder. A limit switch could make sure that if the potentiometer ever failed, the limit switch would stop the robot from going too far and causing damage.

Limit switches can have "normally open" or "normally closed" outputs. This will control if a high signal means the switch is opened or closed. To learn more about limit switch hardware see this *article*.

### Controlling a Motor with Two Limit Switches

Java

```
DigitalInput toplimitSwitch = new DigitalInput(0);
DigitalInput bottomlimitSwitch = new DigitalInput(1);
PWMVictorSPX motor = new PWMVictorSPX(0);
Joystick joystick = new Joystick(0);

@Override
public void teleopPeriodic() {
    setMotorSpeed(joystick.getRawAxis(2));
}

public void setMotorSpeed(double speed) {
    if (speed > 0) {
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                                                 { ())get(toplimitSwitch. if
                     stop so tripped is limit top and up going are We //
                                                           );0(setmotor.
                                                                    { else }
speed commanded at go so tripped not is limit top but up going are We //
                                                       (speed);setmotor.
                                                                           }
                                                                        { else }
                                              { ())get(bottomlimitSwitch. if
                stop so tripped is limit bottom and down going are We //
                                                           );0(setmotor.
                                                                    { else }
␣commanded at go so tripped not is limit bottom but down going are We //
                                                                             speed ↪
                                                       (speed);setmotor.
                                                                           }
                                                                               }
                                                                                   }
```

C++

```
                                               ;}0{ toplimitSwitch DigitalInput::frc
                                            ;}1{ bottomlimitSwitch DigitalInput::frc
                                                        ;}0{ motor PWMVictorSPX::frc
                                                         ;}0{ joystick Joystick::frc

                                                             { ()TeleopPeriodic void
                                          ));2SetMotorSpeed(joystick.GetRawAxis(
                                                                                   }

                                                  { speed) double(SetMotorSpeed void
                                                                { )0 > (speed if
                                                 { (toplimitSwitch.Get()) if
                     stop so tripped is limit top and up going are We //
                                                           );0motor.Set(
                                                                    { else }
speed commanded at go so tripped not is limit top but up going are We //
                                                       motor.Set(speed);
                                                                           }
                                                                        { else }
                                              { (bottomlimitSwitch.Get()) if
                stop so tripped is limit bottom and down going are We //
                                                           );0motor.Set(
                                                                    { else }
␣commanded at go so tripped not is limit bottom but down going are We //
                                                                             speed ↪
                                                       motor.Set(speed);
                                                                           }
                                                                               }
                                                                                   }
```

## APIs Hardware Miscellaneous 14.4

standalone. are that APIs hardware miscellaneous highlights section This

### LEDs Addressable 14.4.1

They reasons. of variety a for years several for teams by used commonly been have strips LED their for marker visual a provide audience, the from functionality robot debug to teams allow WS2812 controlling for API an has WPILib appeal. visual some add simply can and robot, PWM. via connected pin data their with LEDs

#### Object AddressableLED the Instantiating

*must* It argument. an as port PWM the takes that object `AddressableLED` an create first You LED your on located LEDs of number the set you Then roboRIO. the on header PWM a be function. `setLength()` the with done be can with strip,

---

task expensive an is header LED the of length the setting that note to important is It :□□□□ periodically. this run to recommended **not** it's and

---

`AddressableLEDBuffer` an create to have you'll set, been has strip the of length the After `myAddressableLed.` call then You'll input. an as LEDs of number the takes that object call can you Finally, data. output led the set to `setData(myAddressableLEDBuffer)` the of example full a is Below continuously. output the write to `myAddressableLed.start()` process. initialization

---

Array. an uses instead and AddressableLEDBuffer, an have not does C++ :□□□□

---

Java

```
                                                          @Override
                                              { ()robotInit void public
                                                        9 port PWM //
                                  DIO or MXP not header, PWM a be Must //
                                           );9AddressableLED( new = m_led

                                                        buffer Reuse //
                             output empty start 60, of length a to Default //
           data update just then once, it set only so set, to expensive is Length //
                                 );60AddressableLEDBuffer( new = m_ledBuffer
                                  ());getLength(m_ledBuffer.setLengthm_led.

                                                        data the Set //
                                           (m_ledBuffer);setDatam_led.
                                                        ();startm_led.
                                                                    }
```

C++

```
{ TimedRobot::frc public : Robot class
  :private
;60 = kLength int constexpr static

9 port PWM //
DIO or MXP not header, PWM a be Must //
;}9m_led{ AddressableLED::frc
>kLength LEDData,::AddressableLED::frc<array::std
buffer the Reuse //  m_ledBuffer;
is pixel first the of hue last the what Store //
;0 = firstPixelHue int
```

```
{ ()Robot::RobotInit void
output empty start 60, of length a to Default //
data update just then once, it set only so set, to expensive is Length //
m_led.SetLength(kLength);
m_led.SetData(m_ledBuffer);
m_led.Start();
}
```

### Color One to Strip Entire the Setting

takes which `setRGB()` methods. two using strip the on led individual an to set be can Color input. an as values HSV takes which `setHSV()` and input an as values RGB

#### Values RGB Using

easy quite it's as model color common fairly a is This Blue. and Green, Red, for stands RGB the of index arguments: 4 takes that method `setRGB` the with set be can LEDs understand. to Blue and Green, Red, of amount The blue. of amount green, of amount red, of amount LED, 255.0- between values integer are

Java

```
{ )++i ();getLengthm_ledBuffer. < i ;0 = i var( for
red for values RGB the to LED specified the Sets //
);0 ,0 ,255 (i,setRGBm_ledBuffer.
}

(m_ledBuffer);setDatam_led.
```

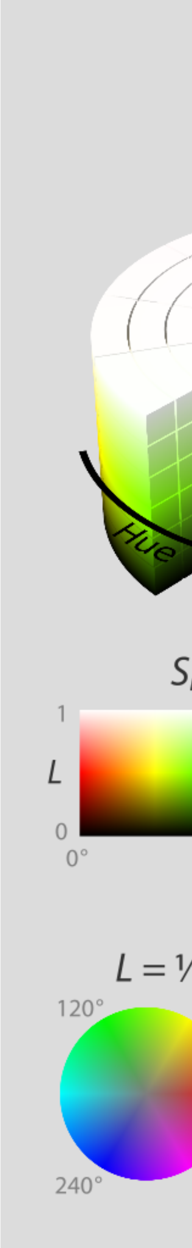
C++

```
{ )++i kLength; < i ;0 = i int( for
);0 ,0 ,255m_ledBuffer[i].SetRGB(
}

m_led.SetData(m_ledBuffer);
```

## Values HSV Using

being saturation tint, or color the describes Hue Value. and Saturation, Hue, for stands HSV 180. - 0 from integer an is Hue WPILib, In brightness. the being value and gray, of amount the ,Google's like picker color a at look you If 255. - 0 from integers are Value and Saturation that way same the is This 100%. to 0% from are Value and Saturation and 360 - 0 be will Hue or correct, are WPILib to entered values HSV the sure Make colors. HSV handles OpenCV expected. was as same the be not might produced color the



hue, LED, the of index arguments: 4 takes that method `setHSV` the with set be can LEDs red to strip LED an of color the setting for below shown is example An value. and saturation, 0). of (hue

Java

```
           { )++i ();getLengthm_ledBuffer. < i ;0 = i var( for
       red for values HSV the to LED specified the Sets //
                 );100 ,100 ,0 (i,setHSVm_ledBuffer.
                                                   }

                         (m_ledBuffer);setDatam_led.
```

C++

```
              { )++i kLength; < i ;0 = i int( for
            );100 ,100 ,0m_ledBuffer[i].SetHSV(
                                              }

                     m_led.SetData(m_ledBuffer);
```

## Effect Rainbow a Creating

equally it loop, *for* the of Inside things. important of couple a does method below The hue LED individual the stores and strand the of length entire the over hue the distributes the using pixel specified that of value HSV the sets loop for the Then .hue called variable a to value. hue

that pixel the iterates then `m_rainbowFirstPixelHue` the loop, for the of outside Moving checks then `m_rainbowFirstPixelHue` effect. rainbow the creating hue "initial" the contains a is hue HSV because is This 180. of boundaries hue the inside is hue the that sure make to 180.0- from value

---

so possible, as clean as method `robotPeriodic()` the keep to practice robot good It's :□□□□ `rainbow()` method this call We'll data. LED our setting handling for method a create we'll .`robotPeriodic()` from it call and

---

Java

```
                                        { ()rainbow void private
                                              pixel every For //
                  { )++i ();getLengthm_ledBuffer. < i ;0 = i var( for
       color the because rainbows for easier is hue - hue the Calculate //
                   precess to needs value one only so circle a is shape //
 ()))getLengthm_ledBuffer. / 180 * (i + (m_rainbowFirstPixelHue = hue var final
                                                              ;180 % ↪
                                                   value the Set //
                         );128 ,255 hue, (i,setHSVm_ledBuffer.
                                                              }
                        move"" rainbow the make to by Increase //
                               ;3 =+ m_rainbowFirstPixelHue
                                               bounds Check //
                              ;180 =% m_rainbowFirstPixelHue
                                                               }
```

C++

```
                        { ()Robot::Rainbow void
                          pixel every For //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                    { )++i kLength; < i ;0 = i int( for
color the because rainbows for easier is hue - hue the Calculate //
               precess to needs value one only so circle a is shape //
  ;180 % kLength)) / 180 * (i + (firstPixelHue = pixelHue auto const
                                                  value the Set //
                           );128 ,255 m_ledBuffer[i].SetHSV(pixelHue,
                                                                 }
                         move"" rainbow the make to by Increase //
                                                 ;3 =+ firstPixelHue
                                                   bounds Check //
                                                ;180 =% firstPixelHue
                                                                   }
```

set and method the call actually to have we created, method rainbow our have we that Now LED. the of data the

Java

```
                                       @Override
                       { ()robotPeriodic void public
                       rainbow a with buffer the Fill //
                                             rainbow();
                                          LEDs the Set //
                        (m_ledBuffer);setDatam_led.
                                                      }
```

C++

```
                  { ()Robot::RobotPeriodic void
                  rainbow a with buffer the Fill //
                                          Rainbow();
                                       LEDs the Set //
                         m_led.SetData(m_ledBuffer);
                                                    }
```

## Controllers Motor 14.5

DC brushed For move. motors making for robot your on responsible is controller motor A motor the that voltage the regulates controller motor the 775s, or CIMs as such motors MAX, Spark the as such controllers motor brushless For bulb. light a like much receives, motor. the of ”phase“ each to delivered power the regulates controller the

---

controller. speed a is controller motor a for name Another :□□□□

---

motor the removing by controller motor legalcompetition-non- quick, a make can One :□□□ leads. motor’s the to equivalents or PowerPoles attaching and drill BRUSHED cordless a from the that note but motor, the damage not will drill the by supplied voltage the that sure Make volts. 24 to up at fine is 775

---

a to as such power, to straight controller motor BRUSHLESS a Connecting :□□□□□ motor! the destroy will controller, motor brushed conventional

### Controllers Motor Legal FRC 14.5.1

FRC® of list full the is This sets. feature and sizes shapes, of lots in come controllers Motor 2023: of as controllers motor Legal

- 2)334-410- 1,334-410- (P/N: Controller Motor 60c 60/DMC DMC
- to connected 3367)217- and BDC24,MDL- BDC,MDL- (P/N: Controller Motor Jaguar only PWM
- (P/N only actuator integral control to Controller with Motor BLDC Dynamo Nidec 3740)am- 000,840205-
- SD540Bx2, SD540Bx1, SD540x4, SD540x2, SD540x1, (P/N: Controller Motor SD540 SD540C) SD540Bx4,
- 4260)am- 1200,11-REV- (P/N: Controller Motor Spark
- 4261)am- 2158,11-REV- (P/N: Controller Motor MAX Spark
- for 6515_Short)am- 6515,am- 708850,19- 6515,217- (P/N: Controller Motor FX Talon only 500 Falcon integral controlling
- 2195)am- and CTRE_Talon_SR, CTRE_Talon, (P/N: Controller Motor Talon
- 838288)14- 2854,am- 8080,217- (P/N: Controller Motor SRX Talon
- only motor integral controlling for 10001)BDC- (P/N Controller with Motor Venom
- 12/12)884-VICTOR- (P/N: Controller Motor 884 Victor
- 2769)217- (P/N: Controller Motor 888 Victor
- 868380)14- 2855,am- 9090,217- (P/N: Controller Motor SP Victor
- 3748)am- 868388,17- 9191,217- (P/N: Controller Motor SPX Victor

## פניאומטיקה 14.6

using another or state one in that’s something make to way easy and quick a are Pneumatics compressed air. For information on operating pneumatics, see □□□□□ □□□□□□ □□□□□□□□□.

### controllers Pneumatics Legal FRC 14.6.1

- 4243)217- 2858,am- (P/N: Module Control Pneumatics
- 1852)11-REV- (P/N Hub Pneumatic

# Relays 14.7

fashion. On/Off an in electronics custom or motor a to power controls relay A

## Modules Relay Legal FRC 14.7.1

- H)RELAY-SPIKE- and 0220217- (P/N: Relay BridgeH- Spike
- AD- DC200D,SSR6M25-AD- DC200D,SSR6M12-AD- (P/N: Relay Direct Automation DC200D)SSR6M40-
- 1850)11-REV- (P/N channel switched (PDH) Hub Distribution Power

# 51

[redacted]

## Devices CAN Using 15.1

controller robot the between connection of methods other over advantages many has CAN devices. peripheral and

- much in results often which device, to device from chaineddaisy- are connections CAN itself. RIO the to device each wire to having than runs wire shorter
- thus, - connection PWM a over than connection CAN a over sent be can data more Much PWM are than setfeature- expansive more much a of capable are controllers motor CAN controllers. motor
- again RIO, the to back data send can controllers motor CAN so directional,bi- is CAN Controllers. PWM by offered be can than setfeature- expansive more a facilitating

.*guide wiring robot* the of section relevant the see devices, CAN wiring on instructions For

describe will sections following The classes. WPILib own their have generally devices CAN classes. these of several of use the

## Module Control Pneumatics 15.2

control complete provides that device basedCAN- a is (PCM) Module Control Pneumatics The WPILib into integrated is PCM The module. per solenoids 8 to up and compressor the over use. to simple it make that classes of series a through

`Compressor` the by handled is switch Pressure and Compressor the of control loop closed The and )C++ ,Java( `Solenoid` the by handled are Solenoids the and ),C++ ,Java( class classes. )C++ ,Java( `DoubleSolenoid`

are solenoids corresponding module's the where used be can module PCM additional An Compressor and Solenoid the of constructors the in number module the by differentiated classes.

*for Compressor a Operating* see compressor, the controlling on information more For *.Pneumatics*

*.Cylinders Pneumatic Operating* see solenoids, controlling on information more For

## Hub Pneumatic 15.3

the over control complete provides that device basedCAN- a is (PH) Hub Pneumatic The a through WPILib into integrated is PH The module. per solenoids 16 to up and compressor use. to simple it make that classes of series

`Compressor` the by handled is switch Pressure and Compressor the of control loop closed The and )C++ ,Java( `Solenoid` the by handled are Solenoids the and ),C++ ,Java( class classes. )C++ ,Java( `DoubleSolenoid`

are solenoids corresponding module's the where used be can module PH additional An Compressor and Solenoid the of constructors the in number module the by differentiated classes.

*for Compressor a Operating* see compressor, the controlling on information more For .*Pneumatics*

.*Cylinders Pneumatic Operating* see solenoids, controlling on information more For

## Module Distribution Power 15.4

use can (PDH) Hub Distribution Power Rev and (PDP) Panel Distribution Power CTRE The robot’s the regarding information status of wealth a communicate to connectivity CAN their current report to capability the has This code. user in use for roboRIO, the to use power and use, energy robot total the draw, current robot total the voltage, bus the temperature, number a for used be can data This channel. power device each of draw current individual the avoidance. brownout and limiting *torque* motor as such techniques, control advanced of

### Object Distribution Power a Creating 15.4.1

`PowerDistribution` the of instance an create module, Distribution Power either the use To and detected, be will object Distribution Power the arguments, no With ).C++ ,Java( class additional default,non- is ID CAN the If REV. for 1 or CTRE for 0 of ID CAN use must type. and ID CAN the specify to available are constructors

Java

```
                        PowerDistribution(); new = examplePD PowerDistribution
          );kCTREModuleType. ,0PowerDistribution( new = examplePD PowerDistribution
           );kRevModuleType. ,1PowerDistribution( new = examplePD PowerDistribution
```

C++

```
                                         examplePD{}; PowerDistribution
      kCTRE};::ModuleType::PowerDistribution::frc ,0examplePD{ PowerDistribution
       kRev};::ModuleType::PowerDistribution::frc ,1examplePD{ PowerDistribution
```

values read to need you unless object PowerDistribution a create to necessary not is it Note: never is object the if even channels the all on power supply and work will board The it. from created.

> the for ID CAN the Station, Driver the in logging current and voltage enable To :□□□□□ *must* it Hub Distribution Power REV the for and 0, be *must* Panel Distribution Power CTRE 1. be

### Voltage Bus the Reading 15.4.2

Java

```
                  Volts. in PDP, the into going voltage the Get //
        Volts. 0.05 of increments in voltage the returns PDP The //
                            ();getVoltagem_pdp. = voltage double
                    voltage); ,"Voltage"(putNumberSmartDashboard.
```

C++

```
                  Volts. in PDP, the into going voltage the Get //
        Volts. 0.05 of increments in voltage the returns PDP The //
                            m_pdp.GetVoltage(); = voltage double
                voltage); ,"Voltage"PutNumber(::SmartDashboard::frc
```

Monitoring the bus voltage can be useful for (among other things) detecting when the robot is near a brownout, so that action can be taken to avoid brownout in a controlled manner. See the *roboRIO Brownouts document* for more information.

### 15.4.3 Reading the Temperature

Java

```java
// Retrieves the temperature of the PDP, in degrees Celsius.
double temperatureCelsius = m_pdp.getTemperature();
SmartDashboard.putNumber("Temperature", temperatureCelsius);
```

C++

```cpp
// Retrieves the temperature of the PDP, in degrees Celsius.
double temperatureCelsius = m_pdp.GetTemperature();
frc::SmartDashboard::PutNumber("Temperature", temperatureCelsius);
```

Monitoring the temperature can be useful for detecting if the robot has been drawing too much power and needs to be shut down for a while, or if there is a short or other wiring problem.

### 15.4.4 Reading the Total Current, Power, and Energy

Java

```java
// Get the total current of all channels.
double totalCurrent = m_pdp.getTotalCurrent();
SmartDashboard.putNumber("Total Current", totalCurrent);

// Get the total power of all channels.
// Power is the bus voltage multiplied by the current with the units Watts.
double totalPower = m_pdp.getTotalPower();
SmartDashboard.putNumber("Total Power", totalPower);

// Get the total energy of all channels.
// Energy is the power summed over time with units Joules.
double totalEnergy = m_pdp.getTotalEnergy();
SmartDashboard.putNumber("Total Energy", totalEnergy);
```

C++

```cpp
// Get the total current of all channels.
double totalCurrent = m_pdp.GetTotalCurrent();
frc::SmartDashboard::PutNumber("Total Current", totalCurrent);

// Get the total power of all channels.
// Power is the bus voltage multiplied by the current with the units Watts.
double totalPower = m_pdp.GetTotalPower();
frc::SmartDashboard::PutNumber("Total Power", totalPower);

// Get the total energy of all channels.
// Energy is the power summed over time with units Joules.
double totalEnergy = m_pdp.GetTotalEnergy();
frc::SmartDashboard::PutNumber("Total Energy", totalEnergy);
```

power much how controlling for useful be can energy and power current, total the Monitoring mechanisms that ensuring and brownouts preventing for both battery, the from drawn being is voltage bus the is Power required. actions the perform to available power sufficient have with time over summed power the is Energy Watts. units the with current the by multiplied Joules. units

### Currents Channel Individual Reading 15.4.5

power device individual the by drawn current the monitor to users allows also PDP/PDH The channels PDH 24 or 15)(0- channels PDP 16 the of any on current the read can You channels. 23).(0-

Java

```
            Amperes. in 7, channel through going current the Get //
            0.125A. of increments in current the returns PDP The //
  accurate. less be to tend readings current the currents low At //
                             );7(getCurrentm_pdp. = current7 double
           current7); ,"7 Channel Current"(putNumberSmartDashboard.
```

C++

```
            Amperes. in 7, channel through going current the Get //
            0.125A. of increments in current the returns PDP The //
  accurate. less be to tend readings current the currents low At //
                             );7m_pdp.GetCurrent( = current7 double
     current7); ,"7 Channel Current"PutNumber(::SmartDashboard::frc
```

stalled or shorts detecting for useful be can draws current device individual Monitoring motors.

### (PDH) Channel Switchable the Using 15.4.6

circuits. custom control to off or on switched be can that channel one has PDH REV The

Java

```
 );true(setSwitchableChannelexamplePD.
);false(setSwitchableChannelexamplePD.
```

C++

```
 );trueexamplePD.SetSwitchableChannel(
);falseexamplePD.SetSwitchableChannel(
```

## Devices CAN PartyThird- 15.5

expansive offer devices CAN As peripherals. CAN own their offer vendors FRC® of number A As operate. to libraries code expansive similarly require devices CAN vendor sets,feature- instead are but WPILib, of part official an as maintained not are libraries these result, a *3rd* see libraries, partythird- installing to guide a For themselves. vendors the by maintained *Libraries Party*

to links with along vendors, various from devices CAN partythird- common of list A below: provided is documentation, external corresponding

### Electronics CTR 15.5.1

General libraries. external with peripherals CAN several offers (CTRE) Electronics CTR include: devices CTRE all for resources

Documentation Software Device Phoenix

#### Controllers Motor CTRE

- **Motor) 500 Falcon (with FX Talon**
  - )C++ ,Java Pro: | C++ ,Java (v5: Documentation API
  - Manual User's Hardware
  - )Pro ,v5( Documentation Software
- **SRX Talon**
  - )C++ ,Java( Documentation API
  - Manual User's Hardware
  - Documentation Software
- **SPX Victor**
  - )C++ ,Java( Documentation API
  - Manual User's Hardware
  - Documentation Software

#### Sensors CTRE

- **CANcoder**
  - )C++ ,Java Pro: | C++ ,Java (v5: Documentation API
  - Manual User's Hardware
  - )Pro ,v5( Documentation Software
- **2.0 Pigeon**
  - )C++ ,Java Pro: | C++ ,Java (v5: Documentation API
  - Manual User's Hardware

)Pro ,v5( Documentation Software –

**IMU Pigeon** •

)C++ ,Java( Documentation API –

Manual User's Hardware –

Documentation Software –

**CANifier** •

)C++ ,Java( Documentation API –

Manual User's Hardware –

Documentation Software –

### Devices CAN Other CTRE

**Controller LED CANdle** •

)C++ ,Java( Documentation API –

Manual User's Hardware –

Documentation Software –

## Robotics REV 15.5.2

feature- similar a has which controller, motor MAX SPARK the offers currently Robotics REV
SRX. Talon the to set

### Controllers Motor REV

**MAX SPARK** •

)C++ ,Java( Documentation API –

Manual Technical –

## Fusion With Playing 15.5.3

Time- a as well as motor/controller integrated Venom the offers (PWF) Fusion With Playing
sensor: distance Flightof-

### Controllers Motor PWF

- **Venom**
  - )C++ ,Java( Documentation API
  - Manual Technical

### Sensors PWF

- **Sensor Flight of Time**
  - )C++ ,Java( Documentation API
  - Manual Technical

## 15.6 FRCב CAN ספציפיקציות מכשירי

and system CAN FRC® current the of functions basic the describe to seeks document This system. the with work to seeking devices CAN new any for requirements the

### 15.6.1 Addressing

into ID the breaks that scheme definedpre- a on based IDs arbitration assign nodes CAN FRC components: 5

#### Type Device

currently of table A addressed. being device of type the describing value bit5- a is This assigned type device new a have to wish you If below. found be can types device assigned FIRST. to request a submit please pool, `Reserved` the from

| | Types Device |
|---|---|
| 0 | Messages Broadcast |
| 1 | Controller Robot |
| 2 | Controller Motor |
| 3 | Controller Relay |
| 4 | Sensor Gyro |
| 5 | Accelerometer |
| 6 | Sensor Ultrasonic |
| 7 | Sensor Tooth Gear |
| 8 | Module Distribution Power |
| 9 | Controller Pneumatics |
| 10 | Miscellaneous |
| 11 | Breakout IO |
| 3012- | Reserved |
| 31 | Update Firmware |

### Manufacturer

assigned Currently device. CAN the of manufacturer the indicating value bit8- an is This
from assigned ID manufacturer a have to wish you If below. table the in found be can values
FIRST. to request a submit please pool,`Reserved` the

| Manufacturer | |
|---:|---:|
| Broadcast | 0 |
| NI | 1 |
| Micro Luminary | 2 |
| DEKA | 3 |
| Electronics CTR | 4 |
| Robotics REV | 5 |
| Grapple | 6 |
| MindSensors | 7 |
| Use Team | 8 |
| Labs Kauai | 9 |
| Copperforge | 10 |
| Fusion With Playing | 11 |
| Studica | 12 |
| Bot Thrifty The | 13 |
| Robotics Redux | 14 |
| Reserved | 25515- |

### Identifier API/Message

or command particular a identifies that value bit10- a is Identifier Message or API The
combination Type Device + Manufacturer each for unique are identifiers These type. message
may Controller Motor Micro Luminary a for Set“ ”Voltage a be may that identifier API an (so
Power CTR a for `Get Current` or Controller Motor Electronics CTR a for Get“ ”Status a be
Module). Distribution

the and Class API bit6- the fields:sub- 2 into down broken further is identifier Message The
Index. API bit4-

### Class API

a into grouped are messages Similar grouping. API an for identifier bit6- a is Class API The
in shown is Controller Motor Jaguar the for Classes API the of example An Class. API single
below. table the

| Class API | |
|---:|---:|
| Mode Control Voltage | 0 |
| Mode Control Speed | 1 |
| Mode Compensation Voltage | 2 |
| Mode Control Position | 3 |
| Mode Control Current | 4 |
| Status | 5 |
| Status Periodic | 6 |
| Configuration | 7 |
| Ack | 8 |

### Index API

example An Class. API an within message particular a for identifier bit4- a is Index API The
in shown is Class API Control Speed Controller Motor Jaguar the for values Index API the of
below. table the

| | Index API |
|---|---|
| 0 | Control Enable |
| 1 | Control Disable |
| 2 | Setpoint Set |
| 3 | Constant P |
| 4 | Constant I |
| 5 | Constant D |
| 6 | Reference Set |
| 7 | Enable Trusted |
| 8 | Ack No Set Trusted |
| 10 | Ack No Setpoint Set Trusted |
| 11 | Ack No Setpoint Set |

### Number Device

type. particular a of device the of number the indicating quantity bit6- a is Number Device
System. Control FRC the of components other match to 0 ID device to default should Devices
messages. broadcast specific device for reserved be may 0x3F Device

Field
Value

Bits
Bit Position

## Frames Protected 15.6.2

relays, controllers, (motor capability control actuator implement which Nodes CAN FRC
and enabled is robot the that verify to way a implement must etc.) controllers, pneumatics
roboRIO). the (i.e. controller robot main the with originate commands that

## Messages Broadcast 15.6.3

and type device the setting by nodes all to sent messages are messages Broadcast defined currently The 0. is messages broadcast for Class API The 0. to fields manufacturer below: table the in shown are messages broadcast

| Description | |
|---|---|
| Disable | 0 |
| Halt System | 1 |
| Reset System | 2 |
| Assign Device | 3 |
| Query Device | 4 |
| Heartbeat | 5 |
| Sync | 6 |
| Update | 7 |
| Version Firmware | 8 |
| Enumerate | 9 |
| Resume System | 10 |

0). (arbID message Disable the receiving when immediately disable should Devices optional. is messages broadcast other of Implementation

## Nodes CAN FRC for Requirements 15.6.4

must: they System, FRC the in use for accepted be to Nodes CAN For

- format: FRC prescribed the match which IDs Arbitration using Communicate
  - Types) Device CAN - 1 Table (per Type Device CAN issued valid, A
  - Codes) Manufacturer CAN - 2 Table (per ID Manufacturer issued valid, A
  - manufacturer device the by documented and assigned Index(s) and Class(es) API
  - to intended are type device the of units multiple if number device selectable user A network. same the on existco-
- Broadcast the in detailed as requirements message Broadcast minimum the Support section. Messages
- commands, issuing is robot the that assure to scheme a utilize actuators, controlling If present. still is and enabled, is
- ®*FIRST* with arrange or Java and C++, LabVIEW, for support library software Provide interfaces. such provide to Partners System Control FIRST’s or

## Heartbeat Universal 15.6.5

and listen can bus the on device any that heartbeat CAN universal a provides roboRIO The
`0x01011840` of ID CAN full a has heartbeat The 20ms. every sent is heartbeat This to. react
It ).`0x062` ID API and 0 ID Device type, RobotController ID, Manufacturer NI the is (which
the is layout The 4). (index 5 byte is here in byte important The packet. CAN byte 8 an is
bitfield. following

| Description | Width |
|---:|---:|
| RedAlliance | 1 |
| Enabled | 1 |
| Autonomous | 1 |
| Test | 1 |
| WatchdogEnabled | 1 |
| Reserved | 3 |

are controllers motor means that set, is flag that If .`WatchdogEnabled` is for watch to flag The
enabled.

considered be can program robot the received, was packet this since passed has 100ms If
disabled. been has robot the if as act should devices and hung,

61

[redacted]

## 16.1 מבוא ל-GIt

□□□□: A more in-depth guide on Git is available on the Git website.

Git is a Distributed Version Control System (VCS) created by Linus Torvalds, also known for creating and maintaining the Linux kernel. Version Control is a system for tracking changes of code for developers. The advantages of Git Version Control are:

- Separation of testing environments into *branches*
- Ability to navigate to a particular *commit* without removing history
- Ability to manage *commits* in various ways, including combining them
- Various other features, see here

### 16.1.1 דרישות מקדימות

□□□□: □□□□□□ □□ □□□□□□ □□□□□□□ □□□□□□□ Windows

You have to download and install Git from the following links:

- Windows
- macOS
- Linux

□□□□: You may need to add Git to your path

## Vocabulary Git 16.1.2

commands: and structures data core several around revolves Git

- directory root the in folder `git.` a including code, your of structure data the **Repository:**
- additions and files all includes which repository, the of state saved particular a **Commit:**
- This history. unique a has branch Each commits. of set a grouping of means a **Branch:** branches. stable and development separating for used primarily is
- changes local your with repository remote the update **Push:**
- changes remote the with repository local your update **Pull:**
- modify to repository a of copy local a retrieve **Clone:**
- original the against compare to and modify, to repository existingpre- a duplicate **Fork:**
- single a into branches/commits/forks different from changes various combine **Merge:** history

## Repository 16.1.3

project. a of files and history, structure, the containing structure data a is repository Git A

of: consist usually repositories Git

- repository. the about information various the contains folder This folder. `git.` A
- included want *not* do you that directories or files the contains file This file. `gitignore.` A commit. you when
- repository. the of content main the is This folders. and Files

### repository the Creating

possibly or cloud, the being remote a – remote a through or locally, repository the store can You hosting free popular a is GitHub repository. your hosts that server or medium storage another use. will tutorial this what that’s and it, use developers Numerous service.

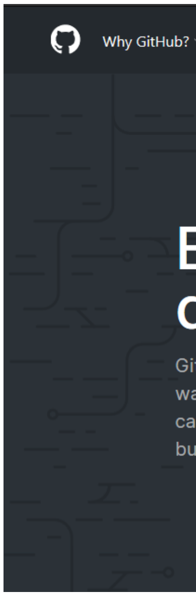
---

few a are Bitbucket and Gitlab repositories. host can that providers various are There **:□□□□** Github. to alternatives

---

### Account GitHub a Creating

screenon- the following and website the visiting by account GitHub a create and ahead Go prompts.



## Creation Local

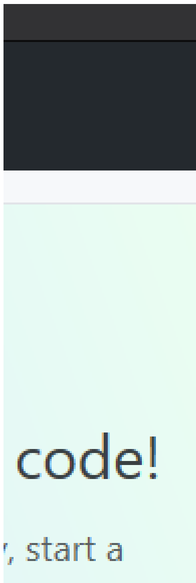
similar look It’ll homepage. the visit to want you’ll account, your verifying and creating After image. shown the to

Repositories

Your most active repositories

Create a repository or explore

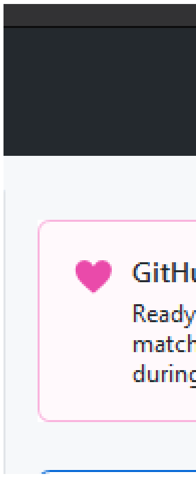
right. top the in icon plus the Click



code!

, start a

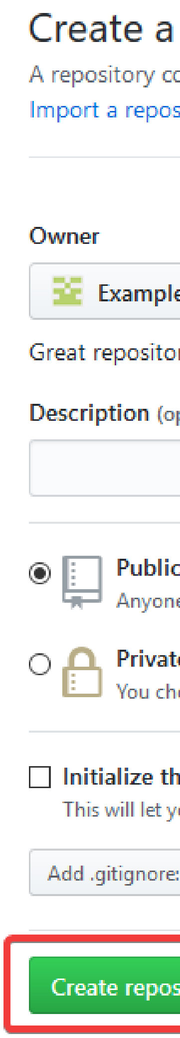
*Repository“ ”New* click Then



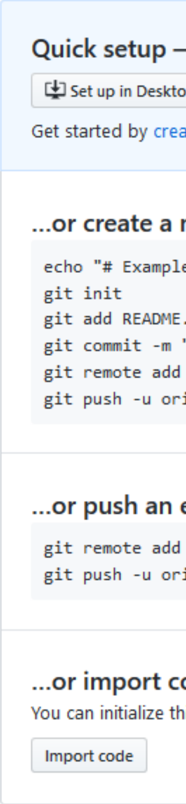
GitHu

Ready
match
during

*repository“ ”Create* click then and information, appropriate the out Fill



this to similar screen a see should You



Quick setup –

Set up in Deskto

Get started by crea

...or create a r

```
echo "# Example
git init
git add README.
git commit -m '
git remote add
git push -u ori
```

...or push an e

```
git remote add
git push -u ori
```

...or import co

You can initialize th

Import code

Code Studio Visual in terminal a open to used be can `Ctrl+~` shortcut keyboard The **:□□□□**
Windows. for

An directory. project your to navigate and window PowerShell a open to want you'll Now
on engine search your consult Please .here found be can PowerShell on tutorial excellent
systems. operating alternative on terminal a open to how

```
PS C:\Users\da
```

track. to something have to git for order in created be to needs file a empty, is directory a If
contents the with `README.md` called file a created we example, Directory Empty below the In
should commands Project Existing below the projects, Robot FRC® For .`Repo Example #` of
details More .*Creator Project WPILib Code VS the by created* project a of root the in run be
sections. subsequent the in found be can commands various the on

[illegible]: Replace the filepath `"C:\Users\ExampleUser9007\Documents\Example Folder"` with the one you want to create the repo in, and replace the remote URL `https://github.com/ExampleUser9007/ExampleRepo.git` with the URL for the repo you created in the previous steps.

Empty Directory

```
> cd "C:\Users\ExampleUser9007\Documents\Example Folder"
> git init
Initialized empty Git repository in C:/Users/ExampleUser9007/Documents/Example Folder/.git/
> echo "# ExampleRepo" >> README.md
> git add README.md
> git commit -m "First commit"
[main (root-commit) fafafa] First commit
 1 file changed, 1 insertions(+), 0 deletions(-)
 create mode 100644 README.md
> git remote add origin https://github.com/ExampleUser9007/ExampleRepo.git
> git push -u origin main
```

[illegible]

```
> cd "C:\Users\ExampleUser9007\Documents\Example Folder"
> git init
Initialized empty Git repository in C:/Users/ExampleUser9007/Documents/Example Folder/.git/
> git add .
> git commit -m "First commit"
[main (root-commit) fafafa] First commit
 1 file changed, 1 insertions(+), 0 deletions(-)
 create mode 100644 README.md
> git remote add origin https://github.com/ExampleUser9007/ExampleRepo.git
> git push -u origin main
```

### 16.1.4 Commits

Repositories are primarily composed of commits. Commits are saved states or *versions* of code.

In the previous example, we created a file called README.md. Open that file in your favorite text editor and edit a few lines. After tinkering with the file for a bit, simply save and close. Navigate to PowerShell and type the following commands.

```
> git add README.md
> git commit -m "Adds a description to the repository"
[main bcbcbc] Adds a description to the repository
 1 file changed, 2 insertions(+), 0 deletions(-)
> git push
```

[illegible]: Writing good commit messages is a key part of a maintainable project. A guide on writing commit messages can be found here.

### Pull Git

the into merge automatically to wish not does user the when used be can `fetch git` :□□□□
branch working current

remote the When repository. remote the from commits or history the retrieves command This .*Merging* See merge. automatically to attempt will it have, not do you work contains

`pull git` Run:

### Add Git

commit. next the in included be will they that so file(s) specified the ”stages“ command This

extension and name the is FILENAME.txt where `FILENAME.txt add git` run file, single a For `.. add git` run ,*gitignore* via excluded isn’t that file/folder every add To add. to file the of unexcluded untracked, every stage will command this repository the of root the in run When file.

### Commit Git

the to it adds and state the saves This locally. it stores and commit the creates command This the to made were (”diffs“) changes whatever of consist will commit The history. repository’s explaining message“ ”commit a specify to required is It commit. last the since files staged accomplishes. change the what or files of set this changed you why

`here" message "type m- commit git` Run:

### Push Git

(Cloud) remote the to changes local your (Push) Upload

`push git` Run:

## Branches 16.1.5

can they then and same, the off start They worlds. parallel to similar are Git in Branches ”branch“ out into different varying paths. Consider the Git control flow to look similar to this.

### Head the Resetting

all erases permanently It command. dangerous a is head the resetting Forcibly :□□□□□
warned! been have You target. the past history

.id-commit hard-- reset git Run:

## Forks 16.1.8

repository) (original upstream the merge can You branches. to similarly treated be can Forks
repository). (forked origin the into

### Repo Existing an Cloning

it clone can you remote, a on stored and created already is repository a that situation the In
using

```
https://github.com/myrepo.git clone git
```

.*commits* to skip can you this, follow you If repo. git your with replaced is `myrepo.git` where

### Fork a Updating

`https://github.com/ORIGINAL_OWNER/ upstream add remote git` upstream: the Add 1.
`ORIGINAL_REPOSITORY.git`

`v- remote git` via: added was it Confirm 2.

`upstream fetch git` upstream: from changes Pull 3.

`name-branch-upstream/upstream merge git` head: into changes the Merge 4.

## Gitignore 16.1.9

---

included is that file `gitignore.` the modify **not do** teams that important extremely is It :□□□□
working. not deployment offline to lead can This project. robot their with

---

`git` with commit automatically not to files of list a as used commonly is file `gitignore.` A
up show not also will They committed. be **not** will file this in listed directory or files Any .add
.status git with

.here found be can Information Additional

#### Folder a Hiding

end the at slash forward a with hide, to folder the containing line new a add Simply

`exclude/-to-directory` EX:

#### File a Hiding

relative directory prepending any including hide, to file the of name the with line new a Add repository. the of root the to

`hide.txt-to-directory/file` EX:

`hide2.txt-to-file` EX:

### Information Additional 16.1.10

website. git official the at found be can tutorial depthin- more much A

repository. rules flight git the at found be can mistakes common correcting for guide A

## Library Units C++ The 16.2

type C++ the leverages library This teams. C++ for library Units a with coupled is WPILib unit perform automatically parameters, method for dimensionality proper enforce to system type C++ the Since types. unit defined arbitrary define to users allow even and conversions, cost. runtime no essentially has library the time,compile- at enforced is system

### Library Units the Using 16.2.1

source your in header relevant the include must You library. onlyheader- a is library units The units. available of list a Here's use. to want you units the for files

```
units/acceleration.h>< include#
units/angle.h>< include#
units/angular_acceleration.h>< include#
units/angular_velocity.h>< include#
units/area.h>< include#
units/capacitance.h>< include#
units/charge.h>< include#
units/concentration.h>< include#
units/conductance.h>< include#
units/current.h>< include#
units/curvature.h>< include#
units/data.h>< include#
units/data_transfer_rate.h>< include#
units/density.h>< include#
units/dimensionless.h>< include#
units/energy.h>< include#
units/force.h>< include#
units/frequency.h>< include#
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
units/illuminance.h>< include#
units/impedance.h>< include#
units/inductance.h>< include#
units/length.h>< include#
units/luminous_flux.h>< include#
units/luminous_intensity.h>< include#
units/magnetic_field_strength.h>< include#
units/magnetic_flux.h>< include#
units/mass.h>< include#
units/moment_of_inertia.h>< include#
units/power.h>< include#
units/pressure.h>< include#
units/radiation.h>< include#
units/solid_angle.h>< include#
units/substance.h>< include#
units/temperature.h>< include#
units/time.h>< include#
units/torque.h>< include#
units/velocity.h>< include#
units/voltage.h>< include#
units/volume.h>< include#
```

.`units::math::abs()` like functions awareunit- provides header `units/math.h` The

### Types Container and Types Unit

container and types unit definitions: type of sorts two around based is library units C++ The types.

### Types Unit

Unit value. stored actual any without unit, a of concept abstract the to correspond types Unit defined are types unit all - library units the of block“ ”building fundamental the are types types unit ”basic“ of number small a from template) `compound_unit` the (using constructively etc). ,`seconds` ,`meters` as (such

means types unit other building in use their values, numerical contain cannot types unit While that dimensionality, its specify to parameter template a uses method or type a when that type. unit a be will parameter

### Types Container

that - unit some to according dimensioned quantity actual an to correspond types Container from constructed are types Container value. numerical the hold actually what are they is, type container corresponding a have types unit Most template. `unit_t` the with types unit corresponds `units::meter` type unit the example, for - `_t` by suffixed name same the has that .`units::meter_t` type container the to

will it parameter), method a or variable a (as used is unit a of quantity specific a Whenever value actual the store will types container default, By type. container the of instance an be manually. template `unit_t` the calling by this change may users advanced - `double` a as

.documentation the in found be can types container and unit of list full A

### Units of Instances Creating

type: container its of instance an create we unit, specific a of instance an create To

```
                           second. per meters 5 of value a has speed variable The //
                                                ;}5.0speed{ meter_per_second_t::units
```

common more the of some for defined literals type has library units the Alternatively, define to `auto` via inference type with conjunction in used be can These types. container succinctly: more unit a

```
                           second. per meters 5 of value a has speed variable The //
                                                                  mps;_5 = speed auto
```

types the as long as type, container another an of value a using initialized be also can Units a from created be can value `meter_t` a example, For another. one between converted be can value. `foot_t`

```
                                                                    ft;_6 = feet auto
                                                      meters{feet}; meter_t::units
```

.*convertible implicitly* are types unit convertible representing types container all fact, In legal: perfectly is following the Thus,

```
                                                    ft;_6 = distance meter_t::units
```

our in anywhere length, of unit *other any* of place in length of unit *any* use can we short, In us. for conversion correct the perform automatically will library units the code;

### Units with Arithmetic Performing

type, data underlying their of operations arithmetic ordinary the of all support types Container must addition Thus, sound. *dimensionally* be must operation the that condition added the with types: container compatible two on performed be always

```
                                                 together values meter_t two Add //
                                                12_m is sum // m;_7 + m_5 = sum auto

                                fine is this so length, are both feet; to meters Adds //
                                                               ft;_7 + m_5 = sum auto

                      error compile-time a throw will second_t, a to meter_t a add to Tries //
                                                                s;_7 + m_5 = sum auto
```

type container the yields and types, container of pair any on performed be may Multiplication unit: compound a of

---

for checked be only will type this type, unit compound a yields calculation a When **:□□□□** used, is `auto` If explicitly. specified is type result the if operation of point the at validity to want may we time, by distance divide we when example, For occur. not will check this type return the If ).`units::meter_per_second_t` (i.e. velocity a indeed, is, result the ensure made. be not will check this ,`auto` as declared is

---

```
square_meter_t is result values, meter_t two Multiply //
35_sq_m is product // m;_7 * m_5 = product auto
```

```
meter_per_second_t a is result second_t, a by value meter_t a Divide //
12_mps is speed // s;_0.5 / m_6 = speed meter_per_second_t::units
```

### Functions ><cmath

arithmetic the which on type any accept to templated are )`clamp` as (such functions `std` Some these with work will types container as stored Quantities performed. be can operations issue. without functions

units The ).`double` (e.g. types numerical ordinary on only work functions `std` other However, accept that functions these of several for wrappers contains namespace `units::math` library's etc. ,`pow` ,`sqrt` include functions such of Examples units.

```
sq_m;_36 = area auto
sqrt(area);::math::units = sideLength meter_t::units
```

### Wrapper Unit the Removing

as serves This method. `value()` the use value, underlying its to type container a convert To necessary. when only used be should which system, type units the from hatch escape an

```
m;_6.5 = distance meter_t::units
distance.value(); = distanceMeters double
```

## Code WPILib in Library Units the of Example 16.2.2

units the use )*kinematics* (ex. WPILib of features new in methods for arguments Several .*trajectory a sampling* of example an is Here library.

```
robot the where represents This seconds. 1.2 at trajectory the Sample //
traversal. of seconds 1.2 after be should //
s);_1.2trajectory.Sample( = point State::Trajectory

␣the to equivalent exactly is this convertible, implicitly are time of units Since //
code above ↪
ms);_1200trajectory.Sample( = point State::Trajectory
```

unit of choices multiple with work naturally could that objects represent classes WPILib Some or meters) (e.g. distance linear either on operate might profile motion a example, for - types template a as required is type unit the classes, such For radians). (e.g. distance angular parameter:

```
constraints profile motion trapezoidal of set new a Creates //
second per meters 10 of velocity Max //
squared second per meters 20 of acceleration Max //
mps_sq};_20 mps,_10Constraints{::>meters::units<TrapezoidProfile::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                        constraints profile motion trapezoidal of set new a Creates //
                                          second per radians 10 of velocity Max //
                                  squared second per radians 20 of acceleration Max //
s};_1 / rad_per_s__20 rad_per_s,_10Constraints{::>radians::units<TrapezoidProfile::frc
```

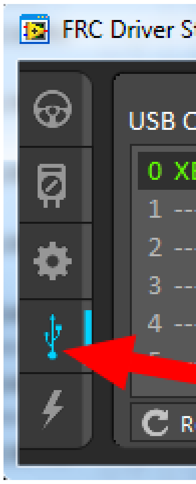
library. units the for page GitHub official the visit please documentation, detailed more For

## Joysticks 16.3

Almost robot. the control to program Station Driver the with used be can joystick A Joysticks joystick. a as used be can Windows by recognized be can that ”controller“ any for subclasses relevant three has class This class. `GenericHID` the using accessed are extending by controllers other for own your implement also may You joysticks. preconfigured second The joysticks. flight standard for useful is which `Joystick` is first The .`GenericHID` XInput (in F310 Logitech or One, Xbox 360, Xbox the for works which `XboxController` is the of axis Each controller. that using for ideal is class `PS4Controller` the Finally, mode). 1. to 1- from ranges controller

*Commands* □□□□□ section: the in detailed is classes these the use to way based command The .*Triggers*-□

### Joysticks Station Driver 16.3.1



use for joystick the configure and setup to used is Station Driver the of *Tab Devices USB* The green. up light to table the in entry its cause will joystick a on button a Pressing robot. the with to used be can that POV the and buttons axes, of values the show will joystick the Selecting numbers. button or axis and features joystick physical between mapping the determine

joysticks the reorder To joystick. each to index joystick a assigns also Tab Devices USB The devices of ordering the preserve to try will software Station Driver The drag. and click simply each check and in be should devices your order what note to idea good a is It runs. between correct. are they that software Station Driver the start you time

the on changes status for looking routinely is it mode, disabled in is Station Driver the When opened are devices new and list the from removed are devices Unplugged devices. joystick Driver the force will joystick a unplugging FMS, the to connected not When added. and that check in, joystick the plug again: joystick the using start To mode. disabled into Station enabled in is Station Driver the While robot. the enablere- then spot, right the in up shows it update timely and operation consuming time a is This devices. new for scan not will it mode, priority. takes devices attached from signals of

---

are joysticks the position whatever read will routine startup the joysticks some For :□□□□ is joystick the when (or on turned is computer the when therefore, position, center the as in position. center their at be should joysticks the in) plugged

---

Driver the competition, at System Management Field the to connected is robot the When the and robot your disable cannot you that means This .*FMS* the by dictated is mode Station the of refresh complete manual A changes. joystick detect to order in itself disable cannot DS close will this that Note keyboard. the on key F1 the pressing by initiated be can joysticks above. noted as position center their in be should devices all so devices, all openre- and

## 16.3.2 Joystick Class

Java

```
Joystick exampleJoystick = new Joystick(0); // 0 is the USB Port to be used as␣
↪indicated on the Driver Station
```

C++

```
Joystick exampleJoystick{0}; // 0 is the USB Port to be used as indicated on the␣
↪Driver Station
```

Python

```
exampleJoystick = wpilib.Joystick(0) # 0 is the USB Port to be used as indicated on␣
↪the Driver Station
```

The `Joystick` class is designed to make using a flight joystick to operate the robot significantly easier. Depending on the flight joystick, the user may need to set the specific X, Y, Z, and accessing for methods special offers class This uses. joystick flight your that channels Throttle joystick. flight the of magnitude and angle the

### Class `XboxController` 16.3.3

Java

```
␣used be to Port USB the is 0 // );0XboxController( new = exampleXbox XboxController
                                               Station Driver the on indicated as ↪
```

C++

```
 ␣the on indicated as used be to Port USB the is 0 // ;}0exampleXbox{ XboxController
                                                             Station Driver ↪
```

Python

```
␣on indicated as used be to Port USB the is 0 # )0XboxController(.wpilib = exampleXbox
                                                         Station Driver the ↪
```

,`getXButtonPressed` ,`getXButton` (e.g. methods named provides class `XboxController` The with accessed be can indices the and buttons, the of each for )`getXButtonReleased` by controlled be can controller the of feature rumble The .`XboxController.Button.kX.value`

Many .value) `XboxController.setRumble(GenericHID.RumbleType.kRightRumble`, using and backwards / forwards just for stick left the uses that drive arcade stick split a do users turning. right / left for stick right the

### Class `PS4Controller` 16.3.4

Java

```
␣as used be to Port USB the is 0 // );0PS4Controller( new = examplePS4 PS4Controller
                                                Station Driver the on indicated ↪
```

C++

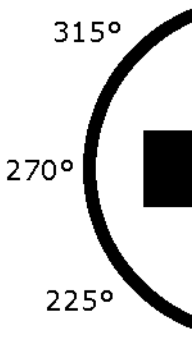
```
␣the on indicated as used be to Port USB the is 0 // ;}0examplePS4{ PS4Controller
                                                            Station Driver ↪
```

Python

```
␣on indicated as used be to Port USB the is 0 # )0PS4Controller(.wpilib = examplePS4
                                                        Station Driver the ↪
```

,`getSquareButton` (e.g. methods named provides class `PS4Controller` The the and buttons, the of each for )`getSquareButtonReleased` ,`getSquareButtonPressed` feature rumble The .`PS4Controller.Button.kSquare.value` with accessed be can indices `PS4Controller.setRumble(GenericHID.` using by controlled be can controller the of .value) `RumbleType.kRightRumble`,

### POV 16.3.5



1- read or angles different 8 of one select can that hat directional a is POV the joysticks, On careful Be POV. a as same the works padD- XboxController/PS4Controller The unpressed. for they ensure to user the for hard is it as requirements angle exact with POV a using when desired. angle the exactly select

### Usage `GenericHID` 16.3.6

above) classes the of any using not (if `index)` `getRawAxis(int.` with used be can axis An as axis an of index the each are example this in one and Zero value. current the returns that above. mentioned Station Driver the in found

Java

```
    );kLeftMotorPortPWMSparkMax(Constants. new = m_leftMotor PWMSparkMax final private
  );kRightMotorPortPWMSparkMax(Constants. new = m_rightMotor PWMSparkMax final private
 m_ DifferentialDrive(m_leftMotor, new = m_robotDrive DifferentialDrive final private
                                                                     rightMotor); ↪
          );kJoystickPortGenericHID(Constants. new = m_stick GenericHID final private

                  ));1(getRawAxism_stick. ),0(getRawAxism_stick.-(arcadeDrivem_robotDrive.
```

C++

```
                              kLeftMotorPort};::m_leftMotor{Constants PWMVictorSPX::frc
                            kRightMotorPort};::m_rightMotor{Constants PWMVictorSPX::frc
                        m_rightMotor}; m_robotDrive{m_leftMotor, DifferentialDrive::frc
                                      kJoystickPort};::m_stick{Constants GenericHID::frc

                  ));1m_stick.GetRawAxis( ),0m_stick.GetRawAxis(-m_robotDrive.ArcadeDrive(
```

Python

```
                                    PWMVictorSPX(LEFT_MOTOR_PORT).wpilib = leftMotor
                                  PWMVictorSPX(RIGHT_MOTOR_PORT).wpilib = rightMotor
               rightMotor) DifferentialDrive(leftMotor,.drive.wpilib = robotDrive.self
                                      GenericHID(JOYSTICK_PORT).wpilib = stick.self

            ))1getRawAxis(.stick.self ),0getRawAxis(.stick.self-arcadeDrive(.robotDrive.self
```

### 16.3.7 Button Usage

□□□□: Usage such as the following is for code not using the command-based framework. For button usage in the command-based framework, see □□□□□ Commands □-Triggers.

Unlike an axis, you will usually want to use the `pressed` and `released` methods to respond to button input. These will return true if the button has been activated since the last check. This is helpful for taking an action once when the event occurs but not having to continuously do it while the button is held down.

Java

```
if (joystick.getRawButtonPressed(0)) {
   turnIntakeOn(); // When pressed the intake turns on
}
if (joystick.getRawButtonReleased(0)) {
   turnIntakeOff(); // When released the intake turns off
}

OR

if (joystick.getRawButton(0)) {
   turnIntakeOn();
} else {
   turnIntakeOff();
}
```

C++

```
if (joystick.GetRawButtonPressed(0)) {
   turnIntakeOn(); // When pressed the intake turns on
}
if (joystick.GetRawButtonReleased(0)) {
   turnIntakeOff(); // When released the intake turns off
}

OR

if (joystick.GetRawButton(0)) {
   turnIntakeOn();
} else {
   turnIntakeOff();
}
```

Python

```
if joystick.getRawButtonPressed(0):
   turnIntakeOn() # When pressed the intake turns on

if joystick.getRawButtonReleased(0):
   turnIntakeOff() # When released the intake turns off

# OR

if joystick.getRawButton(0):
   turnIntakeOn()
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
             :else
turnIntakeOff()
```

should Toggles button. a of press the with off and on something toggle to is request common A state. robot the of track keep to user the require they as caution, with used be

Java

```
                   ;false = toggle boolean

    { ))0(getRawButtonPressed(joystick. if
                          { (toggle) if
off turn so true is state Current //
                    retractIntake();
                     ;false = toggle
                               { else }
on turn so false is state Current //
                     deployIntake();
                      ;true = toggle
                                      }
                                         }
```

C++

```
                       ;}falsetoggle{ bool

    { ))0(joystick.GetRawButtonPressed( if
                          { (toggle) if
off turn so true is state Current //
                    retractIntake();
                     ;false = toggle
                               { else }
on turn so false is state Current //
                     deployIntake();
                      ;true = toggle
                                      }
                                         }
```

Python

```
                            False = toggle

       ):0getRawButtonPressed(.joystick if
                             toggle: if
 off turn so True is state current #
                     retractIntake()
                      False = toggle
                                  :else
 on turn so False is state Current #
                      deployIntake()
                       True = toggle
```

## Preferences Robot Setting 16.4

the on memory flash the in values store to used is class )C++ ,Java( Preferences Robot The calibration as such robot the on preferences remembering for be might values The roboRIO. without change to like would you that etc. setpoints, values, PID potentiometers, for settings Shuffleboard or SmartDashboard on viewed be can values The program. the rebuild to having program. robot the by written and read and

controller PID a of setpoint the change to Preferences utilize to how shows example This ,Java( example Simulation Arm the from adapted are examples code The constant. P the and the use to how see to Simulator Robot the in example Simulation Arm the run can You ).C++ robot. a needing without dashboards the using it with interact and class preference

### Preferences Initializing 16.4.1

Java

```
                        ;"ArmPosition" = kArmPositionKey String final static public
                                      ;"ArmP" = kArmPKey String final static public

                         arm. this drives that controller PID the for gain P The //
                                   ;50.0 = kDefaultArmKp double final static public
                      ;75.0 = kDefaultArmSetpointDegrees double final static public
```

```
                         arm. this drives that controller PID the for gain P The //
                                  ;kDefaultArmKpConstants. = m_armKp double private
        ;kDefaultArmSetpointDegreesConstants. = m_armSetpointDegrees double private
                                                      */ constructor. Subsystem **/
                                                                     { ()Arm public
␣t'don keys the if Preferences to constant P and setpoint position Arm the Set //
                                                                      exist already ↪
         m_armSetpointDegrees); ,kArmPositionKey(Constants.initDoublePreferences.
                             m_armKp); ,kArmPKey(Constants.initDoublePreferences.
                                                                                  }
```

C++

```
                   ;"ArmPosition" = kArmPositionKey string_view::std constexpr static
                                 ;"ArmP" = kArmPKey string_view::std constexpr static

                                        ;50.0 = kDefaultArmKp double constexpr static
                     deg;_75.0 = kDefaultArmSetpoint degree_t::units constexpr static
```

```
                                                                         { Arm()::Arm
         keys the if Preferences to constant P and setpoint position Arm the Set //
                                                             exist already t'don //
              m_armSetpoint.value()); InitDouble(kArmPositionKey,::Preferences::frc
                                   m_armKp); InitDouble(kArmPKey,::Preferences::frc
                                                                                    }
```

like constant, a in key the store to helpful It's key. the name, a using stored are Preferences avoid and times multiple it typing avoid to above code the in `kArmPKey` and `kArmPositionKey` from retrieved data the hold to `armPositionDeg` and `kArmKp` variables, declare also We typos. preferences.

The database. Preferences the in exists already it if see to checked is key each ,`robotInit` In exists already key that for data if check to key the parameter, one takes method `containsKey` `setDouble` The written. is value default a exist, doesn't it If database. preferences the in similar are There write. to data the and write to key the parameters, two takes method strings. and ints, booleans, like types data other for methods

a of constructor the in placed be could code of type this Framework, Command the using If Command. or Subsystem

### Preferences Reading 16.4.2

Java

```
                                          { ()loadPreferences void public
                    Teleop entering on kP and setpoint Arm for Preferences Read //
     m_ ,kArmPositionKey(Constants.getDoublePreferences. = m_armSetpointDegrees
                                                          armSetpointDegrees); ↪
              { m_armKp)) ,kArmPKey(Constants.getDoublePreferences. =! (m_armKp if
                   m_armKp); ,kArmPKey(Constants.getDoublePreferences. = m_armKp
                                          (m_armKp);setPm_controller.
                                                                         }
                                                                           }
```

C++

```
                                            { ()Arm::LoadPreferences void
                     Teleop entering on kP and setpoint Arm for Preferences Read //
                                          degree_t{::units = m_armSetpoint
      m_armSetpoint.value())}; GetDouble(kArmPositionKey,::Preferences::frc
                 { m_armKp)) GetDouble(kArmPKey,::Preferences::frc =! (m_armKp if
                      m_armKp); GetDouble(kArmPKey,::Preferences::frc = m_armKp
                                              m_controller.SetP(m_armKp);
                                                                           }
                                                                             }
```

read, to key the parameters, two takes method `getDouble` The easy. is preference a Reading for methods similar are There exist. doesn't preference the case in use to value default a and strings. and ints, booleans, like types data other

as such it, read you when it use can you preferences, in stored is that data the on Depending the as such later, it use and variable a in it store can you Or above. constant proportional the below. `telopPeriodic` in used is which setpoint,

Java

```
                                                                    @Override
                                               { ()teleopPeriodic void public
                                            { ())getTrigger(m_joystick. if
                               normal. like control PID run we Here, //
                                                  ();reachSetpointm_arm.
                                                                { else }
                                   motor. the disable we Otherwise, //
                                                        ();stopm_arm.
                                                                    }
                                                                      }
```

```
*/ preferences. the from setpoint the maintain and reach to loop control the Run **/
                                                       { ()reachSetpoint void public
                                                                  = pidOutput var
                                                       (calculatem_controller.
   (m_armSetpointDegrees));degreesToRadiansUnits. (),getDistancem_encoder.
                                                    (pidOutput);setVoltagem_motor.
                                                                                  }
```

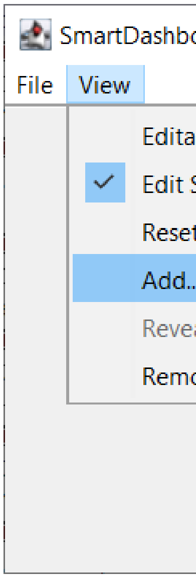
C++

```
                                                        { ()Robot::TeleopPeriodic void
                                                      { (m_joystick.GetTrigger()) if
                                          normal. like control PID run we Here, //
                                                            m_arm.ReachSetpoint();
                                                                            { else }
                                               motor. the disable we Otherwise, //
                                                                     m_arm.Stop();
                                                                                   }
                                                                                     }
```

```
                                                           { ()Arm::ReachSetpoint void
                  from read setpoint a with normal, like control PID run we Here, //
                                                          degrees. in preferences //
                                          m_controller.Calculate( = pidOutput double
             radian_t{m_armSetpoint}.value()));::(units m_encoder.GetDistance(),
                                       volt_t{pidOutput});::m_motor.SetVoltage(units
                                                                                     }
```

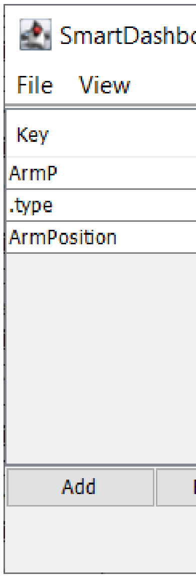
## SmartDashboard in Preferences Using 16.4.3

### SmartDashboard in Preferences Displaying



*View* selecting by display the to added be can display Preferences the SmartDashboard, the In stored file preferences the of contents the reveals This .*Preferences Robot* then *Add…* then memory. flash roboRIO the in

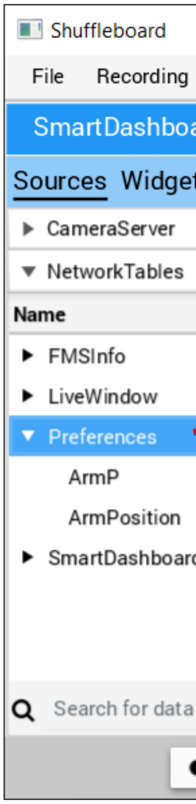
### SmartDashboard in Preferences Editing



be to need values the If code. the from values default the with here shown are values The saved. and here edited be can they adjusted

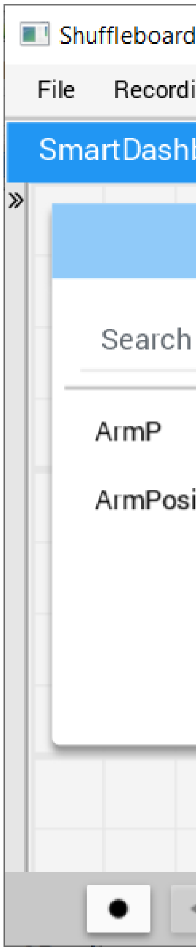
## Shuffleboard in Preferences Using 16.4.4

## Shuffleboard in Preferences Displaying



the dragging by display the to added be can display Preferences the Shuffleboard, In preferences the of contents the reveals This window. sources the from field preferences memory. flash roboRIO the in stored file

**Shuffleboard in Preferences Editing**

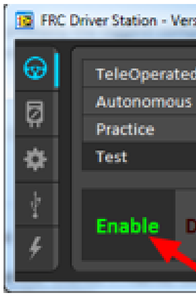


be to need values the If code. the from values default the with here shown are values The here. edited be can they adjusted

## Mode Test Using 16.5

all that verify to code put to place a have to programmers enable to designed is mode Test place a is there templates program robot the of each In functioning. are robot the on systems robot. the to code test add to

### Mode Test Enabling 16.5.1



teleop. or autonomous like just Station Driver the from enabled be can robot the on mode Test
The robot. the enable and button ”Test“ the select Station, Driver the in mode test enable To
run. then will code mode test

### Mode Test in LiveWindow 16.5.2

sensor all and Dashboard the on controlled be can outputs actuator all LiveWindow, With
added are actuators and sensors The tuned. be also can Controllers PID seen. be can values
for *Window Live and Mode Test SmartDashboard:* See necessary. is code no automatically,
details. more

### code robot your to code mode Test Adding 16.5.3

run is method `testPeriodic` the and once, run is method `testInit` the mode, test in When
modes. control autonomous and teleop to similar ,`robotPeriodic` to addition in tick, per once

Test. from methods Teleop written already your calling as painless as be can mode test Adding
before mode, Test in run only is that feature new a out try to code special write can you Or
all move to code write even could You code. autonomous or teleop your into it integrating
crew! pit the help to sensors all check and motors

> that code LiveWindow the with interfere may it code, test own your write you If :□□□□□
> `LiveWindow.` call to need may You automatically. enabled is and actuators control can
> this. avoid to method testInit your in `setEnabled(false)`

## Stacktraces Reading 16.6

`occurred. has error unexpected An`

some in up show message this see will you error, unexpected an hits code robot your When
abruptly robot your notice also probably You’ll RioLog). or Station (Driver output console
.*exceptions unhandled* called are errors unexpected These move. never possibly or stop,

which bugs more or one has code your that means it occurs, exception unhandled an When
fixed. be to need

those fixing and finding in involved techniques and tools the of some explore will article This
bugs.

## Trace“? ”Stack a What’s 16.6.1

printed been has *trace stack* a that signal a is message `occurred has error unexpected` The out.

which about information store to used is structure data *stack call* the C++, and Java In executed. being currently is method or function

exception unhandled the when stack this on was what about information prints *trace stack* A problem the before just running were which code of lines the to you points This occurred. usually it’s issue, your of *cause root* exact the to you point always doesn’t it While happened. looking. start to place best the

## Exception“? ”Unhandled an What’s 16.6.2

continue cannot processor the where arises which condition any is error unrecoverable An started and compiled code the though even that, implies always almost It code. executing continue. to execution for sense makes longer no it running,

correctly isn’t that code is exception unhandled an of cause root the cases, all almost In malfunctioned. has hardware any that implies never almost It implemented.

## Issue? My Fix I Do How So 16.6.3

### Trace Stack the Read

trace. stack the for `occurred has error unexpected` the above search start, To

Java

this: like something look should it Java, In

```
     java.lang. exception: Unhandled frc.robot.Robot.robotInit(Robot.java:24): at Error
                                                              NullPointerException ↪
                              frc.robot.Robot.robotInit(Robot.java:24) at
      edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:94) at
               edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:335) at
    edu.wpi.first.wpilibj.RobotBase.lambda$startRobot$0(RobotBase.java:387) at
                       java.base/java.lang.Thread.run(Thread.java:834) at
```

here: of out pick to things important few a There’s

- `Error` an was There
- `exception Unhandled` an to due was error The
- `java.lang.NullPointerException` a was exception The
- `Robot.java` of inside 24 line running while happened error The
    - happened. error the when executing method the of name the was `robotInit`
- code) team’s your (AKA, package `frc.robot.Robot` the in function a is `robotInit`
- `edu.wpi.first.wpilibj` the from functions of number a from called was `robotInit` libraries) WPILib the (AKA, package

time the at *stack* the of state the represent `at` word the with starting lines indented of list The
right method the *by called* was which method, one represents line Each happened. error the
it. below

entries more see might you codebase, your inside deep happened error the If example, For
stack: the on

```
     ␣exception: Unhandled frc.robot.Robot.buggyMethod(TooManyBugs.java:1138): at Error
                                              java.lang.NullPointerException ↪
                    frc.robot.Robot.buggyMethod(TooManyBugs.java:1138) at
                                   frc.robot.Robot.barInit(Bar.java:21) at
                                   frc.robot.Robot.fooInit(Foo.java:34) at
                               frc.robot.Robot.robotInit(Robot.java:24) at
      edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:94) at
               edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:335) at
    edu.wpi.first.wpilibj.RobotBase.lambda$startRobot$0(RobotBase.java:387) at
                       java.base/java.lang.Thread.run(Thread.java:834) at
```

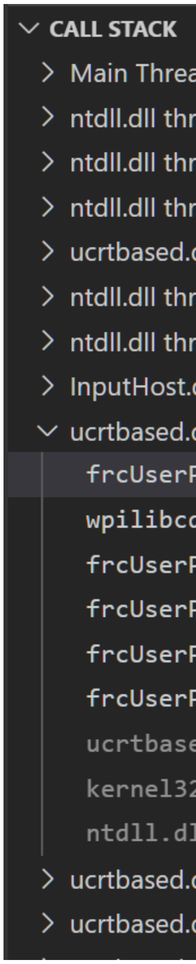
called turn in which ,`barInit` called turn in which ,`fooInit` called `robotInit` case: this In
`NullPointerException` the ,`buggyMethod` of execution the during Then, .`buggyMethod`
occurred.

C++

will C++ issues. into run programs when automatically traces stack produce usually will Java
to need will debugger stepsingle- a Usually, info. same the extract to digging more require
program. robot executing the to up hooked be

Code: VS of tab debugger the in found be can traces Stack

this: to similar look generally will C++ in traces Stack



here: of out pick to things important few a There’s

- paused. currently is execution code The
- `exception` an having thread one was paused it reason The
- `Robot.cpp` of inside `20` line running while happened error The
  - happened. error the when executing method the of name the was `RobotInit`
- code) team’s your (AKA, namespace `Robot::` the in function a is `RobotInit`
- the (AKA, namespace `frc::` the from functions of number a from called was `RobotInit` libraries) WPILib

happened. error the time the at *stack* the of state the represents window stack“ ”call This it. below right method the *by called* was which method, one represents line Each

the with simulation, in examples code running are you assume page this in examples The apply should techniques Similar errors. unexpected for watching and connected debugger robot. real a on running while

### Analysis Code Perform

the triggering are which code of lines the found and trace, stack the found you've Once cause. root determining of process the start can you exception, unhandled

notice may You fruitful. be will code in location problematic the near) (or in looking just Often, referencing. you're example an match don't which lines or forgot, you things

---

luck more have often will code with working experience of lots have who Developers **:□□□□** come will experience The discouraged! be don't ok, That's folks. newer than code at looking time. with

---

questions: following the ask to is code analyzing for strategy key A

- error)? particular this have didn't (I.e., "worked" code the time last the was When
- now? and version, working last the between code the in changed has What

effective. more strategy particular this make help changes code careful and testing Frequent

### Debugger Step Single the Run

is *debugger stepsingle-* The issue. the spot to enough isn't code at looking just Sometimes, the to up leading events of series the inspect to you allows it - case this in option great a exception. unhandled

### Information More for Search

Searches errors. of cause root the understanding for resource phenomenal a is Google good yield often will exception the of name the and language programming the involving potential and about, comes it how means, error the what for explanations more on results fixes.

### Help Outside Seeking

When online). and personin- (both others from help and advice out seek can you fails, else all If the provide to important very it's codebase, your with familiar aren't who folks with working information: following

- )*github.com on* (EX: code, source your to Access
- trace. stack full the including error, the of **text full** The

## Patterns & Examples Common 16.6.4

exceptions. runtime in result which issues common of number a are There

### References and Pointers Null

has which something indicate to it use they - ”null“ of concept the have Java and C++ Both meaningful. anything to refer not does and initialized, been yet not

error. runtime a produce will reference ”null“ a Manipulating

code: following the consider example, For

Java

```
                    armMotorCtrl; PWMSparkMax

                                    @Override
                     { ()robotInit void public
           );true(setInvertedarmMotorCtrl.
                                            }
```

C++

```
         { TimedRobot::frc public : Robot class
                                        :public
              { override RobotInit() void
         );falseSetInverted(>-motorRef
                                             }

                                       :private
         ;}0m_armMotor{ PWMVictorSPX::frc
             motorRef; *PWMVictorSPX::frc
                                            ;}
```

this: like looks that output see you’ll run, When

Java

```
                              ********** starting program Robot **********
   java.lang. exception: Unhandled frc.robot.Robot.robotInit(Robot.java:23): at Error
                                                      NullPointerException ↪
                                 frc.robot.Robot.robotInit(Robot.java:23) at
    edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:107) at
              edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:373) at
            edu.wpi.first.wpilibj.RobotBase.startRobot(RobotBase.java:463) at
                                        frc.robot.Main.main(Main.java:23) at

  ␣robot The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:388): at Warning
                   error. code a to due usually is This unexpectedly. quit program ↪
                 occurred. error the where determine help can stacktrace above The
                             information. more for https://wpilib.org/stacktrace See
           ␣The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:395): at Error
        ␣the handled have should it) by called methods (or method startCompetition() ↪
                                                                  above. exception ↪
```

`robotInit()` the of inside happened issue the that see can you trace, stack the Reading Pointer“. ”Null involved exception the and 23, line on function,

.`armMotorCtrl` - null be could which thing one only is there see can you 23, line to going By never but declared, is object `armMotorCtrl` the that see can you up, further Looking instantiated.

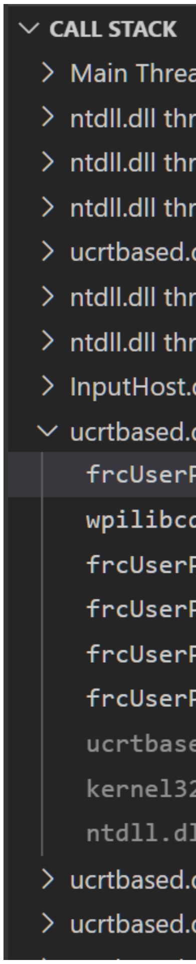
when stop and debugger, step single the with code of lines through step can you Alternatively, null. is it that show would point that at object `armMotorCtrl` the Inspecting 23. line hit you

C++

```
                       W32/0xc0000005 occurred: has Exception
              violation. access read thrown: exception Unhandled
                                     nullptr. was this->motorRef
```

above the in 20 line to points that window debugger a in up show will this Simulation, In code. buggy

Code: VS in tab debugger the clicking by trace stack full the view can You



value. a assigned never but declared, was `motorRef` variable member our - specific is error The exception the operator, `>-` the using method a call to it use to attempt we when Therefore, occurs.

.`nullptr` was type its states exception The

### Issues Object Null Fixing

In it. using before initialized been has reference each ensure to want will you Generally, the calling before `armMotorCtrl` the instantiate to code of line missing a is there case, this method. `setInverted()`

this: like look could implementation functional A

Java

```
                    armMotorCtrl; PWMSparkMax

                                    @Override
                      { ()robotInit void public
      );0PWMSparkMax( new = armMotorCtrl
         );true(setInvertedarmMotorCtrl.
                                            }
```

C++

```
{ TimedRobot::frc public : Robot class
                                  :public
    { override RobotInit() void
     m_armMotor;& = motorRef
);falseSetInverted(>-motorRef
                              }

                                 :private
;}0m_armMotor{ PWMVictorSPX::frc
    motorRef; *PWMVictorSPX::frc
                                       ;}
```

### Zero by Divide

Most results. reasonable expect and zero, by integer an divide to possible generally not is It Exception. Unhandled an raise will roboRIO) the (including processors

code: following the consider example, For

Java

```
                       armLengthRatio; int
                 ;39 = elbowToWrist_in int
     TODO// ;0 = shoulderToElbow_in int

                                 @Override
                   { ()robotInit void public
shoulderToElbow_in; / elbowToWrist_in = armLengthRatio
                                         }
```

C++

```
{ TimedRobot::frc public : Robot class
                                  :public
                { override RobotInit() void
shoulderToElbow_in; / elbowToWrist_in = armLengthRatio
                                         }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```

                                                                  :private
                                                     armLengthRatio; int
                                               ;39 = elbowToWrist_in int
                                   TODO// ;0 = shoulderToElbow_in int

                                                                      ;}
```

this: like looks that output see you’ll run, When

Java

```
                                          ********** starting program Robot **********
    java.lang. exception: Unhandled frc.robot.Robot.robotInit(Robot.java:24): at Error
                                                      zero by / ArithmeticException: ↪
                                      frc.robot.Robot.robotInit(Robot.java:24) at
      edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:107) at
                edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:373) at
              edu.wpi.first.wpilibj.RobotBase.startRobot(RobotBase.java:463) at
                                           frc.robot.Main.main(Main.java:23) at

   ␣robot The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:388): at Warning
                            error. code a to due usually is This unexpectedly. quit program ↪
                          occurred. error the where determine help can stacktrace above The
                                      information. more for https://wpilib.org/stacktrace See
           ␣The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:395): at Error
       ␣the handled have should it) by called methods (or method startCompetition() ↪
                                                                        above. exception ↪
```

`zero by / java.lang.ArithmeticException:` a see can we trace, stack the at Looking the on used are which variables two the at look you If 24. line on occurred has exception zero. to initialized been has them of one notice might you operator, = the of side handright-the in used is variable valuezero- the Furthermore, it! update to forgot someone like Looks happens. error zero by divide the Hence, operation. division a of denominator

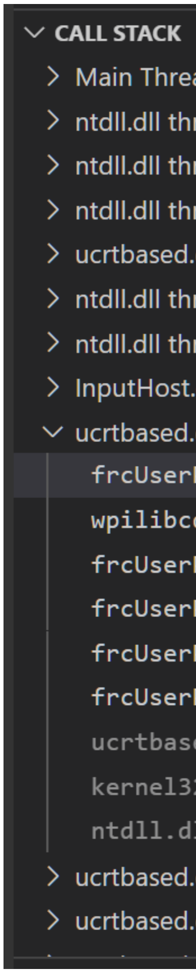
inspect could you 24, line on stopping and debugger stepsingle- the running by Alternatively, the value of all variables to discover `shoulderToElbow_in` has a value of `.0`

C++

```
                                              W32/0xc0000094 occurred: has Exception
  ␣Integer 0xC0000094: frcUserProgram.exe: in 0x00007FF71B223CD6 at exception Unhandled
                                                                        zero. by division ↪
```

above the in 20 line to points that window debugger a in up show will this Simulation, In code. buggy

Code: VS in tab debugger the clicking by trace stack full the view can You



```
CALL STACK
  Main Threa
  ntdll.dll thr
  ntdll.dll thr
  ntdll.dll thr
  ucrtbased.
  ntdll.dll thr
  ntdll.dll thr
  InputHost.
  ucrtbased.
    frcUser
    wpilibc
    frcUser
    frcUser
    frcUser
    frcUser
    ucrtbas
    kernel3
    ntdll.d
  ucrtbased.
  ucrtbased.
```

you If `.zero by division Integer` as described is error the see we message, the at Looking 20, line on operator = the of side handright- the on used are which variables two the at look update to forgot someone like Looks zero. to initialized been has them of one notice might you operation. division a of denominator the in used is variable valuezero- the Furthermore, it! happens. error zero by divide the Hence,

operating an on or roboRIO, the on different slightly look might messages error the that Note windows. than other system

### Issues Zero By Divide Fixing

thinking by start to important It's ways. of number a in fixed be can issues Zero By Divide it did Why plausible? it Is .*means* calculation your of denominator the in zero a what about saw? you case particular the in happen

0. than other number different a use to need just you Sometimes,

this: like look could implementation functional A

Java

```
                                        armLengthRatio; int
                                    ;39 = elbowToWrist_in int
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                        ;3 = shoulderToElbow_in int

                                                          @Override
                                       { ()robotInit void public

           shoulderToElbow_in; / elbowToWrist_in = armLengthRatio

                                                                  }
```

C++

```
                        { TimedRobot::frc public : Robot class
                                                      :public
                                  { override RobotInit() void
       shoulderToElbow_in; / elbowToWrist_in = armLengthRatio
                                                            }

                                                     :private
                                       armLengthRatio; int
                                    ;39 = elbowToWrist_in int
                                    3 = shoulderToElbow_in int

                                                            ;}
```

can calculation the around statements `if/else` adding value, valid a *is* zero if Alternatively, zero. by division a perform processor the making avoid to behavior alternate define you help

- issue the around get you help can `double` or `float` be to types variable changing Finally, by-divide- a of results the represent to NaN like values special have numbers pointfloating- that consumes which code in this handle to have still may you However, operation. zero value. calculation's

### Allocated Already Resource HAL

hardware- two put to attempts code the when occurs error specificFRC- common very A pin). IO roboRIO (usually, resource HAL same the on entities related

code: following the consider example, For

Java

```
                                 leftFrontMotor; PWMSparkMax
                                  leftRearMotor; PWMSparkMax

                                                  @Override
                               { ()robotInit void public
                    );0PWMSparkMax( new = leftFrontMotor
                     );0PWMSparkMax( new = leftRearMotor
                                                          }
```

C++

```
                     { TimedRobot::frc public : Robot class
                                                   :public
                               { override RobotInit() void
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                        );0.5m_frontLeftMotor.Set(
                                                        );0.25m_rearLeftMotor.Set(
                                                                                  }

                                                                              :private
                                              ;}0m_frontLeftMotor{ PWMVictorSPX::frc
                                               ;}0m_rearLeftMotor{ PWMVictorSPX::frc

                                                                                   ;}
```

this: like looks that output see you'll run, When

Java

```
                                               ********** starting program Robot **********
edu.wpi.first. exception: Unhandled frc.robot.Robot.robotInit(Robot.java:25): at Error
                                         1029- Code: hal.util.AllocationException: ↪
                                                  allocated. previously 0 DIO or PWM
                                                allocation: previous the of Location
                                    frc.robot.Robot.robotInit(Robot.java:24) at
     edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:107) at
               edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:373) at
             edu.wpi.first.wpilibj.RobotBase.startRobot(RobotBase.java:463) at
                                         frc.robot.Main.main(Main.java:23) at

                                                 allocation: current the of Location
                  Method) edu.wpi.first.hal.PWMJNI.initializePWMPort(Native at
                              edu.wpi.first.wpilibj.PWM.<init>(PWM.java:66) at
               edu.wpi.first.wpilibj.motorcontrol.PWMMotorController.<init> at
                                                  (PWMMotorController.java:27) ↪
 edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax.<init>(PWMSparkMax.java:35) at
                                    frc.robot.Robot.robotInit(Robot.java:25) at
     edu.wpi.first.wpilibj.TimedRobot.startCompetition(TimedRobot.java:107) at
               edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:373) at
             edu.wpi.first.wpilibj.RobotBase.startRobot(RobotBase.java:463) at
                                         frc.robot.Main.main(Main.java:23) at

   ␣robot The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:388): at Warning
                         error. code a to due usually is This unexpectedly. quit program ↪
                       occurred. error the where determine help can stacktrace above The
                                 information. more for https://wpilib.org/stacktrace See
           ␣The edu.wpi.first.wpilibj.RobotBase.runRobot(RobotBase.java:395): at Error
        ␣the handled have should it) by called methods (or method startCompetition() ↪
                                                                    above. exception ↪
```

occurred. has `edu.wpi.first.hal.util.AllocationException` a that shows trace stack This .`allocated. previously 0 DIO or PWM` message: helpful the gives also It

first the that shows trace stack first The traces. stack two see we trace, stack our at Looking *actually* error the that shows trace stack second The .`Robot.java:25` in occurred allocation Halfway code. own our in looking by start should we However, WPILib. within deep happened that code robot team's the of line last the to reference a find can you trace, stack the through .`Robot.java:25` WPILib: into called

declared is controller motor first the where is 24 line see we code, the at peek a Taking *both* that note also can We declared. is controller motor second the where is 25 line and isn't and sense, logical make doesn't This .`0` output PWM to assigned are controllers motor and message error custom a generates purposely WPILib Therefore, possible. physically configuration. hardware achievablenon- a of developers software the alert to exception

C++

messages get you'll Instead, issue. this from stacktrace a see specifically won't you C++, In following: the like look which

```
                              allocated. previously 0 DIO or PWM [C::31]: PWM at Error
                                                  allocation: previous the of Location
                               [0xb6f01b68] 0x50 + bool) frc::PWM::PWM(int, at
  ␣frc::PWMMotorController::PWMMotorController(std::basic_string_view<char, at
                                  [0xb6ef7d50] 0x70 + int) ,> std::char_traits<char> ↪
                   [0xb6e9af1c] 0x3c + frc::PWMVictorSPX::PWMVictorSPX(int) at
     ␣0xa8 + Robot**) frc::impl::RunRobot<Robot>(wpi::priority_mutex&, void at
                                                                           [0x13718] ↪
                             [0x13c9c] 0x3d4 + frc::StartRobot<Robot>() int at
                                     [0xb57ec580] 0x114 + libc_start_main__ at

                                        0 Channel allocation:: current the of Location
                                                    [0xb6e81b5c] 0x5fb5c +  at
                              [0xb6f01e4c] 0x334 + bool) frc::PWM::PWM(int, at
  ␣frc::PWMMotorController::PWMMotorController(std::basic_string_view<char, at
                                  [0xb6ef7d50] 0x70 + int) ,> std::char_traits<char> ↪
                   [0xb6e9af1c] 0x3c + frc::PWMVictorSPX::PWMVictorSPX(int) at
     ␣0xb4 + Robot**) frc::impl::RunRobot<Robot>(wpi::priority_mutex&, void at
                                                                           [0x13724] ↪
                             [0x13c9c] 0x3d4 + frc::StartRobot<Robot>() int at
                                     [0xb57ec580] 0x114 + libc_start_main__ at

␣to due usually is This unexpectedly. quit program robot The Error: RunRobot: at Error
                                                                       error. code a ↪
                   occurred. error the where determine help can stacktrace above The
                             information. more for https://wpilib.org/stacktrace See

    ␣0x1c8 + Robot**) frc::impl::RunRobot<Robot>(wpi::priority_mutex&, void at
                                                                           [0x13838] ↪
                             [0x13c9c] 0x3d4 + frc::StartRobot<Robot>() int at
                                     [0xb57ec580] 0x114 + libc_start_main__ at

                    'frc::RuntimeError' of instance an throwing after called terminate
                                         allocated. previously 0 DIO or PWM  what():
                                                  allocation: previous the of Location
                               [0xb6f01b68] 0x50 + bool) frc::PWM::PWM(int, at
  ␣frc::PWMMotorController::PWMMotorController(std::basic_string_view<char, at
                                  [0xb6ef7d50] 0x70 + int) ,> std::char_traits<char> ↪
                   [0xb6e9af1c] 0x3c + frc::PWMVictorSPX::PWMVictorSPX(int) at
     ␣0xa8 + Robot**) frc::impl::RunRobot<Robot>(wpi::priority_mutex&, void at
                                                                           [0x13718] ↪
                             [0x13c9c] 0x3d4 + frc::StartRobot<Robot>() int at
                                     [0xb57ec580] 0x114 + libc_start_main__ at

                                        0 Channel allocation:: current the of Location
```

string That .`allocated. previously 0 DIO or PWM` string, the is here notice to thing key The usage. 0 pin on up" "doubled incorrectly has code in something that clue primary your is

it simulation, in running are you If roboRIO. a on generated was above example message The different. look might

## Issues Allocated Already Resource HAL Fixing

Just fix. to errors straightforward most the of some are `allocated already Resource HAL:` what’s to that compare and robot, the on wiring electrical the at looking time of bit a spend code. in

Therefore, `.1` and `0` ports PWM into plugged are controllers motor left the example, the In this: like look would code corrected

Java

```
                  leftFrontMotor; PWMSparkMax
                   leftRearMotor; PWMSparkMax

                                    @Override
                 { ()robotInit void public

             );0PWMSparkMax( new = leftFrontMotor
              );1PWMSparkMax( new = leftRearMotor

                                            }
```

C++

```
                          17 :start-lineno:

        { TimedRobot::frc public : Robot class
                                     :public
               { override RobotInit() void
              );0.5m_frontLeftMotor.Set(
              );0.25m_rearLeftMotor.Set(
                                       }

                                    :private
   ;}0m_frontLeftMotor{ PWMVictorSPX::frc
    ;}1m_rearLeftMotor{ PWMVictorSPX::frc

                                         ;}
```

## recognized… not is gradlew

that error common a is command `external or internal an as recognized not is gradlew` `gradlew` a contain not does in currently are you that directory or project the when occur can directory. wrong the open you when occurs usually This file.

files. many contain not does sidebar handleft- the that see can you screenshot, above the In project. your deploy and build properly to files of couple a needs Code VS minimum, a At

- `gradlew`
- `build.gradle`
- `gradlew.bat`

possible two have you then directory, project your in files above the of one any see not do you If causes.

- project. bad or corrupt A
- directory. wrong the in are You

## recognized... not is gradlew Fixing

problem the identify First fix. to problem easy fairly a is `recognized... not is gradlew` source:

directory correct the is directory project the that Verify - **directory? wrong the in you Are** this. open and

The solve. to complex more is issue This - **files? essential missing project your Is** in. code necessary copy manually and *project your recreate* to is solution recommended

## Data as Functions Treating 16.7

when do to learns anyone things first the of one language, programming of Regardless ”subroutine“). a or ”method“ a as known (also function a write to is computer a programming avoid us lets functions writing - code organized of part fundamental a are Functions duplicated writing of Instead again. over and over code of piece same the duplicating from execute to want we code the contains that function single a call we code, of sections to easier also is name function the well, function the named we (provided places multiple about information additional some needs code of section the If itself!). code the than read needs it if and ”parameters“, as function the to those pass we run, to context surrounding its value“ ”return a that call we finishes, it once code the of rest the to back something yield to ”signature“); function’s the called are value return and parameters the (together,

code. the of part another to code the of part one from functions pass to need we Sometimes, a of part as functions of thinking to used we’re if concept, strange a like seem might This just are functions level, basic a at But right. own their in objects than rather definition class around it pass and variable a as `double` a or `integer` an store can we way same the in - data function a is value whose variable A function. a with thing same the do can we program, our C++. in ”functor“ or pointer“ ”function a and Java, in interface“ ”functional a called is

### Data? as Functions Treat to Want We Would Why 16.7.1

function. the of definition the on) (depends to coupled is function a calls that code Typically, function the *calling* code the when problematic becomes it time, the all occurs this While code the of knowledge direct without and independently developed is WPILib) example, (for this solve we Sometimes team). FRC an from code example, (for function the *defines* that functions and data of collections define which interfaces, class of use the through challenge a on dependency a have only really we often However, together. used be to meant are that .*class entire* an on than rather ,*function single*

joystick a whenever code certain execute to users for ways several offers WPILib example, For *a pass* to user the allow to is this do to ways cleanest and easiest the of one - pressed is button code the write to has only user the way, This methods. joystick WPILib the of one to *function* not and arm“) robot my ”move (e.g., things specificteam- and interesting the with deals that standard a from inputs button read (”properly thing universal and prone,error- boring, the joystick“).

to refer that objects `Command` on built is *framework basedCommand-* the example, another For as (such types `Command` included the of Many classes. `Subsystem` various on defined methods with associated functions just not - function *any* with work )`RunCommand` and `InstantCommand` passing support to need we generically, commands building support To .`Subsystem` single a interacts (which `Command` a to hardware) the with interacts (which `Subsystem` a from functions scheduler). the with

were it if as data, of piece a as function single a pass to able be to want we cases, these In really we when class, entire an provide to user the ask to sense make doesn’t it - variable a function. shapedappropriately- single a us give to them want just

call we When function. a *calling* as same the not is function a *passing* that important It’s some cause value, return a receive either and it of inside code the execute we function, a particular in nothing function, a *pass* we When both. or code, the in elsewhere effectsside- to code *other* some allowing are we function the passing by Instead, *immediately*. happens mean always not does code in function a of name the Seeing *future. the in* function the call run! being is function the in code the that name the to refers either that syntax some see will we function, a passes that code of Inside of inside passed be to function new a defines else or way, special a in function existing an of which on depends it) around rules the (and needed syntax specific The expression. call the using. are we language programming

## Java in Data as Functions Treating 16.7.2

”functional A .interfaces functional of instances as dataas-functions- represents Java originally was Java since - method single a only has that class of kind special a is interface“ single a representing of way no has it programming, orientedobject- for strictly designed *only* that classes of group particular a defines it Instead, class. a from detached function interface, functional own its has signature function of type Each functions. single represent signature. that of definition function single a with interface an is which

worry to need really don’t we WPILib of context the in but complicated, sound might This internal is that does that code the - themselves interfaces functional the using about much a to written we’ve that function a pass to how is know to need we all Instead, WPILib. to the consider example, simple a For parameter. a as interface functional a takes that method scheduled, when that, `InstantCommand` an creates (which `Commands.runOnce` of signature terminates): then and once function given the runs

---

and ,*documentation basedCommand-* the in explained is parameter `requirements` The :□□□□ here. discussed be not will

---

```
requirements) Subsystem... action, (RunnablerunOnce CommandBase static public
```

Java the is `Runnable` A ).`action` (named parameter `Runnable` a it give to us expects `runOnce` ,`runOnce` call we When value. no returns and parameters no takes that function a for term to ways two are There value. return no and parameters no with function a it give to need we define can we or reference“, ”method a using function existing some to refer can we this: do expression“. ”lambda a using inline want we function the

### References Method

:`Runnable` our as function existingalready- an pass us lets reference method A

```
␣`drivetrain` the of method `resetEncoders` the runs that InstantCommand an Create //
                                                                          object ↪
        drivetrain); runOnce(drivetrain::resetEncoders, = disableCommand Command
```

of method `resetEncoders` the to reference a is `drivetrain::resetEncoders` expression The the reset *itself* not does code of line this - *call* method a not is It object. `drivetrain` the *scheduled. is it when* so do will that `Command` a returns it Instead, drivetrain. the of encoders

must it is, that - `Runnable` a be must `resetEncoders` work, to this for order in that Remember this: like look must signature its So, value. no return and parameters no take

```
list parameter empty an has and parameters, no returns it because void //
                                                 ()resetEncoders void public
```

method the interpret to able be not will Java this, match not does signature function the If make is do to need we all that Note compile. not will code the and `Runnable` a as reference functional `Runnable` the in method single the of signature the matches signature the that sure .`Runnable` a as it name *explicitly* to need don’t we - interface

### Java in Expressions Lambda

function a define can we want, we what does that function named a have already not do we If function our writing by this do We !`runOnce` to call the of inside right means, that - ”inline“ function the to list argument the link to symbol ”arrow“ an uses that syntax special a with body:

```
                    speed half at forward drive the runs that InstantCommand an Create //
   ␣,} );0.0 ,0.5(arcadeDrivedrivetrain. { >- runOnce(() = driveHalfSpeed Command
                                                                   drivetrain); ↪
```

may it expression“; ”lambda a `} 0.0); drivetrain.arcadeDrive(0.5, { >- ()` calls Java function“ ”anonymous or function“, ”inline function“, ”arrow an called confusinglyless- be writing of way another just is it funky, bit a look may this While name). no has it (because code the and list, argument function’s the are arrow the before parentheses the - function a a represents here expression“ ”lambda The body. function the is brackets the in contained again note - parameters of set specific a with `drivetrain.arcadeDrive` calls that function be to `Command` the to it passes and it defines merely but function, the *call* not does this that scheduled. is `Command` the when later run

a as expression lambda the name *explicitly* to need not do we references, method with As signature its as long so `Runnable` a is expression lambda our that infer can Java - `Runnable` takes lambda our Accordingly, interface. `Runnable` the in method single the of that matches our contract, `Runnable` the match not did it if - statement return no has and arguments no compile. to fail would code

### Expressions Lambda Java in State Capturing

function the of outside lives that object an references body function our example, above the In the from variable a of ”capture“ a called is This object). `drivetrain` the (namely, itself Usually scope“). ”enclosing or scope“ ”outer the called sometimes is (which code surrounding which in body method enclosing the from variables local either are variables captured the that which in definition class enclosing an of fields else or defined, is expression lambda the defined. is method

can we caveat: major one with general, in do to thing safe fairly a is state capturing Java In variable a capture to legal only is it means That final“. ”effectively is that state capture only that Note initialization. after reassigned never is variable that if scope enclosing the from are objects Java that Remember change: cannot state captured the that mean not does this the but - capture after change may *to points* reference the that object the so references, object. another to point to made be cannot itself reference

they’re if )`boolean` and ,`double` ,`int` (like types primitive capture only can we means This *a in wrapped be must* it change, can that variable state a capture to want we If constants. .*object mutable*

### Expressions Lambda Java for Sugar Syntactic

with help To cases. some in verbose needlessly be can syntax expression lambda full The the of some where cases in sugar“) ”syntactic (called shortcuts some take us lets Java this, redundant. is notation

### Lambdas LineOne- for Brackets Body Function Omitting

brackets the omit us lets Java line, one only is expression lambda our of body function the If semicolons trailing omit also we brackets, function omitting When body. function the around keyword. *return* the And

written: be instead could above lambda `Runnable` our So,

```
 speed half at forward drive the runs that InstantCommand an Create //
drivetrain); ),0.0 ,0.5(arcadeDrivedrivetrain. >- runOnce(() = driveHalfSpeed Command
```

### Parameters Lambda Single around Parentheses Omitting

we argument, single a only takes that interface functional a for is expression lambda the If list: parameter the around parenthesis the omit can

```
argument single its around parenthesis no with lambda this write can We //
                   (a));println.outSystem. >- (a = exampleLambda IntConsumer
```

## C++ in Data as Functions Treating 16.7.3

only we’ll article, this of sake the For data. as functions treat to ways of number a has C++ WPILibC. using to relevant are that parts the about talk

https://en.( class `std::function` the with represented are types function WPILibC, In templated is class library standard This ).cppreference.com/w/cpp/utility/functional/function template a as type function a it provide to have we means that - signature function’s the on have we where above, *Java* to this (compare function the of signature the specify to parameter signature). of kind each for type interface separate a

signature call the at look Let’s practice. in use to is it than complicated more lot a sounds This given the runs scheduled, when that, `InstantCommand` an creates (which `cmd::RunOnce` of terminates): then and once function

and ,*documentation basedCommand-* the in explained is parameter `requirements` The :□□□□ here. discussed be not will

```
                                        (RunOnce CommandPtr
                              action, >()void<function::std
           requirements); >*Subsystem<initializer_list::std
```

A ).action (named parameter `><void()std::function` a it give to us expects `runOnce` and parameters no takes that `std::function` a for type C++ the is `><void()std::function` and parameters no with type function a is ,`void()` parameter, template (the value no returns

no return value). When we call `runOnce`, we need to give it a function with no parameters and no return value. C++ lacks a clean way to refer to existing class methods in a way that can be automatically converted to a `std::function`, so the typical way to do this is to define a new function inline with a "lambda expression".

## Lambda Expressions in C++

To pass a function to `runOnce`, we need to write a short inline function expression using a special syntax that resembles ordinary C++ function declarations, but varies in a few important ways:

```
// Create an InstantCommand that runs the drive forward at half speed
CommandPtr driveHalfSpeed = cmd::RunOnce([this] { drivetrain.ArcadeDrive(0.5, 0.0); }, {drivetrain});
```

C++ calls `[captures] (params) { body; }` a "lambda expression". It has three parts: a *capture list* (square brackets), an optional *parameter list* (parentheses), and a *function body* (curly brackets). It may look a little strange, but the only real difference between a lambda expression and an ordinary function (apart from the lack of a function name) is the addition of the capture list.

Since `RunOnce` wants a function with no parameters and no return value, our lambda expression has no parameter list and no return statement. The "lambda expression" here represents a function that calls `drivetrain.ArcadeDrive` with a specific set of parameters - note again that the above code does not *call* the function, but merely defines it and passes it to the `Command` to be run later when the `Command` is scheduled.

## Capturing State in C++ Lambda Expressions

In the above example, our function body references an object that lives outside of the function itself (namely, the `drivetrain` object). This is called a "capture" of a variable from the surrounding code (which is sometimes called the "outer scope" or "enclosing scope"). Usually the captured variables are either local variables from the enclosing method body in which the lambda expression is defined, or else fields of an enclosing class definition in which that method is defined.

C++ has somewhat more-powerful semantics than Java. One cost of this is that we generally need to give the C++ compiler some help to figure out *exactly how* we want it to capture state from the enclosing scope. This is the purpose of the *capture list*. For the purposes of using the WPILibC Command-based framework, it is usually sufficient to use a capture list of `[this]`, which gives access to members of the enclosing class by capturing the enclosing class's `this` pointer by value.

Method locals cannot be captured with the `this` pointer, and must be captured explicitly either by reference or by value by including them in the capture list (or implicitly by specifying a default capture semantics). It is typically safer to capture locals by-value, since a lambda can outlive the lifespan of an object it captures by reference. For more details, consult the C++ standard library documentation on capture semantics.

# 71

[redacted]

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## 17.1 תיעוד נוסף

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]:

- [illegible] [illegible] FRC [illegible]-NI
- [illegible] [illegible] [illegible] FIRST
- [illegible] [illegible] [illegible] [illegible] CTRE
- REV Robotics Documentation

## 17.2 פורומים

[illegible]? [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]? [illegible] [illegible] [illegible] [illegible] [illegible]:

- NI FRC Support Forum (roboRIO, LabVIEW and Driver Station software questions)
- [illegible] [illegible] [illegible] [illegible] FIRST ([illegible] [illegible] [illegible], [illegible] [illegible]-Driver Station)
- [illegible] [illegible] [illegible] FIRST ([illegible] [illegible] [illegible] [illegible]-C++, Java [illegible] LabVIEW)

## 17.3 תמיכת CTRE

[illegible] [illegible] [illegible] Cross The Road Electronics ([illegible] [illegible] [illegible], PDP, Talon SRX [illegible]-VRM [illegible] [illegible] [illegible] support@crosstheroadelectronics.com.

## Robotics REV תמיכה 17.4

Power Hub, Pneumatic Sensors, MAX, (SPARK components Robotics REV for Support the via or 2267255-844- at phone via provided is Module) Power Radio Hub, Distribution .support@revrobotics.com address email

## ספקים נוספים 17.5

.[illegible] [illegible] [illegible] KoP-[illegible] [illegible] [illegible] [illegible] [illegible]

- Copperforge
- (NavX) Labs Kauai
- Limelight
- (Discord) PhotonVision
- Fusion with Playing

## תמיכה לא רשמית 17.6

[illegible] [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible]-[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] FIRST® [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible]

- Delphi Chief
- Discord FRC

## דיווח על באגים 17.7

https: GitHub:-[illegible] [illegible] WPILibSuite-[illegible] [illegible] Issue [illegible] [illegible] [illegible] ?[illegible] [illegible] //github.com/wpilibsuite

# 81

# [redacted]

**[illegible] [illegible]**

.[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

**[illegible]**

.[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

**EMFback-**

coil a in magnets spinning of interaction the by generated force the motors, electric In motion. spinning opposes which wire of

**boolean**

the represent to intended false), or (true values possible two only with data of form A algebra. Boolean and logic of values truth two

**stack call**

what of track keep program the helps which memory of region organizedspecially- A to added and recorded is point call the another, calls function each As in. is it function variables local Additionally, references. of ”stack“ a forming structure, the of top the info. more for Wikipedia on stack call See stack. this in stored be also will

**theorem limit central**

are variables independent many when that states which probability in concept core A regardless distribution, Gaussian) (or ”normal“ a like look to tends result the up, added Central See distributed. normally are themselves variables independent the whether of info. more for Wikipedia on Theorem Limit

**Mechanics Classical**

large, relatively of motion the describes and studies which physics of branch The info. more for Wikipedia on Mechanics Classical See objects. slow relatively

**COTS [illegible]**

available commonly part order) custom not (i.e. standard a shelf, the off Commercial purchase. for teams all to vendor a from

**composition**

smaller of out entities software ”composing“) (or building for term software formal A info. more for Wikipedia on composition object See entities. component

**CRTP**

derives $X$` class a which in idiom software A - Pattern Template Recurring Continuously on CRTP See argument. template a as itself *X*` using instantiation template class a from info. more for Wikipedia

**C++**

.□□□□□□ □□□□□□□□ □□□□□□□ □□□□□ □□□□□□□ □□□

**programming declarative**

than rather do, should program a *what* describing on focuses which software of style A info. more for Wikipedia on programming declarative See done. gets it *how*

**injection dependency**

upon. depends it objects all receives class each where pattern design software A dependency See always. not but constructor, the through passed are these Sometimes info. more for Wikipedia on injection

**□□□□□□ □□□□**

Deprecated features. new receive longer no will and replaced been has that Software For that. after removed be may but year, 1 least at for maintained be will software 2022 the in usable be will it season, 2022 the to prior deprecated is method a if example, use not to encouraged are Teams season. 2023 the to prior removed be may but season, year one least at features deprecates always WPILib code. new in methods deprecated codebase. the from them removing to prior

**pattern design**

intentionally pattern design A code. organizing of style chosenintentionally- particular, A into developers constrain to language programming a of features certain using excludes on pattern. design See space.problem- particular a to suitedwell- are that solutions info. more for Wikipedia

**DHCP**

assign to device central a allows that protocol the Protocol, Configuration Host Dynamic devices. other all to addresses IP unique

**encapsulation**

other of details implementation the hide to class a uses which pattern design software A info. more for Wikipedia on encapsulation See classes.

**entry**

active, always is subscriber The .*subscriber* and *publisher* combined a ,*NetworkTables* In is value a (e.g. performed is operation publish a until created not is publisher the but a maintaining than convenient more be may This entry). the on published, aka ”set“, subscriber. and publisher separate

**enumeration**

values. definedpre- of set a to refer to used typically set, a of elements all of list A

**programming drivenevent-**

some of result a as ”events“ generate code of parts certain where programming of style A to respond and for listen code of parts other Then, etc). interaction, user (sensors, input info. more for Wikipedia on basedevent- See events. these ”handle“

**point floating**

fixed a using arithmetic, basedcomputer- in numbers real approximating for method A support systems computer Typically exponent. integer an by scaled integer precision floating storage) bit(64- precision ”double“ and storage) bit(32- precision ”single“ both 754. IEEE by defined as values, point

**FMS**

Robotics FIRST□ □□□□ □□ □□□□□□ □□□□□ □□□□□□□ □□□□□□□□□□ □□□□□□ ,□□□□ □□□□□ □□□□□ Competition.

**FPGA**

many of consisting circuit integrated specialized a - array gate programmableField-
its allows This patterns. different in act to configured be can which elements, logic digital
Instruments National FRC, of context the In manufacturing. after changed be to behavior
the process to it allows which FPGA RIO’s the for configuration specific a provides
info. more for Wikipedia on FPGA See rate. high very a at outputs and inputs electrical

**GradleRIO**

roboRIO. the to code robot of deployment the powers that mechanism The

**□□□□’□**

to measurements rotation the up add can It rotation. of rate measures that device A
short) for (“gyro”, robot. the of *heading* determine

**□□□□□**

degrees. in angle an as expressed usually pointed, is robot the direction The

**programming imperative**

step, by step doing, be should code the *what* on focuses that programming of style A
info. more for Wikipedia on programming imperative See loop. every

**IMU**

a and *accelerometer* an both combines that sensor a Unit, Measurement Inertial
sensor. single a into *gyroscope*

**Java**

.□□□□□ □□□□□□□□ □□□□□□□ □□□□□ □□□□□□□ □□□

**JSON**

values. named into data organizing of way standardized A Notation. Object JavaScript
Javascript, in was usage original the While .*serialized* easily be can data organized The
on JSON See languages. programming modern most by interested and used be can it
info. more for Wikipedia

**KOP**

the to distributed checklists, Kit Kickoff the on listed items of collection the Parts, of Kit
Donation Product a with shipping) (except completely for paid or Choice, FIRST via team
(PDV). Voucher

**KOP □□□□**

out) opt not did (that team every to distributed (chassis) base drive a contains KOP The
.AM14U5 the is chassis KOP the season, 2023 the For .*KOP* the of part as

**LabVIEW**

.□□□□□ □□□□□□□□ □□□□□□□ □□□□□ □□□□□□□ □□□

**NetworkTables**

programs. between data communicate to system messaging subscribepublish- A

**mass**

in changes resist will mass more with Objects object. physical a in matter of amount the
info. more for Wikipedia on mass See mass. less with objects than more motion

**inertia of moment**

is mass that how and has, it mass much how both describes that object an of property The
inertia of moments higher with Objects rotation. of axis certain a to relative distributed
inertia. of moments lower with objects than more motion rotational in changes resist
the moving or mass, more adding by accomplished is inertia of moment the Increasing
for Wikipedia on inertia of moment See rotation. of axis the from away further mass
info. more

**mutable**

created. is it after modified be can that object An

**motor DC magnetpermanent-**

of type This competition. robotics FIRST the for motors legal all of classification The
this turn, In field. magnetic a create to it uses and input, as current direct takes motor
output the turns that force a create to magnet physical a with interacts field magnetic
the ensure to used are means (”brushed“) mechanical or (”brushless“) Electrical shaft.
forces creates that direction a in points always field magnetic generatedelectrically-
See rotates. shaft motor’s the as even magnet, physical the with interacts it when
info. more for Wikipedia on motor magnetpermanent-

**persistent**

startup. at restored and server the by file a to saved is that *topic* a ,*NetworkTables* In

**property**

updated and stored *topic* a about (metadata) information named ,*NetworkTables* In
A properties. of number any have may topic A data. topic’s the from separately
JSON. in represented be can that type data any be can value property’s

**publisher**

timestamped sends and creates and *topic* a defines that object an ,*NetworkTables* In
values. data

**pose**

is body rigid a how describes that information rotation and position of collection The
point. reference fixed some to relative space, in oriented

**RAII**

Java) in not but C++, (in behavior language a Initialization; Is Acquisition Resource
lifetime. object to tied is resource a holding where

**reflectionretro-**

rather at, in came it angle same the at back light incoming reflecting of property The
FRC Most it. scattering or it, absorbing mirror), a (like angle incident an than
more for Wikipedia on retroreflector See reflective.retro- are targets processing vision
information.

**composition recursive**

same the of components contain may object composite the which in *composition* of type A
groups. command more or one contain may group command a example, For itself. as type
.*composition recursive* also See info. more for Wikipedia on composition recursive See

**retained**

stop publishers all after even server the by alive kept is that *topic* a ,*NetworkTables* In
publishing.

**serialized**

be to data the of description the allows that scheme organization data a of property The
file a writing or Reading channel. communication some over byte, by byte order, in sent
all not byte, by byte written or read is data the (IE, fashion serial this in done is disk on
requiring again byte, by byte done also is bus I2C or SPI a over data Sending once). at
serialized. be can data the

**[illegible]**

.[illegible]

**library software**

software See software. other by used and into imported be can that code of collection A
info. more for Wikipedia on library

**valve solenoid**

speaking, Strictly electromagnet. small a by actuated is which valve controllingairflow- A
the is *valve* the and electromagnet, the forms which wire of coil the is *solenoid* the
valve and solenoid of set the However, airflow. redirects actually which mechanism
more for Wikipedia on .valve solenoid See solenoid“. ”a called simply often is together
info.

**machine state**

defined,well- discrete, many into problem a divides that construct programming A
between moving by solved is problem the how defines then ”states“, exclusivemutually-
info. more more for Wikipedia on machine state See states. different

**subscriber**

or one to updates value data timestamped receives that object an ,*NetworkTables* In
s.*topic* more

**telemetry**

robot your of performance the about data timereal- sending and recording of process The
”tele“ are roots word’s the us, among linguists the For file. log or readout timereal- a to
info. more for Wikipedia on telemetry See (measurement). ”metry“ and (remote)

**□□□□□**

consists and (teleop) Period Teleoperated the called is match each of phase second The
robots. their controlling drivers of

**topic**

channel. data named a ,*NetworkTables* In

**torque**

rotation of axis some from distance a at applied force A

**□□□□□**

the along point each at accelerations and velocities with curve, smooth a is trajectory A
field. the on endpoints two connecting curve,

**transitory**

publishing. stops *publisher* last the after disappear will that *topic* a ,*NetworkTables* In

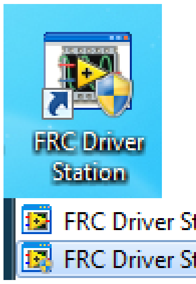
[redacted]

## LabVIEW NI by Powered Station Driver FRC 19.1

NI by Powered Station Driver FRC® the of features and use the describes article This LabVIEW.

.*document this* see software Station Driver the installing on information For

### Station Driver FRC the Starting 19.1.1



by or Desktop the on icon the clickingdouble- by launched be can Station Driver FRC The Station. Driver >FRCPrograms- >AllStart- selecting

---

be also can It .*Dashboard LabVIEW* the launches Station Driver FRC the default By :□□□□ .*Shuffleboard* and *SmartDashboard* Dashboards: other the launch to *Tab Setup* on configured Shuffleboard. and SmartDashboard use to *installed* be must WPILib

---

## Shortcuts Key Station Driver 19.1.2

- refresh. Joystick a Force - *F1*
- keyboards) most on Enter above keys 3 (the robot the Enable - *\ + ] + [*
- Robot the Disable - *Enter*
- roboRIO the triggered is stop emergency an After robot. the Stop Emergency - *Space* again. enabled be can robot the before rebooted be to need will

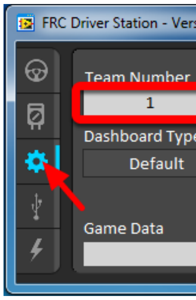
---

focus has window Station Driver the if of regardless robot the StopE- will bar Space **:□□□□** not or

---

StopE- Station Team the press must teams match, a in FMS to connected When **:□□□□□** shortcuts key StopE- and enable/disable DS the as robot their stop emergency to button ignored. are

## Station Driver the Up Setting 19.1.3



Team Number
1

do to order In robot. your to connect to order in number team your to set be should DS The return Press box. number team the in number team your enter then tab Setup the click this effect. take to setting the for box the outside click or

already, robot the to connect to DS the for settings network correct the have typically will PCs DHCP. to set is adapter Network your sure make not, if but

## Pane Status 19.1.4

always is and display the of center the in located is Station Driver the of Pane Status The the about information critical of selection a displays It selected. tab the of regardless visible robot: and DS the of state

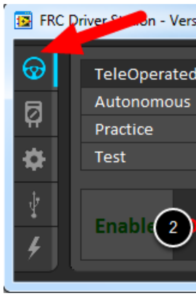
your match should This for. configured currently is DS the number Team The - # Team 1. Tab. Setup the see number team the change To number. team FRC

this roboRIO the with communicating and connected is DS the If - Voltage Battery 2. over voltage of chart small a with and number a as voltage battery current displays when red turn will indicator numeric the of background The icon. battery the in time *Current Understanding and Brownout roboRIO* See triggered. is brownout roboRIO the information. more for *Draw*

DS. the for items status major display indicators three These - Indicators Status Major 3. the with communicating currently is DS the whether indicates ”Communications“ The and TCP the for half in split is (it roboRIO the on Task Communications Network FRC Code Robot team the whether shows indicator Code“ ”Robot The communication). UDP robot the in Task Station Driver the not or whether by (determined running currently is one least at if shows indicator ”Joysticks“ The voltage), battery the updating is code DS. the by recognized and in plugged is joystick

the indicating message status overall an provides String Status The - String Status 4. Code“, Robot ”No Communication“, Robot ”No are examples Some robot. the of state is brownout roboRIO the When Enabled“. ”Teleoperated and Stopped“, ”Emergency Brownout“. ”Voltage display will this triggered

## Tab Operation 19.1.5



status key additional provide and robot the of mode the control to used is Tab Operations The running. is robot the while indicators

Mode. Robot the controls section This - Mode Robot 1.

the of portion Teleoperated the in code the run to robot the causes Mode Teleoperated match. •

the of portion Autonomous the in code the run to robot the causes Mode Autonomous match. •

match FRC an as transitions same the through cycle to robot the causes Mode Practice setup the on found be can mode practice for (timing pressed is button Enable the after tab). •

can match regular a in run doesn't that code test where mode additional an is *Mode Test* tested. be •

*Station Driver* also See robot. the disable and enable controls These - Enable/Disable 2. *.Shortcuts Key*

enabled. been has robot the time of amount the Indicates - Time Elapsed 3.

in. plugged is PC the whether and battery PC DS of state current Indicates - Battery PC 4.

PC. DS the of Utilization CPU the Indicates - CPU% PC 5.

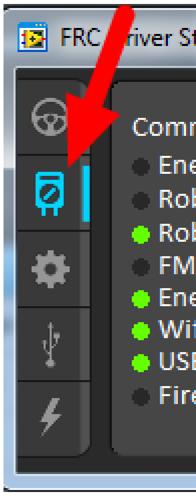
to user the allows Classmate the on account Driver the on not When - Mode Window 6. (rectangle). docked and (arrow) floating between toggle

the to transmit to station team the sets FMS, to connected not When - Station Team 7. robot.

---

will 2 and 1 sections in controls the System Management Field the to connected When :□□□□ out. greyed be will 7 Section in control the and Connected FMS words the by replaced be

## Tab Diagnostics 19.1.6



diagnose to use can teams that indicators status additional contains Tab Diagnostics The robot: their with issues

number. Version Station Driver the Indicates - Version DS 1.

Image. roboRIO the of version the indicating String - Version Image roboRIO 2.

use. in WPILib of version the indicating String - Version WPILib 3.

to connected devices of version firmware the indicating String - Versions Device CAN not has Framework Phoenix CTRE the if present be not may items These bus. CAN the loaded. been 4.

memory. roboRIO the about stats shows section This - Stats Memory 5.

various to status connection show indicators these of half top The - Indicators Connection components. 6.

- port. ethernet the to connected something has computer the indicates Link" "Enet
- 10.XX.YY.1. at bridge wireless robot the to status ping the indicates Radio" "Robot
- a of fallback a (with mDNS using roboRIO the to status ping the indicates "Robot" address). 10.TE.AM.2 static
- ping a NOT is (this FMS from packets receiving is DS the if indicates "FMS" indicator).

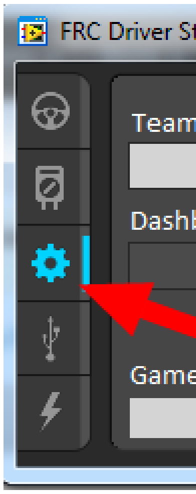
network of status indicates indicators of section second The - Indicators Network communication purposes; informational for provided are These firewalls. and adapters may be established even with one or more unlit indicators in this section. 7.

- adapter Ethernet detected the of address IP the indicates "Enet"
- enabled as detected been has adapter wireless a if indicates "WiFi"
- detected been has connection USB roboRIO a if indicates "USB"
- will firewalls Enabled enabled. as detected are firewalls any if indicates "Firewall" Private) = Prv Public, = Pub Domain, = (Dom orange in show

(after roboRIO the of reboot remote a perform to attempts button This - roboRIO Reboot dialog). confirmation a through clicking 8.

(but robot the on running code the restart to attempts button This - Code Robot Restart 9.
OS). the restart not

## Tab Setup 19.1.7



the of operation the control to use can teams buttons of number a contains Tab Setup The
Station: Driver

name mDNS the controls This Number. Team FRC your contain Should - Number Team 1.
show will arrow dropdown the on clicking Shift at. be to robot the expects DS the that
purposes. troubleshooting for network the on detected names roboRIO all

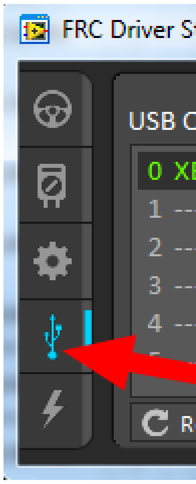
*Default* Station. Driver the by launched is Dashboard what Controls - Type Dashboard 2.
information more (for Storage.ini“ Data DS ”FRC the by to pointed file the launches
Program the in Dashboard.exe is this default By ).*dashboard custom* a setting about
the at dashboard a launch to attempts *LabVIEW* folder. Dashboard (x86)\FRC Files
default the to back fall will but dashboard, LabVIEW built custom a for location default
respective the launch *Shuffleboard* and *SmartDashboard* found. is dashboard no if
forwards *Remote* installation. WPILib Java and C++ the with included dashboards
field. *IP Dashboard* in specified IP the to data dashboard LabVIEW

entered Text API. Data Game the of testing home at for used be can box This - Data Game 3.
to connected When Side. Robot the on API Data Game the in appear will box this into
automatically. field the by populated be will data this FMS,

practice the of portion each of timing the control boxes These - Timing Mode Practice 4.
automatically DS the mode practice in enabled is robot the When sequence. mode
bottom. to top from indicated modes the through proceeds

Practice the when sounded are tones audio whether controls button This - Control Audio 5.
used. is Mode

## Tab Devices USB 19.1.8



DS the to connected Devices USB the about information the includes tab Devices USB The

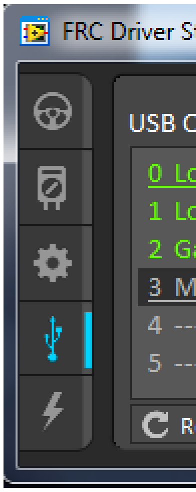
DS. the to connected devices USB compatible all of list a contains This - List Setup USB 1.
the before *s 2 put and green in name the highlight will device a on button a Pressing
name device

disabled, is robot the While devices. USB the of Rescan a force will button This - Rescan 2.
a force To list. the to them add and devices new for scan automatically will DS the
to connected when as (such Enabled is robot the while scanre- to or scanre- complete
button. this use or F1 press match) a during FMS

and buttons Axes, the of status current the show indicators These - indicators Device 3.
joystick. the of POV

appear. will control Rumble the controllers) BoxX- as (such devices XInput For - Rumble 4.
”Right is bar top The device. the of functionality rumble the test to used be can This
the along anywhere holding and Clicking Rumble“. ”Left is bar bottom the and Rumble“
= rumble full is right 0, = rumble no is (left proportionally rumble the activate will bar
code. robot in set value Rumble the indicate not will and only control a is This 1).

## Devices Locking and ArrangingRe-



is This slot. specific a into device USB a ”locking“ of capability the has Station Driver The by triggered be also can and position new a to dragged is device the if automatically done the under underline an with up show will devices ”Locked“ device. the on clicking double the to connected not is device the when even slot its reserve will device locked A device. unconnected (and unlocked be can Devices underlined). and out grayed as (shown computer entry. the on clicking double by removed) devices

---

long as position their maintain should they device, same the of more or two have you If **:□□□□** you If in. locked were they ports same the in computer the into plugged remain devices all as If device. the not port, the follow should lock the devices identical two of ports the switch the swapping) of instead port new a into it plug and device one (take ports the arrangere- you the of more or one unplug you If slots). swap may devices (the determinate not is behavior locked proper the to return should they move; may others the of positions the devices, of set slots when all devices are reconnected.

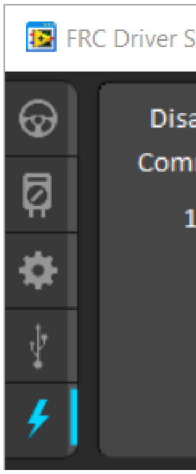
---

devices: 4 shows above image The Example:

- unless position this in stay will device This joystick. 3“ Attack ”Logitech Locked A unlocked or else somewhere dragged
- joystick 3D“ Extreme ”Logitech unlocked An
- gamepad F310 Logitech a is which (Controller)“ F310 ”Gamepad unlocked An
- Xbox MadCatz a is which (Controller)“ GamePad ”MadCatz disconnected but Locked, A Controller 360

Gamepad F310 the in result will joystick 3D Extreme Logitech the unplugging example, this In 2 and 1 Slots in devices the if (even Gamepad MadCatz the in Plugging 1. slot to up moving 3. Slot occupying it in result will empty) are slots those and removed are

## Tab CAN/Power 19.1.9



contains tab This Tab. Power CAN/Robot the is DS the of side left the on tab last The bus: CAN the of status the and roboRIO the of status power the about information

DS the since occurred have that faults Comms of number the Indicates - Faults Comms 1.
connected been has

occurred have that (Brownouts) faults power input of number the Indicates - Faults 12V 2.
connected been has DS the since

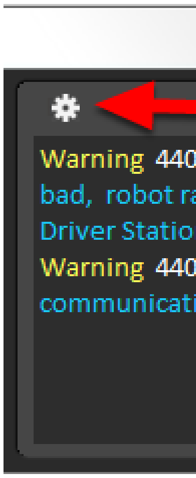
circuits) short by caused (typically faults of number the Indicates - Faults 6V/5V/3.3V 3.
connected been has DS the since Rails Voltage User the on occurred have that

bus CAN the of utilization percentage the Indicates - Utilization Bus CAN 4.

has DS the since faults CAN of types 4 the of each of counts the Indicates - faults CAN 5.
connected been

turn will above) image the in blue in (shown tab this for indicator the detected, is fault a If red.

## Tab Messages 19.1.10

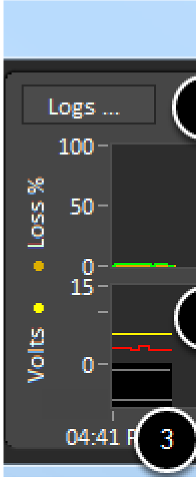


Warning 440
bad, robot ra
Driver Statio
Warning 440
communicati

the and/or Code, User WPILib, DS, the from messages diagnostic displays tab Messages The
displayed. are Errors only default, By severity. by filtered are messages The roboRIO.

will that menu a display will This icon. Gear the click tab, Messages the for settings access To
Errors+Warnings+Prints), or Errors+Warnings (Errors, level detail the select to you allow
Log DS the launch or messages, viewing for window Console larger a launch box, the clear
Viewer.

## Tab Charts 19.1.11



diagnose teams help to status robot of indicators advanced displays and plots tab Charts The
issues: robot

right) the on axis the (against green in milliseconds in time trip charts graph top The 1.
left). the on axis the (against orange in second per packets lost and

roboRIO left), the on axis the (against yellow in voltage battery plots graph bottom The 2.
on line continuous a as mode Requested DS right), the on axis the (against red in CPU
it. above line discontinuous a as mode robot and chart the of bottom the

the in modes Reported Robot and Requested DS the for used colors the shows key This 3.
chart. bottom

Charts. DS the of scale time the change controls These - scale Chart 4.

.*Viewer File Log DS* the launches button This 5.

be to robot the commanding is Station Driver the that mode the is mode Requested DS The
methods reporting on based running actually is code what is mode Reported Robot The in.
language. each for frameworks coding the in contained

### Tab Both 19.1.12

side. by side Charts and Messages displays which tab Both the is side right the on tab last The

## Practices Best Station Driver 19.2

James Chong, Juan from contributions with Peterson, Steve by created was document This Ryan and Ross, Joe Roadfeldt, Chris Picone, Chris McKaskle, Greg Kosbab, Rick Henry,Cole- .here found be can posts upfollow- and post original The Sjostrand.

Robotics FIRST the at team your for stopper a isn't station driver the ensure to Want easy an is laptop station driver solid a configuring and Building field? (FRC) Competition lessons find to on Read competition. your and day build stop between time the for project matches. of thousands over teams many by learned

### Competition The For Departing To Prior 19.2.1

1. dedicated A do. teams Many station. driver a as solely used be to laptop a Dedicate at compete to ready being – goal one for configuration the manage you allows machine Station Driver providedFRC- the except software other no means Dedicated field. the running. or installed Dashboard associated and software

2. durable more much They're Why? station. driver your for laptop classbusiness- a Use around banged being survive They'll Buy. Best at special Friday Black $300 the than the and drivers, device quality higher have laptops classBusiness- competition. the at your makes This laptops. consumer than period longer a for maintained are drivers popular two are Latitude Dell and series T ThinkPad Lenovo longer. last investment for thousands are There competitions. at see commonly you'll brands classbusiness- level entry good a is kits rookie recent in provided laptop The eBay. on day every sale vision with more do they as displays bigger to it from graduate often Teams machine. dashboards. and

3. dashboard and Station Driver FRC® The new. than rather laptops used Consider instead, – laptop new a buy to need don't you so resources, system few very uses software computer used a by donated one get even might You one. used old year 54- cheap a buy area. your in store

4. features recommended Laptop
   - RAM of 4GB – RAM
   - 1440x1050. of resolution minimum with greater, or 13" of size display A
   - Ports
     1. The port. sizedfull- a it's that Ensure preferred. highly is port Ethernet inbuilt- A use. repeated to up hold don't ports Ethernet hinged
     2. extends This connection. Ethernet your make to saver port Ethernet an Use a have you if important particularly is This laptop. the on port the of life the port. Ethernet hinged a with laptop gradeconsumer-
     3. laptop the replace either dodgy, is laptop your on port Ethernet the If Many brand. reputable a from dongle Ethernet USB a buy or (recommended) primarily Ethernet, inbuilt- than reliable less is Ethernet USB that find teams

the in rookies to given dongles The drivers. bad and hardware cheap to due
well. working for reputation a have KOP

minimum ports USB 2 iv.

the at computers onlytouch- on troubleshooting do quickly to hard It’s keyboard. A .
field.

it replace and $50 spend disk, rotating a has laptop the If (SSD). disk statesolid- A .
SSD. a with

OS common most the Being 11. or 10 Windows of release current the to Updated .
Windows for fixed and found be to likely more are bugs competitions, at seen now
versions. Windows older on than 11 and 10

to time you allows This competition. the before week a updates Windows all Install 5.
the open so, do To functions. station driver with interfere not will updates the ensure
updates pending Install date.to-up- you’re that see and page settings Update Windows
date. to up you’re sure make to again check and Reboot not. if

during installing from updates prevent to Updates Windows for Hours“ ”Active Change 6.
Windows >- Security & Update >- Settings >- Start to Navigate hours. competition
time take competition, a to traveling you’re If hours. active Change select then Update,
reboot not does station driver your ensure help will This account. into differences zone
field. the on installing update to due fail or

Windows use Instead, software. antimalware or antivirus party 3rd any Remove 7.
Windows for internet the to connecting only you’re Since 11. or 10 Windows on Defender
station driver your on software install Only low. is risk the updating, software FRC and
interfere might that variables eliminate to is here goal Your driving. for needed that’s
that (”bloatware“) software preinstalled unneeded any Remove operation. proper with
back gaming for machine Steam your as laptop the use Don’t machine. the with came
separate a having as far as go teams Many event. the before night the hotel the at
laptop. programming

These department. IT school’s the from installations 11 or 10 Windows managed Avoid 8.
unwanted with come often and environment school the for built are deployments
operation. robot’s your with interferes that software

power / battery Laptop 9.

powered and battery both for plan power your in sleep to computer the Put off Turn .
operation.

Suspend: Selective USB off Turn .

Options. Power select then tray, the in icon battery/charging the on click Right i.

plan. power your of settings plan the Edit ii.

link. settings power advanced Change the Click iii.

suspend selective USB the disable and settings advanced the in down Scroll iv.
in. Plugged and Battery both for setting

the making after hour an least at for charge a hold can battery laptop the Ensure .
through go to team drive and robot the for time of plenty allows This above. changes
power. mains without station alliance the reach and queue the

roboRIO. the to connecting use for cable Ethernet and USB trusted a Bring 10.

on falling from controllers joystick/gamepad your prevent to relief retention/strain Add 11.
intermittent with issues prevent helps This ports. USB the on yanking and/or floor the
connections. controller

Administrator the of member a be must drive to use you account user Windows The 12.
group.

### Competition The At 19.2.2

.*instructions these* using firewall Windows off Turn 1.

by or switch FiWi- hardware dedicated the using either adapter, FiWi- the off Turn 2.
panel. control Settings Adapter the in it disabling

pit. the in it’s when station driver the Charge 3.

password. the knows team drive the on everyone ensure or passwords login Remove 4.
password the knowing without field the at arrive drivers often how at surprised be You’d
laptop. the for

using startup“, as ”run to set and permanently deployed is code LabView your Ensure 5.
turn you time every code deploy must you If Tutorial. LabView the in instructions the
wrong. it doing you’re on, robot the

getting of chance the minimizes This sites. web related FRC to browsing web Limit 6.
competition. the during malware

any be won’t likely There updates. software do to access internet using on plan Don’t 7.
a contact updates, need do you If quality. in widely varies FiWi- hotel and venue, the in
pit. the in Advisor System Control

### Match Each Before 19.2.3

yours. before match the of end the to prior in logged and on is laptop the sure Make 1.

or Code Studio Visual e.g., – match the during needed aren’t that programs Close 2.
competing. are you when – LabView

station. player each in you for provided is Power field. the to charger laptop your Bring 3.

know never You shelf. station player the to tape loopand-hook- with laptop your Fasten 4.
the blast and issue programming autonomous an have will partner alliance your when
wall.

ports. USB correct the to assigned are controllers and joysticks Ensure 5.

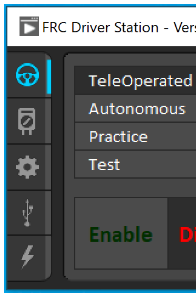
joysticks assign to drop and drag software, Station Driver FRC the in tab USB the In .□
needed. as

green appear not do controllers / joysticks if (F1) button rescan the Use .□

become controllers or joystick if competition during (F1) button rescan the Use .□
competition. during gray turn otherwise or in back plugged are then and unplugged

## Viewer File Log Station Driver 19.3

log creates Station Driver FRC® the debugging, in aid to information provide to effort an In
the using later reviewed be can logs These running. while data diagnostic important of files
in installed shortcut the via found be can Viewer Log The Viewer. Log Station Driver FRC
the in icon Gear the via or Files, Program in folder Station Driver FRC the menuin Start the
Station. Driver



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Driver FRC the to functionality similar provide that exist tools partythird- Several :□□□□
offers WPILib that Note .Reader DSLOG and AdvantageScope including Viewer, Log Station
projects. partythird- for support no

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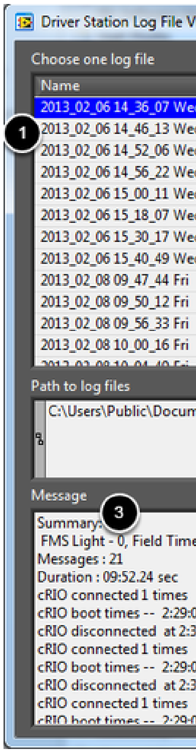
### Logs Event 19.3.1

(not tab Diagnostics the on box Messages the to sent messages all logs Station Driver The
Log viewing When file. Log Event new a into tab) Operation the on box Messages User the
a in overlaid are files DSLog and Log Event the Viewer, File Log Station Driver the with Files
display. single

and date has log Each .`Files Log\FRC\Documents\Public\Users\C:` in stored are files Log
`.dsevents.` and `dslog.` extension with files two has and name file the in timestamp

## UI Viewer Log 19.3.2



Driver Station Log File V

Choose one log file

Name
2013_02_06 14_36_07 We
2013_02_06 14_46_13 We
2013_02_06 14_52_06 We
2013_02_06 14_56_22 We
2013_02_06 15_00_11 We
2013_02_06 15_18_07 We
2013_02_06 15_30_17 We
2013_02_06 15_40_49 We
2013_02_08 09_47_44 Fri
2013_02_08 09_50_12 Fri
2013_02_08 09_56_33 Fri
2013_02_08 10_00_16 Fri

Path to log files

C:\Users\Public\Docum

Message

Summary:
FMS Light - 0, Field Time
Messages : 21
Duration : 09:52.24 sec
cRIO connected 1 times
cRIO boot times -- 2:29:
cRIO disconnected at 2:
cRIO connected 1 times
cRIO boot times -- 2:29:
cRIO disconnected at 2:
cRIO connected 1 times

Driver the of analysis the in aid to displays and controls of number a contains Viewer Log The files: log Station

1. selected currently the in files log available all displays window This - Box Selection File it. select to list the in file log a on Click folder.
2. log for in looking is viewer the folder current the displays box This - Files Log to Path folder the Click in. files log stores Station Driver the that folder the to defaults This files. location. different a to browse to icon
3. When Log. Event the from messages all of summary a displays box This - Box Message that for information the display to changes box this graph the on event an over hovering event.
4. scrolling horizontal for allows bar scroll this in, zoomed is graph the When - Bar Scroll graph. the of
5. The on). to (defaults off and on Filter Voltage the turns control This - Filter Voltage Battery no when time trip and mode robot %, CPU as such data out filters Filter Voltage roboRIO). the with communication in no is DS the that (indicating received is Voltage
6. log. the in data all show to out graph the zooms button This - AutoScale
7. FRC an of length the approximately to graph the scales button This - Length Match of start the locate automatically not does It shown). seconds 30 and minutes (2 match the of beginning the locate to bar scroll the using scroll to have will you match, the mode. Autonomous
8. roboRIO time, trip (voltage, file Log DS the from data graph shows display This - Graph on dots as (shown data event overlaid as well as mode) robot and Packets, Lost CPU%, Hovering graph). entire the across lines vertical as showing events select with graph the

Messages the in event the about information displays graph the on markers event over screen. the of left bottom the in window

screen the of top the at displayed Mode Robot the for Key - Key Mode Robot 9.

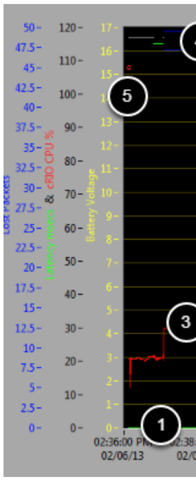
graph the on lines vertical as displayed events, major the for Key - key event Major 10.

data graph the for Key - key Graph 11.

below) explained modes (filter mode filter the select to downDrop- - Control Filter 12.

Event and Time) vs. Events and (Data Graph the between switch to Control - Control Tab 13.
displays. List

### Display Graph the Using 19.3.3



information: following the contains Display Graph The

blue as (displayed second per Packets Lost and line) (green ms in Time Trip of Graphs 1.
of bottom the at line green flat a is Time Trip images example these In bars). vertical packets lost no are there and graph the

line. yellow a as displayed voltage Battery of Graph 2.

line red a as % CPU roboRIO of Graph 3.

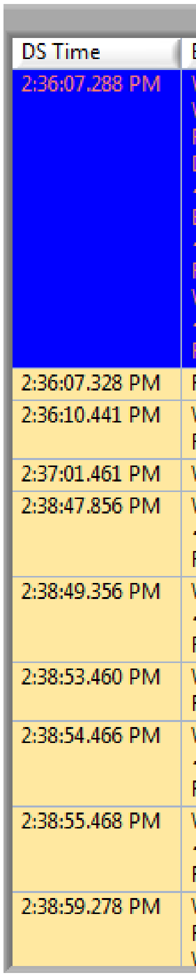
mode the shows display the of set top The mode. DS and mode robot of Graph 4.
the by reported mode the shows set bottom The Station. Driver the by commanded and disabled the during mode it's reporting not is robot the example this In code. robot Teleop. during reported is but modes, autonomous

occurred. event the time the indicating graph the on displayed be will markers Event 5.
marker event an over Hovering yellow. in display will warnings red; in display will Errors the of left bottom the at box Messages the in event the about information display will screen.

display. graph the across lines vertical as shown are events Major 6.

You area. viewing desired the around drag and click graph, the of portion a on in zoom To vertically. zoom cannot you axis, time the zoom only can

### List Event 19.3.4



DS Time
2:36:07.288 PM
2:36:07.328 PM
2:36:10.441 PM
2:37:01.461 PM
2:38:47.856 PM
2:38:49.356 PM
2:38:53.460 PM
2:38:54.466 PM
2:38:55.468 PM
2:38:59.278 PM

Driver the by recorded errors) and (warnings events of list a displays tab List Event The (images filter active currently the by determined are displayed detail and events The Station. active). filter Info“ All Events, ”All shows

### Filters 19.3.5

Viewer: Log the in available currently are filters Three

Driver the by produced warnings and errors the of many out filters filter This Default: 1.
Robot. the on code the by thrown errors identifying for useful is filter This Station.

occurred they time the and events all shows filter This Time: and Events All 2.

the time this At info. recorded all and events all shows filter This Info: All Events, All 3.
shows option this that is Time“ and Events ”All and filter this between difference primary
message. particular a of occurrence first the for designator ”unique“ the

## 19.3.6 Identifying Logs from Matches

A common task when working with the Driver Station Logs is to identify which logs came from competition matches. Logs which were taken during a match can now be identified using the FMS Connected event which will display the match type (Practice, Qualification or Elimination), match number, and the current time according to the FMS server. In this example, you can see that the FMS server time and the time of the Driver Station computer are fairly close, approximately 7 seconds apart.

## 19.3.7 Identifying Common Connection Failures with the Log Viewer

When diagnosing robot issues, there is no substitute for thorough knowledge of the system and a methodical debugging approach. If you need assistance diagnosing a connection problem at your events it is strongly recommended to seek assistance from your FTA and/or CSA. The goal of this section is to familiarize teams with how some common failures can manifest themselves in the DS Log files. Please note that depending on a variety of conditions a particular failure show slightly differently in a log file.

---

**□□□□:** Note that all log files shown in this section have been scaled to match length using the Match Length button and then scrolling to the beginning of the autonomous mode. Also, many of the logs do not contain battery voltage information, the platform used for log capture was not properly wired for reporting the battery voltage.

---

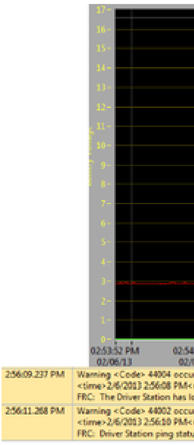
**□□□:** Some error messages that are found in the Log Viewer are show below and more are detailed in the *Driver Station Errors/Warnings* article.

## Log ”Normal“

```
2:46:13.575 PM
2:46:13.617 PM
2:46:16.471 PM
```

first the in contained warnings and errors The log. match normal a of example an is This observing by confirmed is This ignored. be can and started first DS the when from are box that these events occurred prior to the ”FMS Connected:“ event. The last event shown can also be ignored, it is also from the robot first connecting to the DS (it occurs 3 seconds after connecting to FMS) and occurs roughly 30 seconds before the match started.

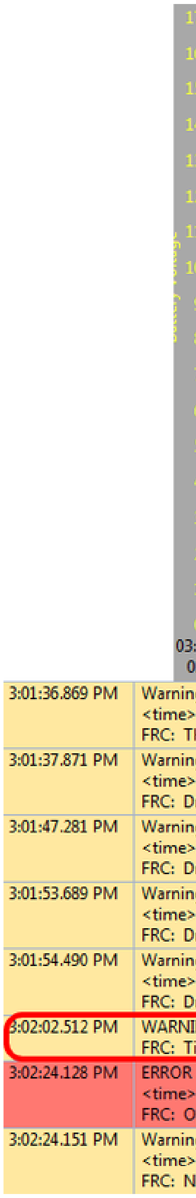
### FMS from Disconnected



```
2:56:09.237 PM   Warning <Code> 44004 occu
                 <time>2/6/2013 2:56:08 PM<
                 FRC:  The Driver Station has lo
2:56:11.268 PM   Warning <Code> 44002 occu
                 <time>2/6/2013 2:56:10 PM<
                 FRC:  Driver Station ping statu
```

segment may it match the during robot, the therefore and FMS, from disconnects DS the When log, first the of event last the are failure this to indicators key The pieces. into log the log 2nd the from event second the and ”bad“ now is FMS to connection the that indicating into transitioning immediately DS the by followed message connected FMS new a is which no with cable ethernet an is failure of type this of cause common most The Enabled. Teleop computer. DS the on port ethernet damaged a or tab latching

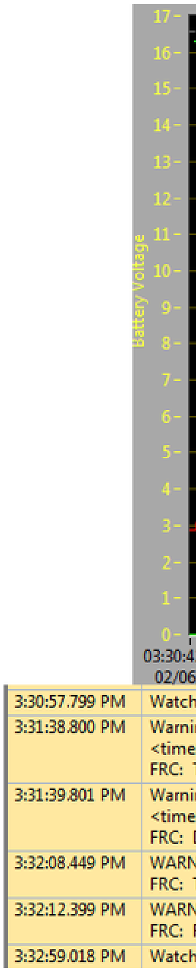
## Reboot roboRIO



```
3:01:36.869 PM  Warnin
                <time>
                FRC: Tl
3:01:37.871 PM  Warnin
                <time>
                FRC: D
3:01:47.281 PM  Warnin
                <time>
                FRC: D
3:01:53.689 PM  Warnin
                <time>
                FRC: D
3:01:54.490 PM  Warnin
                <time>
                FRC: D
3:02:02.512 PM  WARNI
                FRC: Ti
3:02:24.128 PM  ERROR
                <time>
                FRC: O
3:02:24.151 PM  Warnin
                <time>
                FRC: N
```

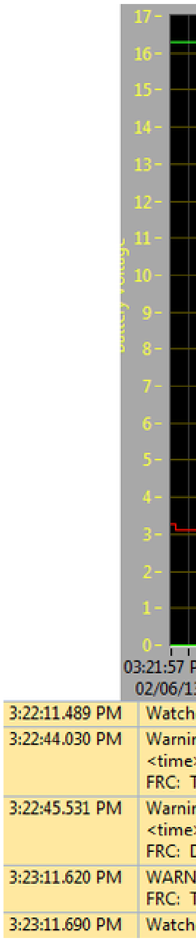
caused failure connection a in indicator primary the is message boot“ robot since ”Time The 3:01:36 at roboRIO the with connection loses DS the log this In rebooting. roboRIO the by the after initiated ping the that indicates event second The event. first the by indicated as roboRIO the 3:01:47 At roboRIO. the than other devices all to successful was failed connection Driver the 3:02:02 At 3:01:52. at fails ping additional one again, pings to responding begins seconds. 3.682 for up been has it that reports roboRIO the and roboRIO the to connects Station at and load to continues code The rebooted. has roboRIO the that indicator clear a is This reported also is warning A camera. the with communicating error an reports code the 3:02:24 up. starting finishes code the before right running is code robot no that indicating

### robot on issue cable Ethernet



roboRIO the to ping the by indicated primarily is robot the on cable ethernet the with issue An ”Time The reconnects. roboRIO the when events Seen Radio and Lost Radio and bad to going roboRIO the that indicate also will reconnects roboRIO the when message boot“ robot since The 3:31:38. at disconnected was cable Ethernet robot the example, this In rebooted. not has 3:32:08 at reconnects robot the When connected. still is radio the that indicates status ping reboot. not did clearly roboRIO the that indicating seconds 1809 is boot“ robot since ”Tim the 0.000 returned it and ago seconds 24.505 radio the lost it that indicates robot the 3:32:12 At and lost radio for yellow graph, the on lines vertical as plotted are points These ago. seconds shown as events actual the from offset slightly are times the that Note seen. radio for green what about information additional provide to help but connection, and disconnection the via occurring. is

## reboot Radio



for radio the to connection of loss a by characterized typically is radio robot the of reboot A start to it causing 3:22:44, at power lost briefly radio the example, this In seconds. 45~40- the 3:23:11, At failed. radio the to ping the that indicates 3:22:45 at event The rebooting. for up been has it indicates roboRIO the and roboRIO the with communication regains DS radio the on switch network the that Note reboot. roboRIO a out ruling seconds, 1272.775 lost“/“radio ”radio a in result not may loss power momentary a so quickly very up back comes DS. the by logged being events radio in result may disturbance longer A pair. event seen“ status ping the is reboot radio a towards points which factor distinguishing the case, that In a is issue the If unreachable. be will radio the resets, radio the If DS. the from radio the of ”GOOD“. remain should ping radio the robot, the on issue connection or cabling

# Errors/Warnings Station Driver 19.4

use to information more (FTAs/CSAs/etc.) Volunteers and Teams both provide to effort an In
added been have messages Error and Warning of number a problems, robot diagnosing when
they when tab diagnostics DS the in displayed are messages These Station. Driver the to
Viewer. File Log the with viewed be can that Files Log DS the in included also are and occur
WPILib by produced (messages DS the by produced messages the discusses document This
Logs). DS the and box this in appear also can

## Unplugged Joystick 19.4.1

```
                                   Station Driver at occurred 44009->Code<ERROR
                                            1>#unique< PM 54:43:4 2013/5/2>time<
                      .enabled was robot the while disconnected was joystick A FRC:
```

error this text message the to Contrary unplugged. is Joystick a when triggered is error This
a see will You DS. the to connected even or enabled, not is robot the if even printed be will
Joysticks if even started, is Station Driver the time each occur message this of instance single
functioning. and connected properly are

DriverStation. calling by silenced be can warnings Unplugged Joystick :□□□□
)C++ ,Java( `silenceJoystickConnectionWarning(true)`

## Communication Lost 19.4.2

```
                                 Station Driver at occurred 44004>Code<Warning
                                          2>#unique<AM 53:07:11 2013/6/2>time<
                   .robot the with communication lost has Station Driver The FRC:
```

the with communication loses Station Driver the whenever printed is message Warning This
this of instance single A red). to green from changing indicator (Communications robot
established. is communication before up, starts DS the when printed is message

## Status Ping 19.4.3

```
     ␣robot bad,-)4.radio( DS GOOD,-link Results: Ping at occurred 44002>Code<Warning
                          Station Driver bad -FMS bad,-)2.cRIO( GOOD,-)1.radio( ↪
                                          5>#unique<AM 59:07:11 2013/6/2>time<
                                      .changed has status ping Station Driver FRC:
```

the while changes device a to Status Ping the time each generated is warning Status Ping A
when established being is communications As roboRIO. the with communication in not is DS
then up, comes link Ethernet the as appear will warnings these of few a up, starts DS the
If applicable). if in mixed FMS (with roboRIO the then radio, robot the to connection the
component which at identify help may change status ping the lost, later are communications
broke. chain communication the

### Boot Robot Since Time 19.4.4

```
FRC_NetworkCommunications at occurred 44007>Code<WARNING
**3.585 >secondsSinceReboot<**
.boot robot since Time FRC:
```

The roboRIO. the with communicating begins DS the time each printed is message This determine to used be can and roboRIO the of seconds, in time,up- the indicates message Reboot. roboRIO a to due was communication of loss a if

### Times Detection Radio 19.4.5

```
FRC_NetworkCommunications at occurred 44008>Code<WARNING
0.000 >radioSeenEvents<19.004 >radioLostEvents<
times dectection radio Robot FRC:

FRC_NetworkCommunications at occurred 44008>Code<WARNING
147.005,0.000 >radioSeenEvents<422.008,2.501 >radioLostEvents<
.times dectection radio Robot FRC:
```

and roboRIO the with communicating begins DS the when printed be may message This first the In seen. and lost was radio the time last the since seconds, in time, the indicates was radio the to connection roboRIO's the that indicates message the above image example when right again seen was radio the and printed was message the before seconds 19 lost the since occurred have events radioSeen or radioLost multiple If printed. was message the commas. by separated included, be will type each of events 2 to up booted, roboRIO

### Code Robot No 19.4.6

```
Station Driver at occurred 44003>Code<Warning
8>#unique<AM 13:50:9 2013/8/2>time<
.running currently is code robot No FRC:
```

no detects but roboRIO, the with communicating begins DS the when printed is message This is Station Driver the if printed be will message this of instance single A running. code robot the with communication begin will DS the as booting is roboRIO the while running and open loading. finishes code robot the before roboRIO

## Offseason FMS for Radios Programming 19.5

access single a use to is setup networking typical the software, Offseason FMS the using When programmed be all should radios the that means This key. WPA and SSID single a with point the of version Team The team. each for IPs different with but network, this to connect to this do to used be can that mode Offseason FMS an has Utility Configuration Bridge FRC® configuration.

## RequisitesPre- 19.5.1

*Programming* in instructions the per software Utility Configuration Radio FRC® the Install
*radio your*

:[illegible]

1. utility configuration the prevent may it as computer, your on connections WiFi Disable
bridge the with communicating properly from
2. the to closest port ethernet bridge wireless the into computer your from directly Plug
If ethernet. via computer your to connected are devices other no sure Make jack. power
the of side socket the into PC the from cable Ethernet an plug PoE, via radio the powering
configuring issues experience you If in). plug would roboRIO the (where adapter PoE
the on port alternate the to PC the connecting try may you adapter, PoE the through
radio.

### Configuration Programmed

radio the into settings configuration of number a programs Utility Configuration Radio The
include: These events). at (including modes all in radio the to apply settings These run. when

- `10.TE.AM.1` of IP static a Set
- programming future for `192.168.1.1` of side wired the on IP alternate an Set
- interchangeably used be may they so ports wired the Bridge
- below. referenced light status the in noted configuration LED The
- disabled be (may interface wireless the of side outbound the on limit bandwidth 4Mb/s
use) home for
- to packets which and buffer internal (affects prioritization packet internal for rules QoS
are: rules These reached). is limit bandwidth if discard
  - `)1150 ,1115 ,1110` (UDP Status and Control Robot
  - `)1740 ,1735` (TCP *NetworkTables* & TCP Robot
  - disabled) is limit BW if (disabled traffic). other (All Bulk
- out: Serves enabled. server DHCP
  - side wired the on `10.TE.AM.111` - `10.TE.AM.11`
  - side wireless the on `10.TE.AM.237` - `10.TE.AM.138`
  - `255.255.255.0` of mask Subnet
  - `10.TE.AM.255` address Broadcast
- the of part as served are `)lan.(` suffix domain and IP server DNS enabled. server DNS
DHCP.

---

lights status radio the of behavior the on details for *Reference Light Status* the See **:[illegible]**
configured. when

---

user the Utility, - Configuration Radio the of version team the with programmed When
:**only DAPs the for** defaults - firmware the to) set (or at left be will accounts

root Username: •

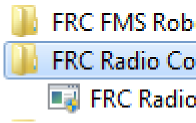
root Password: •

---

manually configuration the modify to recommended not is It :□□□□

---

### software the Launch 19.5.2



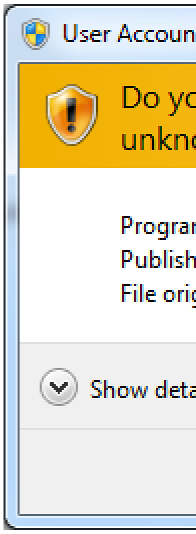
program. the launch to shortcut desktop or menu Start the Use

---

`FRC\(x86) Files Program\C:` to installed is it program, the locate to need you If :□□□□ `FRC\Files Program\C:` is path the machines bit32- For `.Utility Configuration Radio` `Utility Configuration Radio`

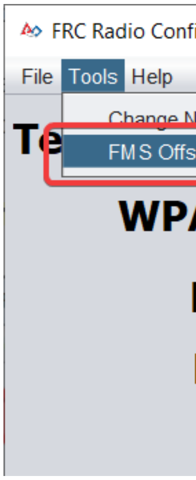
---

### prompted if changes, make to program the Allow 19.5.3



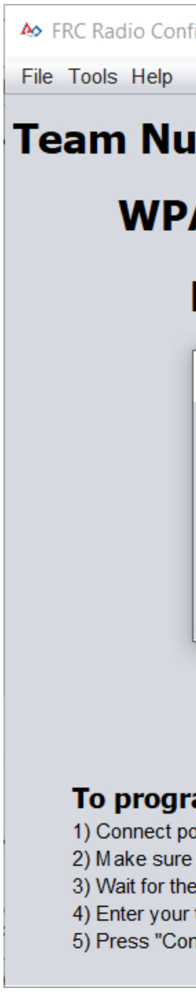
the to changes make to utility configuration the allowing about appear may prompt A computer. Click *Yes* if the prompt appears.

### Mode Offseason FMS Enter 19.5.4



Mode. LiteFMS- enter to `Mode Lite-FMS` >- `Tools` Click

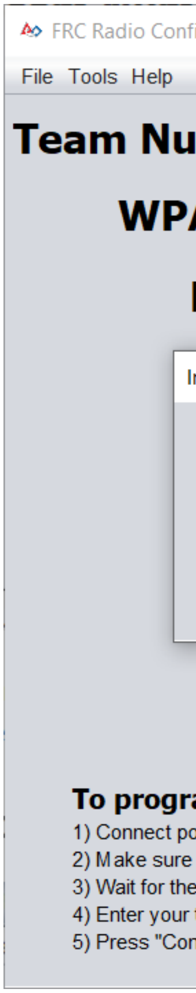
### SSID Enter 19.5.5



**To progra**
1) Connect po
2) Make sure
3) Wait for the
4) Enter your
5) Press "Cor

OK. click and box the in network wireless your of (name) SSID the Enter

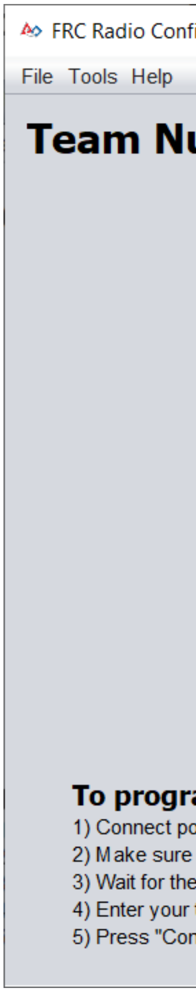
### Key WPA Enter 19.5.6



To progra
1) Connect po
2) Make sure
3) Wait for the
4) Enter your
5) Press "Con

are you if blank box the Leave OK. click and box the in network your for key WPA the Enter network. unsecured an using

## Radios Program 19.5.7



Team Nu

To progra
1) Connect po
2) Make sure
3) Wait for the
4) Enter your
5) Press "Cor

entered. network the to connect to radios of number any program to ready now is Kiosk The and box, the in Number Team the set Kiosk, the to radio the connect radio, each program To Configure. click

an on work to radios B Rev LinkD- or A Rev LinkD- OpenMesh, program will kiosk The dropdown. ”Radio“ the from option appropriate the selecting by network FMS offseason

---

this in radios LinkD- the on configured be not will QoS and limitations Bandwidth :□□□□ mode.

---

### Key or SSID Changing 19.5.8

Tools the to go Key, WPA or SSID the change to need or incorrectly something enter you If again click you When Mode. LiteFMS- of out kiosk the take to Mode LiteFMS- click and menu Key. and SSID the for promptedre- be will you Mode, LiteFMS- in back Kiosk the put to

### פתרון בעיות 19.5.9

*radio your Programming* in steps troubleshooting the See

## Download) Image (Veteran Classmate your Imaging 19.6

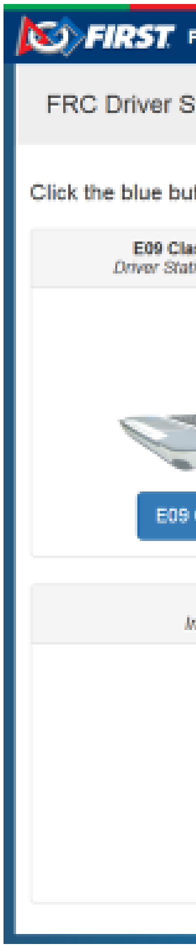
classmate their imagere- to required not are teams Veteran :□□□□

FRC® the restore to drive USB bootable a creating for procedure the describes document This can you then Classmate your imagere- to wish not do you If computer. Classmate a on image only. DS or LabVIEW, C++/Java, for document appropriate the with start

### דרישות מקדימות 19.6.1

1. computer ES1 Acer or computer Classmate E14 or E12, E11, E09,
2. drive USB larger or 16GB
3. current the document, this of writing the of As ).here (download installed software Zip7- 21).02-(2019- 19.00 is version released
4. the select and page the down Scroll ).here (download installed software RMprepUSB stable current the document, this of writing the of As link. download version (Full) stable 2.1.745. is version

## Image Computer the Download 19.6.2



are There .Portal Image System Station Driver FRC FIRST the from image the Download the select site, download the On model. each for one available, images computer several limited the to Due image. the below button the clicking by computer your matches that option not does and only image DS/Utilities a with supported is it E09, the in drive hard the of size base LabVIEW the have images other All installed. C++/Java or LabVIEW for IDEs the have present. already installation

---

to necessary still is it software, FRC core prerequisite the install only images These :□□□□ information. more for step Software Update the See updates. specific FRC the install

---

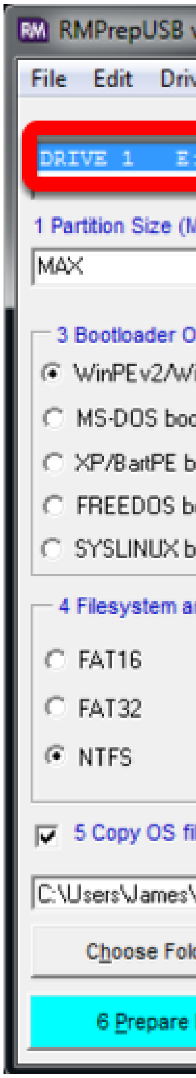
using If image. 2018 the is provided image E14 the availability, computer to Due :□□□□□ the install and Eclipse) or (LabVIEW IDE old the remove to need may teams image, this IDE. new

### Preparation 19.6.3

`\C:` (e.g. drive root your on folder a to site the from downloaded file image the Place 1.
`).2016_Image`

drive. restoration new the as use to PC the to drive Flash USB larger or 16GB Connect 2.

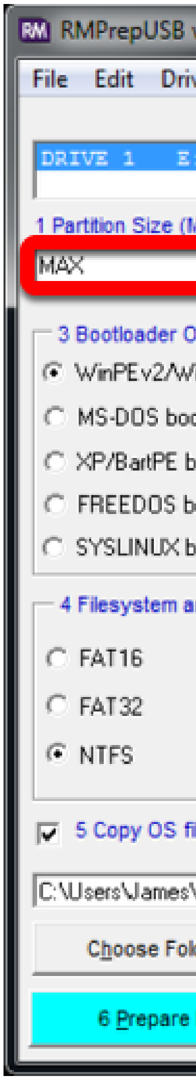
### RMPrep 19.6.4



RMprepUSB Start/Run

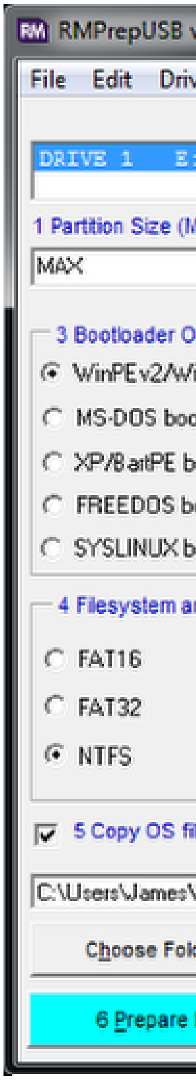
Drive USB Select

### Size Partition Set



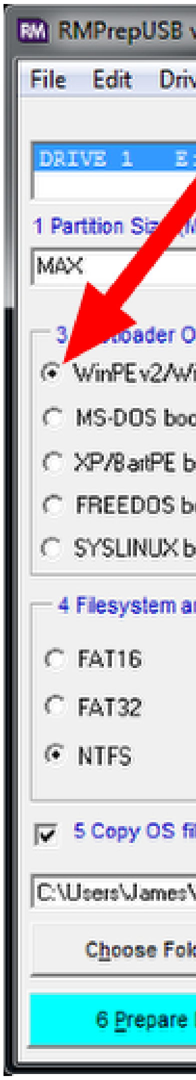
MAX to Size Partition Set

### Label Volume Set



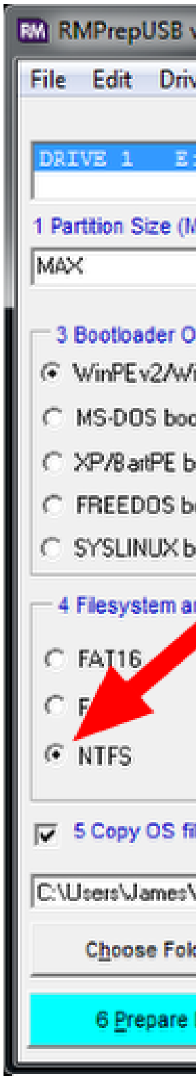
Generic to Label Volume Set

## Option Bootloader Set



bootable“ v3/Vista/Win7 v2/WinPE ”WinPE Option Bootloader Select

### Filesystem Select



DRIVE 1 E:

1 Partition Size (M

MAX

3 Bootloader O

● WinPE v2/Wi

○ MS-DOS boo

○ XP/BartPE b

○ FREEDOS b

○ SYSLINUX b

4 Filesystem a

○ FAT16

○ F

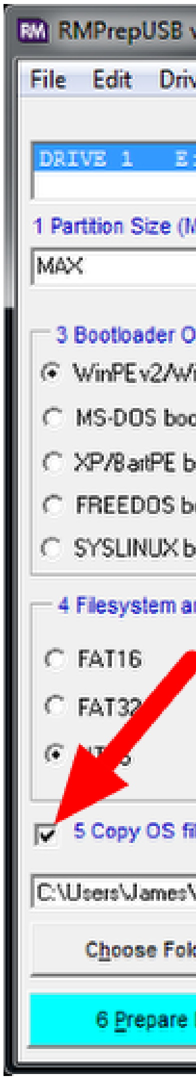
● NTFS

☑ 5 Copy OS fi

C:\Users\James\

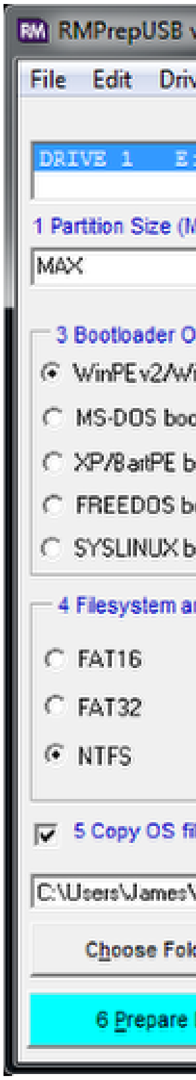
Filesystem NTFS Select

### Option Files OS Copy



checked is box Format“ after files OS ”Copy the Ensure

## Image Locate



DRIVE 1 E:

1 Partition Size (M

MAX

3 Bootloader O

● WinPEv2/Wi

○ MS-DOS boo

○ XP/BartPE b

○ FREEDOS b

○ SYSLINUX b

4 Filesystem ar

○ FAT16

○ FAT32

● NTFS

☑ 5 Copy OS fi

C:\Users\James\

button Folder/File“ ”Choose the Select

### Dialog Files Copy

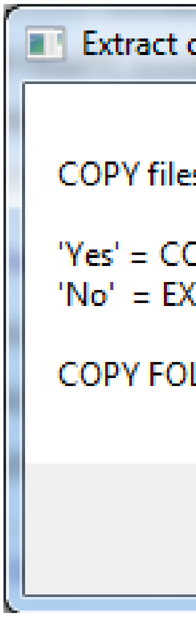
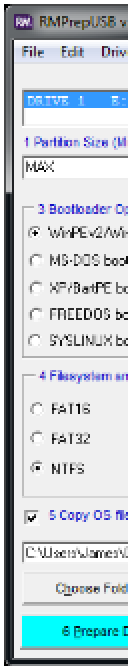


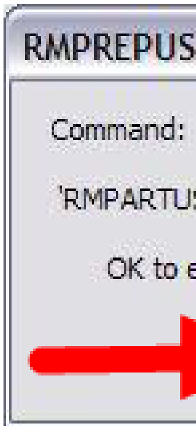
image 7z. your select and ”No“ Choose

### Drive Prepare



process the begin to Drive“ ”Prepare Select complete. now are settings configuration All

### 1 Dialog Confirmation



Prompt Command A  drive. Flash USB selected the on command the execute to ”OK“ Click progress the showing open will

### 2 Dialog Confirmation

drive USB the format to ”OK“ Click

**ERASED! BE WILL DRIVE THE ON DATA ALL  :□□□□**

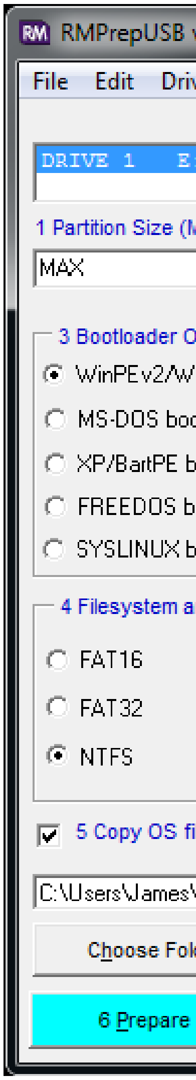
### Decryption

will you kickoff before downloaded image the of version encrypted an using are you If  :□□□□ be prompted to enter the decryption key found at the end of the Kickoff video.

### Complete Copy

USB the to copied and extracted be will files restoration the complete, is formatting Once all When port. 2.0 USB a to connected when minutes ~15 take should process This drive. continue. to OK press appear, will message this copied, been have files

## Drive Eject

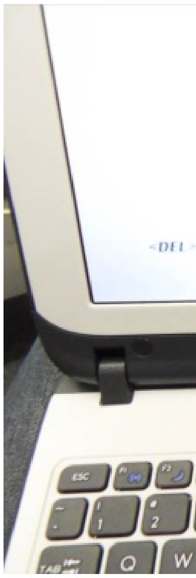


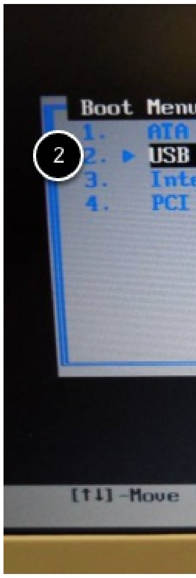
ready now is drive USB The drive. USB the remove safely to button Drive“ ”Eject the Press PC. the onto image the restore to used be to

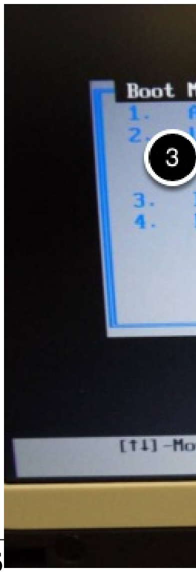
### 19.6.5 Hardware Setup

1. Make sure the computer is turned off, but plugged in.
2. Insert the USB Thumb Drive into a USB port on the Driver Station computer.

## USB to Boot







**Classmate:**

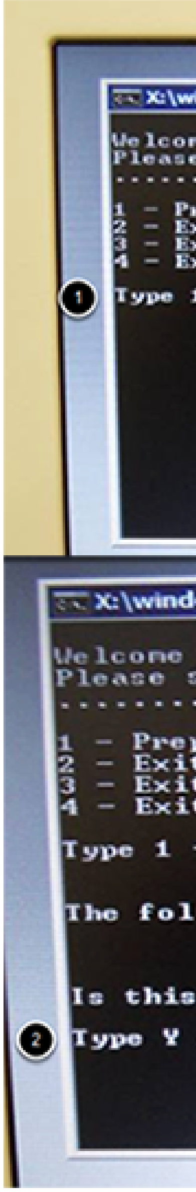
1. key F11 the Tapping keyboard. the on key F11 the tap and Classmate the on Power menu. boot the up bring will boot during
2. right the press then menu, the on entry **HDD: USB** the select to keys up/down the Use listing the expand to arrow
3. called be will (it device USB the select to keyboard the on keys arrow up/down the Use highlighted. is device USB the when key ENTER the Press Disk“). Flash ”Generic

**ES1: Acer**

1. during key F12 the Tapping keyboard. the on key F12 the tap and computer the on Power menu. boot the up bring will boot
2. press then menu, the on entry **Generic HDD: USB** the select to keys up/down the Use highlighted. is device USB the when key ENTER the

**not is device USB the if or menu boot the up pull not does F12 pressing If ES1: Acer article. this of bottom the at Settings“ BIOS ”Checking see menu, boot the in listed**

### Classmate the Image



1. ENTER. press and ”1“ type Classmate, the reimage to want you that confirm To
2. installation The imaging.re- begin will Classmate The ENTER. press and ”Y“ type Then, minutes. 3015- take will
3. drive. USB the remove complete, is installation the When
4. Windows. into boot will Classmate The Classmate. the Restart

### 19.6.6 Initial Driver Station Boot

The first time the Classmate is turned on, there are some unique steps, listed below, that you'll need to take. The initial boot may take several minutes; make sure you do not cycle power during the process.

---

□□□□: These steps are only required during original startup.

---

#### Enter Setup

1. Log into the Developer account.
2. Click ”Ask me later“.
3. Click ”OK“. The computer now enters a Set Up that may take a few minutes.

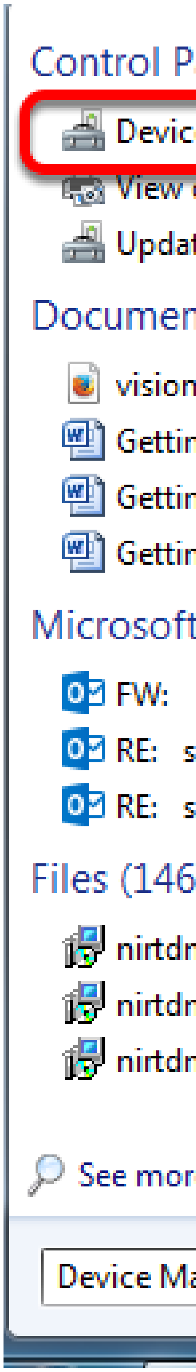
#### Activate Windows

1. Establish an Internet connection.
2. Once you have an Internet connection, click the Start menu, right click ”Computer“ and click ”Properties“.
3. Scroll to the bottom section, ”Windows activation“, and Click ”Activate Windows now“
4. Click ”Activate Windows online now“. The activation may take a few minutes.
5. When the activation is complete, close all of the windows.

#### Microsoft Security Essentials

Navigate through the Microsoft Security Essentials Setup Wizard. Once it is complete, close all of the windows.

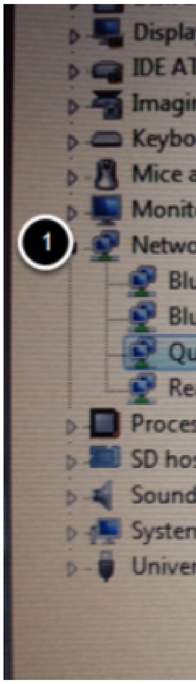
### Driver Wireless Fix ES1: Acer



**only! PC ES1 Acer**

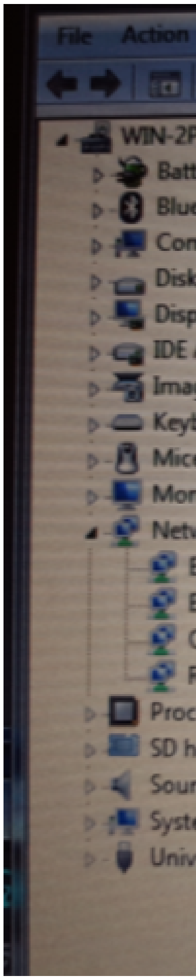
communication intermittent with issues have may image the in driver wireless default The by load to set be not could but image, the in is driver correct The radio. robot the with "Device typing start, clicking by Manager Device the open driver, correct the load To default. Manager. Device clicking and box the in Manager"

### Properties Device Wireless Open



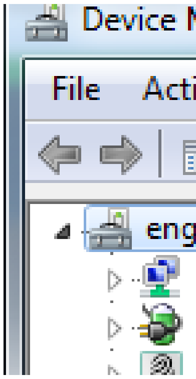
Network Wireless the locate and it expand to Adapters Network to next arrow the on Click Properties. select and adapter the click Right Adapter.

### DriverUninstall-



prompts. any at Yes Click button. Uninstall the click then tab, Driver the on Click

### Hardware New for Scan

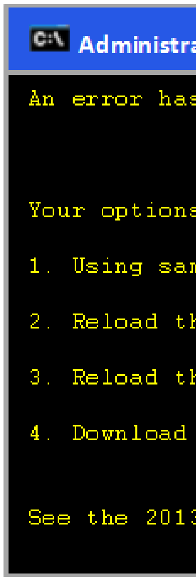


wireless The changes“. hardware for ”Scan click and tree the of entry top the on click Right installed. be should driver correct the and detectedre- be automatically should adapter

## Software Update 19.6.7

final the before created are they time, on prepared be to images Classmate the for order In components additional some FRC for software the use To ready. were software the of versions Tools Game FRC the Installing with continue should teams LabVIEW installed. be to need will Development Java and C++ Installing continue should teams Java or C++ Languages). (All FRC. for Tools

## Process Imaging during Errors 19.6.8



```
An error has
Your options
1. Using sam
2. Reload th
3. Reload th
4. Download
See the 2013
```

Note appear. will screen following the process, imaging the during detected is error an If the for image onlyStation- Driver the for screen error the shows below screenshot the that applied. being image the on depending vary will shown filename image specific The E09.

device USB the with error an to due is message this of appearance the for reason typical The actions the to as details further with below listed is option Each stored. is image the which on will shown is message error this once key any Pressing solution. a pursuing in take can you Classmate. the Image in shown screen menu the to user the return

### 1 Option

**drive Flash USB existing the on image same Using**
run will This #1. select and menu main the to return to key any press option, this try To again. process imaging the

## 2 Option

### RMPrepUSB using drive Flash USB the onto image same the Reload

creation the during caused error an to due displayed was message error the possible It’s
return to key any Press etc.) corruption, data error, copy file (e.g. drive Flash USB the of
steps the follow then Classmate the shutdown safely to #4 select and menu main the to
Flash USB same the using Key Restoration USB new a create to RMPrep with starting
drive.

## 3 Option

### RMPrepUSB using drive Flash USB new a onto image same the Reload

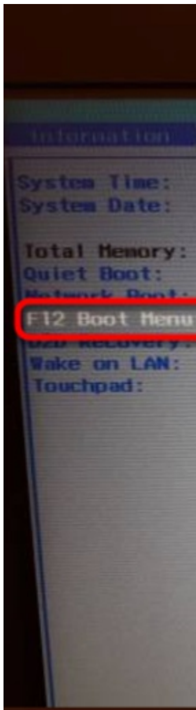
drive Flash USB the with error an by caused be also may displayed message error The
the shutdown safely to #4 select and menu main the to return to key any Press itself.
RMPrep. with starting steps the follow and drive Flash USB new a Select Classmate.

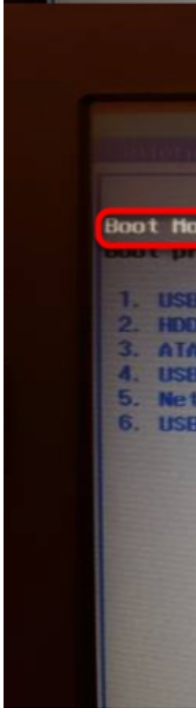
## 4 Option

### image new a Download

any Press imaging. when error an cause also may image downloaded the with issue An
Staring Classmate. the shutdown safely to #4 select and menu main the to return to key
stick. imaging the of copy new a create Image Classmate the Download with

### Settings BIOS Checking





correct. are they insure to settings BIOS the check USB, to booting difficulty having are you If this: do To

- settings BIOS the enter to booting is computer the while key **F2** the tap Repeatedly
- the select to keys arrow left and right the use loaded, has screen settings BIOS the Once not, is it If ”Enabled“. to set is Menu“ Boot ”F12 for line the if check then tab, ”Main“ and ”Enabled“ select to Up/Down use Enter, press it, highlight to keys Up/Down the use

again. Enter press

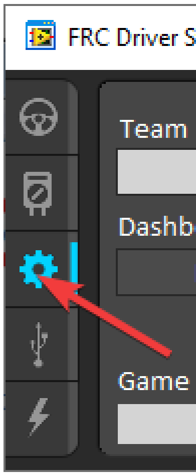
- Mode“ ”Boot the that sure Make tab. ”Boot“ the select to keys Left/Right the use Next, ”Legacy“ highlight Enter, press UpDown, using it highlight not, is it If ”Legacy“. to set is see. may you dialogs uppop- any through move to Enter Press again. Enter press and
- exit. and changes any save to F10 Press

## Custom Start to Station Driver the Setting Manually 19.7 Dashboard

to copied are files when as (such location default the to installed not is WPILib If :□□□□ a start DS the have To properly. launch not may choice of dashboard the manually), PC a default the for settings the modify manually to have you up, starts it when dashboard custom dashboard.

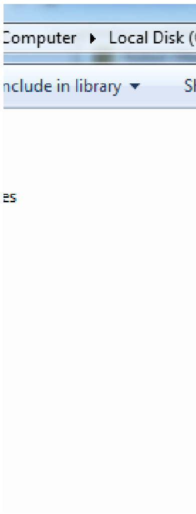
*Dashboard* appropriate the using try installations, most for needed not is This :□□□□□ first. language your for *setting Type*

### Default to Station Driver Set 19.7.1



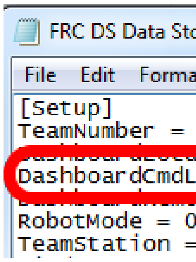
to setting Dashboard the set and tab Setup the on click software, Station Driver the Open **Station! Driver the close Then** Default.

### 19.7.2 Open DS Data Storage file



Browse to `C:\Users\Public\Documents\FRC` and double click on `FRC DS Data Storage` to open it.

### 19.7.3 DashboardCmdLine



```
[Setup]
TeamNumber =
DashboardCmdL
RobotMode = 0
TeamStation =
```

Locate the line beginning with `DashboardCmdLine`. Modify it to point to the dashboard to launch when the driver station starts.

### Dashboard Custom LabVIEW

is specified path the where `DASHBOARD.exe"\\TO\\PATH\\"C:` with = after string the Replace
file. `Storage Data DS FRC` the Save file. `exe` dashboard the to path the

### Dashboard Java

path the where `DASHBOARD.jar"\\TO\\PATH\\"C: jar- java` with = after string the Replace
file. `Storage Data DS FRC` the Save file. `jar` dashboard the to path the is specified

---

11. Java require Smartdashboard and Shuffleboard **:**

---

### installer WPILib from Dashboard

`\\tools\\YYYY\\wpilib\\Public\\Users\\"C: wscript` with = after string the Replace
or `Shuffleboard.vbs` either is `DASHBOARD.vbs` and year the is `YYYY` where `DASHBOARD.vbs"`
file. `Storage Data DS FRC` the Save `.Smartdashboard.vbs`

## Station Driver Launch 19.7.4

opened. is it time each dashboard the launch now should Station Driver The

[redacted]

# Introduction - RobotBuilder 20.1

## Overview RobotBuilder 20.1.1

RobotBuilder process. development robot the aid to designed application an is RobotBuilder
you: help can

- code. boilerplate Generating
- are. subsystems key its what out figure and robot your Organize
- actuators. and sensors your of all for channels enough have you that Check
- diagrams. wiring Generate
- interface. operator your modify Easily
- More...

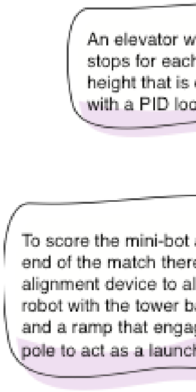
a following by procedure forward straight very a is RobotBuilder with program a Creating follow. can you that steps the describes lesson This robot. any for same the are that steps few document. the of sections subsequent in steps these of each about details more find can You

---

details more For Framework. Command new the using code generates RobotBuilder :□□□□
.*Programming Based Command* see framework new the on

---

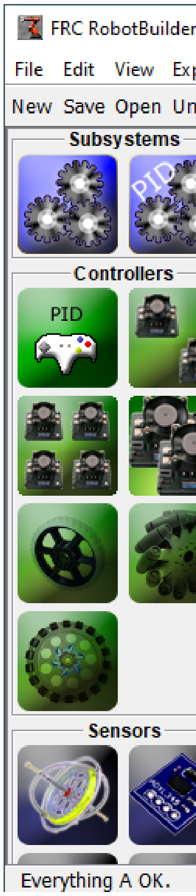
## Subsystems into Robot the Divide



arms, trains, drive the like systems smaller of number a of up made naturally is robot Your your of design the at look should You etc. joints, wrist manipulators, collectors, shooters, example particular this In subsystems. operated separately smaller, into up it break and robot addition In system. camera a and gripper, a device, alignment minibot a elevator, an is there controlled separately are robot the of parts these of Each base. drive the include might one subsystems. for candidates good make and

.*Subsystem a Creating* see information more For

## Project the to Subsystem each Adding



a given and RobotBuilder the in folder ”Subsystems“ the to added be will subsystem Each
to in filled get that attributes several are there subsystems the of each For name. meaningful
subsystems of types two are there addition In subsystems. the about information more specify
create: to want might you that

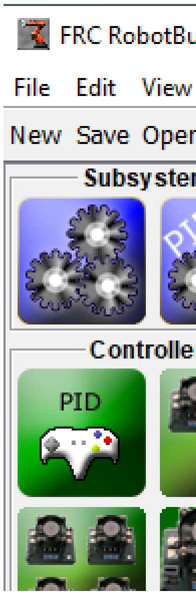
PID a with operation subsystems a control to desirable is it often - PIDSubsystems 1.
example for element, subsystem the makes that program your in code is This controller.
PIDSubsystems it. reaching when stop then position desired a to quickly more angle, arm
it adding then convenient more often are and inbuilt- code Controller PID the have
reached has device the when determines that sensor a have PIDSubsystems yourself.
setpoint. the to driven is that controller) (motor actuator an and position target the

are and controller PID integrated an have don’t subsystems these - subsystem Regular 2.
more requiring subsystems for or feedback for control PID without subsystems for used
controller. PID embedded default the with handled be can than control complex

types subsystem the between differences the documentation this of more through look you As
apparent. more become will

.*Subsystem a for Code Writing* and *Subsystem a Creating* see information more For

## Subsystems the of each to Components Adding



to uses it that controllers and sensors actuators, of number a of consists subsystem Each
which with subsystem the to added are actuators and sensors These operations. its perform
palette RobotBuilder the from comes actuators and sensors the of Each associated. are they
properties other usually are there each, For subsystem. appropriate the to dragged is and
component. the to specific parameters other and numbers port as such set be must that

(motor potentiometer a and motor a uses that subsystem Elevator an is there example this In
subsystem. Elevator the to dragged been have that pot) and

## Goals Subsystem Describe That Commands Adding

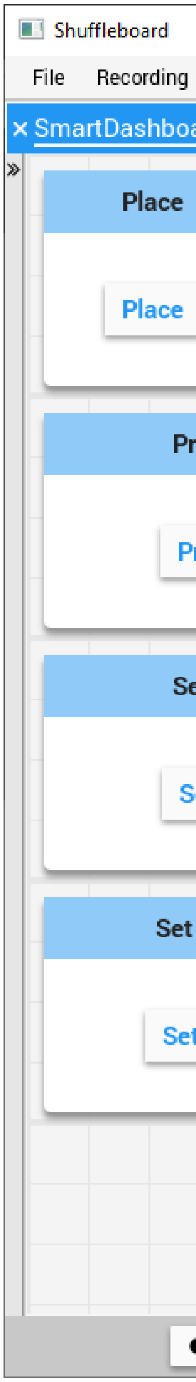
by added are commands These perform. will robot the that goals distinct are Commands
are there command, a creating When folder. ”Commands“ the under command the dragging
picture): the of left the on palette the on (shown choices 7

- the of all write to have you command, flexible most the are these - commands Normal goal. the accomplish to necessary actions desired the perform to code
- ends that command a of version simplified a are commands these - commands Timed timeout a after
- runs that command a of version simplified a are commands these - commands Instant ends then and iteration one for
- both running commands other of combination a are commands these - groups Command actions complicated more up build to these Use parallel. in and order sequential a in implemented. commands basic of number a have you after
- or setpoint, fixed a to Subsystem PID a move commands setpoint - commands Setpoint location. desired the
- regular a with used be to controller PID inbuilt- a have commands these - commands PID subsystem.

- time the at run to commands two of one select commands these - commands Conditional initialization. of

.*Code Command Writing* and *Command a Creating* see information more For

### Command each Testing

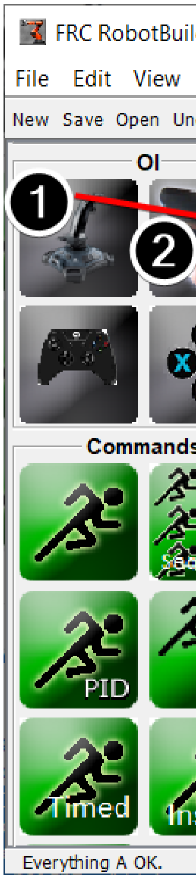


testing for useful is This SmartDashboard. or Shuffleboard from run be can command Each as long As group. command a to or interface operator the to them add you before commands the on created be will button a checked, property SmartDashboard“ on ”Button the leave you that check can you and run will command the button, the press you When SmartDashboard. action. desired the performs it

work commands the all If individually. tested be can command each buttons, creating By whole. a as work will robot the that sure pretty be can you individually,

.*Smartdashboard with Testing* see information more For

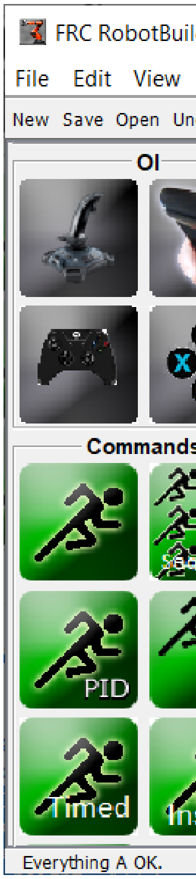
## Components Interface Operator Adding



You devices. input HID other and gamepads joysticks, of consists interface operator The in program your to buttons) joystick (joysticks, components interface operator add can components the of all initialize will that code generate automatically will It RobotBuilder. commands. to connected be to them allow and

Interface“ ”Operator the to palette the from dragged are components interface operator The buttons put then program the to Joysticks add (1) First program. RobotBuilder the in folder ShootButton. like names, meaningful them give and (2) joysticks associated the under

## Interface Operator the to Commands the Connecting



Everything A OK.

is command the pressed is button a when that so buttons with associated be can Commands robot your of part operatedtele- the of most handle part, most the for should, This scheduled. program.

the in object JoystickButton the to command the adding (1) by done simply is This scheduled. is command the which in condition the setting (2) then program, RobotBuilder

.*Command a to Interface Operator the Connecting* see information more For

## Commands Autonomous Developing

which specify simply You  programs. autonomous develop to simple it make Commands automatically will it and period autonomous the enters robot the when run should command matter a be simply should this above, discussed as commands tested have you If scheduled. be run. should command which choosing of

Autonomous the edit then (1), project RobotBuilder the of root the at robot the Select simple! that It's run. to command the choose to (2) property Command

.*Commands Autonomous the Setting* see information more For

### Code Generating

You have successfully

or C++ a generate RobotBuilder have can you above outlined process the in point any At
specifying by done is This created. have you project the represent will that program Java
toolbar appropriate the clicking then (1), properties project the in project the of location the
(2). code the generate to button

.*Code RobotBuilder Generating* see information more For

## RobotBuilder Starting 20.1.2

---

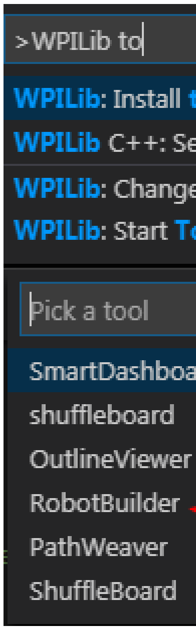
that platform any on run to able be should such as and program Java a is RobotBuilder :□□□□
various and Windows, macOS, on RobotBuilder running been have We Java. by supported is
successfully. Linux of versions

---

### RobotBuilder Getting

see information, more For Installer. Offline WPILib the of part as downloaded is RobotBuilder
*guides installation Windows/macOS/Linux* the

### Code Studio Visual from Starting - 1 Option

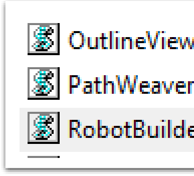


the launch to right top the in logo WPILib the click or ”WPILib“ type and `Ctrl+Shift+P` Press .*Builder Robot* select then ,*Tool Start* Select Palette. Command WPILib

### Shortcuts - 2 Option

the on folder `Tools WPILib 2023` the and Menu Start Windows the to installed are Shortcuts desktop.

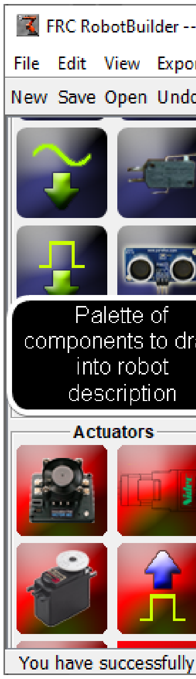
### Script the from Running - 3 Option



~ and year the is YYYY (where `~/wpilib/YYYY/tools` to tools the installs process install The Windows). on `Public\Users\C:` is

use can you that files (macOS/Linux) `py.` and (Windows) `vbs.` find will you folder this Inside what are and JDK correct the using tools the launch help scripts These tool. each launch to tools. the launch to use should you

### Interface User RobotBuilder 20.1.3



Palette of components to dr into robot description

You have successfully

Almost programs. robot of development rapid for designed interface user a has RobotBuilder lists. downdrop- from options selecting or dropand-drag- by performed are operations all

#### Description Robot the to Palette the from Items Dragging

You have successfully

palette the on drag the starting by description robot the to palette the from items drag can You example, this In located. be to item the like would you where container the on ending and item subsystem. Elevator the to potentiometer a dropping

### Menu Context ClickRight- the using Components Adding

container the on clickright- to is description robot the to items adding of method shortcut A
identical is This (Potentiometer). added be should that item the select and (Elevator) object
people. some for easier be might but drop and drag using to

## Items Description Robot of Properties Editing

You have successfully

can properties The viewer. properties the in appear will item selected a for properties The column. hand right the in value the selecting by edited be

## System Menu the Using

You have successfully

equivalent the or system menu the through selected be either can RobotBuilder for Operations toolbar. the from available) is it (if item

## Project Robot the up Setting 20.1.4

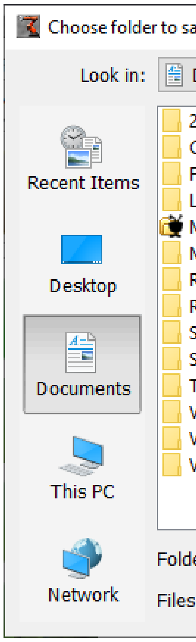
generated the so up set be to need that properties default some has program RobotBuilder The
the in stored is information setup This properly. work files generated other and program
line). first (the description robot for properties

### Properties Project Robot

are: robot the describe that properties The

- created is that project robot the of name The - **Name**
- is program the when default by run will that command the - **Command Autonomous** mode autonomous in placed
- Command Autonomous the for Parameters - **Parameters Command Autonomous**
- robot the locate to used be will which project, the for number team The - **Number Team** code. deploying when
- package default the use will RobotBuilder checked If - **Package Java Default Use** used. be to name package custom a specify can you Otherwise (frc.robot).
- the generating when used package Java generated the of name The - **Package Java** code project
- or Java to Export when into generated is project the that folder The - **Directory Export** selected is C++
- classes Subsystem the export should RobotBuilder if Checked - **Subsystems Export** project your from
- from classes Command the export should RobotBuilder if Checked - **Commands Export** project your
- wiring the contains that generate to file html the of location the - **location File Wiring** robot your for diagram
- third this, supports WPILib While simulation. and test unit Enables - **Support Desktop** may code your then desktop, support not do libraries If not. may libraries software party simulation or testing unit unless unchecked left be should It crash. may or compile not it. support libraries all and needed is

### Project RobotBuilder the with Control Source Using



and computers of number a on used be typically will project the control source using When If another. to computer users one from different be might directory project the to path the user the contain typically will it path, absolute an using stored is file project RobotBuilder the ”relative select work, this make To computers. multiple across usable be won’t and name example, above the In files. project the from offset directory an as path the specify and path“ this In hierarchy. file the in files project the above just folder the in stored is file project the computers. your of all across portable be will it and path the of part not is name user the case,

## Subsystem a Creating 20.1.5

a make that code and data the all contain) (or encapsulate that classes are Subsystems the with program robot a creating in step first The operate. robot your on subsystem of Examples robot. the on subsystems the all create and identify to is RobotBuilder subsystem Each etc. arms, elevators, base, drive the collectors, ball grippers, are subsystems elevator an example, For work. it make to used are that actuators and sensors the all contains robot the of feedback provide to potentiometer a and controller motor SPX Victor a have might position.

### Palette the using Subsystem a Creating

description robot the in folder Subsystems the to palette the from icon subsystem the Drag class. subsystem a create to

### Menu Context the using Subsystem a Creating

folder. that to subsystem a add to description robot the in folder Subsystem the on clickRight-

### Subsystem the Name

described as menu context the using or dragging either by subsystem the creating After multiple be can name The subsystem. the give to like would you name the type simply above, Java proper a make to words the concatenate will RobotBuilder spaces, by separated words you. for name class C++ or

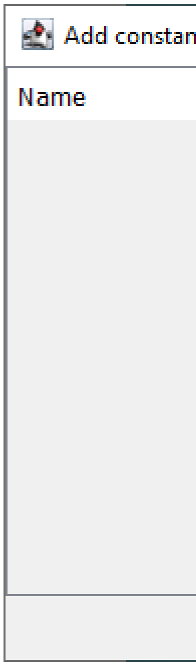
### Constants Adding

In code. your in numbers magic of amount the reduce to useful very are Constants

specific for values sensor as such values, certain of track keep to used be can they subsystems,
robot. the drive to which at speed the or elevator, an of heights

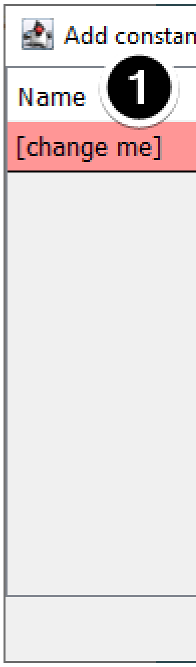
”Constants“ to next button the Press subsystem. a in constants no be will there default, By
some. create to dialog a open to

## Constants Creating



one. add to constant“ ”Add Press first. at empty be will table constants The

## Constants Add

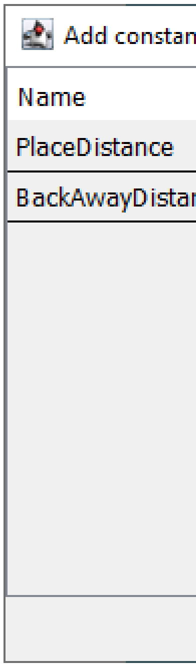


a of example this In descriptive. something to this Change constant. the of name The 1.
”BackAwayDistance“. and ”PlaceDistance“ be might constants good some drivetrain

one from choose can you but double, a be likely most will This constant. the of type The 2.
byte. or boolean, long, int, double, String, of:

constant. the of value The 3.

## Constants Saving



the save to close“ and ”Save press just values, their setting and constants adding After top the on button exit the press save, to want don’t you If dialog. the close and constants window. the of

## Saving After

subsystem the in button ”Constants“ the in appear will names the constants, saving After properties.

### Subsystem the into Actuators/Sensors Dragging

subsystem: a to components adding to steps three are There

required. as subsystem the into palette the from sensors or actuators Drag 1.

name meaningful a sensor or actuator the Give 2.

the in item each for numbers channel and numbers module as such properties the Edit 3.
subsystem.

the on module each for numbers channel incrementing use automatically will RobotBuilder channel unique assign RobotBuilder let just can you robot the wired yet haven't you If robot. wiring generating the to according robot the wire and actuator or sensor each for numbers table.

code skeleton generate subsequently will and RobotBuilder, in subsystem the creates just This *a for Code Writing* to refer please robot your operate actually it make To subsystem. the for *.Subsystem*

## Command a Creating 20.1.6

The subsystems. your for actions or behaviors provide that create you classes are Commands the start to MoveElevator like subsystem, the of operation the set should class subsystem commands The setpoint. PID elevator's the set to ElevatorToSetPoint or moving, elevator finished. is it when of track keep and operation subsystem the initiate

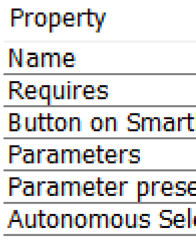
### Folder Commands the to Command the Drag

command The description. robot the to palette the from dragged be can commands Simple folder. Commands the under created be will

### Menu Context the using Commands Creating

in folder Command the on menu context clickright- the using commands create also can You description. robot the

## Command the Configuring


Property
Name
Requires
Button on Smart
Parameters
Parameter prese
Autonomous Sel

will command the what describes that meaningful something with command the Name 1.
spaces be can there although code, in were they if as named be should Commands do.
words. between

it scheduled, is command this When command. this by required is that subsystem the Set 2.
command. this requires also that running currently command any stop automatically will
and subsystem) claw the (requiring running currently is claw the open to command a If
closing. start and opening stop immediately will it scheduled, is command claw close the

command. the for SmartDashboard the on buttons create should it if RobotBuilder Tell 3.
preset. parameter each for created be will button A

the do can parameters with command single A takes. command this parameters the Set 4.
”Drive example, For parameters. take not do that commands more or two as thing same
into consolidated be can commands Distance“ ”Drive and Backward“, ”Drive Forward“,
distance. and direction for values takes that command single a

using when RobotBuilder in elsewhere used be can These parameters. for presets Set 5.
for command default the setting or button joystick a to it binding as such command, the
subsystem. a

However, disabled. is robot the when run to command the Allows .*Disabled When Run* 6.
actuate. not will disabled while commanded actuators any

Chooser Sendable the to added be should command the Whether .*Selection Autonomous* 7.
autonomous. for selected be can it that so

parameters double); type of (»setpoint«, parameter single a with come commands Setpoint
commands. setpoint for deleted or edited, added, be cannot

## Parameters Editing and Adding

parameters: edit or add To

table property the of column *Value* the in button the Click 1.

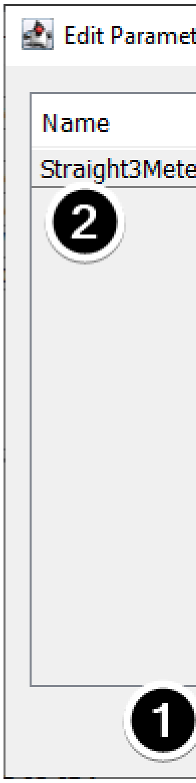
parameter a add to button *Parameter Add* the Press 2.

type the and *me] [change* to defaults name The added. been just has that parameter A before it change to have will you so invalid, is name default The String. to defaults the click Double name. the changing start to cell *Name* the click Double exporting. type. the select to cell *Type* 3.

window. the close and changes all save will button close and Save 4.

pressing and them selecting by deleted be can and dragging, by simply reordered be can Rows backspace. or delete

#### Presets Parameter Editing and Adding



1. preset. new a add to *set parameter Add* Click
2. example this in presets The descriptive. something to preset the of name the Change subsystem. gripper the closing and opening for are
3. (e.g. in value a type either can You preset. the for parameter(s) the of value the Change requires. command the that subsystem the in defined constants from select or ”3.14“) can’t you – parameter the as type same the be to has constant the of type the that Note example for parameter, typedouble- a to passed be constant typeint- an have
4. press saving, without exit to dialog; the exit and changes save to *close and Save* Click window. the of bar top the in button exit the

### Commands Autonomous the Setting 20.1.7

makes it performs, robot the that (behaviors) actions more or one simply is command a Since a be could it While command. a as robot a of operation autonomous the describe to sense that commands of group (a group command a be to going likely more is it command, single together). happen

command autonomous the allows which *Chooser Sendable* a for code generates RobotBuilder dashboard. the from chosen be to run to

You have successfully

selected not is command another if runs that command autonomous default the designate To dashboard: the on

- description program robot the in robot the Select
- robot the when run should that command the with field command Autonomous the in Fill to option the you give will and field downdrop- a is This mode. autonomous in placed is defined. been has that command any select
- any. if takes, command the parameters the Set

Everything A OK.

Autonomous the select Chooser, Sendable the to options as add to commands select To box. check Selection

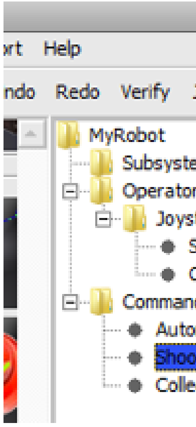
be will command Autonomous chosen the mode, autonomous into put is robot the When scheduled.

## Command a Test to Shuffleboard Using 20.1.8

trigger to Shuffleboard/SmartDashboard to button a adding by tested easily are Commands and necessary is program robot the of rest the with integration no way, this In command. the commands verify to way easiest the is This tested. independently be easily can commands Shuffleboard on created be can button a program, your in code of line single a with since and subsystems verify to place in left be then can buttons These command. the run will that future. the in operations command

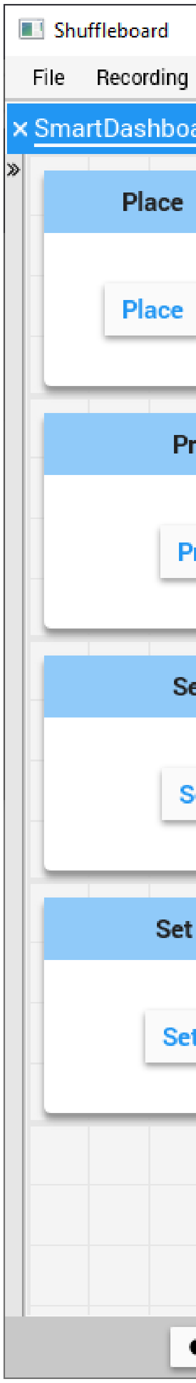
commands. writing each programmers, multiple accommodating of benefit added the has This tested. individually be can commands the project, robot main the into checked is code the As

### Shuffleboard on Button the Creating



the from command the of instance an putting by SmartDashboard the on created is button The to added been has it that operation common a such is This dashboard. the to program robot checked, is box the that sure be commands, your writing When checkbox. a as RobotBuilder you. for generated automatically be will buttons and

## Buttons the Operating



You  screen. dashboard the on appear will and automatically generated be will buttons The commands, of number a are there example this In Shuffleboard. on buttons the rearrange can the run will button commands the Pressing  testing. for button associated an with each the causing command the interrupt will it again pressing pressed, is it Once  command. called. be to method `Interrupted()`

### Manually Commands Adding

Java

```
AutonomousCommand()); new ,"Command Autonomous"(putDataSmartDashboard.
OpenClaw(m_claw); new ,"Claw Open"(putDataSmartDashboard.
CloseClaw(m_claw)); new ,"Claw Close"(putDataSmartDashboard.
```

C++

```
AutonomousCommand()); new ,"Command Autonomous"PutData(::SmartDashboard
m_claw));&OpenClaw( new ,"Claw Open"PutData(::SmartDashboard
m_claw));&CloseClaw( new ,"Claw Close"PutData(::SmartDashboard
```

is This yourself. code the writing by manually Shuffleboard the to added be can Commands that name the with along method PutData the to command the of instances passing by done scheduled are instances These Shuffleboard. the on button the with associated be should generated RobotBuilder as same the exactly is result The pressed. is button the whenever code the all writing than easier much is RobotBuilder in checkbox the clicking although code, hand. by

## Command a to Interface Operator the Connecting 20.1.9

some to subsystem a starts command The robot. your for behaviors the handle Commands setpoint some reaches it until running continues and elevator and raising like mode operating way That finish. to subsystem the for waiting handles then command The timeout. or behaviors. complex more develop to sequence in run can commands

your on button a whenever run to command a schedule to code generate also will RobotBuilder particular a when command a run to code write also can You pressed. is interface operator happened. has condition trigger

## Press Button a with Command a Run

Everything A OK.

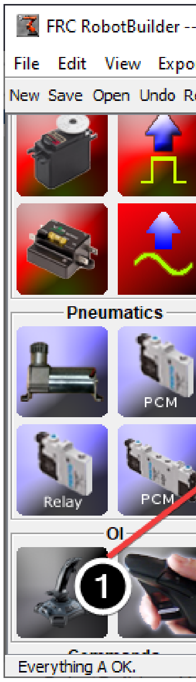
dpad the whenever run to command Claw“ ”Close the schedule to want we example this In pressed. is 6) (button gamepad logitech a on pressed is button direction right

the of claw the close to is function its and Claw“ ”Close called is run to command The robot 1.

this that ensure will This subsystem. Claw the requires command the that Notice same the at happening operation another was there if even running starts command interrupted. be would command previous the case this In claw. the used that time 2.

you let presets things; multiple do to command one for possible it make Parameters them reuse and command the to pass you values define 3.

## Program Robot the to Joystick the Adding



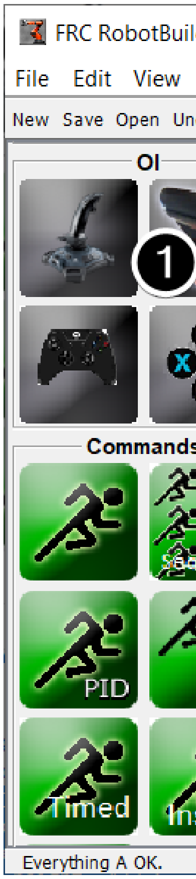
Everything A OK.

program robot the to joystick the Add

program robot the in folder Interface Operator the to joystick the Drag 1.

number port USB the set and joystick the of use the reflects it that so joystick the Name 2.

### Command Elevator“ ”Move the to Button a Linking



program the to pressed be should that button the Add

the under it’s that so Controller) (Logitech Joystick the to button joystick the Drag 1.
joystick

the when run to command the number, button the button: the for properties the Set 2.
to property *run to When* the and takes, command the parameters pressed, is button
pressed. is button joystick the whenever run should command the that indicate to *onTrue*

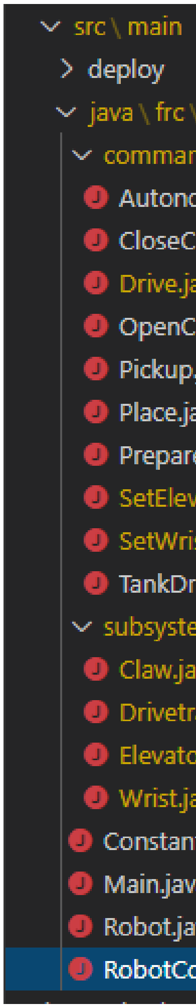
---

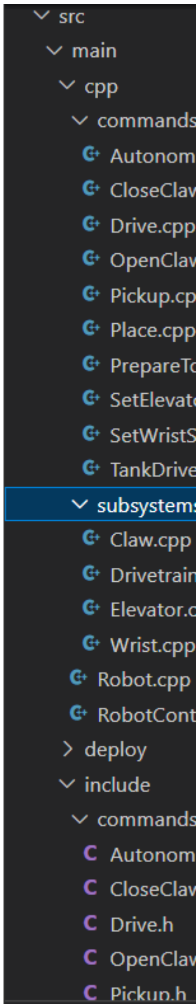
in joystick a have must You Joystick. a (under) to dragged be must buttons Joystick **:□□□□**
buttons. adding before folder Interface Operator the

---

## Code Created RobotBuilder 20.1.10

### Project Generated RobotBuilder a of Layout The




src
main
cpp
commands
Autonom
CloseClaw
Drive.cpp
OpenClaw
Pickup.cp
Place.cpp
PrepareTo
SetElevato
SetWristS
TankDrive
subsystems
Claw.cpp
Drivetrain
Elevator.c
Wrist.cpp
Robot.cpp
RobotCont
deploy
include
commands
Autonom
CloseClaw
Drive.h
OpenClaw
Pickup.h

for C++) (in folder a or Java) (in package a of consists project generated RobotBuilder A stored is object subsystem or command Each Subsystems. for another and Commands program main robot the find you'll project the of level top the At containers. those under (RobotContainer.java/C++).

*a Structuring* see robot, Based Command a of organization the on information more For *Project Robot BasedCommand-*

### Code Autogenerated

Java

```
ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
      Autonomous()); new ,"Autonomous"(setDefaultOptionm_chooser.
   ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                 m_chooser); ,"Mode Auto"(putDataSmartDashboard.
```

C++

```
ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
      Autonomous()); new ,"Autonomous"m_chooser.SetDefaultOption(
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

m_chooser);& ,"Mode Auto"PutData(::SmartDashboard::frc
```

designed is RobotBuilder exportedre- is code and modified is description robot the When makes This code. your preserving thus file, the to made you changes any modify not to RobotBuilder, by modified be to OK is code what know To tool. lifecyclefull- a RobotBuilder special some with delimited rewritten be to have potentially will that sections generates it these within code any add Don’t above. example the in shown are comments These comments. RobotBuilder. from exported is project the time next rewritten be will it blocks, comment

this but removed, be can comments the modified, be must blocks these of one inside code If //BEGIN the if example, above the In later. happening from updates further prevent will in added was subsystem required another later then removed, were comments //END and export. next that on generated be not would it RobotBuilder,

Java

```
Robot. TYPE: ROBOTBUILDER //
```

C++

```
Robot. TYPE: ROBOTBUILDER //
```

deleted, or modified is this If file. of type the defining comment a has file each Additionally, and inside both added code any deleting file the regenerate completely will RobotBuilder blocks. CODE AUTOGENERATED the outside

### Program Robot Main

Java

```
Robot. TYPE: ROBOTBUILDER //

;frc.robot package

;edu.wpi.first.hal.FRCNetComm.tInstances import
;edu.wpi.first.hal.FRCNetComm.tResourceType import
;edu.wpi.first.hal.HAL import
;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.wpilibj2.command.Command import
;edu.wpi.first.wpilibj2.command.CommandScheduler import

**/
the call to and class, this run automatically to configured is VM The *
TimedRobot the in described as mode, each to corresponding functions *
after package the or class this of name the change you If documentation. *
in file build.properties the update also must you project, this creating *
project. the *
*/


m_autonomousCommand; Command private

m_robotContainer; RobotContainer private
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                    **/
        be should and up started first is robot the when run is function This *
                                                   code. initialization any for used *
                                                                                    */
                                                                        @Override
                                                    { ()robotInit void public
bindings, button our all perform will This  RobotContainer. our Instantiate //
                                                                      our put and ↪
                                     dashboard. the on chooser autonomous //
                              ();getInstanceRobotContainer. = m_robotContainer
      kFramework_tInstances. ,kResourceType_Framework(tResourceType.reportHAL.
                                                                   );RobotBuilder ↪
                                                                                    }

                                                                                 **/
   ␣for this Use mode. the matter no packet, robot every called is function This *
                                                                      like items ↪
    ␣and teleoperated autonomous, disabled, during ran want you that diagnostics *
                                                                            test. ↪
                                                                                   *
          before but functions, periodic specific mode the after runs p>This< *
                         updating. integrated SmartDashboard and LiveWindow *
                                                                                  */
                                                                        @Override
                                                   { ()robotPeriodic void public
newly- adding buttons, polling for responsible is This  Scheduler. the Runs //
                                                                         scheduled ↪
        ␣or finished removing commands, already-scheduled running commands, //
                                                          commands, interrupted ↪
   ␣the from called be must This  methods. periodic() subsystem running and //
                                                                   periodic s'robot ↪
        work. to framework Command-based the in anything for order in block //
[redacted]
                                                                                    }



                                                                                 **/
        mode. Disabled enters robot the time each once called is function This *
                                                                                  */
                                                                        @Override
                                                   { ()disabledInit void public
                                                                                    }

                                                                        @Override
                                                { ()disabledPeriodic void public
                                                                                    }

                                                                                 **/
              ␣@link{ your by selected command autonomous the runs autonomous This *
                                                            class. RobotContainer} ↪
                                                                                  */
                                                                        @Override
                                                  { ()autonomousInit void public
[redacted]
```

page) next on (continues

(□□□□ □□□□□ □□□□)

[redacted]

```
                                                      }

                                                    **/
         autonomous. during periodically called is function This *
                                                    */
                                              @Override
                        { ()autonomousPeriodic void public
                                                      }

                                              @Override
                                { ()teleopInit void public
   when running stops autonomous the that sure makes This //
     to autonomous the want you If running. starts teleop //
    remove command, another by interrupted until continue //
                              out. it comment or line this //
                       { )null =! (m_autonomousCommand if
                        ();cancelm_autonomousCommand.
                                                  }
                                                      }

                                                    **/
 control. operator during periodically called is function This *
                                                   */
                                              @Override
                           { ()teleopPeriodic void public
                                                      }

                                              @Override
                                  { ()testInit void public
  mode. test of start the at commands running all Cancels //
             ();cancelAll().getInstanceCommandScheduler.
                                                      }

                                                    **/
              mode. test during periodically called is function This *
                                                    */
                                              @Override
                             { ()testPeriodic void public
                                                      }

                                                          }
```

(Header) C++

```
                      Robot. TYPE: ROBOTBUILDER //
                                      once pragma#

                          frc/TimedRobot.h>< include#
                  frc2/command/Command.h>< include#

                        RobotContainer.h"" include#
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                              :public
                          ;override RobotInit() void
                      ;override ()RobotPeriodic void
                       ;override ()DisabledInit void
                   ;override ()DisabledPeriodic void
                     ;override ()AutonomousInit void
                 ;override ()AutonomousPeriodic void
                         ;override ()TeleopInit void
                     ;override ()TeleopPeriodic void
                       ;override ()TestPeriodic void

                                             :private
  it teleop testing if that so default by null it Have //
crash. potentially and behavior undefined have t'doesn //
             ;nullptr = m_autonomousCommand *Command::frc2

GetInstance();::RobotContainer = m_container *RobotContainer
                                                       ;}
```

(Source) C++

```
                                Robot. TYPE: ROBOTBUILDER //

                                           Robot.h"" include#

              frc/smartdashboard/SmartDashboard.h>< include#
                  frc2/command/CommandScheduler.h>< include#

                                     }{ ()Robot::RobotInit void

                                                          **/
   Use mode. the matter no packet, robot every called is function This *
 disabled, during run to want you that diagnostics like items for this *
                           test. and teleoperated autonomous, *
                                                            *
    before but functions, periodic specific mode the after runs This p>< *
                  updating. integrated SmartDashboard and LiveWindow *
                                                           */

                                                          **/
  You mode. Disabled enters robot the time each once called is function This *
   the when clear to want you information subsystem any reset to it use can *
                                           disabled. is robot *
                                                           */
                                  }{ ()Robot::DisabledInit void

                              }{ ()Robot::DisabledPeriodic void

                                                          **/
     @link{ your by selected command autonomous the runs autonomous This *
                                          class. RobotContainer} *
                                                           */
                                 { ()Robot::AutonomousInit void
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
[redacted]
}

}{ ()Robot::AutonomousPeriodic void

{ ()Robot::TeleopInit void
when running stops autonomous the that sure makes This //
to autonomous the want you If running. starts teleop //
remove command, another by interrupted until continue //
out. it comment or line this //
{ )nullptr =! (m_autonomousCommand if
Cancel();>-m_autonomousCommand
;nullptr = m_autonomousCommand
}
}

**/
control. operator during periodically called is function This *
*/
}{ ()Robot::TeleopPeriodic void

**/
mode. test during periodically called is function This *
*/
}{ ()Robot::TestPeriodic void

RUNNING_FRC_TESTS ifndef#
} ();>Robot<StartRobot::frc return { ()main int
endif#
```

this to parts of number a are There RobotBuilder. by generated program main the is This sections): (highlighted program

1. and `autonomousPeriodic()` your call will TimedRobot TimedRobot. extends class This 20ms. every methods `teleopPeriodic()`
2. pass. scheduling one make 20ms, every called is which method robotPeriodic the In
3. the in autonomous of start the at scheduled is provided command autonomous The in period autonomous the of end the at canceled and method `autonomousInit()` .`teleopInit()`

### RobotContainer

Java

```
RobotContainer. TYPE: ROBOTBUILDER //

;frc.robot package

;frc.robot.commands.* import
;frc.robot.subsystems.* import
;edu.wpi.first.wpilibj.smartdashboard.SendableChooser import
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
;edu.wpi.first.wpilibj.smartdashboard.SmartDashboard import
;edu.wpi.first.wpilibj2.command.Command.InterruptionBehavior import

ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
;edu.wpi.first.wpilibj2.command.Command import
;edu.wpi.first.wpilibj2.command.InstantCommand import
;edu.wpi.first.wpilibj.Joystick import
;edu.wpi.first.wpilibj2.command.button.JoystickButton import
;frc.robot.subsystems.* import

ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //


**/
␣Command-based Since  declared. be should robot the of bulk the where is class This *
a is ↪
the in handled be actually should logic robot little very paradigm, declarative"" *
Robot} {@link ↪
␣the of structure the Instead,  calls). scheduler the than (other methods periodic *
robot ↪
here. declared be should mappings) button and commands, subsystems, (including *
*/
{ RobotContainer class public

RobotContainer(); new = m_robotContainer RobotContainer static private

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
subsystems s'robot The //
[redacted]

Joysticks //
[redacted]
);1Joystick( new = joystick1 Joystick final private
);0Joystick( new = logitechController Joystick final private

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //



commands autonomous for chooser A //
();><SendableChooser new = m_chooser >Command<SendableChooser

**/
commands. and devices, OI subsystems, Contains  robot. the for container The *
*/
{ ()RobotContainer private
ID=SMARTDASHBOARD SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
Subsystems Smartdashboard //
(6) // (m_wrist);putDataSmartDashboard.
(m_elevator);putDataSmartDashboard.
(m_claw);putDataSmartDashboard.
(m_drivetrain);putDataSmartDashboard.


```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                    Buttons SmartDashboard //

        m_claw)); ,1.0OpenClaw( new ,"OpenTime Claw: Open"(putDataSmartDashboard.
                                      Pickup()); new ,"Pickup"(putDataSmartDashboard.
                                        Place()); new ,"Place"(putDataSmartDashboard.
                          PrepareToPickup()); new ,"Pickup To Prepare"(putDataSmartDashboard.
,0SetElevatorSetpoint( new ,"Bottom Setpoint: Elevator Set"(putDataSmartDashboard.
                                                                  m_elevator)); ↪
                           ␣new ,"Platform Setpoint: Elevator Set"(putDataSmartDashboard.
                                           m_elevator)); ,0.2SetElevatorSetpoint( ↪
␣,0.3SetElevatorSetpoint( new ,"Top Setpoint: Elevator Set"(putDataSmartDashboard.
                                                                   m_elevator)); ↪
 ␣,0SetWristSetpoint( new ,"Horizontal Setpoint: Wrist Set"(putDataSmartDashboard.
                                                                      m_wrist)); ↪
  -SetWristSetpoint( new ,"Wrist Raise Setpoint: Wrist Set"(putDataSmartDashboard.
                                                                m_wrist)); ,45 ↪
  m_drivetrain)); ,0 ,3Drive( new ,"Straight3Meters Drive:"(putDataSmartDashboard.
       ␣,PlaceDistanceDrive(Drivetrain. new ,"Place Drive:"(putDataSmartDashboard.
                                       m_drivetrain)); ,BackAwayDistanceDrivetrain. ↪

                    ID=SMARTDASHBOARD SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                       bindings button the Configure //
                                                            configureButtonBindings();

                                                          commands default Configure //
 ID=SUBSYSTEM_DEFAULT_COMMAND SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //




         ID=SUBSYSTEM_DEFAULT_COMMAND SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                            chooser sendable autonomous Configure //
                   ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

m_ ,0SetElevatorSetpoint( new ,"Bottom Setpoint: Elevator Set"(addOptionm_chooser.
                                                                    elevator)); ↪
 0.SetElevatorSetpoint( new ,"Platform Setpoint: Elevator Set"(addOptionm_chooser.
                                                             m_elevator)); ,2 ↪
 m_ ,0.3SetElevatorSetpoint( new ,"Top Setpoint: Elevator Set"(addOptionm_chooser.
                                                                    elevator)); ↪


                       ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                       m_chooser); ,"Mode Auto"(putDataSmartDashboard.
                                                                                 }

                                          { ()getInstance RobotContainer static public
                                                       m_robotContainer; return
                                                                                 }

                                                                               **/
␣created be can Buttons  mappings. button->command your define to method this Use *
                                                                               by ↪
                 ({@link subclasses its of one or GenericHID} @link{ a instantiating *
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
 ␣it passing then and XboxController}), @link{ or edu.wpi.first.wpilibj.Joystick} *
                                                                            a to ↪
                  edu.wpi.first.wpilibj2.command.button.JoystickButton}. @link{ *
                                                                               */
                                          { ()configureButtonBindings void private
                 ID=BUTTONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                              buttons some Create //
[redacted]
   ));kCancelSelf(InterruptionBehavior.withInterruptBehaviorAutonomous(). new(onTruer1.

                  );11 JoystickButton(logitechController, new = l1 JoystickButton final
         ));kCancelSelf(InterruptionBehavior.withInterruptBehaviorPlace(). new(onTruel1.

                  );10 JoystickButton(logitechController, new = r2 JoystickButton final
        ));kCancelSelf(InterruptionBehavior.withInterruptBehaviorPickup(). new(onTruer2.

                   );9 JoystickButton(logitechController, new = l2 JoystickButton final
            (InterruptionBehavior.withInterruptBehaviorPrepareToPickup(). new(onTruel2.
                                                                    ));kCancelSelf ↪

              );8 JoystickButton(logitechController, new = dpadLeft JoystickButton final
  (InterruptionBehavior.withInterruptBehaviorm_claw). ,1.0OpenClaw( new(onTruedpadLeft.
                                                                    ));kCancelSelf ↪

             );6 JoystickButton(logitechController, new = dpadRight JoystickButton final
   (InterruptionBehavior.withInterruptBehavior). m_claw CloseClaw( new(onTruedpadRight.
                                                                    ));kCancelSelf ↪

              );7 JoystickButton(logitechController, new = dpadDown JoystickButton final
                              m_elevator). ,0SetElevatorSetpoint( new(onTruedpadDown.
                          ));kCancelSelf(InterruptionBehavior.withInterruptBehavior ↪

                );5 JoystickButton(logitechController, new = dpadUp JoystickButton final
                              m_elevator). ,0.3SetElevatorSetpoint( new(onTruedpadUp.
                          ));kCancelSelf(InterruptionBehavior.withInterruptBehavior ↪



                        ID=BUTTONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                                }

                     ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                           { ()getLogitechController Joystick public
                                                      logitechController; return
                                                                              }

                                                    { ()getJoystick1 Joystick public
                                                               joystick1; return
                                                                              }

                                                    { ()getJoystick2 Joystick public
                                                               joystick2; return
                                                                              }


                       ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
```

page) next on (continues

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```

                                                                        **/
        class. Robot} @link{ main the to command autonomous the pass to this Use *
                                                                         *
                                     autonomous in run to command the @return *
                                                                         */
                                        { ()getAutonomousCommand Command public
                             autonomous in run be will command selected The //
                                                 ();getSelectedm_chooser. return
                                                                          }


                                                                            }
```

(Header) C++

```
                                        RobotContainer. TYPE: ROBOTBUILDER //

                                                                once pragma#

                       ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                              frc/smartdashboard/SendableChooser.h>< include#
                                           frc2/command/Command.h>< include#

                                              subsystems/Claw.h"" include#
                                        subsystems/Drivetrain.h"" include#
                                          subsystems/Elevator.h"" include#
                                             subsystems/Wrist.h"" include#

                                          commands/Autonomous.h"" include#
                                           commands/CloseClaw.h"" include#
                                               commands/Drive.h"" include#
                                            commands/OpenClaw.h"" include#
                                              commands/Pickup.h"" include#
                                               commands/Place.h"" include#
                                     commands/PrepareToPickup.h"" include#
                                 commands/SetElevatorSetpoint.h"" include#
                                    commands/SetWristSetpoint.h"" include#
                                           commands/TankDrive.h"" include#
                                                 frc/Joystick.h>< include#
                              frc2/command/button/JoystickButton.h>< include#

                     ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                     { RobotContainer class

                                                                   :public

                                      GetAutonomousCommand(); *Command::frc2
                                       ();GetInstance *RobotContainer static

                 ID=PROTOTYPES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                    subsystems s'robot The //
[redacted]
                                                                m_claw; Claw
                                                    m_elevator; Elevator
```

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```
m_wrist; Wrist


();getJoystick2 *Joystick::frc
();getJoystick1 *Joystick::frc
();getLogitechController *Joystick::frc

ID=PROTOTYPES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

:private

RobotContainer();

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
Joysticks //

;}1m_joystick1{ Joystick::frc
;}2m_joystick2{ Joystick::frc

m_chooser; >*Command::frc2<SendableChooser::frc

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

m_autonomousCommand; Autonomous
m_robotContainer; *RobotContainer static

();ConfigureButtonBindings void
;}
```

(Source) C++

```
RobotContainer. TYPE: ROBOTBUILDER //

RobotContainer.h"" include#
frc2/command/ParallelRaceGroup.h>< include#
frc/smartdashboard/SmartDashboard.h>< include#



;NULL = m_robotContainer::RobotContainer *RobotContainer

m_autonomousCommand( : RobotContainer()::RobotContainer
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
){



ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

ID=SMARTDASHBOARD SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
Subsystems Smartdashboard //
m_drivetrain);&PutData(::SmartDashboard::frc
m_claw);&PutData(::SmartDashboard::frc
m_elevator);&PutData(::SmartDashboard::frc
m_wrist);&PutData(::SmartDashboard::frc

```

page) next on (continues

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```
                                                      Buttons SmartDashboard //

␣PlaceDistance,::Drive(Drivetrain new ,"Place Drive:"PutData(::SmartDashboard::frc
                                    m_drivetrain));& BackAwayDistance,::Drivetrain ↪
              ␣new ,"Horizontal Setpoint: Wrist Set"PutData(::SmartDashboard::frc
                                                 m_wrist));& ,0SetWristSetpoint( ↪
             ␣new ,"Wrist Raise Setpoint: Wrist Set"PutData(::SmartDashboard::frc
                                               m_wrist));& ,45-SetWristSetpoint( ↪
               ␣new ,"Bottom Setpoint: Elevator Set"PutData(::SmartDashboard::frc
                                          m_elevator));& ,0SetElevatorSetpoint( ↪
             ␣new ,"Platform Setpoint: Elevator Set"PutData(::SmartDashboard::frc
                                        m_elevator));& ,0.2SetElevatorSetpoint( ↪
                  ␣new ,"Top Setpoint: Elevator Set"PutData(::SmartDashboard::frc
                                        m_elevator));& ,0.3SetElevatorSetpoint( ↪
         PrepareToPickup()); new ,"Pickup To Prepare"PutData(::SmartDashboard::frc
                                  Place()); new ,"Place"PutData(::SmartDashboard::frc
                                Pickup()); new ,"Pickup"PutData(::SmartDashboard::frc
m_claw));& s,_1.0OpenClaw( new ,"OpenTime Claw: Open"PutData(::SmartDashboard::frc
             )); m_claw& CloseClaw( new ,"Claw Close"PutData(::SmartDashboard::frc

                 ID=SMARTDASHBOARD SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                       ConfigureButtonBindings();

             ID=DEFAULT-COMMANDS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //


               ID=DEFAULT-COMMANDS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                   ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

 & ,0SetElevatorSetpoint( new ,"Bottom Setpoint: Elevator Set"m_chooser.AddOption(
                                                                   m_elevator)); ↪
 0.SetElevatorSetpoint( new ,"Platform Setpoint: Elevator Set"m_chooser.AddOption(
                                                               m_elevator));& ,2 ↪
m_& ,0.3SetElevatorSetpoint( new ,"Top Setpoint: Elevator Set"m_chooser.AddOption(
                                                                     elevator)); ↪


                     ID=AUTONOMOUS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                  m_chooser);& ,"Mode Auto"PutData(::SmartDashboard::frc

                                                                                 }

                                          { GetInstance()::RobotContainer *RobotContainer
                                                          { )NULL == (m_robotContainer if
                                         RobotContainer(); new = m_robotContainer
                                                                                }
                                                         (m_robotContainer);return
                                                                                 }
```

page) next on (continues

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```
{ ConfigureButtonBindings()::RobotContainer void
ID=BUTTONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //


;}7 m_logitechController,&m_dpadDown{ JoystickButton::frc2
;}6 m_logitechController,&m_dpadRight{ JoystickButton::frc2
;}8 m_logitechController,&m_dpadLeft{ JoystickButton::frc2
;}9 m_logitechController,&m_l2{ JoystickButton::frc2
;}10 m_logitechController,&m_r2{ JoystickButton::frc2
;}11 m_logitechController,&m_l1{ JoystickButton::frc2
;}12 m_logitechController,&m_r1{ JoystickButton::frc2

m_elevator).& ,0.3m_dpadUp.OnTrue(SetElevatorSetpoint(
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_elevator).& ,0m_dpadDown.OnTrue(SetElevatorSetpoint(
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

). m_claw& m_dpadRight.OnTrue(CloseClaw(
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_claw).& s,_1.0m_dpadLeft.OnTrue(OpenClaw(
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_l2.OnTrue(PrepareToPickup().
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_r2.OnTrue(Pickup().
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_l1.OnTrue(Place().
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪

m_r1.OnTrue(Autonomous().
kCancelSelf));::InterruptionBehavior::Command::WithInterruptBehavior(frc2 ↪


ID=BUTTONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}

ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

{ getLogitechController()::RobotContainer *Joystick::frc
m_logitechController;& return
}
{ getJoystick1()::RobotContainer *Joystick::frc
m_joystick1;& return
}
{ getJoystick2()::RobotContainer *Joystick::frc
m_joystick2;& return
}

ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //


{ GetAutonomousCommand()::RobotContainer *Command::frc2
```

page) next on (continues

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```
autonomous in run be will command selected The //
                  m_chooser.GetSelected(); return
                                                 }
```

and subsystems the where is which RobotBuilder by generated RobotContainer the is This (highlighted program this to parts of number a are There defined. are interface operator sections):

1. any to parameters as passed be can They here. declared is subsystems the of Each them. require that commands
2. is it properties, robot RobotBuilder in provided command autonomous an is there If dashboard. the on selected be to Chooser Sendable the to added
3. here. generated is components interface operator the all for code The
4. generated also is run should that commands to buttons OI the link to code the addition In here.
5. defined are running are commands other no when subsystem a on run be to Commands here.
6. here. defined are dashboard a via run be to Commands

## Code the Writing - RobotBuilder 20.2

### Project a for Code Generating 20.2.1

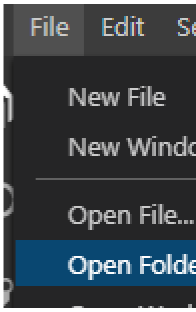
and code the export to need you'll RobotBuilder, in framework robot your up set you've After so. doing for process the describes article This Code. Studio Visual into it load

### Project the for Code the Generate

You have successfully

(2) C++ or Java click then and (1) want you where to points Directory Export the that Verify code. update or project Code VS a generate to

### Code Studio Visual in Project the Open

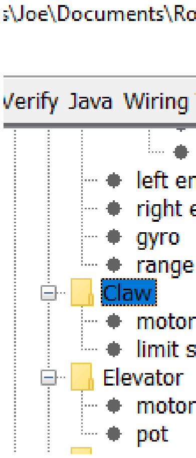


click and location Export your to Navigate .**Folder Open >- File** select and Code VS Open .**Folder Select**

## Subsystem a for Code the Writing 20.2.2

simple For straightforward. very is subsystem working actual an create to code Adding we section this In simple. extremely be to out turns it feedback use don’t that subsystems to switch limit a has also subsystem *Claw* The subsystem. *Claw* a of example an at look will grip. the in is object an if determine

### Subsystem Claw the of Representation RobotBuilder



Motor VictorSPX single a by operated subsystem a is arm robot a of end the at claw The and closing, start opening, start do, to motor the want we things three are There Controller. closing and opening for timing The subsystem. the of responsibility the is This moving. stop the if get to method a define also will We tutorial. this in later command a by handled be will claw gripping is an object.

### Capabilities Subsystem Adding

Java

```
                            Subsystem. TYPE: ROBOTBUILDER //

                               ;frc.robot.subsystems package


                                ;frc.robot.commands.* import
         ;edu.wpi.first.wpilibj.livewindow.LiveWindow import
        ;edu.wpi.first.wpilibj2.command.SubsystemBase import

 ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                  ;edu.wpi.first.wpilibj.DigitalInput import
  ;edu.wpi.first.wpilibj.motorcontrol.MotorController import
     ;edu.wpi.first.wpilibj.motorcontrol.PWMVictorSPX import

 ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //


                                                         **/
```

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```
 *
 */
public class Claw extends SubsystemBase {
    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=CONSTANTS
public static final double PlaceDistance = 0.1;
public static final double BackAwayDistance = 0.6;

    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=CONSTANTS

    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
private PWMVictorSPX motor;
private DigitalInput limitswitch;

    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS

    /**
    *
    */
    public Claw() {
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=CONSTRUCTORS
motor = new PWMVictorSPX(4);
 addChild("motor",motor);
 motor.setInverted(false);

limitswitch = new DigitalInput(4);
 addChild("limit switch", limitswitch);



    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=CONSTRUCTORS
    }

    @Override
    public void periodic() {
        // This method will be called once per scheduler run

    }

    @Override
    public void simulationPeriodic() {
        // This method will be called once per scheduler run when in simulation

    }

```

[redacted]

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[redacted]

```
}
```

C++

```
Subsystem. TYPE: ROBOTBUILDER //

ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
subsystems/Claw.h"" include#
frc/smartdashboard/SmartDashboard.h>< include#

ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

Claw(){::Claw
    );"Claw"SetName(
    ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
    );"Claw"SetSubsystem(

    m_limitswitch);& ,"switch limit"AddChild(


    m_motor);& ,"motor"AddChild(
    );falsem_motor.SetInverted(

    ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}

{ Periodic()::Claw void
    loop every run be to here code Put //

}

{ SimulationPeriodic()::Claw void
    simulation in when run scheduler per once called be will method This //

}

ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
```

[redacted]

page) next on (continues

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[redacted]

from claw the stop and close, open, will that `claw.cpp` or `claw.java` the to methods Add operate actually that commands by used be will Those switch. limit claw the get and moving claw. the

---

changes the see to easier it make to file this from removed been have comments The :□□□□ document. this for

---

so RobotBuilder by created are `limitswitch` and `motor` called variable member that Notice a have will items palette indragged- your of Each subsystem. the throughout used be can it RobotBuilder. in given name the with variable member

### Only) (C++ File Header the to Declarations Method the Adding

C++

```
                                        Subsystem. TYPE: ROBOTBUILDER //
                                                          once pragma#

                   ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                  frc2/command/SubsystemBase.h>< include#
                                           frc/DigitalInput.h>< include#
                                frc/motorcontrol/PWMVictorSPX.h>< include#

                     ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                                      **/
                                                                       *
                                                                       *
                                                     ExampleAuthor @author *
                                                                      */
                                   { SubsystemBase::frc2 public :Claw class
                                                                 :private
                 except private is possible everything that desirable s'It //
                         capabilities subsystem implement that methods for //
          ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                         ;}4m_limitswitch{ DigitalInput::frc
                                                ;}4m_motor{ PWMVictorSPX::frc

            ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                  :public
                                                                  Claw();

                                              ;override ()Periodic void
                                     ;override ()SimulationPeriodic void
```

[redacted]

page) next on (continues

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```
                     ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

                       ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                         ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                        ;0.1 = PlaceDistance double const constexpr static
                                     ;0.6 = BackAwayDistance double const constexpr static

                           ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //



                                                                                      ;}
```

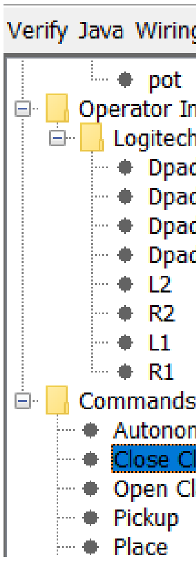
declarations the ,`Claw.cpp` file, implementation class the to methods the adding to addition In be must that declarations Those .`Claw.h` file, header the to added be to need methods the for here. shown are added

*define* to need you closing and opening handle to subsystem claw the to behavior the add To .*commands*

### Command a for Code the Writing 20.2.3

right the at stop to it get to but moving, robot your on mechanisms the get classes Subsystem in Previously Commands. write you operations complex more through sequence and time to robot a on subsystem *Claw* the for code the developed we *subsystem a for code the writing* command a for code the write will we Now moving. stop to or closing, opening, claw the start Our close. and open to claw the get to time right the for motor claw the run actually will that or it open to second 1 for motor the run we where mechanism simple very a is example claw it. close to tripped is switch limit the until

#### RobotBuilder in Command Claw Close



the requires it that Notice RobotBuilder. in command *CloseClaw* the of definition the is This step. next the in explained is This subsystem. *Claw*

### Class CloseClaw Generated

Java

```
Command. TYPE: ROBOTBUILDER //

;frc.robot.commands package
;edu.wpi.first.wpilibj2.command.CommandBase import

ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
;frc.robot.subsystems.Claw import

ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

**/
*
*/
{ CommandBase extends CloseClaw class public

ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
m_claw; Claw final private

ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //


{ subsystem) (ClawCloseClaw public


ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
ID=VARIABLE_SETTING SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

ID=VARIABLE_SETTING SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
ID=REQUIRES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

subsystem; = m_claw
addRequirements(m_claw);

ID=REQUIRES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}

scheduled. initially is command the when Called //
@Override
{ ()initialize void public

}

scheduled. is command the while runs scheduler the time every Called //
@Override
{ ()execute void public
}

interrupted. is or ends command the once Called //
@Override
{ interrupted) boolean(end void public

}
```

page) next on (continues

(▯▯▯▯ ▯▯▯▯▯ ▯▯▯▯)

```
end. should command the when true Returns //
@Override
{ ()isFinished boolean public

}

@Override
{ ()runsWhenDisabled boolean public
ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
;false return

ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}
}
```

C++

```
Command. TYPE: ROBOTBUILDER //

ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

commands/CloseClaw.h"" include#

m_claw) *CloseClaw(Claw::CloseClaw
m_claw(m_claw){:

dependencies subsystem declare to here AddRequirements() Use //
AddRequirements(m_Subsystem); eg. //
);"CloseClaw"SetName(
AddRequirements({m_claw});

ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

}

time first the runs Command this before just Called //
{ Initialize()::CloseClaw void

}

run to scheduled is Command this when repeatedly Called //
{ Execute()::CloseClaw void

}

execute() run to needs longer no Command this when true return this Make //
{ IsFinished()::CloseClaw bool

}

true returns isFinished after once Called //
{ interrupted) boolEnd(::CloseClaw void

}
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                 { const RunsWhenDisabled()::CloseClaw bool
                ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                          ;false return

                  ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                          }
```

command The  command. *CloseClaw* the for files class the generate will RobotBuilder
very this operate To  time. over operation the is that claw, the of behavior the represents
*Claw* The  direction,. close the in operate to needs motor the mechanism claw simple
The  it. stop to and direction right the in running motor the start to methods has subsystem
are that code of lines The  time. correct the for motor the run to is responsibility commands
behavior. this add to added are boxes the in shown

1. that method `Close()` the calling by direction closing the in moving motor claw the Start
method. Initialize *CloseClaw* the in subsystem *Claw* the to added was
2. tripped. is subsystem *Claw* the in switch limit the when finished is command This
3. In up. clean to place a is and finished is command the when called is method `End()` The
out. run has time the since stopped is motor the case, this

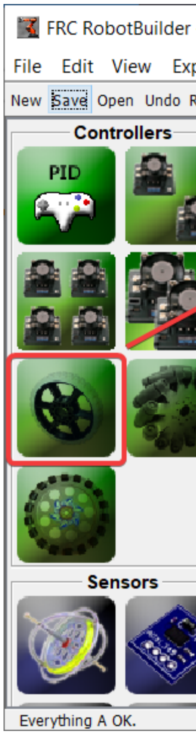
### Joysticks and Drive Tank with Robot the Driving 20.2.4

a of part are that actuators some drive should that joystick a have to is case use common A
the and class RobotContainer the in created is joystick the that is problem The  subsystem.
when that, command a create to is idea The  subsystem. the in are controlled be to motors
subsystem the on created is that method a calls and joystick the from input reads scheduled,
motors. the drives that

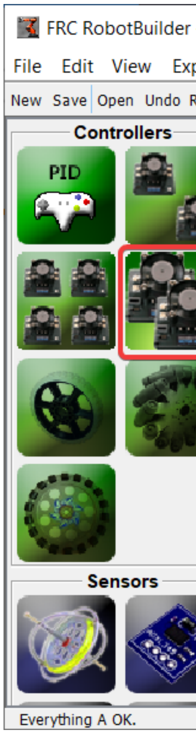
of pair a using drive tank in operated is that shown is subsystem base drive a example this In
joysticks.

### Subsystem Train Drive a Create

the for driving the handle to be will responsibility Its Train. Drive called subsystem a Create base. robot



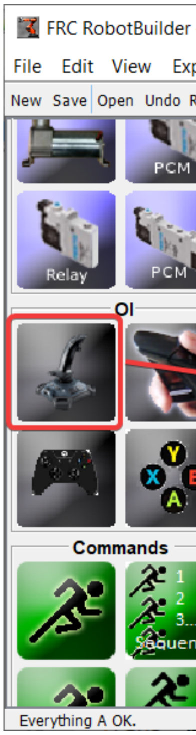
left a is There drive. motor two a for object Drive Differential a create Train Drive the Inside class. Drive Differential the of part as motor right and motor



Drive, Differential the inside robot, the drive to motors two then more use to want we Since can they so controllers motor multiple group will These Groups. Controller Motor two create Drive. Differential with used be

Group. Controller Motor each in Controllers Motor two create Finally,

### Interface Operator the to Joysticks the Add



right the is other the and stick left the is one Interface, Operator the to joysticks two Add sides. right and left robots the drive to used are joysticks two the on axisy- The stick.

step. next the to continuing before Java or C++ to program your export to sure Be :□□□□

### Subsystem the on Motors the Write to Method a Create

java

```
Subsystem. TYPE: ROBOTBUILDER //

;frc.robot.subsystems package


;frc.robot.commands.* import
;edu.wpi.first.wpilibj.livewindow.LiveWindow import
;edu.wpi.first.wpilibj2.command.SubsystemBase import

ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
;edu.wpi.first.wpilibj.AnalogGyro import
;edu.wpi.first.wpilibj.AnalogInput import
;edu.wpi.first.wpilibj.CounterBase.EncodingType import
;edu.wpi.first.wpilibj.Encoder import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
;edu.wpi.first.wpilibj.motorcontrol.MotorController import
;edu.wpi.first.wpilibj.motorcontrol.MotorControllerGroup import
```

page) next on (continues

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```
                  ;edu.wpi.first.wpilibj.motorcontrol.PWMVictorSPX import

            ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //


                                                                     **/
                                                                      *
                                                                     */
                                   { SubsystemBase extends Drivetrain class public
     ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                   ;0.1 = PlaceDistance double final static public
                                ;0.6 = BackAwayDistance double final static public

       ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

  ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                 left1; PWMVictorSPX private
                                                 left2; PWMVictorSPX private
                                       leftMotor; MotorControllerGroup private
                                                right1; PWMVictorSPX private
                                                right2; PWMVictorSPX private
                                      rightMotor; MotorControllerGroup private
                                            drive; DifferentialDrive private
                                                leftencoder; Encoder private
                                               rightencoder; Encoder private
                                                   gyro; AnalogGyro private
                                            rangefinder; AnalogInput private

    ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                                 **/
                                                                  *
                                                                 */
                                                   { ()Drivetrain public
ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                              );0PWMVictorSPX( new = left1
                                                left1);,"left1"addChild(
                                               );false(setInvertedleft1.

                                              );1PWMVictorSPX( new = left2
                                                left2);,"left2"addChild(
                                               );false(setInvertedleft2.

                        );  left2 MotorControllerGroup(left1, new = leftMotor
                                        leftMotor);,"Motor Left"addChild(


                                             );5PWMVictorSPX( new = right1
                                              right1);,"right1"addChild(
                                             );false(setInvertedright1.

                                             );6PWMVictorSPX( new = right2
                                              right2);,"right2"addChild(
                                             );false(setInvertedright2.

                     );  right2 MotorControllerGroup(right1, new = rightMotor
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                         rightMotor);,"Motor Right"addChild(


                      rightMotor); DifferentialDrive(leftMotor, new = drive
                                                  drive);,"Drive"addChild(
                                             );true(setSafetyEnableddrive.
                                                 );0.1(setExpirationdrive.
                                                  );1.0(setMaxOutputdrive.


                 );k4XEncodingType. ,false ,1 ,0Encoder( new = leftencoder
                                 leftencoder);,"encoder left"addChild(
                                 );1.0(setDistancePerPulseleftencoder.

                );k4XEncodingType. ,false ,3 ,2Encoder( new = rightencoder
                               rightencoder);,"encoder right"addChild(
                               );1.0(setDistancePerPulserightencoder.

                                                  );0AnalogGyro( new = gyro
                                                    gyro);,"gyro"addChild(
                                              );0.007(setSensitivitygyro.

                                           );1AnalogInput( new = rangefinder
                              rangefinder); ,"finder range"addChild(



            ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                        }

                                                                @Override
                                                { ()periodic void public
                   run scheduler per once called be will method This //

                                                                        }

                                                                @Override
                                      { ()simulationPeriodic void public
  simulation in when run scheduler per once called be will method This //

                                                                        }

                              subsystem this controlling for methods Put //
                                        Commands. from these Call here. //
```

[redacted]

```
                                                                          }
```

(Header) C++

```
                                               Subsystem. TYPE: ROBOTBUILDER //
                                                                   once pragma#

                  ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                              frc2/command/SubsystemBase.h>< include#
                                    frc/AnalogGyro.h>< include#
                                   frc/AnalogInput.h>< include#
                                     frc/Encoder.h>< include#
                             frc/drive/DifferentialDrive.h>< include#
                      frc/motorcontrol/MotorControllerGroup.h>< include#
                          frc/motorcontrol/PWMVictorSPX.h>< include#

                 ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                                   **/
                                                                     *
                                                                     *
                                                    ExampleAuthor @author *
                                                                    */
                             { SubsystemBase::frc2 public :Drivetrain class
                                                                :private
      except private is possible everything that desirable s'It //
                  capabilities subsystem implement that methods for //
  ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                   ;}1m_rangefinder{ AnalogInput::frc
                                            ;}0m_gyro{ AnalogGyro::frc
          k4X};::Encoder::frc ,false ,3 ,2m_rightencoder{ Encoder::frc
           k4X};::Encoder::frc ,false ,1 ,0m_leftencoder{ Encoder::frc
            m_rightMotor}; m_drive{m_leftMotor, DifferentialDrive::frc
        ;}  m_right2 m_rightMotor{m_right1, MotorControllerGroup::frc
                                         ;}6m_right2{ PWMVictorSPX::frc
                                         ;}5m_right1{ PWMVictorSPX::frc
           ;}  m_left2 m_leftMotor{m_left1, MotorControllerGroup::frc
                                          ;}1m_left2{ PWMVictorSPX::frc
                                          ;}0m_left1{ PWMVictorSPX::frc

    ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                 :public
                                                           Drivetrain();

                                         ;override ()Periodic void
                           ;override ()SimulationPeriodic void

 ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

   ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
     ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                       ;0.1 = PlaceDistance double const constexpr static
                    ;0.6 = BackAwayDistance double const constexpr static

       ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //



                                                                      ;}
```

(Source) C++

```
                                       Subsystem. TYPE: ROBOTBUILDER //

           ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
subsystems/Drivetrain.h"" include#
frc/smartdashboard/SmartDashboard.h>< include#

ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

Drivetrain(){::Drivetrain
);"Drivetrain"SetName(
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
);"Drivetrain"SetSubsystem(

m_rangefinder);& ,"finder range"AddChild(


m_gyro);& ,"gyro"AddChild(
);0.007m_gyro.SetSensitivity(

m_rightencoder);& ,"encoder right"AddChild(
);1.0m_rightencoder.SetDistancePerPulse(

m_leftencoder);& ,"encoder left"AddChild(
);1.0m_leftencoder.SetDistancePerPulse(

m_drive);& ,"Drive"AddChild(
);truem_drive.SetSafetyEnabled(
s);_0.1m_drive.SetExpiration(
);1.0m_drive.SetMaxOutput(


m_rightMotor);& ,"Motor Right"AddChild(


m_right2);& ,"right2"AddChild(
);falsem_right2.SetInverted(

m_right1);& ,"right1"AddChild(
);falsem_right1.SetInverted(

m_leftMotor);& ,"Motor Left"AddChild(


m_left2);& ,"left2"AddChild(
);falsem_left2.SetInverted(

m_left1);& ,"left1"AddChild(
);falsem_left1.SetInverted(

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}

{ Periodic()::Drivetrain void
loop every run be to here code Put //

}

{ SimulationPeriodic()::Drivetrain void
simulation in when run scheduler per once called be will method This //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                  }

          ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

            ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //


                              subsystem this controlling for methods Put //
                                        Commands. from these Call here. //
```

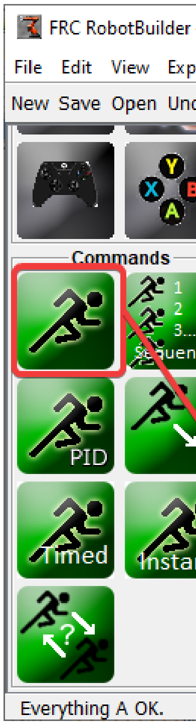
[redacted]

joystick. driver right and left the case this in inputs, joystick the takes that method a Create using steering tank does turn in that object DifferentialDrive the to passed are values The this driving, from robot the stops that stop() called method a create Also values. joystick the later. handy in come might

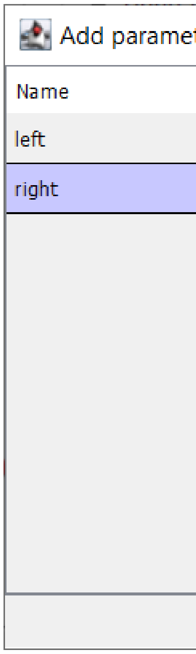
---

clarity for example this for removed been has output RobotBuilder Some :□□□□

## Methods Subsystem the Call and Values Joystick Read

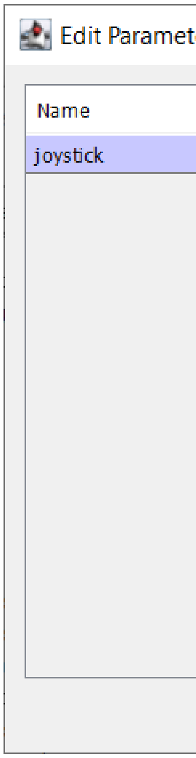


joystick the read to be will purpose Its Drive. Tank called case this in command, a Create the Requires command this that Notice subsystem. Base Drive the to them send and values use to tries else anything whenever running stop to it cause will This subsystem. Train Drive Train. Drive the



left
right

for C++) for `><double()std::function` or Java for `DoubleSupplier(` parameters two Create speeds. right and left the



joystick

`()` enter parameter left the For Java: values. joystick retrieve to preset parameter a Create For C++: `.getJoystick2().getY() >- ()` enter right for and `getJoystick1().getY() >-` enter right the for and `>GetY();}-getJoystick1() {return [this]` enter parameter left the `>GetY();}-getJoystick2() {return [this]` step. next the to continuing before Java or C++ to program your export to sure Be **:□□□□**

### Driving the do to Code the Add

java

```
                                                         Command. TYPE: ROBOTBUILDER //

                                                            ;frc.robot.commands package
                                                 ;edu.wpi.first.wpilibj.Joystick import
                                     ;edu.wpi.first.wpilibj2.command.CommandBase import
                                                       ;frc.robot.RobotContainer import
                            ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                ;frc.robot.subsystems.Drivetrain import

                          ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                                                    **/
                                                                                     *
                                                                                    */
                                           { CommandBase extends TankDrive class public

          ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                         m_drivetrain; Drivetrain final private

            ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                   ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //


                                           { subsystem) (DrivetrainTankDrive public


                     ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
           ID=VARIABLE_SETTING SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

                 ID=VARIABLE_SETTING SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                   ID=REQUIRES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

                                                      subsystem; = m_drivetrain
                                                 addRequirements(m_drivetrain);

                         ID=REQUIRES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                                  }

                                 scheduled. initially is command the when Called //
                                                                          @Override
                                                         { ()initialize void public
                                                                                  }

            scheduled. is command the while runs scheduler the time every Called //
                                                                          @Override
                                                            { ()execute void public
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                                 }

                                interrupted. is or ends command the once Called //
                                                                         @Override
                                            { interrupted) boolean(end void public

                                                                                 }

                                      end. should command the when true Returns //
                                                                         @Override
                                                     { ()isFinished boolean public
                                                                 ;false return
                                                                                 }

                                                                         @Override
                                               { ()runsWhenDisabled boolean public
                  ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                                 ;false return

                        ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                                 }
                                                                                     }
```

(Header) C++

```
                                                        Command. TYPE: ROBOTBUILDER //

                                                                          once pragma#

                      ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

                                               frc2/command/CommandHelper.h>< include#
                                                 frc2/command/CommandBase.h>< include#

                                                    subsystems/Drivetrain.h"" include#

                        ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                           RobotContainer.h"" include#
                                                             frc/Joystick.h>< include#

                                                                                   **/
                                                                                    *
                                                                                    *
                                                              ExampleAuthor @author *
                                                                                   */
           { >TankDrive CommandBase,::frc2<CommandHelper::frc2 public :TankDrive class
                                                                               :public
                   ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                     m_drivetrain); *TankDrive(Drivetrain explicit

                     ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

                                                           ;override ()Initialize void
                                                              ;override ()Execute void
                                                           ;override ()IsFinished bool
                                                  ;override interrupted) bool(End void
```

page) next on (continues

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```
                    ;override const ()RunsWhenDisabled bool


                                                  :private
   ID=VARIABLES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //


                                    m_drivetrain; *Drivetrain



      ID=VARIABLES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                          ;}
```

(Source) C++

```
                               Command. TYPE: ROBOTBUILDER //

     ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

                              commands/TankDrive.h"" include#

                   m_drivetrain) *TankDrive(Drivetrain::TankDrive
                                     m_drivetrain(m_drivetrain){:

   dependencies subsystem declare to here AddRequirements() Use //
                           AddRequirements(m_Subsystem); eg. //
                                          );"TankDrive"SetName(
                                    AddRequirements({m_drivetrain});

       ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                 }

             time first the runs Command this before just Called //
                                          { Initialize()::TankDrive void

                                                                 }

           run to scheduled is Command this when repeatedly Called //
                                             { Execute()::TankDrive void

                                                                 }

execute() run to needs longer no Command this when true return this Make //
                                          { IsFinished()::TankDrive bool
                                                         ;false return
                                                                 }

                    true returns isFinished after once Called //
                              { interrupted) boolEnd(::TankDrive void

                                                                 }

                            { const RunsWhenDisabled()::TankDrive bool
        ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                         ;false return
```

page) next on (continues

(□□□□ □□□□□ □□□□)

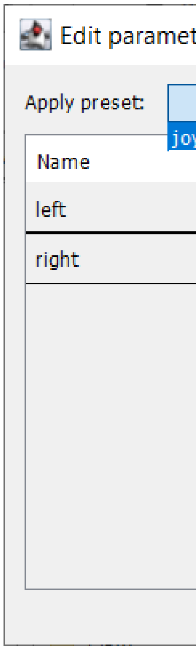
```
                    ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                                             }
```

the for the pass is needed is that All driving. actual the do to method execute the to code Add the for them uses just subsystem The subsystem. Train Drive the to parameters right and left steering. tank get we And object. DifferentialDrive its on method steering tank

the stopped, or interrupted is command this when that so method end() the in filled also We precaution. safety a as stopped be will motors

### Command Default Make

the for Command" "Default the be command Drive Tank the make to is step last The Drive the using is command other no whenever that means This subsystem. Train Drive the When behavior. desirable the probably is This control. in be will Joysticks the Train, Drive Tank the interrupt and train drive the require also will it running, is code autonomous will command DriveWithJoysticks the finished, is code autonomous the When command. back be will operators the and command), default the is it (because automatically restart should commands those driving, automatic teleop does that code any write you If control. in have and command Drive Tank the interrupt will too they that so DriveTrain the "require" also control. full



up. set previously preset parameter joystick the choose to is step final The

continuing. before Java or C++ to program your export to sure Be :

## Advanced - RobotBuilder 20.3

### Actuators Control to PIDSubsystem Using 20.3.1

for results guaranteed get to feedback for sensors use will subsystems advanced More to feedback use PIDSubsystems angles. wrist or heights elevator setting like operations an use we example this In position. particular a to it drive and actuator the control The height. the on feedback give to it to connected potentiometer turn10- a with elevator the to mechanism the control automatically to PIDController inbuilt- a has PIDSubsystem setpoints. correct

## Create a PIDSubsystem

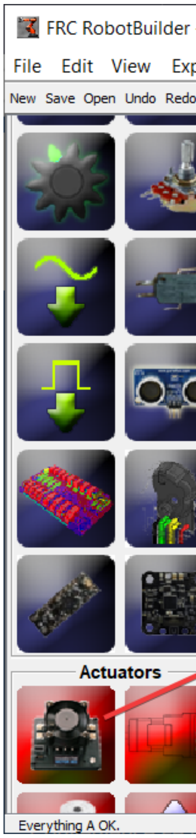
Error! Please fix the red compor

Creating a subsystem that uses feedback to control the position or speed of a mechanism is very easy.

1. Drag a PIDSubsystem from the palette to the Subsystems folder in the robot description
2. Rename the PID Subsystem to a more meaningful name for the subsystem, in this case Elevator

Notice that some of the parts of the robot description have turned red. This indicates that these components (the PIDSubsystem) haven't been completed and need to be filled in. The properties that are either missing or incorrect are shown in red.

### PIDSubsystem the to Actuators and Sensors Adding



PIDSubsystem the for components missing the Add

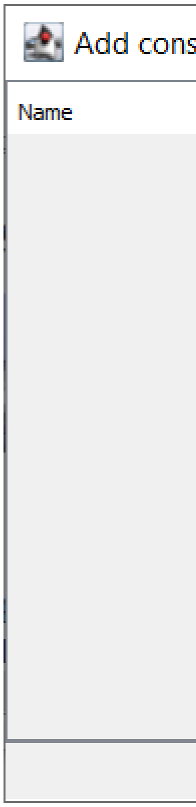
1. the case this in - subsystem particular the to controller) motor (a actuator the in Drag Elevator
2. sensor the case this in subsystem, the to feedback for used be will that sensor the Drag feedback. height elevator give might that potentiometer a is

## Parameters PID the in Fill

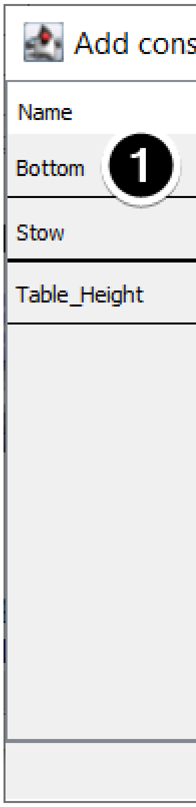
the of stability and sensitivity desired the get to in filled be to need values D and I, P, The I the for 0 and 6.0 of constant proportional a use we elevator our of case the In component. terms. D and

## Constants Setpoint Create

manage to constants create will we setpoints, elevator manage to easier it make to order In dialog. constants the up bring to box constants the on Click setpoints. the



button *constant add* the on Click



Bottom case: this in constant, the for name a in Fill 1.
double case: this in menu, downdrop- the from constant the for type a Select 2.
4.65 case: this in constant, the for value a Select 3.
constants adding continue to *constant add* Click 4.
*close and Save* Click constants, all entering After 5.

### PIDSubsystem a for Code the Writing 20.3.2

the in fill to have we and RobotBuilder the by generated is PIDSubsystem the of skeleton The the of output the with motor the drive and value potentiometer the provide to code the of rest PIDController. embedded

all it's Once RobotBuilder. the in created been has subsystem PID Elevator the sure Make toolbar Java/C++ the or menu Export the using project the for code Java/C++ generate set, menu.

needed is code additional no that such methods PIDSubsystem the generates RobotBuilder operation. basic for

### Constants PID the Setting

generated. automatically are constants PID and constants height The

Java

```
{ PIDSubsystem extends Elevator class public

 ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                     ;4.6 = Bottom double final static public
                     ;1.65 = Stow double final static public
              ;1.58 = Table_Height double final static public

   ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
   motor; PWMVictorSPX privatepot; AnalogPotentiometer private
                                            Variables D I P//
                        ;6.0 = kP double final static private
                        ;0.0 = kI double final static private
                        ;0.0 = kD double final static private
                        ;0.0 = kF double final static private
  ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
```

C++

```
 ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                 ;4.6 = Bottom double const constexpr static
                   ;1.65 = Stow double const constexpr static
           ;1.58 = Table_Height double const constexpr static

                     ;6.0 = kP double const constexpr static
                     ;0.0 = kI double const constexpr static
                     ;0.0 = kD double const constexpr static
                     ;0.0 = kF double const constexpr static
   ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
```

### Measurement Potentiometer Get

Java

```
                                                    @Override
                            { ()getMeasurement double public
    ID=SOURCE SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                         ();getpot. return

      ID=SOURCE SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                            }
```

C++

```
                      { ()Elevator::GetMeasurement double
    ID=SOURCE SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                       m_pot.Get(); return

      ID=SOURCE SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                            }
```

the providing is that sensor the of value the set to used is method `getMeasurement()` The
returns and generated automatically is code the case, this In controller. PID the for feedback
method. `get()` the by returned as voltage potentiometer the

### Output PID Calculate

Java

```
                                                  @Override
               { setpoint) double output, double(useOutput void public
                                                  kF;*setpoint =+ output
           ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                                  (output);setmotor.

            ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                  }
```

C++

```
        { setpoint) double output, double(Elevator::UseOutput void
                                          kF;*setpoint =+ output
   ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
                                             m_motor.Set(output);

    ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
                                                             }
```

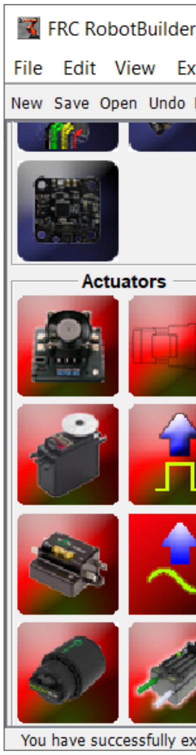
motor. the to directly output PID calculated the writes method `useOutput` The

PIDSubsystem. Elevator the create to required is that all That's

## Command Setpoint 20.3.3

a to actuator an drive to PIDSubsystem a with conjunction in works Command Setpoint A
happens This encoder. or potentiometer a using measured is that position or angle particular
task. this do to RobotBuilder in shortcut a is there that often so

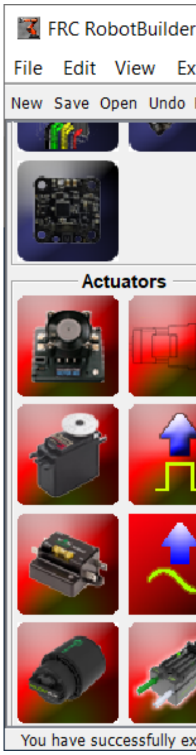
## PIDSubsystem a with Start



angle. the measures that potentiometer a with joint wrist a is there robot a in Suppose the and joint wrist the moves that motor the include that *PIDSubsystem a create* First constants PID the all have should PIDSubsystem The angle. the measures that potentiometer properly. working and in filled

current the off far how controls This parameter. **Tolerance** the set to important is It the that criteria the is This target. on considered be and setpoint the from be can value command. next the onto move to uses SetpointCommand

## Command Setpoint the Creating

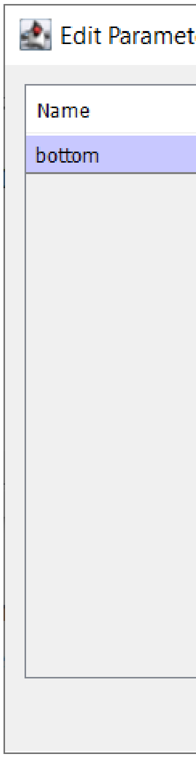


You have successfully ex

command“. Setpoint ”Add select and palette the in folder Commands the on clickRight-

## Parameters Command Setpoint

being is that PIDSubsystem the is field Requires The command. new the of name the in Fill subsystem. Elevator the case this in setpoint, a to driven


Edit Paramet

Name
bottom

setpoints. the up set to Presets Parameter the on Click 1.

*Preset Add* Select 2.

»bottom« case this (in name preset a Enter 3.

box entry setpoint the to next dropdown the Click 4.

subsystem Elevator the in created was that constant, Elevator.Bottom the Select 5. previously

setpoints. other the for 52- steps Repeat 6.

*close and Save* Click 7.

by created automatically is it command, this for code any in fill to need no is There RobotBuilder.

the to subsystem the drive automatically will it scheduled, is command this Whenever the in specified tolerance the within reached is setpoint the When setpoint. specified specify to important is It starts. command next the and ends command the PIDSubsystem, is tolerance the because end never might command this or PIDSubsystem the in tolerance a achieved. not

---

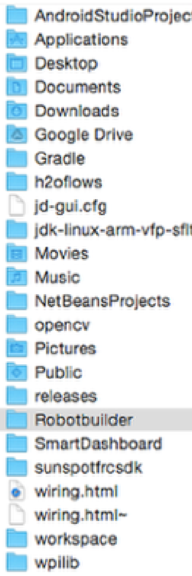
*Controls Advanced* the see please Control, PID about information more For :□□□□ *.Introduction*

---

### Components Custom Adding 20.3.4

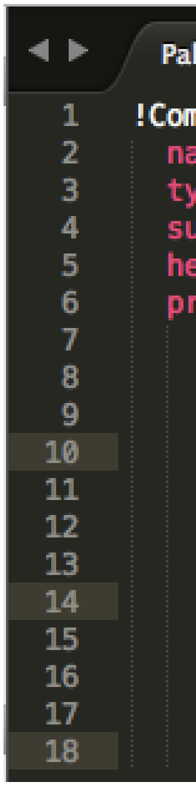
motors, for WPILib use just that programs robot creating for well very works RobotBuilder have doesn't RobotBuilder classes, custom use that teams for But sensors. and controllers, RobotBuilder in them use to taken be to need steps few a so classes, those for support any

#### Structure Component Custom


AndroidStudioProjec
Applications
Desktop
Documents
Downloads
Google Drive
Gradle
h2oflows
jd-gui.cfg
jdk-linux-arm-vfp-sfl
Movies
Music
NetBeansProjects
opencv
Pictures
Public
releases
Robotbuilder
SmartDashboard
sunspotfrcsdk
wiring.html
wiring.html~
workspace
wpilib

`\C:` is ~ where `~/wpilib/YYYY/Robotbuilder/extensions` in go all components Custom year. FRC® the is YYYY and Windows on `Public\Users` folder The component. custom a for needed are that folder one and files seven are There same the have should It it. export to how and component the describing files the contains a for 6“ Drive ”Robot controller, drive kiwi a for Drive“ (e.g.“Kiwi component the as name the as extensions and names same the have should files The etc.). controller, drive motorsix- must seven the but seven, these with along folder the in be can files Other here. shown ones component. custom the recognize to RobotBuilder for present be

### PaletteDescription.yaml



line:by-Line-

- component new a of beginning the Declares !Component:
- this – palette/tree the in up show will what is This component. the of name The name: folder containing the of name the as same the be also should
- on) later depth in explained be will (these component the of type the type:
- Motor support. can this component of type each of amount the of map a supports: three support can drive kiwi a so PIDOutputs, all are RobotBuilder in controllers motor or sensors as (such anything support doesn’t component a If PIDOutputs. out line this leave just controllers),
- is components these of one when message helpful a gives that string short a help: over hovered
- there example, drive kiwi this In component. this of properties the of list a properties: allows ChildSelectionProperty A motor. each for one properties, similar very three are one the of subcomponents the from type given the of component a choose to user the motor a i.e. - PIDOutput a for asking dropdown a show would they here, (so edited being drive) kiwi the to added been has that - controller

sensitive):case- are (these supports RobotBuilder component of types The

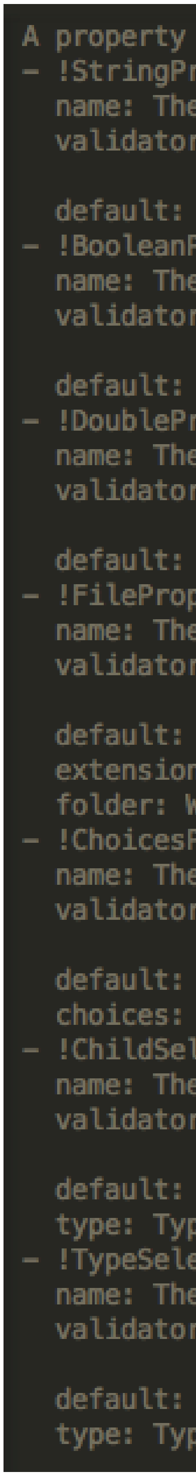
- Command
- Subsystem
- controller) (motor PIDOutput
- encoder) potentiometer, analog e.g. PIDSource implements that (sensor PIDSource
- switch) limit e.g. PIDSource implement not does that (sensor Sensor
- etc.) controller, PID drive, (robot Controller
- servo) solenoid, e.g. motor, a not is that output (an Actuator
- Joystick
- Button Joystick

## Properties

component: custom a for relevant properties The

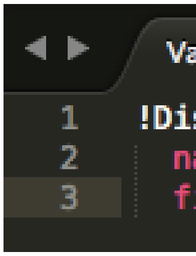
- component the of name the e.g. string a needs component a when used StringProperty:
- button a putting e.g. value boolean a needs component a when used BooleanProperty: SmartDashboard the on
- PID e.g. value number a needs component a when used DoubleProperty: constantsChoicesProperty
- motor e.g. component child a choose to need you when used ChildSelectionProperty: RobotDrive a in controllers
- type given the of component any choose to need you when used TypeSelectionProperty: command PID a for output and input e.g. program the in anywhere from

below: described are property each for fields The



```
A property
- !StringPr
  name: The
  validator

  default:
- !BooleanP
  name: The
  validator

  default:
- !DoublePr
  name: The
  validator

  default:
- !FileProp
  name: The
  validator

  default:
  extension
  folder: W
- !ChoicesP
  name: The
  validator

  default:
  choices:
- !ChildSel
  name: The
  validator

  default:
  type: Typ
- !TypeSele
  name: The
  validator

  default:
  type: Typ
```

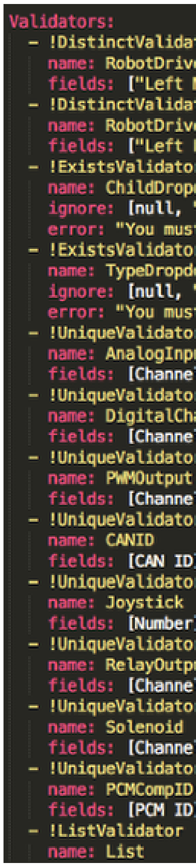
### Validators.yaml



```
Va
!Di
  n
  f
```

motor the of each of entry validators the in ”KiwiDriveValidator“ noticed have may You defined be to had it so validator, inbuilt- a not It’s PaletteDescription.yaml. in properties the of each that sure makes just it - simple very is validator example This Validators.yaml. in others. the than value different a has fields named

### Types Validator and Validators inBuilt-



```
Validators:
  - !DistinctValida
    name: RobotDrive
    fields: ["Left M
  - !DistinctValida
    name: RobotDrive
    fields: ["Left
  - !ExistsValidato
    name: ChildDrop
    ignore: [null, '
    error: "You mus
  - !ExistsValidato
    name: TypeDropd
    ignore: [null, '
    error: "You must
  - !UniqueValidato
    name: AnalogInp
    fields: [Channe
  - !UniqueValidato
    name: DigitalCha
    fields: [Channe
  - !UniqueValidato
    name: PWMOutput
    fields: [Channe
  - !UniqueValidato
    name: CANID
    fields: [CAN ID
  - !UniqueValidato
    name: Joystick
    fields: [Number
  - !UniqueValidato
    name: RelayOutp
    fields: [Channe
  - !UniqueValidato
    name: Solenoid
    fields: [Channe
  - !UniqueValidato
    name: PCMCompID
    fields: [PCM ID
  - !ListValidator
    name: List
```

use), port/channel for UniqueValidators the (especially useful very are validators inbuilt- The step previous the in like needed, is validator custom a sometimes but

- unique are fields given the of each of values the sure Makes DistinctValidator:
- validator this using property the for set been has value a that sure Makes ExistsValidator:
- the for globally unique is property the for value the that sure Makes UniqueValidator: fields given

- valid are property list a in values the all that sure Makes ListValidator:

## Export.yaml C++

```
C++ Export.ya
Kiwi Drive:
  Defaults: "
  ClassName:
  Constructio
```

file: the of breakdown lineby-line- A

- name the as same the is This exported. being component the of name the Drive: Kiwi file this containing folder the of name the and PaletteDescription.yaml, in set
- name the component, this by needed includes for values default some provides Defaults: an adds default CustomComponent The more. and template, construction a class, the of component the uses that file generated every to `Custom/${ClassName}.h` for include file) the of top the `"Custom/KiwiDrive.h #include` have would `RobotDrive.h` (e.g.
- adding. you're class custom the of name the ClassName:
- Variables constructed. be should component the how for instruction an Construction: "KiwiDrive"), with replaced be will ("`${ClassName}`" values their with replaced be will with replaced be may `#variable($Name)` example, (for evaluated be will macros then ).`drivebaseKiwiDrive`

constructor the with class KiwiDrive a expects example This

```
SpeedController) SpeedController, KiwiDrive(SpeedController,
```

.[illegible] Java,-[illegible]

## Export.yaml Java

```
Java Export.ya
Kiwi Drive:
  Defaults: "
  ClassName:
  Constructio
```

This line. Construction the be should difference only the file; export C++ the to similar Very constructor the with class KiwiDrive a expects example

```
SpeedController) SpeedController, KiwiDrive(SpeedController,
```

.[illegible] C++,-[illegible]

## Variables and Macros Using

be will that text into variables turn to uses RobotBuilder that functions simple are Macros syntax a have and symbol, ”#“ the with start always They code. generated into inserted you’ll macro only The `.)... arg2, arg1, arg0, >(<macro_name` functions: to similar `) component_name #variable(` is use to need probably

name the is ”Name“ (i.e. somewhere defined variable a the usually string, a takes `#variable` of name the into it turns and Motor“), ”Arm as such RobotBuilder, in component the to given in results `Motor") #variable("Arm` example, For code. generated the in defined variable a `ArmMotor` string the

an which name, variable the of front in (”$“) sign dollar a placing by referenced are Variables in text other from variable the distinguish easily to braces curly inside placed be optionally replaced are braces curly and name, variable sign, dollar the parsed, is file the When file. the ).`KiwiDrive` with replaced is `${ClassName}` (e.g. variable the of value the with

kiwi the in 3“ ”Motor 2“, ”Motor 1“, ”Motor (e.g. properties component either are Variables following: the of one or example), drive

RobotBuilder in panel editor the in component the to given name the Short_Name: 1.

be will this subsystem, a in is component the If component. the of name full the Name: 2. the short name appended to the name of the subsystem

be should This any. if in, created be should component this file the of name The Export: 3. things for ”OI“ or sensors; and controllers, actuators, like components for ”RobotMap“ ”CustomComponent“ the that Note components. OI custom other or gamepads like RobotMap. the to export will default

be to able be to component this for imported or included be to need that Files Import: 4. used.

this of variable a declare to how for Construction, to similar instruction, an Declaration: 5. ”None“ default the by of care taken is This type. component

component this of instance new a create to how for instruction an Construction: 6.

LiveWindow the to component this add to how for instruction an LiveWindow: 7.

behave to component this for calls method or functions extra any for instructions Extra: 8. type. encoding the set to needing encoders as such correctly,

the file the in created be to function a for prototype The only): (C++ Prototype 9. class OI the in getter a typically in, declared is component

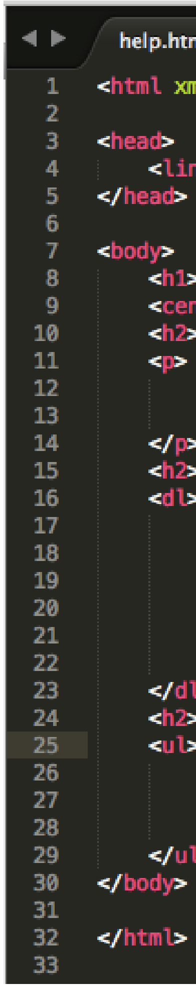
a typically in, declared is component the file the in created be to function A Function: 10. class OI the in getter

(e.g. one has it if component, the of output PID the get to how for instruction An PID: 11. `)>PIDGet()-#variable($Short_Name)`

or `KiwiDrive` (e.g. represents component the that class the of name The ClassName: 12. `)Joystick`

etc.), Motor“, Front ”Right 1“, ”Motor as (such name the in spaces with variables have you If files. export the in them using when underscores with replaced be to need spaces the

## help.html



```
<html xm

<head>
    <lir
</head>

<body>
    <h1>
    <cer
    <h2>
    <p>


    </p>
    <h2>
    <dl>






    </dl
    <h2>
    <ul>



    </ul
</body>

</html>

```

as detailed as be this have to better is It component. the on information giving file HTML A with enough familiar are programmer(s) the if necessary isn’t certainly it though possible, description. detailed a in point little there’s that simple so it’s if or component, the

## config.txt

```
sec
```

this Currently, component. the about information miscellaneous hold to file configuration A in. component the put to palette the of section the has only

sensitive): case are (these palette the of sections The

- ▯▯▯▯▯▯
- Controllers

- □□□□□□□
- Actuators
- □□□□□□□□□□
- OI
- Commands

### icon.png

file. `png.` 64x64 a be should This page. help the and palette the in up shows that icon The

avoid to in it’s section the of style general and scheme color the use should It and icons the of files `psd.` Photoshop optional. entirely is this but clutter, visual in are backgrounds and icons the of files png and src/main/icons/icons in are backgrounds .src/main/resources/icons

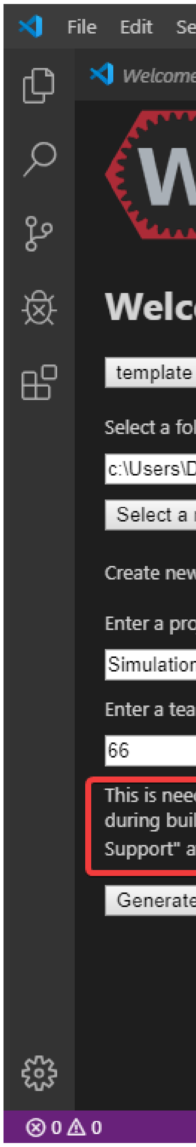
[redacted]

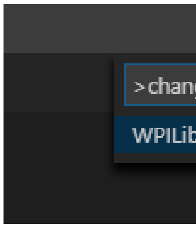
## Simulation Robot to Introduction 21.1

WPILib available. robot actual an having without code their test to want may team a Often gradle simple using features robot various simulate to ability the with teams provides commands.

### Support Desktop Enabling 21.1.1

by done be can This enabled. be to Support Desktop requires Simulator Desktop the of Use by or project robot your creating when Checkbox“ Support Desktop ”Enable the checking Code Studio Visual the from Setting“ Enabled Support Desktop Change ”WPILib: running palette. command





located file `build.gradle` your editing manually by enabled be also can support Desktop to `false = includeDesktopSupport` change Simply project. robot your of root the at `true = includeDesktopSupport`

```
true = includeDesktopSupport def
```

unintended have can support desktop/simulation enabling that note to important is It :□□□□ may libraries their uses that code and option, this support will vendors all Not consequences.

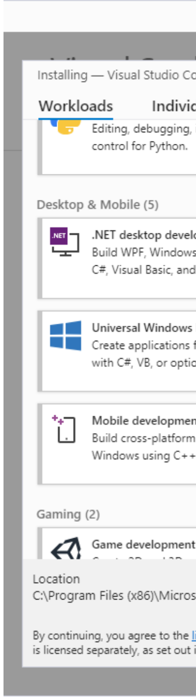
simulation! run to attempting when crash even

”WPILib: the runre- simply Support, Desktop disable to want you time in point any at If palette. command the from Setting“ Enabled Support Desktop Change

### Dependency C++ Additional

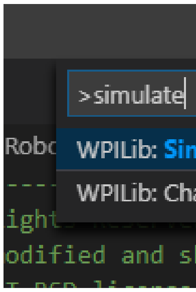
would this Windows, For installed. be to compiler native a that requires simulation robot C++ (Ubuntu) Linux and ,later or 13 Xcode requires macOS Code), VS **not**( 2022 Studio Visual be package. `essential-build` the requires

installer Studio Visual the in checked is option *C++ with Development Desktop* the Ensure support. simulation for



## Simulation Robot Running 21.1.2

any using without done be can This Code. VS using run be can simulation robot Basic palette. command Code’s VS using by commands



teams However, below. the like look should Code Studio Visual in output console Your can This simulation. the running just versus code their *test* actually to want will probably .*GUI Simulation WPILib's* using done be

```
********** starting program Robot **********
me! Override method... disabledInit() Default
me! Override method... disabledPeriodic() Default
me! Override method... robotPeriodic() Default
```

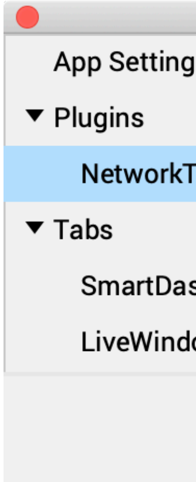
for `simulateJava gradlew/.` using Code VS of outside run be also can Simulation :□□□□ C++. for `simulateNative gradlew/.` or Java

## Dashboards Robot Running 21.1.3

simulation. WPILib with used be can SmartDashboard and Shuffleboard Both

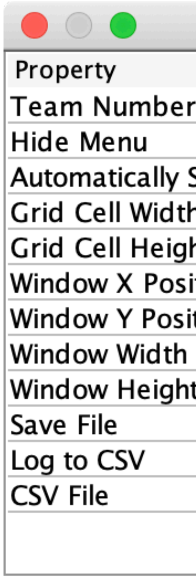
### Shuffleboard

the from instance NetworkTables a for look to configured automatically is Shuffleboard Shuffleboard open simulation, a to connect To .**sources other from not** but robotRIO navigation left the on *Plugins* under *NetworkTables* select and menu *File* the from preferences a For host. NetworkTables the of hostname or address IP the in type field, *Server* the In bar. .`localhost` use configuration, simulation standard



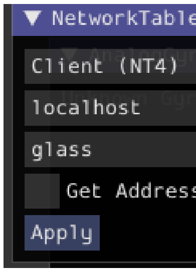
### SmartDashboard

the from instance NetworkTables a for look to configured automatically is SmartDashboard SmartDashboard open simulation, a to connect To .**sources other from not** but roboRIO, or address IP the enter field, *Number Team* the in and menu *File* the under preferences .`localhost` use configuration, simulation standard a For host. NetworkTables the of hostname



### Glass

but roboRIO, the from instance NetworkTables a for look to configured automatically is Glass under *Settings NetworkTables* open simulation, a to connect To .**sources other from not** the of hostname or address IP the enter field, *Team/IP* the in and menu *NetworkTables* the .`localhost` use configuration, simulation standard a For host. NetworkTables



Client (NT4)
localhost
glass

## Elements Interface User Specific Simulation 21.2

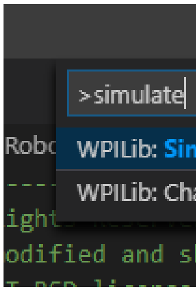
(GUI) interface user graphical a introduce to simulation robot extended has WPILib outputs. and inputs robot's their visualize easily to teams allows This component.

---

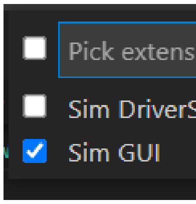
pages following the of Some .*Glass* to ways many in similar very is GUI Simulation The :□□□□ GUIs. both to common elements describe that sections Glass to link will

---

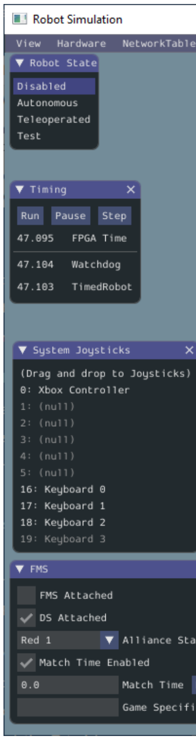
## GUI the Running 21.2.1



option. palette command **Simulation Run** the via GUI the launch simply can You

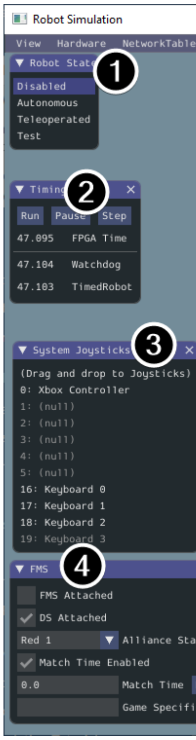


Press default. by selected be will and dialog new a in popup should option `GUI Sim` the And GUI! Simulation the launch now will This *.Ok*



## GUI the Using 21.2.2

### Layout the Learning



47.095 FPGA Time
47.104 Watchdog
47.103 TimedRobot

(Drag and drop to Joysticks)
0: Xbox Controller
1: (null)
2: (null)
3: (null)
4: (null)
5: (null)
16: Keyboard 0
17: Keyboard 1
18: Keyboard 2
19: Keyboard 3

☐ FMS Attached
☑ DS Attached
Red 1 ▼ Alliance Sta
☑ Match Time Enabled
0.0 Match Time
Game Specifi

default: by GUI simulation the on shown are items following The

to labels the on click can You ”mode“. or state current robot’s the is This - **State Robot** 1.
Station. Driver normal the on would you as mode change

manipulated. be to timing the allows and timers Robot’s the of values the Shows - **Timing** 2.

currently. system your to connected joysticks of list a is This - **Joysticks System** 3.

systems. FMS common the of many simulating for used is This - **FMS** 4.

NetworkTables. to published been has that data the shows This - **NetworkTables** 5.

from. pull directly can code robot the that joysticks is This - **Joysticks** 6.

categories, other the of any into fall not do that devices includes This - **Devices Other** 7.
that devices party third or Parts of Kit the in included is that gyro ADXRS450 the as such
simulation. support

default. by shown not are but menu, Hardware the from added be can items following The

Class. `AddressableLED` the by controlled LEDs shows This - **LEDs Addressable** 1.

**IN ANALOG** the use normally would that devices any includes This - **Inputs Analog** 2.
gyros. based Analog any as such roboRIO, the on connector

on connector **DIO** the use that devices any includes This Output) Input (Digital - **DIO** 3.
roboRIO. the

class. `Encoder` the use or extend that devices instantiated any show will This - **Encoders** 4.

object. Panel Distribution Power the shows This - **PDPs** 5.

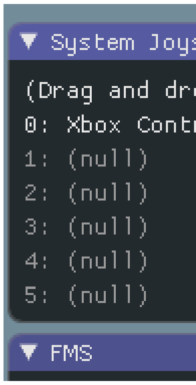
many as appear will This devices. PWM instantiated of list a is This - **Outputs PWM** 6.
outputs. their as well as code, robot in instantiate you as devices

relays. Spike VEX includes This devices. relay any includes This - **Relays** 7.

object solenoid a create you When solenoids. ”connected“ of list a is This - **Solenoids** 8.
here. shown are these outputs, push and

## Joysticks to Joystick System a Adding

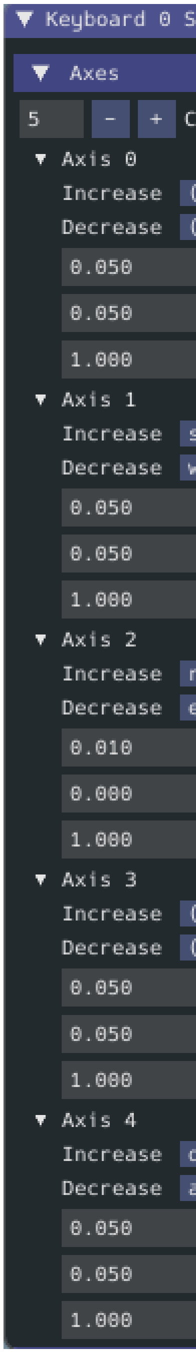
joystick shown a drag and click simply joysticks, system of list the from joystick a add To
menu“. ”Joysticks“ the to menu Joysticks“ ”System the under



**:□□□□** the and connected gamepads to mapping special does Station Driver FRC® The
pressing by behavior this on turn can You default. by these ”map“ not does simulator WPILib
menu. ”Joysticks“ the underneath toggle gamepad“ ”Map the

## Joystick a as Keyboard the Using

keyboard the of one dragging and clicking by joysticks system of list the to keyboard a add You
to go keyboard the of settings the edit To above. joystick a like just 0) Keyboard (e.g. items
control to you allows This .*Settings 0 Keyboard* choose then bar menu the in item *DS* the
the make to how of example common a is This axis. which control buttons keyboard which
4): & 1 axis (uses controller Xbox an on drive arcade sticks split a to similar keyboard


Keyboard 0 S
Axes
5
-
+
C
Axis 0
Increase
Decrease
0.050
0.050
1.000
Axis 1
Increase
Decrease
0.050
0.050
1.000
Axis 2
Increase
Decrease
0.010
0.000
1.000
Axis 3
Increase
Decrease
0.050
0.050
1.000
Axis 4
Increase
Decrease
0.050
0.050
1.000

### Inputs ADXRS450 Modifying

up show will This outputs. based gyro test to way fantastic a is object ADXRS450 the Using options various shows that exposed then is menu down drop A menu. Devices“ ”Other the in change, can you that values are values these of All ”Rate“. and ”Angle“, ”Connected“, as such fly.the-on- use and code robot your that and

true
0.000000
0.000000

## Code Robot from Simulation Determining 21.2.3

can you simulation, robot the running when compile not do libraries vendor where cases In wrap their content with `RobotBase.isReal()` which returns a `boolean.`

Java

```
                         motorLeft; TalonSRX
                        motorRight; TalonSRX

                               { ()Robot public
                  { ())isReal(RobotBase. if
              );0TalonSRX( new = motorLeft
             );1TalonSRX( new = motorRight
                                          }
                                           }
```

---

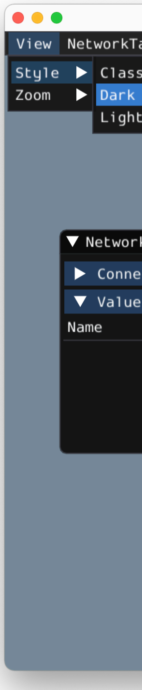
classes vendors assignment; copy or move requires C++ in types value Reassigning :□□□□ be cannot operator assignment copy or move a lack and SIM the support not do both that type. value a of instead used, is pointer a unless allocation conditional with around worked

---

## Settings View Changing 21.2.4

*Zoom* The customized. be can that settings *Style* and *Zoom* contains item menu *View* The to you allows option *Style* the whereas application the in text the of size the dictates option modes. `Dark` and ,`Light` ,`Classic` the between select

below: is setting style `Dark` the of example An



### Data Application Clearing 21.2.5

other as well as positions and sizes widget including GUI, Simulation the for data Application of root the in stored is file This file. `imgui.ini` a in stored is widgets for information custom from. run is simulation the that directory project the

a to GUI Simulation the restore to deleted be simply can file configuration `imgui.ini` The slate“. ”clean

## WPILib with Simulation Physics 21.3

we ,*systems* of *dynamics* the represent compactly to us allows *notation spacestate-* Because of goal The robots. on systems physical simulating for backend a provide to it leverage can existing modifying without mechanisms robot of motion the simulate to is simulators these follows: as is simulators such of flow basic The code. user simulationnon-

- code: user normal In
  - other (or encoder from commands voltage generate algorithms control similar or PID readings sensor)
  - set are outputs Motor
- code: periodic simulation In
  - from set motors from voltages usually ,*inputs* using updated is *state* simulation’s The loop PID a

- next the in use to code user for set are readings sensor) other (or encoder Simulated – timestep

## Classes Simulation WPILib's 21.3.1

WPILib: in available are classes simulation physics following The

- dynamics linear with systems modeling for LinearSystemSim,
- FlywheelSim
- DifferentialDrivetrainSim
- motion elevator of direction the in gravity models which ElevatorSim,
- angle arm the to proportional gravity models which SingleJointedArmSim,
- currents drawn on based sag voltage battery estimates simply which BatterySim,

the from inherit simulator) drive differential the of exception the (with classes simulation All $\mathbf{x}_{k+1}$ = dynamics system linear the are dynamics the default, By class. `LinearSystemSim` nonlinear custom, provide to method `dt) u, UpdateX(x,` the override Subclasses .$\mathbf{A}\mathbf{x}_k + \mathbf{B}\mathbf{u}_k$ gravity. modeling as such dynamics,

---

For ETA. an provide cannot we but works, the in is simulation for support Swerve **:□□□□** .request pull this follow please progress, on updates

---

## Code User in Usage 21.3.2

.project example `elevatorsimulation` WPILib the from available is following The

elevator our instantiate we encoders, and motors as such objects standard to addition In also We reduction. gearing and mass carriage as such constants known using simulator .`Encoder` our by read rate and distance the sets which ,`EncoderSim` an instantiate

(in carriage moving the of mass the given elevator an simulate we example, following the In reduction gearing the meters), (in elevator the driving drum the of radius the kilograms), minimum the one), than greater usually (so input over output as drum and motor between position our to add to noise random some and meters), (in elevator the of height maximum and estimate.

---

exceeding from position simulated the prevent will simulators arm and elevator The **:□□□□** with mechanism a simulate to wish you If angles. or heights maximum or minimum given option. better a be may `LinearSystemSim` motion, or rotation infinite

---

Java

```
          gravity. including on, going s'what simulate us help classes Simulation //
                                       = m_elevatorSim ElevatorSim final private
                                                             ElevatorSim( new
                                                        m_elevatorGearbox,
                                              ,kElevatorGearingConstants.
                                                  ,kCarriageMassConstants.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                              ,kElevatorDrumRadiusConstants.
                         ,kMinElevatorHeightMetersConstants.
                         ,kMaxElevatorHeightMetersConstants.
                                                       ,true
                                   ));0.01(fillVecBuilder.
          EncoderSim(m_encoder); new = m_encoderSim EncoderSim final private
```

C++

```
      gravity. including on, going s'what simulate us help classes Simulation //
                    m_elevatorSim{m_elevatorGearbox, ElevatorSim::sim::frc
           kElevatorGearing,::Constants
              kCarriageMass,::Constants
         kElevatorDrumRadius,::Constants
          kMinElevatorHeight,::Constants
          kMaxElevatorHeight,::Constants
                                 ,true
                              ;}}0.01{
                             m_encoderSim{m_encoder}; EncoderSim::sim::frc
```

drive to loop control PID simple a uses (Java/C++) TeleopPeriodic/teleopPeriodic Next, ground. the off inches 30 setpoint a to elevator our

Java

```
                                                           @Override
                                   { ()teleopPeriodic void public
                                 { ())getTrigger(m_joystick. if
                     meters. 0.75 of setpoint constant the set we Here, //
                    );kSetpointMeters(Constants.reachGoalm_elevator.
                                                          { else }
                          0. to setpoint the update we Otherwise, //
                                    );0.0(reachGoalm_elevator.
                                                                 }
                                                                  }
```

```
                          { goal) double(reachGoal void public
                                     (goal);setGoalm_controller.

                   normal like control PID run we value setpoint the With //
             ());getDistance(m_encoder.calculatem_controller. = pidOutput double
   ().getSetpoint(m_controller.calculatem_feedforward. = feedforwardOutput double
                                                        );velocity ↪
                 feedforwardOutput); + (pidOutputsetVoltagem_motor.
                                                                  }
```

C++

```
                                    { ()Robot::TeleopPeriodic void
                                   { (m_joystick.GetTrigger()) if
                     meters. 0.75 of setpoint constant the set we Here, //
                            kSetpoint);::m_elevator.ReachGoal(Constants
                                                          { else }
                           0. to setpoint the update we Otherwise, //
                                        m);_0.0m_elevator.ReachGoal(
                                                                 }
                                                                  }
```

```
                                         { goal) meter_t::(unitsElevator::ReachGoal void
                                                                m_controller.SetGoal(goal);
                             normal like control PID run we value setpoint the With //
                                                                     = pidOutput double
                 meter_t{m_encoder.GetDistance()});::m_controller.Calculate(units
                                                 = feedforwardOutput volt_t::units
                   m_feedforward.Calculate(m_controller.GetSetpoint().velocity);
                   feedforwardOutput); + volt_t{pidOutput}::m_motor.SetVoltage(units
                                                                                         }
```

the to applied voltage the uses (Java/C++) SimulationPeriodic/simulationPeriodic Next, because SimulationPeriodic use We elevator. the of position simulated the update to motor be not will code simulation our that means This robots. simulated for only periodically runs it robot. real a on run

---

inherited the override can Subsystem based'scommand- from inheriting Classes :□□□□ methods update simulation their need will classes Other method. simulationPeriodic() .simulationPeriodic 'sRobot from called

---

elevator's simulated the using set is reading distance encoder's simulated the Finally, the by drawn current estimated the using set is voltage battery robot's the and position, elevator.

Java

```
                                                    { ()simulationPeriodic void public
      doing is elevator our what of simulation our update we method, this In //
                                           (voltages) inputs"" our set we First, //
                     RobotController. * ()getSpeed(m_motorSim.setInputm_elevatorSim.
                                                         ());getBatteryVoltage ↩

                         20ms. is time loop standard The it. update we Next, //
                                                     );0.020(updatem_elevatorSim.

  voltage battery simulated and readings s'encoder simulated our set we Finally, //
                     ());getPositionMeters(m_elevatorSim.setDistancem_encoderSim.
                                     voltages battery loaded estimates SimBattery //
                                                      (setVInVoltageRoboRioSim.
          (m_elevatorSim.calculateDefaultBatteryLoadedVoltageBatterySim.
                                                       ()));getCurrentDrawAmps ↩
                                                                               }
```

C++

```
                                            { ()Elevator::SimulationPeriodic void
      doing is elevator our what of simulation our update we method, this In //
                                         (voltages) inputs"" our set we First, //
                                        {>1<Vectord::m_elevatorSim.SetInput(frc
          GetInputVoltage()});::RobotController::frc * m_motorSim.GetSpeed()

                         20ms. is time loop standard The it. update we Next, //
                                                  ms);_20m_elevatorSim.Update(

      battery simulated and readings s'encoder simulated our set we Finally, //
                                                                    voltage //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                         m_encoderSim.SetDistance(m_elevatorSim.GetPosition().value());
                                           voltages battery loaded estimates SimBattery //
                                                          SetVInVoltage(::RoboRioSim::sim::frc
             Calculate({m_elevatorSim.GetCurrentDraw()}));::BatterySim::sim::frc
                                                                                           }
```

## Simulation Device 21.4

API. SimDevice the of form the in data device simulation manage to way a provides WPILib

### Classes Device WPILib Core Simulating 21.4.1

named classes simulation have etc.) ,`Ultrasonic` ,`Encoder` (i.e classes device WPILib Core device the with interactions allow classes These on. so and ,`UltrasonicSim` ,`EncoderSim` outside them Constructing simulation. of outside valid or possible be wouldn't that data the and functions their calling but code, your with interfere won't likely simulation of might cases worse nothing, do will they case best the in - behavior undefined is like as (such functions onlysimulation- in code simulation functional Place code! your crash `RobotBase::IsReal()` /`RobotBase.isReal()` with them wrap or )`simulationPeriodic()` C++). in `constexpr` are (which checks

---

simulation other of Use example. an as class `EncoderSim` the use will example This :□□□□ identical. almost be will classes

---

#### objects Device Simulation Creating

ways: two in constructed be can object device Simulation

- object. hardware regular the accepts that constructor a
- the that number port/index/channel the accepts that method factory or constructor a the construct to used was that number same the be would These to. connected is device .*testing unit* for useful especially is This object. hardware regular

Java

```
                                                   2,3 DIO on object encoder real a create //
                                                         );3 ,2Encoder( new = encoder Encoder
                                                    encoder the for controller sim a create //
                                                EncoderSim(encoder); new = simEncoder EncoderSim
```

C++

```
                                                   2,3 DIO on object encoder real a create //
                                                                ;}3 ,2encoder{ Encoder::frc
                                                    encoder the for controller sim a create //
                                                      simEncoder{encoder}; EncoderSim::sim::frc
```

## Data Device Writing and Reading

setter and )GetXxx()/getXxx()( getter has class simulation Each
will functions getter The .Xxx field each for functions )SetXxx(value)/setXxx(value)(
class. device regular the of getter the as same the return

Java

```
);100(setCountsimEncoder.
100 // ();getCountencoder.
100 // ();getCountsimEncoder.
```

C++

```
);100simEncoder.SetCount(
100 // encoder.GetCount();
100 // simEncoder.GetCount();
```

## Callbacks Registering

registerXxxCallback() a has also field each setters, and getters the to addition In
and changes value field the whenever run be to callback a registers that function
name the of parameter string a accept callbacks The object. CallbackStore a returns
values retrieving Before value. new the containing object HALValue a and field the of
HALValue. are types Possible contained. value of type the check ,HALValue a from
HALValue. ,HAL_ENUM/HALValue.kEnum ,HAL_DOUBLE/HALValue.kDouble ,HAL_BOOL/kBoolean
.HAL_LONG/HALValue.kLong ,HAL_INT/kInt

to reference a Keep callback. the cancel to object CallbackStore the on close() call Java, In
GC. by canceled be will callback the otherwise - collectedgarbage- get doesn't it so object the
reference. method a use or lambda the in it capture callback, the to data arbitrary provide To

when canceled be will callback the - scope right the in object CallbackStore the save C++, In
callbacks the to passed be can data Arbitrary destroyed. is and scope of out goes object the
parameter. param the via

> different a containing HALValue a from type a of value a retrieve to Attempting :□□□□□
> behavior. undefined is type

Java

```
{ >- value) HALValue name, (String = callback NotifyCallback
   { )kIntHALValue. == ()getType(value. if
())getIntvalue. + " is " + name + " of Value"(println.outSystem.
   }
}
(callback);registerCountCallbacksimEncoder. = store CallbackStore

callback the cancel // ();closestore.
```

C++

```
        ␣*HALValue const param, *void name, *char const[]( = callback HAL_NotifyCallback
                                                                              { value) ↪
                                                        { HAL_INT) == type>-(value if
    ;'n\' << data.v_int>-value << " is " << name << " of Value" << outs()::wpi
                                                                                   }
                                                                                  ;}
       simEncoder.RegisterCountCallback(callback); = store CallbackStore::sim::frc
                        scope of out goes ``store`` when canceled be will callback the //
```

## Class SimDeviceSim The - Devices Other Simulating 21.4.2

---

than different slightly API SimDevice the to connection their implement might Vendors :□□□□ See class. device their for specific class simulation a provide also might They here. described how. and support they what to as information more for documentation vendor's your

---

devices for object simulation device general a is class !)SimDevice **not**( `SimDeviceSim` The as such - classes simulation specific have don't therefore and devices WPILib core aren't that .*SimGUI* the of tab *Devices Other* the in up show will devices These devices. vendor

used vendor the key the to identical key string a using created is object `SimDeviceSim` The the that one the is key This class. device their in `SimDevice` underlying the construct to `Prefix:Device` form the of typically is and tab, *Devices Other* the in with up shows device as passed be can they numbers, ports/index/channel contains key the If .`Name[index]` hidden is that prefix a contains key The constructor. `SimDeviceSim` the to arguments separate including Not option. *prefix Show* the selecting by shown be can it SimGUI, the in default by device! the match not will `SimDeviceSim` to passed key the in prefix this

Java

```
                          index); SimDeviceSim(deviceKey, new = device SimDeviceSim
```

C++

```
                                   index}; device{deviceKey, SimDeviceSim::sim::frc
```

device's the representing objects `SimValue` get can we ,`SimDeviceSim` the have we Once also subclasses `SimEnum` and ,`SimBoolean` ,`SimLong` ,`SimInt` ,`SimDouble` specificType- fields. constructed are These class. `SimValue` unsafetype- the of instead used be should and exist, the define to used vendor the one the to identical key string a using `SimDeviceSim` the from `SimValue` a retrieve to Attempting SimGUI. the in as appears field the one the is key This field. return will unmatched are keys field or device the either when or simulation of outside object C++. in behavior undefined or Java in `NullPointerException` cause can this - `null`

Java

```
                              (fieldKey);getDoubledevice. = field SimDouble
                                                                 ();getfield.
                                                            (value);setfield.
```

C++

```
device.GetDouble(fieldKey); = field SimDouble::hal
                                      field.Get();
                                  field.Set(value);
```

## Tutorial Simulation Drivetrain 21.5

the using drivetrain differential your of model simulation a implementing for tutorial a is This agnostic,framework- is tutorial this in cover will we that code the Although classes. simulation framework. each for one – available examples full two are there

- basedcommand- the uses )C++ ,Java( `StateSpaceDifferentialDriveSimulation` framework.
- to approach traditional more a uses )C++ ,Java( `SimpleDifferentialDriveSimulation` flow. data

window. *Project New* Code VS the in available also are examples these of Both

### Overview Simulation Drivetrain 21.5.1

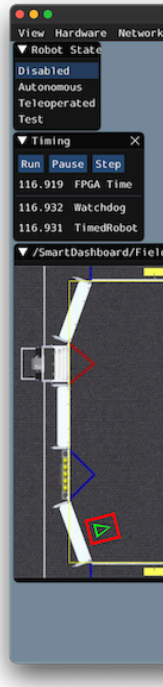
---

basedcommand- (i.e. framework specific any use not does tutorial this in code The :□□□□ best to how for areas certain in provided be will guidance however, flow); data simple vs. types. framework specific in code of pieces certain implement

---

a for capabilities simulation implementing on guidance provide to is tutorial this of goal The to: able be should you tutorial, this of end the By robot. drivetraindifferential-

1. framework. simulation WPILib the behind concepts underlying basic the Understand
2. parameters. physical robot's your using model simulation drivetrain a Create
3. voltage specific given move will robot real your how predict to model simulation the Use inputs.
4. having before inversion) motor (e.g. bugs common squash and constants feedback Tune hardware. physical to access
5. field. virtual a on movement robot visualize to GUI Simulation the Use



### Drivetrain? a Simulate Why

therefore, – robot the on mechanisms important most the of one is robot a of drivetrain The possible. as robust as is drivetrain your powering software the that ensure to important is it on start head a get can you responds, drivetrain physical a how simulate to able being By simulation the With hardware. physical the to access have you before software quality writing on inversions the that sure making like functionality, basic only not verify can you framework, accuracy verifying as such capabilities advanced also but correct, are encoders and motors following. path of

## Hardware of Instances Simulated Creating :1 Step 21.5.2

represents `XXX` where classes, `XXXSim` several contains framework simulation WPILib The to used be can classes simulation These gyroscopes. or encoders as such hardware physical your of model a from gyroscopes) (for angles and encoders) (for velocities and positions set hardware simulation these about info more for *article Simulation Device the* See drivetrain. devices. vendor of simulation and classes

---

that in live should subsystem particular a with associated objects Simulation :□□□□ example. )C++ ,Java( `StateSpaceDriveSimulation` the in is this of example An subsystem.

---

## Encoders Simulating

`Encoder` given a on velocities and positions encoder set to users allows class `EncoderSim` The to sensors real with interacts class `Encoder` the hardware, real on running When object. so); do to configured if automatically units distance to them convert (and revolutions count can class `EncoderSim` The make. to measurements such no are there simulation in however, drivetrain. your of model a from readings simulated these accept

---

motor CAN to connected directly are that encoders simulate to possible not is It **:□□□□** controller, motor specific your about information more For classes. WPILib using controllers documentation. vendor’s your read please

---

Java

```
would we which objects, encoder regular our represent These //
robot. real a on use to create //
);1 ,0Encoder( new = m_leftEncoder Encoder private
);3 ,2Encoder( new = m_rightEncoder Encoder private

in use only will we which objects, EncoderSim our are These //
these out comment to need not do you However, simulation. //
roboRIO. the to code deploying are you when declarations //
EncoderSim(m_leftEncoder); new = m_leftEncoderSim EncoderSim private
EncoderSim(m_rightEncoder); new = m_rightEncoderSim EncoderSim private
```

C++

```
frc/Encoder.h>< include#
frc/simulation/EncoderSim.h>< include#

...

would we which objects, encoder regular our represent These //
robot. real a on use to create //
;}1 ,0m_leftEncoder{ Encoder::frc
;}3 ,2m_rightEncoder{ Encoder::frc

in use only will we which objects, EncoderSim our are These //
these out comment to need not do you However, simulation. //
roboRIO. the to code deploying are you when declarations //
m_leftEncoderSim{m_leftEncoder}; EncoderSim::sim::frc
m_rightEncoderSim{m_rightEncoder}; EncoderSim::sim::frc
```

## Gyroscopes Simulating

used commonly for exist also classes gyroscope simulated class, `EncoderSim` the to Similar the in constructed also are These .`ADXRS450_GyroSim` and `AnalogGyroSim` – gyros WPILib manner. same

---

using NavX) and IMU Pigeon (i.e. gyros vendor certain simulate to possible not is It **:□□□□** their on information for documentation vendors« respective the read Please classes. WPILib support. simulation

---

Java

```
                    robot. real a on would we like object gyro our Create //
                               );1AnalogGyro( new = m_gyro AnalogGyro private

                 gyro the setting for used object, gyro simulated the Create //
               out commented be to need not does this EncoderSim, Like angle. //
                                       roboRIO. the to code deploying when //
                AnalogGyroSim(m_gyro); new = m_gyroSim AnalogGyroSim private
```

C++

```
                                                  frc/AnalogGyro.h>< include#
                                       frc/simulation/AnalogGyroSim.h>< include#

                                                                             ...

                    robot. real a on would we ike objectl gyro our Create //
                                                ;}1m_gyro{ AnalogGyro::frc

                 gyro the setting for used object, gyro simulated the Create //
               out commented be to need not does this EncoderSim, Like angle. //
                                       roboRIO. the to code deploying when //
                                 m_gyroSim{m_gyro}; AnalogGyroSim::sim::frc
```

### Model Drivetrain a Creating :2 Step 21.5.3

motor given to respond will drivetrain physical your how determine accurately to order In usually is model This created. be must drivetrain your of model accurate an inputs, voltage this WPILib, In robot. real your of parameters physical various measuring by created class. `DifferentialDrivetrainSim` the by represented is model simulation drivetrain

#### Measurements Physical from `DifferentialDrivetrainSim` a Creating

physical using by is instance `DifferentialDrivetrainSim` a creating to way One real- or software CAD through obtained either – robot and drivetrain the of measurements match closely more will it as results better yield usually will latter (the measurements world parameters: following the takes constructor This reality).

- drivetrain. the of side one on motors of number and type The
- *torque* input over *torque* output as wheels the and motors the between ratio gear The drivetrains). for 1 than greater usually is number (this
- your of model CAD a from obtained be can (this drivetrain the of inertia of moment The ).$kgm^2$ 8 and 3 between is this Usually, drivetrain.
- as itself, robot entire the of mass the use to recommended is (it drivetrain the of mass The trajectory for robot your of characteristics acceleration the model accurately more will it tracking).
- wheels. drive the of radius The
- wheels). right and left between (distance width track The
- measurement much how represents this noise: measurement of deviations Standard 7 with array an is noise measurement The sensors. real your from expect you noise

noise measurement of deviation standard the representing element each with elements,
respectively. position right and position, left velocity, right velocity, left heading, y, x, in
not is noise measurement if Java in `null` to set or C++ in omitted be can option This
desirable.

of points data multiple taking by sensors your of noise measurement the calculate can You
like tool a using deviation standard the calculating and measure to trying are you state the
estimate, velocity encoders« your in deviation standard the calculate to example, For Python.
calculate and measurements, multiple take velocity, constant a at robot your move can you
used values the tedious, too is process this If mean. known the from deviation standard their
encoders. from noise average of representation good a be should below example the in

that as units same the has measurement a for noise the of deviation standard The :□□□□
m/s. of units has noise velocity the of deviation standard the example, For measurement.

parameters passing when radians) and meters (i.e. units SI use to important very is It :□□□□
type. unit any specify to used be can *library units* the C++, In Java. in

Java

```
                  drivetrain. our of model simulation the Create //
         DifferentialDrivetrainSim( new = m_driveSim DifferentialDrivetrainSim
drivetrain. the of side each on motors NEO 2 //      ),2(getNEODCMotor.
               reduction. gearing 7.29:1 //                        ,7.29
           model). CAD (from m^2 kg 7.5 of MOI //                   ,7.5
             kg. 60 is robot the of mass The //                    ,60.0
            wheels. radius 3" uses robot The // ),3(inchesToMetersUnits.
            meters. 0.7112 is width track The //                 ,0.7112

                      noise: measurement for deviations standard The //
                                      m 0.001          y: and x //
                                    rad 0.001          heading: //
                                    m/s   0.1 velocity: r and l //
                                      m 0.005 position: r and l //
           ));0.005 ,0.005 ,0.1 ,0.1 ,0.001 ,0.001 ,0.001(fillVecBuilder.
```

C++

```
                   frc/simulation/DifferentialDrivetrainSim.h>< include#

                                                                    ...

                     drivetrain. our of model simulation the Create //
                      m_driveSim{ DifferentialDrivetrainSim::sim::frc
drivetrain. the of side each on motors NEO 2 // ),2GetNEO(::DCMotor::frc
                   reduction. gearing 7.29:1 //                  ,7.29
               model). CAD (from m^2 kg 7.5 of MOI //     kg_sq_m,_7.5
                   kg. 60 is robot the of mass The //           kg,_60
                  wheels. radius 3" uses robot The //            in,_3
                 meters. 0.7112 is width track The //        m,_0.7112

                      noise: measurement for deviations standard The //
                                      m 0.001          y: and x //
                                    rad 0.001          heading: //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                m/s    0.1 velocity: r and l //
                                 m 0.005 position: r and l //
           ;}}0.005 ,0.005 ,0.1 ,0.1 ,0.001 ,0.001 ,0.001{
```

### Gains SysId from `DifferentialDrivetrainSim` a Creating

performed have may you which ,*Identification System* by produced gains the use also can You
simulation a create to *here* outlined workflow tracking trajectory the up setting of part as
method the than behavior worldreal- to closer results yield often and drivetrain your of model
above.

from one – tool identification the from gains `Ka` and `Kv` of sets two need must You :□□□□
of sets two these to refer will We place. in rotating from other the and motion linestraight-
respectively. gains angular and linear as gains

parameters: following the takes constructor This

- identification the using created be can this – drivetrain the representing system linear A
gains.
- wheels). right and left the between (distance width track The
- drivetrain. the of side one on motors of number and type The
- *torque* input over *torque* output as wheels the and motors the between ratio gear The
drivetrains). for 1 than greater usually is number (this
- wheels. drive the of radius The
- measurement much how represents this noise: measurement of deviations Standard
7 with array an is noise measurement The sensors. real your from expect you noise
noise measurement of deviation standard the representing element each with elements,
respectively. position right and position, left velocity, right velocity, left heading, y, x, in
not is noise measurement if Java in `null` to set or C++ in omitted be can option This
desirable.

of points data multiple taking by sensors your of noise measurement the calculate can You
like tool a using deviation standard the calculating and measure to trying are you state the
estimate, velocity encoders« your in deviation standard the calculate to example, For Python.
calculate and measurements, multiple take velocity, constant a at robot your move can you
used values the tedious, too is process this If mean. known the from deviation standard their
encoders. from noise average of representation good a be should below example the in

that as units same the has measurement a for noise the of deviation standard The :□□□□
m/s. of units has noise velocity the of deviation standard the example, For measurement.

parameters passing when radians) and meters (i.e. units SI use to important very is It :□□□□
type. unit any specify to used be can *library units* the C++, In Java. in

Java

```
                      identification the (from constants gain feedforward our Create //
                                                                               tool) //
                                                 ;1.98 = KvLinear double final static
                                                  ;0.2 = KaLinear double final static
                                                 ;1.5 = KvAngular double final static
                                                 ;0.3 = KaAngular double final static

                                   drivetrain. our of model simulation the Create //
        DifferentialDrivetrainSim( new = m_driveSim DifferentialDrivetrainSim private
                             gains. identification our from system linear a Create //
 KaAngular), KvAngular, KaLinear, (KvLinear,identifyDrivetrainSystemLinearSystemId.
             drivetrain. the of side each on motors NEO 2 //      ),2(getNEODCMotor.
                               reduction. gearing 7.29:1 //                   ,7.29
                        meters. 0.7112 is width track The //                ,0.7112
                         wheels. radius 3" uses robot The // ),3(inchesToMetersUnits.

                                 noise: measurement for deviations standard The //
                                                   m 0.001          y: and x //
                                                 rad 0.001          heading: //
                                                 m/s   0.1 velocity: r and l //
                                                   m 0.005 position: r and l //
                   ));0.005 ,0.005 ,0.1 ,0.1 ,0.001 ,0.001 ,0.001(fillVecBuilder.
```

C++

```
                          frc/simulation/DifferentialDrivetrainSim.h>< include#
                                   frc/system/plant/LinearSystemId.h>< include#
                                             units/acceleration.h>< include#
                                     units/angular_acceleration.h>< include#
                                         units/angular_velocity.h>< include#
                                                  units/voltage.h>< include#
                                                 units/velocity.h>< include#

                                                                          ...

                      identification the (from constants gain feedforward our Create //
                                units. correct have to need these that Note tool). //
                                  mps;_1 / V_1.98 = KvLinear auto constexpr static
                                mps_sq;_1 / V_0.2 = KaLinear auto constexpr static
                            rad_per_s;_1 / V_1.5 = KvAngular auto constexpr static
                         rad_per_s_sq;_1 / V_0.3 = KaAngular auto constexpr static
                                            meters. 0.7112 is width track The //
                                     m;_0.7112 = kTrackwidth auto constexpr static

                                   drivetrain. our of model simulation the Create //
                                     m_driveSim{ DifferentialDrivetrainSim::sim::frc
                             gains. identification our from system linear a Create //
                                      IdentifyDrivetrainSystem(::LinearSystemId::frc
                         kTrackWidth), KaAngular, KvAngular, KaLinear, KvLinear,
                                                                     kTrackWidth,
             drivetrain. the of side each on motors NEO 2 // ),2GetNEO(::DCMotor::frc
                                    reduction. gearing 7.29:1 //              ,7.29
                               wheels. radius 3" uses robot The //            in,_3

                                 noise: measurement for deviations standard The //
                                                   m 0.001          y: and x //
                                                 rad 0.001          heading: //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                           m/s   0.1 velocity: r and l //
                                            m 0.005 position: r and l //
                          ;}}0.005 ,0.005 ,0.1 ,0.1 ,0.001 ,0.001 ,0.001{
```

## Chassis KoP the of `DifferentialDrivetrainSim` a Creating

`createKitbotSim()` static a has also class `DifferentialDrivetrainSim` The
the of instance an create can that method (C++) `CreateKitbotSim()` / (Java)
This parameters. Chassis Parts of Kit standard the using `DifferentialDrivetrainSim`
optional: are which of two arguments, 5 takes method

- drivetrain. the of side one on motors of number and type The
- *torque* input over *torque* output as wheels the and motors the between ratio gear The
drivetrains). for 1 than greater usually is number (this
- drivetrain. the on installed wheels the of diameter The
- (optional). base drive the of inertia of moment The
- measurement much how represents this noise: measurement of deviations Standard
7 with array an is noise measurement The sensors. real your from expect you noise
noise measurement of deviation standard the representing element each with elements,
respectively. position right and position, left velocity, right velocity, left heading, y, x, in
not is noise measurement if Java in `null` to set or C++ in omitted be can option This
desirable.

of points data multiple taking by sensors your of noise measurement the calculate can You
like tool a using deviation standard the calculating and measure to trying are you state the
estimate, velocity encoders« your in deviation standard the calculate to example, For Python.
calculate and measurements, multiple take velocity, constant a at robot your move can you
used values the tedious, too is process this If mean. known the from deviation standard their
encoders. from noise average of representation good a be should below example the in

---

that as units same the has measurement a for noise the of deviation standard The :□□□□
m/s. of units has noise velocity the of deviation standard the example, For measurement.

---

parameters passing when radians) and meters (i.e. units SI use to important very is It :□□□□
type. unit any specify to used be can *library units* the C++, In Java. in

---

Java

```
                DifferentialDrivetrainSim. = m_driveSim DifferentialDrivetrainSim private
                                                                     (createKitbotSim ↪
                              side. per CIMs 2 // ,kDualCIMPerSideKitbotMotor.
                                    10.71:1 //         ,k10p71KitbotGearing.
                           wheels. diameter 6" //     ,kSixInchKitbotWheelSize.
                          noise. measurement No //                        null
                                                                              );
```

C++

```
                  frc/simulation/DifferentialDrivetrainSim.h>< include#

                                                                    ...

                        = m_driveSim DifferentialDrivetrainSim::sim::frc
                     CreateKitbotSim(::DifferentialDrivetrainSim::sim::frc
  ␣per CIMs 2 // DualCIMPerSide,::KitbotMotor::DifferentialDrivetrainSim::sim::frc
                                                                  side. ↪
     10.71:1 //       k10p71,::KitbotGearing::DifferentialDrivetrainSim::sim::frc
 ␣diameter 6" //    kSixInch::KitbotWheelSize::DifferentialDrivetrainSim::sim::frc
                                                                wheels. ↪
                                                                      );
```

---

/ (Java) enum `KitbotWheelSize` and ,`KitbotGearing` ,`KitbotMotor` the use can You :□□□□
Chassis. Parts of Kit the of configurations used commonly get to (C++) struct

---

an just is way this in instance `DifferentialDrivetrainSim` your Constructing :□□□□
Using simulation. with running and up quickly teams get to intended is and approximation
results. accurate more yield always will robot physical your from measured values empirical

---

## Model Drivetrain the Updating :3 Step 21.5.4

with periodically updated be to needs it made, been has model drivetrain the that Now
separate a in step this do to recommended is It commands. voltage motor latest the
call only and subsystem your inside method `SimulationPeriodic()` / `simulationPeriodic()`
simulation. in method this

---

extends that subsystem every framework, basedcommand- the using are you If :□□□□
be can which `SimulationPeriodic()` / `simulationPeriodic()` a has `SubsystemBase`
the using not are you If simulation. during only run automatically is method This overridden.
overridden the inside method simulation your call you sure make library, basedcommand-
periodic These class. `Robot` main the of `SimulationPeriodic()` / `simulationPeriodic()`
simulation. during only called automatically also are methods

---

model: the updating to steps main three are There

sides two the from voltages motor the are These model. drivetrain the of *input* the Set 1.
drivetrain. the of

ms). 20 (Usually timestep periodic nominal the by time in forward model the Advance 2.
as velocities) and positions encoder pose, (i.e. states drivetrain's the of all updates This
passed. had ms 20 if

other in use to angles and velocities, positions, new with sensors simulated Update 3.
places.

Java

```
             );0PWMSparkMax( new = m_leftMotor PWMSparkMax private
            );1PWMSparkMax( new = m_rightMotor PWMSparkMax private
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                 { ()Drivetrain public
                                                                                  ...
 kEncoderResolution); / kWheelRadius * PIMath. * 2(setDistancePerPulsem_leftEncoder.
kEncoderResolution); / kWheelRadius * PIMath. * 2(setDistancePerPulsem_rightEncoder.
                                                                                     }

                                                    { ()simulationPeriodic void public
                       convert to need we that Note system. the to inputs the Set //
                       the by it multiplying by voltage to signal PWM 1] [-1, the //
                                                        voltage. controller robot //
         (),getInputVoltageRobotController. * ()get(m_leftMotor.setInputsm_driveSim.
       ());getInputVoltageRobotController. * ()getm_rightMotor.

                    this running are you if that Note ms. 20 by model the Advance //
              timestep nominal the changed have or thread separate a in subsystem //
                                     it. match to needs value this TimedRobot, of //
                                                            );0.02(updatem_driveSim.

                                                       sensors. our of all Update //
                   ());getLeftPositionMeters(m_driveSim.setDistancem_leftEncoderSim.
              ());getLeftVelocityMetersPerSecond(m_driveSim.setRatem_leftEncoderSim.
                 ());getRightPositionMeters(m_driveSim.setDistancem_rightEncoderSim.
            ());getRightVelocityMetersPerSecond(m_driveSim.setRatem_rightEncoderSim.
                          ());getDegrees().getHeadingm_driveSim.-(setAnglem_gyroSim.
                                                                                     }
```

C++

```
                                                      ;}0m_leftMotor{ PWMSparkMax::frc
                                                     ;}1m_rightMotor{ PWMSparkMax::frc

                                                                        { Drivetrain()
                                                                                  ...
            ␣/ kWheelRadius * pi::numbers::std * 2m_leftEncoder.SetDistancePerPulse(
                                                                kEncoderResolution); ↪
           ␣/ kWheelRadius * pi::numbers::std * 2m_rightEncoder.SetDistancePerPulse(
                                                                kEncoderResolution); ↪
                                                                                     }

                                                           { SimulationPeriodic() void
                       convert to need we that Note system. the to inputs the Set //
                       the by it multiplying by voltage to signal PWM 1] [-1, the //
                                                        voltage. controller robot //
                                                               m_driveSim.SetInputs(
       GetInputVoltage()),::RobotController::volt_t(frc::units * m_leftMotor.get()
     GetInputVoltage()));::RobotController::volt_t(frc::units * m_rightMotor.get()

                    this running are you if that Note ms. 20 by model the Advance //
              timestep nominal the changed have or thread separate a in subsystem //
                                     it. match to needs value this TimedRobot, of //
                                                           ms);_20m_driveSim.Update(

                                                       sensors. our of all Update //
                 m_leftEncoderSim.SetDistance(m_driveSim.GetLeftPosition().value());
                     m_leftEncoderSim.SetRate(m_driveSim.GetLeftVelocity().value());
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
               m_rightEncoderSim.SetDistance(m_driveSim.GetRightPosition().value());
                   m_rightEncoderSim.SetRate(m_driveSim.GetRightVelocity().value());
                             m_driveSim.GetHeading().Degrees());-m_gyroSim.SetAngle(
                                                                                   }
```

---

in voltage right the negate MUST you inverted, is drivetrain your of side right the If :□□□□ movement. forward to correspond voltages positive that ensure to call `SetInputs()` the

---

meters in velocities and positions returns model simulator drivetrain the Because :□□□□ calling when ticks/s and ticks encoder to converted be must these respectively, m/s and on `SetDistancePerPulse` configure can you Alternatively, .`SetRate()` and `SetDistance()` approach the is this – automatically this of care take object `Encoder` the have to encoders the above. example the in taken is that

---

set, been have angles gyroscope and velocities, positions, encoder simulated the that Now will it and normal as code robot your in etc. ,`m_leftEncoder.GetDistance()` call can you calculations, odometry performing involves This robot. real a on would it like exactly behave etc. tracking, trajectory for loops feedback PID velocity running

### Position Robot Visualizing and Odometry Updating :4 Step 21.5.5

with updated being are angles gyro and velocities, positions, encoder simulated the that Now a in robot the of pose the update to used be can data this periodically, information accurate periodic the simulation, In ).`Subsystem` a in method `periodic()` the as (such loop periodic real the on whereas odometry update to readings gyro and encoder simulated use will loop hardware. physical from readings real use will code same the robot,

---

.*document this* see odometry, using on information more For :□□□□

---

#### Visualization Pose Robot

dashboard a on or simulation) (during GUI Simulator the on visualized be can pose robot The `Field2d` A object. `Field2d` a over pose odometry the sending by robot) real a (on Glass as such arguments: constructor any without constructed trivially be can

Java

```
Field2d(); new = m_field Field2d private
```

C++

```
frc/smartdashboard/Field2d.h>< include#

                                      ..

                   m_field; Field2d::frc
```

in is this do to place best The NetworkTables. over sent be then must instance `Field2d` This subsystem. your of constructor the

Java

```
{ ()Drivetrain public
...
m_field); ,"Field"(putDataSmartDashboard.
}
```

C++

```
frc/smartdashboard/SmartDashboard.h>< include#

{ Drivetrain()
...
m_field);& ,"Field"PutData(::SmartDashboard::frc
}
```

---

using or API NetworkTables levellower- a using sent be also can instance `Field2d` The :□□□□ .*API Shuffleboard* the

---

object. `Field2d` the into periodically updated be must odometry your from pose the Finally, during both runs that one i.e. method `periodic()` general a in be should this that Remember operation. robot real during and simulation

Java

```
{ ()periodic void public
...
set we that readings sensor simulated the get will This //
use will but simulation, in while article previous the in //
itself. robot the on values real //
(),getRotation2d(m_gyro.updatem_odometry.
(),getDistancem_leftEncoder.
());getDistancem_rightEncoder.
());getPoseMeters(m_odometry.setRobotPosem_field.
}
```

C++

```
{ ()Periodic void
...
set we that readings sensor simulated the get will This //
use will but simulation, in while article previous the in //
itself. robot the on values real //
m_odometry.Update(m_gyro.GetRotation2d(),
meter_t(m_leftEncoder.GetDistance()),::units
meter_t(m_rightEncoder.GetDistance()));::units
m_field.SetRobotPose(m_odometry.GetPose());
}
```

---

one – method `periodic()` regular a in placed is code this that important is It :□□□□ command- the using are you If operation. of mode of regardless periodically called is that method this calling for responsible are you not, If exists. already method this library, based class. `Robot` main the from periodically

---

You code. your run to required changes code the of all covered have we point this At :□□□□ simulation the run to how on info more for *page Interface User Simulation* the to head should GUI. the to on run will robot simulated your that field the add to *page Widget Field2d* the and

---

# Testing Unit 21.6

possible ”units“ smallest the into code the dividing by code testing of method a is testing Unit subsystem each for code the testing mean can this code, robot In unit. each testing and projects robot Java languages. most for frameworks testing unit many are There individually. .Test Google have projects robot C++ and default, by available 5 JUnit have

## Code Testable Writing 21.6.1

---

`Intake` having by paradigm basedcommand- the to adapted easily be can example This :□□□□ .`SubsystemBase` from inherit

---

motor: a and piston a containing mechanism intake Recharge Infinite an be will subsystem Our don’t We inside. Cells Power the pull will motor the and intake, the deploys/retracts piston the anything. do won’t it because deployed isn’t mechanism intake the if run to motor the want

object the destroy to function a have to need we test, each for slate“ ”clean a provide To `AutoCloseable` the implementing by done is this Java, In allocations. hardware all free and member’s the calling by object member each destroying method, `close()`. its and interface closed. be to need doesn’t probably method `close()`. a without object an - method `close()`. scope of out goes object the when automatically called be will destructor default the C++, In objects. member of destructors call will and

---

See here. shown way the to identically closing resource support not might Vendors :□□□□ how. and support they what to as information more for documentation vendor’s your

---

Java

```
                                           ;edu.wpi.first.wpilibj.DoubleSolenoid import
                                     ;edu.wpi.first.wpilibj.PneumaticsModuleType import
              ;edu.wpi.first.wpilibj.examples.unittest.Constants.IntakeConstants import
                                 ;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import

                                         { AutoCloseable implements Intake class public
                                                   m_motor; PWMSparkMax final private
                                               m_piston; DoubleSolenoid final private

                                                                    { ()Intake public
                             );kMotorPortPWMSparkMax(IntakeConstants. new = m_motor
                                                                         = m_piston
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
DoubleSolenoid( new
,CTREPCMPneumaticsModuleType.
,kPistonFwdChannelIntakeConstants.
);kPistonRevChannelIntakeConstants.
}

{ ()deploy void public
);kForward.Value(DoubleSolenoid.setm_piston.
}

{ ()retract void public
);kReverse.Value(DoubleSolenoid.setm_piston.
motor the off turn // );0(setm_motor.
}

{ speed) double(activate void public
{ (isDeployed()) if
(speed);setm_motor.
nothing do open, t'isn piston if // { else }
);0(setm_motor.
}
}

{ ()isDeployed boolean public
;kForward.ValueDoubleSolenoid. == ()getm_piston. return
}

@Override
{ Exception throws ()close void public
();closem_piston.
();closem_motor.
}
}
```

(Header) C++

```
frc/DoubleSolenoid.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#

Constants.h"" include#

{ Intake class
:public
Deploy(); void
();Retract void
speed); double(Activate void
;const ()IsDeployed bool

:private
kMotorPort};::m_motor{IntakeConstants PWMSparkMax::frc
CTREPCM,::PneumaticsModuleType::m_piston{frc DoubleSolenoid::frc
kPistonFwdChannel,::IntakeConstants
kPistonRevChannel};::IntakeConstants
;}
```

(Source) C++

```
                                          subsystems/Intake.h"" include#

                                                  { ()Intake::Deploy void
                 kForward);::Value::DoubleSolenoid::m_piston.Set(frc
                                                                        }

                                                 { ()Intake::Retract void
                 kReverse);::Value::DoubleSolenoid::m_piston.Set(frc
                                 motor the off turn //  );0m_motor.Set(
                                                                        }

                                       { speed) double(Intake::Activate void
                                                       { (IsDeployed()) if
                                                      m_motor.Set(speed);
                      nothing do open, t'isn piston if //  { else }
                                                          );0m_motor.Set(
                                                                      }
                                                                        }

                                      { const ()Intake::IsDeployed bool
            kForward;::Value::DoubleSolenoid::frc == m_piston.Get() return
                                                                        }
```

### Tests Writing 21.6.2

---

`src/test/cpp//` and `src/test/java//` set: source `test` the inside placed are Tests :□□□□ the to access have not do root source that outside Files respectively. tests, C++ and Java for references. unresolved to due compilation fail will this - framework test

---

`@org.junit.jupiter.` with marked method test one least at contains class test each Java, In resources opening for methods Additional case. test a representing method each ,`api.Test` marked respectively are after them closing and test each before object) `Intake` our as (such In .`@org.junit.jupiter.api.AfterEach` and `@org.junit.jupiter.api.BeforeEach` with and subsystem our contain `testing::Test` from inheriting classes fixture test C++, `TEST_F(testfixture,` the using written are methods test and objects, hardware simulation fixture test the in overridden be can methods `TearDown()` and `SetUp()` The macro. `testname)` test. each after and before respectively run be will and class

in `EXPECT_*()` or Java in `assert*()`( *assertion* one least at contain should method test Each isn't condition the if test the fail and runtime at condition a verify assertions These C++). crash will assertion failed first the method, test a in assertion one than more is there If met. assertions. later the reach won't execution - test the

equality: is common most the types; assertion multiple have GoogleTest and JUnit Both comparing When .`actual)` `EXPECT_EQ(expected,/actual)` `assertEquals(expected,` (Java), JUnit In given. be can error, acceptable the ,`delta` - parameter third a numbers, static the adding by qualification without used be can and methods static are assertions these (C++), Test Google In .`org.junit.jupiter.api.Assertions.* static import` import star header. >`<gtest/gtest.h` the from macros are assertions

---

done be should them comparing so accurate, isn't values pointfloating- of Comparison :□□□□ ).DELTA( parameter error acceptable an with

---

Java

```
                           ;org.junit.jupiter.api.Assertions.assertEquals static import

                                                          ;edu.wpi.first.hal.HAL import
                                           ;edu.wpi.first.wpilibj.DoubleSolenoid import
                                     ;edu.wpi.first.wpilibj.PneumaticsModuleType import
              ;edu.wpi.first.wpilibj.examples.unittest.Constants.IntakeConstants import
                             ;edu.wpi.first.wpilibj.simulation.DoubleSolenoidSim import
                                        ;edu.wpi.first.wpilibj.simulation.PWMSim import
                                                ;org.junit.jupiter.api.AfterEach import
                                               ;org.junit.jupiter.api.BeforeEach import
                                                     ;org.junit.jupiter.api.Test import

                                                                     { IntakeTest class
                      range deviation acceptable // ;1e-2 = DELTA double final static
                                                                     m_intake; Intake
                                                                   m_simMotor; PWMSim
                                                       m_simPiston; DoubleSolenoidSim

                                 test each before run will method this // @BeforeEach
                                                                       { ()setup void
              failed if crash HAL, the initialize // );0 ,500(initializeHAL. assert
                                      intake our create // Intake(); new = m_intake
                                                                       = m_simMotor
    ␣motor PWM simulation our create // );kMotorPortPWMSim(IntakeConstants. new
                                                                           controller ↪
                                                                      = m_simPiston
                                                         DoubleSolenoidSim( new
                                              ,CTREPCMPneumaticsModuleType.
                                         ,kPistonFwdChannelIntakeConstants.
      solenoid simulation our create // );kPistonRevChannelIntakeConstants.
                                                                                    }

                             )"PMD.SignatureDeclareThrowsException"(@SuppressWarnings
                                   test each after run will method this // @AfterEach
                                                   { Exception throws ()shutdown void
                                     object intake our destroy // ();closem_intake.
                                                                                    }

                                                 test a as method this marks // @Test
                                                        { ()doesntWorkWhenClosed void
                                            intake the close // ();retractm_intake.
                               motor the activate to try // );0.5(activatem_intake.
                                                                      assertEquals(
    ␣the to set value the that sure make // DELTA); (),getSpeedm_simMotor. ,0.0
                                                                           0 is motor ↪
                                                                                    }

                                                                                @Test
                                                               { ()worksWhenOpen void
                                                                 ();deploym_intake.
                                                            );0.5(activatem_intake.
                                   DELTA); (),getSpeedm_simMotor. ,0.5assertEquals(
                                                                                    }

                                                                                @Test
                                                                 { ()retractTest void
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                ();retractm_intake.
                    ());getm_simPiston.  ,kReverse.ValueassertEquals(DoubleSolenoid.
                                                                                    }

                                                                                @Test
                                                                  { ()deployTest void
                                                                 ();deploym_intake.
                    ());getm_simPiston.  ,kForward.ValueassertEquals(DoubleSolenoid.
                                                                                    }
                                                                                      }
```

C++

```
                                                               gtest/gtest.h>< include#

                                                        frc/DoubleSolenoid.h>< include#
                                          frc/simulation/DoubleSolenoidSim.h>< include#
                                                     frc/simulation/PWMSim.h>< include#

                                                                 Constants.h"" include#
                                                         subsystems/Intake.h"" include#

                                              { Test::testing public : IntakeTest class
                                                                            :protected
                                                 intake our create //  intake; Intake
                                                           simMotor{ PWMSim::sim::frc
                      PWM simulation our create //  kMotorPort};::IntakeConstants
                                               simPiston{ DoubleSolenoidSim::sim::frc
          kPistonFwdChannel,::IntakeConstants CTREPCM,::PneumaticsModuleType::frc
          solenoid simulation our create //  kPistonRevChannel};::IntakeConstants
                                                                                     ;}

                                             { DoesntWorkWhenClosed) TEST_F(IntakeTest,
                                           intake the close //      intake.Retract();
                                  motor the activate to try //  );0.5intake.Activate(
                                                                    EXPECT_DOUBLE_EQ(
                                                                             ,0.0
         0 is motor the to set value the that sure make //  simMotor.GetSpeed());
                                                                                      }

                                                    { WorksWhenOpen) TEST_F(IntakeTest,
                                                                     intake.Deploy();
                                                                );0.5intake.Activate(
                                          simMotor.GetSpeed());  ,0.5EXPECT_DOUBLE_EQ(
                                                                                      }

                                                          { Retract) TEST_F(IntakeTest,
                                                                    intake.Retract();
                    simPiston.Get()); kReverse,::Value::DoubleSolenoid::EXPECT_EQ(frc
                                                                                      }

                                                           { Deploy) TEST_F(IntakeTest,
                                                                     intake.Deploy();
                    simPiston.Get()); kForward,::Value::DoubleSolenoid::EXPECT_EQ(frc
                                                                                      }
```

docs. framework the see Test, Google and JUnit of usage advanced more For

### Tests Running 21.6.3

:□□□□ more and prerequisites For desktop. your on simulation in run be always will Tests .*introduction simulation the* see info,

block: following the contains file `build.gradle` your that sure make run, to tests Java For

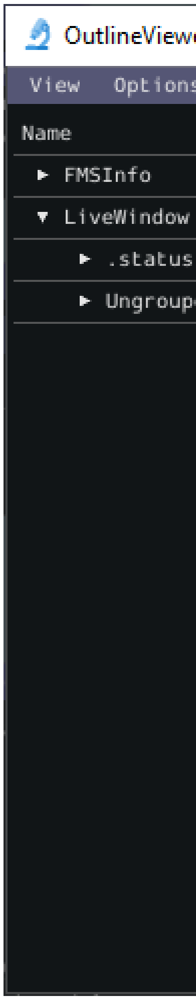
```
                                                                  { test
                                                       )(useJUnitPlatform
          'true' ,'junit.jupiter.extensions.autodetection.enabled' systemProperty
                                                                         }
```

reported be will Results tests. the run to Palette Command the from *Code Robot Test* Use name test the to next label `OK/PASSED` or `FAILED` a have will test each output, terminal the in `build/reports/tests/` in document HTML a generate will only) (Java JUnit output. the in link a test failed are there if results; the of overview detailed more a with `test/index.html` output. terminal the in printed be will browser your in document the render to

will This deploys. including built, is code robot whenever tests the runs Gradle default, By this prevent To fail. to deploy and build the cause will tests failing and time, deploy increase Palette Command the from *Setting Deploy On Tests Skip Change* use can you happening, from deploying. when tests run to whether configure to

# 22

[redacted]



NetworkTables the of contents the to add and modify view, to used utility a is OutlineViewer
and NetworkTables the in currently pairs value key all displays It purposes. debugging for
OutlineViewer table. the to keys new add or keys existing of value the modify to used be can
installations. language C++ and Java the in included is

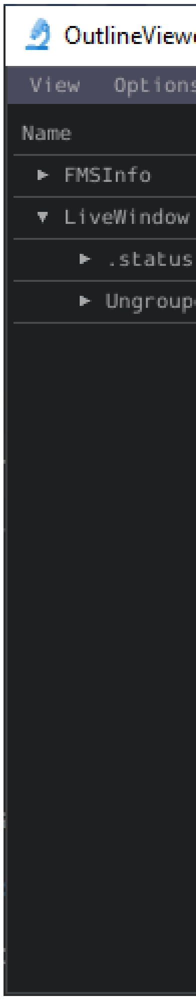
top the in logo WPILib the click or `WPILib` type and `Ctrl+Shift+P` press Code, Studio Visual In
.*OutlineViewer* select then ,*Tool Start* Select Palette. Command WPILib the launch to right

team your be to `Location Server` the set and OutlineViewer open robot, your to connect To
to connecting trouble have you If connect. will OutlineViewer start, click you After number.
.*Steps Troubleshooting Dashboard* the see please OutlineViewer

---

simulated a at OutlineViewer point to number team a of instead `localhost` use can You **:□□□□**
Romi. a or robot

---



the choose and location a on click right NetworkTables, to pairs key/value additional add To
type. data corresponding

---

accomplish to Dashboard LabVIEW the of tab Variables the use can teams LabVIEW **:□□□□**
OutlineViewer. as functionality same the

---

[redacted]

## Introduction Vision 23.1

### Vision? is What 23.1.1

drive, and score teams help to order in robot the to connected camera a uses FRC® in Vision
periods. teleoperated and autonomous the both during

#### Methods Vision

FRC. in vision for use teams most that method main two are There

#### Streaming

and driver the that so Station Driver the to camera the streaming involves method This
simple is method This view. of point robot's the from information visual get can manipulator
of features need not do you if option good a it making implement, to time little takes and
processing. vision

- *roboRIO the using Streaming*

#### Processing

the using involves method this Station, Driver the to camera the streaming only of Instead
target's or piece's game a as such information, compute to camera the by captured frames
and knowledge technical more requires method This camera. the from distance and angle
this However, expensive. computationally more being as well as implement, to order in time
operations scoring“”auto- in assist and performance autonomous improve help can method
coprocessor a or roboRIO the using done be can method This period. teleoperated the during
GRIP. as such programs or OpenCV either using Pi Raspberry the as such

- *Pi Raspberry with Processing Vision*
- *GRIP with Processing Vision*

*roboRIO the with Processing Vision* •

processing, vision for coprocessor a using of cons and pros the on information additional For
.*Programming Vision for Strategies* page, next the see

## Programming Vision for Strategies 23.1.2

on elements the to responsive be robot your making of way great a is vision computer Using
points bonus are there games FRC® in Often autonomous. more much it make and field the
on locations to navigating or goals into pieces game other or balls shooting autonomously for
have you if And problems. these of many solving of way great a is vision Computer field. the
as period teleop the during used be can it then challenge, the do can that code autonomous
drivers. human the help to well

the where and processing vision for components the choosing for options many are There
and options of number a support tools associated and WPILib run. should program vision
some you give to attempt will article This do. to what decide to flexibility of lot a teams give
available. are that tradeoffs and choices the of many into insight

## Library Vision Computer OpenCV

academia throughout used widely is that library vision computer source open an is **OpenCV**
accelerated GPU providing manufactures hardware from support has It industry. and
It Python. and Java, C++, including languages of number a for bindings has it processing,
there so courses training and videos, books, sites, web many with documented well also is
of versions Java and C++ The it. use to how learn help to available resources of lots are
processing capturing, for library the in support is there libraries, OpenCV the include WPILib
information more For algorithms. vision your create you help to tools and video, viewing and
.https://opencv.org see OpenCV about

## roboRIO on Code Vision

since choice good a makes Python choosing. your of language a using program vision own good. very are bindings OpenCV the and implementation NetworkTables native a is there

or distance position, target the as such values key the processed, are images the After approach This NetworkTables. with robot the to back sent be can need you else anything the to sent be to needing images the to due added is delay as latency, higher has generally used images the of FPS and resolution maximum the limit also limitations Bandwidth laptop. processing. for

GRIP. in or Shuffleboard on displayed be can stream video The

## Coprocessor on Code Vision

### Options Camera

of number a have Cameras WPILib. by supported options camera of number a are There the affect resolution image and rate frame example, for operation; affect that parameters to sent if and, time processing impact high too set when but images, received the of quality field. the on bandwidth available the exceed may station, driver the

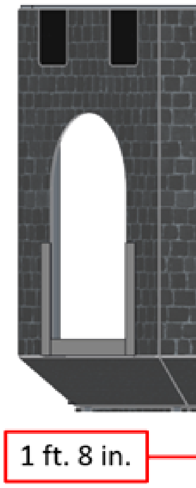
the to connected cameras with interface to used is Java and C++ in class CameraServer The stream the sends and object Source a through processing local for frames retrieve It robot. there. processing or viewing for station driver your to

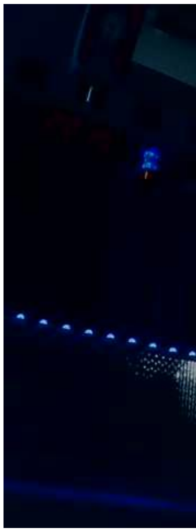
## Retroreflection and Info Target 23.1.3

vision in aid to elements field to attached tape retroreflective have games FRC® Many the and game FRC 2016 the from Targets Vision the describes document This processing. targets. the up making material the of properties visual

Official the see please components, field all of drawings and dimensions official For :□□□□ Drawings. Field

### Targets





wide 2“ of made shapeU- tall 1« wide, 8“ 1« a of consists target vision 2016 Each immediately located are targets The Film). Marking Silver 8830 (3M material retroreflective produces tape retroreflective the lit, properly When goal. high each of bottom the to adjacent marker. saturatedcolor- and/or bright a

### Reflectivity vs. Retroreflectivity

back light of majority the return materials reflectiveRetro- however. ,*reflectionretro-* exhibit the and surface the between angles of range wide a for this do they and source, light the to using this accomplish materials reflectiveRetro- case. degree 90 the just not source, light with spheres small using by or reflector, roadside or bicycle a on found as such prisms, small nature, In reflections. internal multiple accomplish that refraction of index appropriate the typically effect reflectiveretro- the exhibit also cats, house including animals, some of eyes the shine.night- as to referred

### Retroreflection of Examples

visibility nighttime enhance to used often is it as familiar relatively be should material This
pedestrians. and bicycles, signs, road of

when but safety, nighttime for property useful a like seem not may reflectionretro- Initially,
eye, the to returns light reflected the above, shown as another, one near are eye and light the
the between angle small the to Due distances. large at even brightly shines material the and
visibility increase greatly can materials reflectiveretro- headlights, vehicle and eyes driver's
driving. nighttime during objects distant of

## Demonstration

properties: material reflectiveretro- explore further To

surface vertical or wall a on material the of piece a Place 1.

material. the at flashlight small a shine and away, feet 2010- Stand 2.

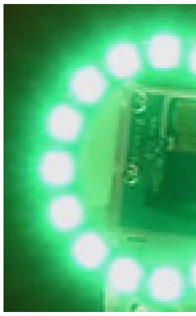
your between is it until slowly it raise and button, belly your at held light the with Start 3.
rapidly. increase will light returned the of intensity the eyes, your nears light the As eyes.

bright The repeating. and room the in locations other to moving by angle the Alter 4.
light from angle the but angles, viewing of range wide a over occur should reflection
small. quite be must and key is eye to source

reflective more times of hundreds is material The sources. light different with Experiment
safety bicycle red a example, For fine. work will sources light dim so paint; white than
reflected the of color the determines source light the of color the that demonstrate will light
own their with each locations, different at members team several position possible, If light.
can material the and independent, largely are effects the that show will This source. light
that demonstrates also This members. team various to colors different appear simultaneously
is viewer the to returning light The lighting. environmental to immune largely is material the
Using them. behind directly one or control they source light a by determined entirely almost

clothing, on environment: your in already articles reflectiveretro- other identify flashlight, the etc. shoes, backpacks,

### Lighting



it, at directed is source light a unless shine not will tape reflectiveretro- the that seen have We there While eyes. observer's the or lens camera the near very pass must source light the and is investigate to source light of type useful very a this, accomplish to ways of number a are the around or on directly source light the places It above. shown light, ring or flash, ring the size, small and output bright their of Because lighting. even very provides and lens camera device. of type this constructing for useful particularly are LEDs

of variety a in available are LEDs of arrangements circular inexpensive above, shown As a of off powered be even can some and cameras, to attach to easy are and sizes and colors causing for well quite work they lighting, even diffuse for designed not While Pi. Raspberry Choice. FIRST through available is ring LED green small A shine. to tape reflectiveretro- SuperBrightLEDs. as such suppliers from available are rings LED similar Other

### Images Sample

with (packaged language each for examples code the with located are images Sample samples). C++/Java the as location same the in ZIP separate a in and LabVIEW,

## Targets the Processing and Identifying 23.1.4

This image. the in Target(s) Vision identify to is step next the captured, is image an Once the that Note targets. 2016 the identifying to approach one through walk will document the underexpose to set intentionally camera the with taken were section this in used images on section the see targets, lit the of exception the with images dark very producing images, details. for Settings Camera

## Options Additional

LabVIEW in provided code example the by used approach the through walks document This the of aware be should teams options these to addition In Java. and C++ roboRIO), or PC (for boardon- an or PC Station Driver the on processing vision for allow that alternatives following PC:

RoboRealm 1.

robot any with works Java, in (programmed Extension Camera SmartDashboard 2.
language)

GRIP 3.

## Image Original

was image The here. described example the for image starting the is below shown image The ring additional an with combined Choice ®*FIRST* in available light ring green the using taken light a of different size. Additional sample images are provided with the code vision examples.

## HSL/HSV? is What

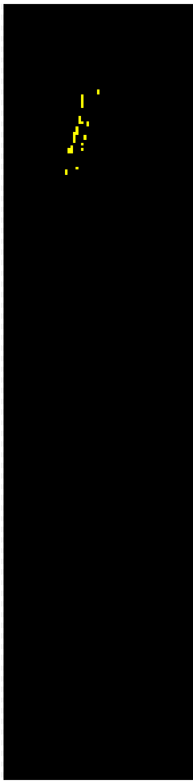
contains and wheel color artist's the on seen commonly is color the of tone or Hue The hue The Violet. and Indigo, Blue, Green, Yellow, Orange, Red, rainbow the of colors the only contains typically circle the imaging in but wheel, the on angle radial a using specified is at red to back wrapping and rainbow, the through cycling zero, at red with starting units, 256 to color hue the of ratio the or color, of amount specifies color a of Saturation end. upper the and hue no has saturation Zero gray. less colorful, more means ratio Higher gray. of shade a blended is hue the that gray of shade the indicates Value or Luminance gray. completely is 255. is white and 0 is Black with.

primary The target. the of color the specify to space color HSV the uses code example The of rest the to relative targets the of brightness the using for allows readily it that is reason component. (HSL) Luminance or (HSV) Value the using by criteria filtering a as image the the in used operation thresholding the that is system color HSV the use to reason Another space. color HSV the in done when roboRIO the on efficiently more runs example

## Masking

create to values brightness or color constant to compared are values pixel step, initial this In are that pixels the of most eliminates step single This yellow. in below shown mask binary a color the provided well works masking based Color tape. reflectiveretro- target's a of part not accurate more generally are inequalities Color consistent. and bright, saturated, relatively is Saturation, (Hue, HSV or Luminance) and Saturation, (Hue, HSL the using specified when true especially is This space. Blue) and Green, (Red, RGB the than space color Value) and dimension. more or one in large quite is range color the when

tower and light (overhead image the of parts bright other target, the to addition in that Notice step. masking the by caught also are lighting)



### Analysis Particle

bounding area, the examine to used is operation report particle a operation, masking the After several compute to used are These particles. the for rectangle equivalent and rectangle, below described test Each rectangular. most are that shapes the pick help to terms scored the if decide to limits score definedpre- to compared then is which 100)(0- score a generates not. or target a is particle

### Area Coverage

the of area the to compared particle the of area the comparing by calculated is score Area The square 80 is strips retroreflective the of area The particle. the around drawn box bounding inches square 240 is target the contains that rectangle the of area The ).$cm^2$ (~516 inches Area 1/3. is area box bounding and area between ratio ideal the that means This ).$m^2$ (~0.15 will score the 1/3 from diverges ratio the as 100, near score a produce will 1/3 to close ratios 0. approach

### Ratio Aspect

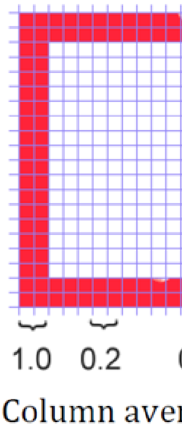
height and width The Height). Particle / Width (Particle on based is score ratio aspect The The rectangle". "equivalent the called something using determined are particle the of particle the equals $2x+2y$ where $y$ and $x$ lengths side with rectangle the is rectangle equivalent aspect the for used is rectangle equivalent The area. particle the equals $x \cdot y$ and perimeter bounding the using than rectangle the of skewing by affected less is it as calculation ratio the skewed is rectangle the as ratio, aspect for rectangle box bounding the using When box. decreases. width the and increases height

aspect detected The 1.6. of ratio a for tall, mm) (304.8 12" by wide mm) (508 20" is target The when 100 return to normalized is score ratio aspect The ratio. ideal this to compared is ratio the matches ratio the as linearly drops and ratio target the matches ratio the above. or below varies ratio the as linearly drops and ratio target the

### Moment

the of center the from is pixel each out spread how calculates measurement "moment" The It particle. the in distribution pixel the of representation a provides measurement This blob. score ideal The calculation. *inertia of moment* physics a to analogous as of thought be can ~0.28. is test this for

### Profiles X/Y



X the both in profile appropriate the matches particle the whether describes score edge The the across averages column and row the using calculated is it shown, As directions. Y and The mask. profile a to that comparing and image original the from extracted box bounding averages column or row the within values of number the on based 100 to 0 from ranges score values. limit lower and upper the between are that

### Measurements

some calculate to sense makes it target, a considered be to enough well scores particle a If these includes code example The distance. and position as such measurements worldreal-basic measurements, so let's look at the math involved to better understand it.

### Position

all but box, bounding the and particle the both by described well is position target The bottom and right the and screen the of left top the at being 0,0 with pixels in are coordinates not but math, pixel for system useful a is This resolution. camera the by determined edges useful. more be may that something to it change let's so robot; a driving for useful as nearly

shown formula the use can we system, aiming the to system pixel the from point a convert To below.

This inverted. is axis Y the but want, may you what to close are coordinates resulting The sample the in done not is this (Note: 1][1,- by point the multiplying by corrected be could is scale the and origin centered a has it because useful is system coordinate This code). inputs. Drive and outputs joystick to similar

$$A_{x,y} = \left(P_{x,y} - \frac{resolution_{x,y}}{2}\right) / \frac{resolution_{x,y}}{2}$$

### View of Field

to plane coordinate the on target the of position the and constants known use can You these, calculate to order in However, target. the from pitch and yaw, distance, your determine field vertical determine empirically to order In view). of (field FOV your determine must you distance the measure and surface, flat an from away distance set a camera your set view, of pixels. of row bottommost and topmost the between

$$\frac{1}{2}FOV_{vertical} = tan\left(\frac{\frac{1}{2}distance_y}{distance_z}\right)$$

the between distance the using but method, same the using FOV horizontal the find can You pixels. of column last and first

### Yaw and Pitch

your know you once simple is robot your to relative target the of yaw and pitch the Finding system. coordinate aiming the in target your of location the and FOVs

$$pitch = \frac{A_y}{2}FOV_{vertical}$$

$$yaw = \frac{A_x}{2}FOV_{horizontal}$$

### Distance

known use can you robot, your than height different significantly a at is target your If
angle the as well as camera, your and target the of height physical the as such constants,
target. the and camera your between distance the calculate to mounted, is camera your

$$distance = \frac{height_{target} - height_{camera}}{tan(angle_{camera} + pitch)}$$

inverse the estimate to or distance, to area for table lookup a create to is option Another
accurate. less is method this However, distance. and area of constant variation

---

can you distance, and angle estimating of methods above the for results best For **:□□□□**
affecting be may that distortions any of rid get to OpenCV using camera your calibrate
matrix. calibration the using target the of pixels the reprojecting by accuracy

---

## Class CameraServer Video: Process and Read 23.1.5

### Concepts

Axis the as such cameras Ethernet and USB (commodity FRC® in used typically cameras The
single a only provide they general, In operation. of modes limited relatively offer camera)
and resolution single a at JPG) as such format compressed RGB an in (typically output image
the access may application one only as limited particularly are cameras USB rate. frame
time. a at camera

automatically as such details handles It cameras. multiple supports CameraServer
camera the from images makes also and disconnected, is camera a when reconnecting
connect can dashboard the and code robot your both (e.g. ”clients“ multiple to available
simultaneously). camera the to

### Names Camera

for appears that name the also is This named. uniquely be must CameraServer in camera Each
`startAutomaticCapture()` CameraServer the of variants Some Dashboard. the in camera the
0“ Camera ”USB (e.g. camera the name automatically will functions `addAxisCamera()` and
Cam“). ”Intake (e.g. name descriptive more a camera the give can you or Camera“), ”Axis or
name. unique a have camera each that is requirement only The

### Notes Camera USB

#### Usage CPU

and compression performing only by usage CPU minimize to designed is CameraServer The
no when streaming disabling automatically and required when operations decompression
connected. are clients

the as resolution same the to set be should resolution dashboard the usage, CPU minimize To
instead, image, the recompress and decompress not to CameraServer the allows this camera;
It’s dashboard. the to directly camera the from received image JPEG the forward simply can it

camera the change *not* does dashboard the on resolution the changing that note to important the on `setResolution()` calling by done be may resolution camera the changing resolution; object. camera

### Bandwidth USB

interfaces. USB its over time a at data much so receive and transmit only can roboRIO The The limit. this into run to easy relatively is it so and data, of lot a require can images Camera running or mode video JPEGnon- a selecting is error bandwidth USB a of cause common most connected. are cameras multiple when particularly resolution, a of high too

### Architecture

and **class CameraServer** WPILib level high the layers, two of consists CameraServer The .**library cscore** level low the

### Class CameraServer

cameras adding for interface level high a provides WPILib) of (part class CameraServer The and cameras the about information publishing for responsible is also It code. robot your to LabVIEW the as such dashboards Station Driver that so NetworkTables to servers camera are streams their where determine and cameras the list can Shuffleboard and Dashboard servers. and cameras created all of database a maintain to pattern singleton a uses It located.

are: CameraServer in functions key Some

- a starts and LifeCam) Microsoft (e.g. camera USB a Add :`startAutomaticCapture()` dashboard. the from viewed be can it so it for server
- the from images processing aren’t you if Even camera. Axis an Add :`addAxisCamera()` camera Axis the that so function this use to want may you code, robot your in camera Axis Axis the so server a starts also It cameras. of list down drop Dashboard’s the in appears USB via roboRIO the to connected is station driver your when viewed be still can stream the to connected roboRIO and camera Axis the both have you if competition at (useful ports). Ethernet radio robot two
- the from images get to you allows This camera. a to access OpenCV Get :`getVideo()` code). robot your (in roboRIO the on processing image for camera
- pass to you allows This to. images OpenCV feed can you that server a Start :`putVideo()` dashboard. the to images annotated and/or processed custom

### Library cscore

to: implementation level lower the provides library cscore The

- cameras Axis) (e.g. HTTP and USB from images Get
- brightness) and contrast (e.g. settings camera Change
- rate) frame and resolution format, (pixel modes video camera Change
- stream MJPEG standard a as images serve and server web a as Act
- processing image for objects `Mat` OpenCV to/from images Convert

## Sinks and Sources

with MJPGStreamer, of that to similar is library cscore the of architecture basic The
multiple and sources multiple be can There sinks. and sources between split functionality
simultaneously. operating and created sinks

a is images accepts/consumes that object an and source a is images generates that object An
sources are cameras Thus library. the of perspective the from is generate/consume The sink.
from images accepts it because sink a is server web MJPEG The images). generate (they
or browser web a to on images those forwarding be may it though (even program the within
one to connected be can sinks but sinks, multiple to connected be may Sources dashboard).
of care takes library cscore the source, a to connected is sink a When source. one only and
sink. the to source the from image each passing

- event an fire and camera) USB a by provided as (such frames individual obtain **Sources**
library the source, particular a to listening are sinks no If available. is frame new a when
library The resources. I/O and processor save to source a from disconnect or pause may
resuming and pausing simply by disconnects/reconnects camera handles autonomously
error). an not frames, new no in results disconnect a (e.g. events of firing
- its to it forward and image, latest the grab event, source's particular a to listen **Sinks**
inactive is sink particular a if sources, to Similarly format. appropriate the in destination
may library the server), HTTP over MJPEG configured a to connected is client no (e.g.
resources. processor save to processing its of parts disable

(providing source a either as act can program) robot FRC a in used that as (such code User
via processing) for frame a (receiving sink a as or camera) a were it if as frames processed
a from images gets that pipeline processing image an Thus objects. sink and source OpenCV
graph: below the like looks out images processed the serves and camera

of out go they if destroyed aren't they so objects created of registry singleton a keeps also scope.

Java

```
;edu.wpi.cscore.CvSink import
;edu.wpi.cscore.CvSource import
;edu.wpi.cscore.MjpegServer import
;edu.wpi.cscore.UsbCamera import

them connects and [1] MjpegServer and UsbCamera Creates //
);0 ,"0 Camera USB"UsbCamera( new = usbCamera UsbCamera
);1181 ,"0 Camera serve_USB"MjpegServer( new = mjpegServer1 MjpegServer
(usbCamera);setSourcemjpegServer1.

UsbCamera the to it connects and CvSink the Creates //
);"0 Camera opencv_USB"CvSink( new = cvSink CvSink
(usbCamera);setSourcecvSink.

them connects and [2] MjpegServer and CvSource the Creates //
);30 ,480 ,640 ,kMJPEGPixelFormat. ,"Blur"CvSource( new = outputStream CvSource
);1182 ,"serve_Blur"MjpegServer( new = mjpegServer2 MjpegServer
(outputStream);setSourcemjpegServer2.
```

C++

```
cscore_oo.h"" include#

them connects and [1] MjpegServer and UsbCamera Creates //
);0 ,"0 Camera USB"usbCamera( UsbCamera::cs
);1181 ,"0 Camera serve_USB"mjpegServer1( MjpegServer::cs
mjpegServer1.SetSource(usbCamera);

UsbCamera the to it connects and CvSink the Creates //
);"0 Camera opencv_USB"cvSink( CvSink::cs
cvSink.SetSource(usbCamera);

them connects and [2] MjpegServer and CvSource the Creates //
);30 ,480 ,640 kMJPEG,::PixelFormat::cs ,"Blur"outputStream( CvSource::cs
);1182 ,"serve_Blur"mjpegServer2( MjpegServer::cs
mjpegServer2.SetSource(outputStream);
```

## Counting Reference

increments source a to sink a Connecting counted. reference internally are objects cscore All The scope. in sink the keep to necessary strictly only it's so count, reference source's the so functions, CameraServer with created objects all of registry a keeps class CameraServer explicitly (unless scope of out go never effectively way that in created sinks and sources removed).

## Examples Vision 2017 23.1.6

### LabVIEW

the From examples. LabVIEW other the with included is Example Vision LabVIEW 2017 The window, LabVIEW other any from or Examples FRC® >FindSupport- click screen, Splash The Example. Vision 2017 the find to folder Vision the locate and Examples >FindHelp- click example. the with bundled are images example

### C++/Java

images, example the as well as below, description the and project GRIP a provided have We .TeamForge on found be can that ZIP a into bundled

generated GRIP integrating about details for *Program Robot a in Code Generated Using* See program. robot your in code

green for contours OpenCV find will project GRIP included the by generated code The there From ZIP. this of folder Images Vision the in included ones the like images in particles this: do To target. the are they if assess to contours these process further to wish may you

1. contours the around rectangles bounding draw to method boundingRect the Use
2. these of Each target. the for ratios separate 5 calculates code example LabVIEW The starting then size, by contours the sorts it this, do To 1.0. equal nominally should ratios be may that contours of pair possible every for values these calculates largest, the with found. it pair best the returns or target a finds it if stops and target, the

Height, = (H rect bounding the of coordinate a to refers letter each below, formulas the In contour the to refers subscript numeric the and Width) = W Bottom, = B Top, = T Left, = L etc). largest, second the is 2 contour, largest the is (1 number

- in): 10 / in (4 height total of 40% be should height Top

$$\textit{Height Group} = \frac{H_1}{0.4(B_2 - T_1)}$$

- in): 10 / in (6 height total of 60% be should stripe top of top to stripe bottom of Top

$$\textit{dTop} = \frac{T_2 - T_1}{0.6(B_2 - T_1)}$$

- be should 2 contour of edge left the and 1 contour of edge left the between distance The centered ratio the make to 1 add we then contour; 1st the of width the to relative small 1: on

$$\textit{LEdge} = \frac{L_1 - L_2}{W_1} + 1$$

- same: the about be should contours both of widths The

$$\textit{ratio Width} = \frac{W_1}{W_2}$$

- one smaller the as tall as twice be should stripe larger The

$$\textit{ratio Height} = \frac{H_1}{2H_2}$$

calculating: by score 1000- a into turned then is ratios these of Each

$$100 - (100 \cdot \text{abs}(1 - \textit{Val}))$$

bottom of bottom to box bounding top of top from pixels measure distance, determine To 3.
box: bounding

$$\textit{distance} = \frac{\textit{ft. in height Target}(10/12) \cdot \textit{YRes}}{2 \cdot \textit{PixelHeight} \cdot \tan(\textit{camera of viewAngle})}$$

to prone most the are target round the of edges the as height uses example LabVIEW The
The green). less looks color the camera the from further points angle the (as detection in noise
perspective by affected is image the in target the of height pixel the that is this of downside
include: fixes Possible camera. the of angle the from distortion

- instead width using Try
- regression or table lookup a create and distances various at height measure Empirically
  function
- servo use and image the in vertically target the center servo, a to camera the Mount
  a find or yourself trig proper the out work to have (you'll calculation distance for angle
  help!) to teacher math
- calibrate to need will you this do To OpenCV. using distortion perspective the for Correct
  You matrix. camera and matrix distortion a in result will This .OpenCV with camera your
  the map to function undistortPoints the with them use and matrices two these take will
  (this coordinates ”correct“ the to calculation distance the for measure to want you points
  image) whole the undistorting than intensive CPU less much is

## WPILibPi with Vision 23.2

### Pi Raspberry the with WPILibPi using of Walkthrough Video A 23.2.1

WPILibPi. of name old the is which FRCVision mentions video The :□□□□

WPILib the from Johnson Peter 2020, in WPI“ by Presented Conference, Spring ”RSN the At
Pi. Raspberry a with Vision FRC® on presentation a gave team

.here available is presentation the to link The

### processing vision for Coprocessor a Using 23.2.2

pieces game or targets field recognizing for OpenCV like libraries using processing Vision processing the and significant too isn't load the Often process. intensive CPU a be often can the or streams camera more are there where cases In roboRIO. the by handled be easily can and code the putting by roboRIO the loadoff- to desirable is it complex, is processing image processors of choices of number a are There processor. different a on connection camera the LimeLight the Kangaroo, basedintel- the PI, Raspberry the as such FRC® in popular are that as such accelerator graphics a code vision complex more for or simplicity, in ultimate the for models. Jetson nVidia the of one

#### Strategy

generally that software required the with coprocessor the up set to is idea the Generally includes:

- library vision computer source open the - OpenCV
- program roboRIO the to processing image the of results the commute to - *NetworkTables*
- can that streams publish and connections camera the handle to - library server Camera dashboard a on viewed be
- program vision the for used is language computer whatever for library language The
- detection object the does that program vision actual The

ethernet extra the into it plugging by network roboRIO the to connected is coprocessor The the to switch network small a adding connections, more for or, router network the on port them, processes images, the acquires it coprocessor, the into plugged are cameras The robot. can is it so NetworkTables to information, location target usually results, the publishes and aiming. and steering for program robot the by consumed be

### Streaming camera data to the dashboard

It is often desirable to simply stream the camera data to the dashboard over the robot network. In this case one or more camera connections can be sent to the network and viewed on a dashboard such as Shuffleboard or a web browser. Using Shuffleboard has the advantage of having easy controls to set the camera resolution and bit rate as well as integrating the camera streams with other data sent from the robot.

It is also possible to process images and add annotation to the image, such as target lines or boxes showing what the image processing code has detected then send it forward to the dashboard to make it easier for operators to see a clear picture of what's around the robot.

## 23.2.3 Using the Raspberry Pi for FRC

One of the most popular coprocessor choices is the Raspberry Pi because:

- Low cost - around $35
- High availability - it's easy to find Raspberry Pis from a number of suppliers, including Amazon
- Very good performance - the current Raspberry Pi 3b+ has the following specifications:
- Technical Specifications: - Broadcom BCM2837BO 64 bit ARMv8 QUAD Core A53 64bit Processor powered Single Board Computer run at 1.4GHz - 1GB RAM - BCM43143 WiFi on board - Bluetooth Low Energy (BLE) on board - 40 pin extended GPIO - 4 x USB2 ports - 4 pole Stereo output and Composite video port - Full size HDMI - CSI camera port for connecting the Raspberry Pi camera - DSI display port for connecting the Raspberry Pi touch screen display - MicroSD port for loading your operating system and storing data - Upgraded switched Micro USB power source (now supports up to 2.5 Amps.

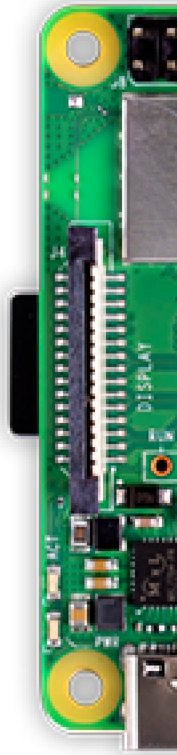
### Pre-built Raspberry Pi image

To make using the Raspberry Pi as easy as possible for teams, there is a provided Raspberry Pi image. The image can be copied to a micro SD card, inserted into the Pi, and booted. By default it supports:

- A web interface for configuring it for the most common functions
- Supports an arbitrary number camera streams (defaults to one) that are published on the network interface
- OpenCV, *NetworkTables*, Camera Server, and language libraries for C++, Java, and Python custom programs

If the only requirement is to stream one or more cameras to the network (and dashboard) then no programming is required and can be set up completely through the web interface.

The next section discusses how to install the image onto a flash card and boot the Pi.

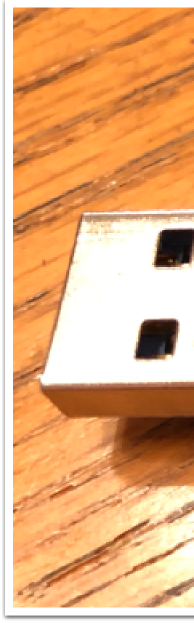


### running image Pi the get to need you What 23.2.4

following: the need you coprocessor image or video a as Pi Raspberry the using start To

- B 4 Pi Raspberry a or B+, 3 Pi Raspberry B, 3 Pi Raspberry A
- a with software, provided the all hold to GB 8 least at is that card SD micro A (10MB/s) 10 of Class Speed recommended
- network roboRIO your to Pi the connect to cable ethernet An
- your on (VRM) Module Regulator Voltage the to connect to cable power micro USB A it powering than rather power for connection VRM the use to recommended is It robot. reliability higher for ports USB roboRIO the of one from
- SD a or (preferred) dongle USB a using either card, MicroSD the write can that laptop A cards MicroSD most with ships that adapter MicroSD to

card. MicroSD the to image FRC® the write will that dongle USB inexpensive an is Shown



### 23.2.5 Installing the image to your MicroSD card

#### Getting the FRC Raspberry PI image

The image is stored on the GitHub release page for the WPILibPi repository.

In addition to the instructions on this page, see the documentation on the GitHub web page (below).

The image is fairly large so have a fast internet connection when downloading it. Always use the most recent release from the top of the list of releases.

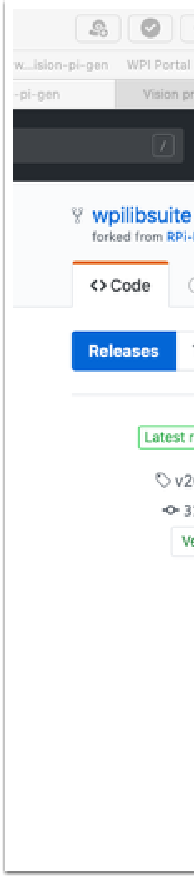
#### Copy the image to your MicroSD card

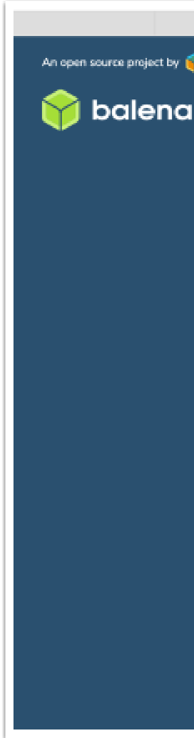
Download and install Etcher to image the micro SD card. The micro SD card needs to be at least 8 GB. A micro SD to USB dongle works well for writing to micro SD cards.

Flash the MicroSD card with the image using Etcher by selecting the zip file as the source, your SD card as the destination and click “Flash”. Expect the process to take about 3 minutes on a fairly fast laptop.

#### Testing the Raspberry PI

1. Put the micro SD card in a rPi 3 and apply power.
2. Connect the rPi 3 ethernet to a LAN or PC. Open a web browser and connect to `http://wpilibpi.local` to open the web dashboard. On the first bootup the filesystem will be writable, but later bootups will default to read only, so it's necessary to click the “writable” button to make changes.


w...ision-pi-gen
WPI Portal
-pi-gen
Vision pr
wpilibsuite
forked from RPi-
Code
Releases
Latest r
v2
3
Ve


An open source project by
balena

### PI Raspberry the into Logging

advanced for Sometimes interface. console web the from done be can rPi the with tasks Most default the use in, log To in. log to necessary is it rPi the on development program as such use password: PI Raspberry

```
pi Username:
raspberry Password:
```

## PI Raspberry The 23.2.6

### Console FRC

web any in viewed be can that console a includes PI Raspberry the for image FRC® The to: easy it makes that browser

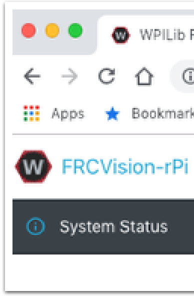
- status PI Raspberry the at Look
- camera the running process background the of status the View
- settings network change or View
- cameras additional add and rPI the into plugged camera each at Look
- rPI the onto program vision new a Load

### Writable vs. OnlyRead- be to rPI the Setting

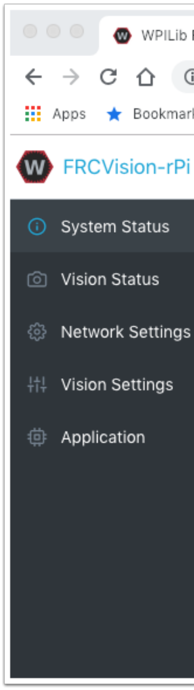
changed. be cannot system file the that means which OnlyRead- to set normally is rPI The
isn’t system file the rPi the down shutting first without removed is power if that ensures This
saved be cannot settings new the sections), (following changed are settings When corrupted.
system file the allow that provided are Buttons Only.Read- as set is system file rPI the while
other the If made. are changes whenever back and Writable to OnlyRead- from changed be to
status OnlyRead- the check press, be cannot rPI the on stored information change that buttons
system. the of

### rPI the to connection network the of Status

currently is rPi the if indicates that console the of corner right top the in label a is There
network a longer no is there if Disconnected to Connected from change will It connected.
rPi. the to connection



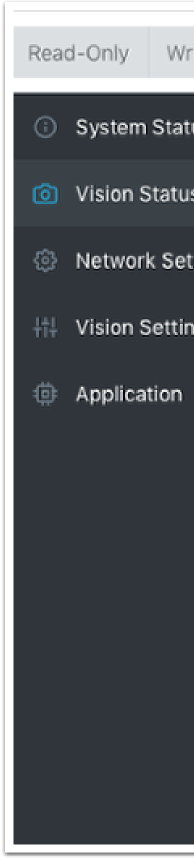
### status System



columns two are There time. any at doing is rPI the on CPU the what shows status system The is: Shown average. second 5 a other the and average second 1 a being on values, status of

- PI the on RAM available and free
- time. idle as well as processes system and processes user for usage CPU
- bandwidth camera used the if determine to one allows which - bandwidth network And year. any for rules robot the in allowed bandwidth maximum the exceeding is

## Status Vision

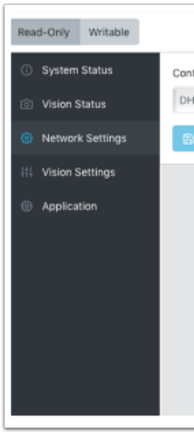


the of one either rPI, the in code camera the running is which task the of monitoring Allows and enable also can You Python. or C++, Java, in program own your or programs default In service. camera background the from coming messages see to output console the view *NetworkTables* to connect to unable being about messages of number are there case this no with laptop a to connected simply is rPI the example this in because connect()) (NT: roboRIO.) the (usually running server NetworkTables

## Settings Network

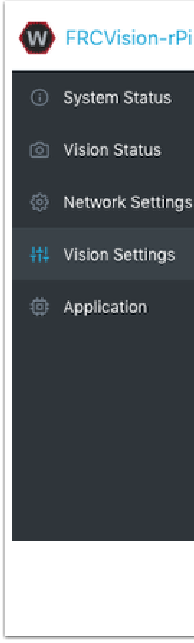
PI: the to connect to options have settings network rPI The

- is name default The roboRIO. the by used usually resolution name default the - DHCP wpilibpi.local.
- explicitly in filled are settings router and mask, network address, IP fixed a where - Static
- IP an get to try will PI the - Fallback Static with DHCP - Fallback Static with DHCP IP static provided the use will it server, DHCP a find can't it if but DHCP, via address parameters and address



mDNS The Addressing. IP Static and DHCP both for settings the showing is above picture The above. selected options the of regardless work always should rPi the for name

## Settings Vision



should rPI the whether and camera each for parameters the set to are Settings Vision The
the and network the on server one be only can There server. or client NetworkTables a be
be always should rPI the roboRIO, a to connected when Therefore server. a always is roboRIO
roboRIO no with setup desktop a on testing If in. filled number team the with mode client in
off). is switch (Client Server to set be should it then server a as acting anything or

case this In question. in camera the on click settings camera the all manipulate and view To
current the reveals name the on clicking and 0“ Camera rPi ”Camera called is camera the
settings. associated the and view camera

the of bottom The view. camera current the in reflected is settings camera the Manipulating
rates) frame and Height, Width, of (combinations modes camera possible the all shows page
camera. this by supported are that

supported the check then screen *Stream Open* the on visible not is image camera the If **:□□□□**
the on click and Settings« »Vision to back go Then page. the of bottom the at modes video
the in listed are FPS and height, width, format, pixel the that verify and question in camera
modes. video supported

### reboots over persist to settings current the Getting

the in configuration camera the Editing startup. on settings camera the all load will rPi The
From Config Source ”Load the on click persist values the make To temporary. is screen above
Then fields. settings camera the on in filled be will settings current the and button Camera“
order in Writeable system file the set must you Note: page. the of bottom the at ”Save“ click
*page. the of top the at is button Writeable The* settings. the save to

(above). settings camera the in shown values settings camera used commonly some are There
the before camera the into loaded are Exposure and Balance, White Brightness, values These
overwrite will they settings those contains file JSON user a if So applied. is file JSON user
field. text the from ones the

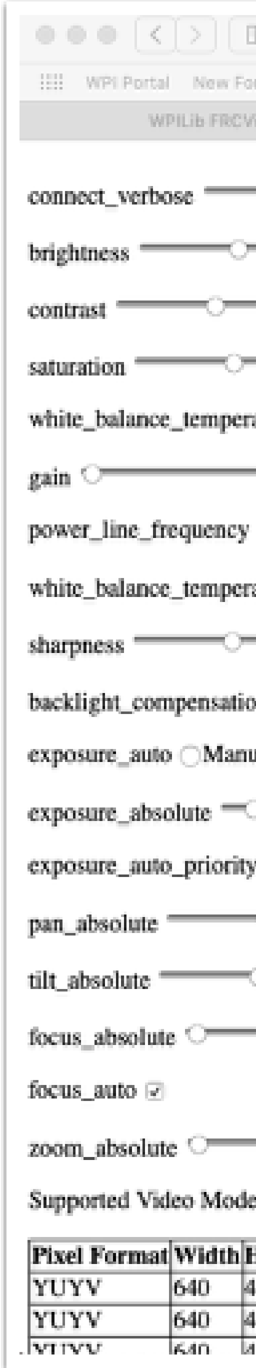
### Application

rPi. the on running currently is that application the shows tab Application The

### workflows Vision

C++, languages, supported the of each in OpenCV using program vision sample a is There
addition, In rPi. the from video stream and capture can program sample Each Python. or Java,
replace to extended be to up set all are They OpenCV. minimal some have samples the
rPi The application. robot the for needed code the with code sample OpenCV provided the
workflows: programming of number a supports tab Application

- computer station driver the on consumption for rPi the from cameras more or one Stream
ShuffleBoard using displayed and
- Python) or C++ Java, language: each for (one programs sample the of one build and Edit
toolchains included the using rPi the on
- your on it build and edit and language chosen the for program sample a Download
rPi the to back program built that upload Then computer. development



connect_verbose

brightness

contrast

saturation

white_balance_tempera

gain

power_line_frequency

white_balance_tempera

sharpness

backlight_compensatio

exposure_auto ○Manu

exposure_absolute

exposure_auto_priority

pan_absolute

tilt_absolute

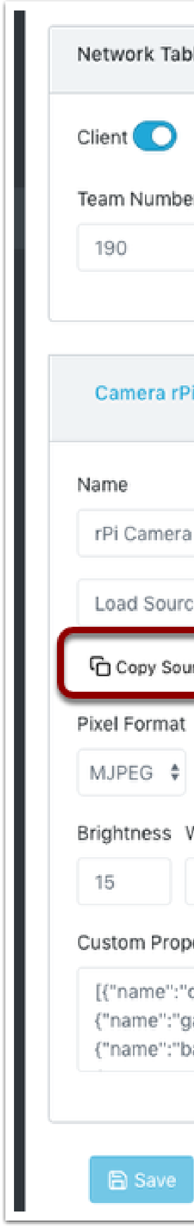
focus_absolute

focus_auto ☑

zoom_absolute

Supported Video Mode

| Pixel Format | Width | H |
|---|---|---|
| YUYV | 640 | 4 |
| YUYV | 640 | 4 |
| YUYV | 640 | 4 |


Network Tab

Client

Team Numbe
190

Camera rPi

Name
rPi Camera

Load Sourc

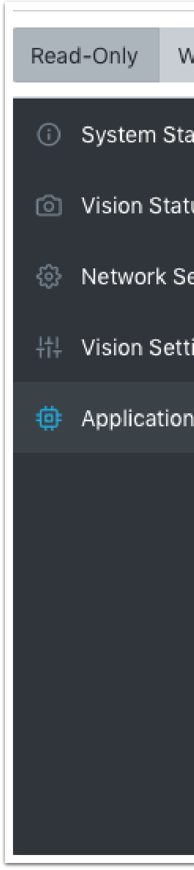
Copy Sou

Pixel Format
MJPEG

Brightness
15

Custom Prop
[{"name":"c
{"name":"g
{"name":"b

- based (probably scripts and applications custom completely using yourself everything Do samples) the of one on

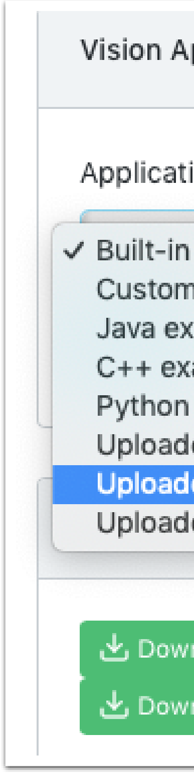


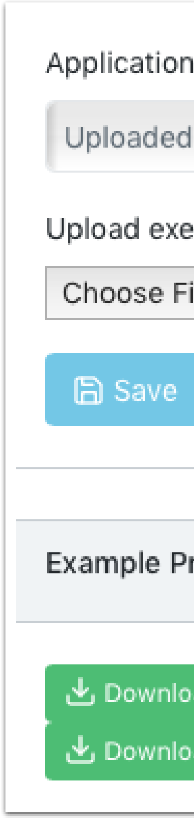
downdrop- the in choices the of one selecting by changed be can application running The are: choices The menu.

- the into plugged are cameras whatever streams which streaming camera multi inBuilt- ”Vision the on set be can cameras of number including configuration camera The rPi. tab. Settings“
- the that assumes and rPi the to anything upload doesn’t which application Custom script. and program custom a have to wants developer
- own your into edited be can that programs sample installedpre- Python or C++ Java, application.
- the with file `jar.` a require programs Java program. uploaded Python or C++, Java, the to uploaded be to executable rPi an require programs C++ and program compiled rPI.

executable jar, the where presented is chooser file a options, Upload the of one selecting When an picture following the In rPi. the to uploaded and selected be can program Python or the on clicking and file a select will button File“ ”Choose the and chosen is jar Java Uploaded file. selected the upload will button ”Save“

Note: using writeable set be to has system file the rPi, the onto file new a Save to order in file the set file, new the saving After page. web the of left top the at button ”Writable“ the system back to Only“”Read- so that it is protected against accidental changes.


Vision Ap
Applicati
✓ Built-in
Custom
Java ex
C++ ex
Python
Uploade
Uploade
Uploade
Dow
Dow


Application
Uploaded
Upload exe
Choose Fi
Save
Example Pr
Downlo
Downlo

## CameraServer Using 23.2.7

### CameraServer from Frames Grabbing

processing vision own your make to libraries necessary the all with comes image WPILibPi The system. CameraServer the use can you camera, the from frame current the get to order In library. *CameraServer Video: Process and Read* the CameraServer, about information For *.Class*

Python

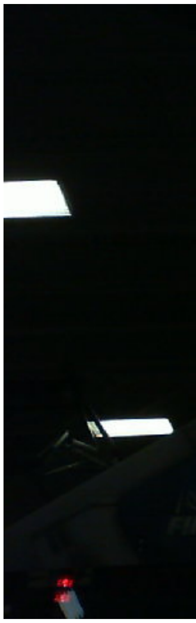
```
CameraServer import cscore from
cv2 import
np as numpy import

enableLogging().CameraServer

startAutomaticCapture().CameraServer = camera
height) setResolution(width,.camera

getVideo().cs = sink

:True while
grabFrame(input_img).cvSink = input_img time,

error an is There # :0 == time if
continue
```

---

**:□□□□** OpenCV reads in the image as **BGR**, not **RGB** for historical reasons. Use `cv2.cvtColor` if you want to change it to RGB.

---

CameraServer. from grabbed be might that image an of example an is Below



### CameraServer to frames Sending

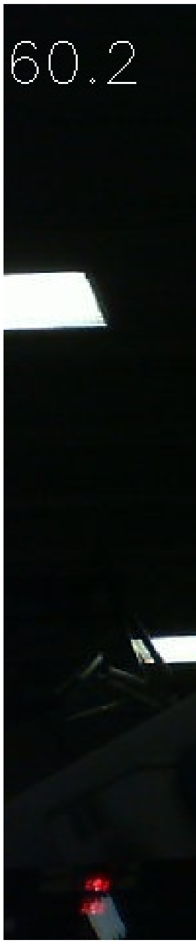
instance CameraServer the to back frames video processed send to want may you Sometimes, Shuffleboard. like application dashboard a in viewing or purposes, debugging for

Python

```
                                                      #
                  here code initialization CameraServer #
                                                      #

              height) width, ,"Name"putVideo(.cs = output

                                              :True while
         grabFrame(input_img).cvSink = input_img time,

                      error an is There # :0 == time if
                     getError()).notifyError(sink.output
                                                continue

                                                    #
                              here code processing Insert #
                                                    #

                            putFrame(processed_img).output
```

in corners the show and red, in target the outline could code processing the example, an As purposes. debugging for yellow

and CameraServer to back sent be would that image processed fully a of example an is Below computer. Station Driver the on displayed



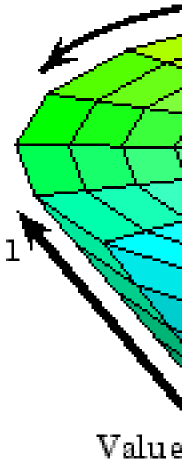
### Image an Thresholding 23.2.8

binary a into camera, your by captured one the as such image, colored a turn to order In
hue, the using image the threshold to need we ”foreground“, the as target the with image,
pixel. each of value and saturation,

#### Model HSV The

by also but pixels, the of colors the on based filter only not to you allows HSV RGB, Unlike
brightness. the and color of intensity the

- pixel. the of color the Measures Hue:
- pixel. the of color of intensity the Measures Saturation:
- pixel. the of brightness the Measures Value:



HSV. to matrix image BGR a convert to OpenCV use can You

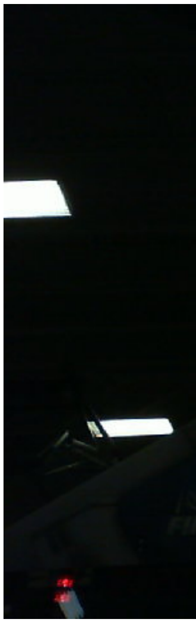
Python

```
COLOR_BGR2HSV).cv2 cvtColor(input_img,.cv2 = hsv_img
```

to order In 360°. to 1° common the of instead 180° to 1° from is range hue OpenCV's :□□□□ 2. by divide OpenCV, to value hue common a convert

## Thresholding

processing. image of process whole the for example an as image field this use will We



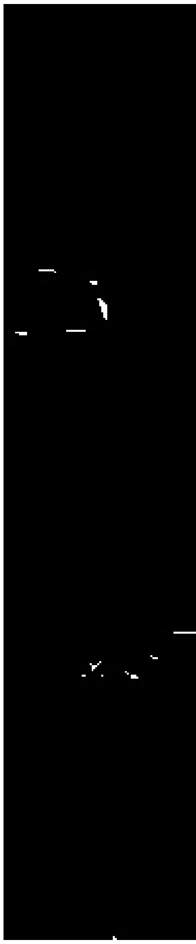
target vision the into image the separate can you HSV, using image the thresholding By code following The (background). sees camera the that things other the and (foreground), values. HSV with thresholding by image binary a into image HSV a converts example

Python

```
max_ max_sat, (max_hue, min_val), min_sat, (min_hue, inRange(hsv_img,.cv2 = binary_img
                                                                             val)) ↪
```

lighting ambient as basis, venueper- an on tuned be to have may values These **:□□□□** through values these of editing allow to recommended is It venues. across differ may editing. flythe-on- facilitate to order in NetworkTables

this. like look should image your thresholding, After



morphological use can You clean. 100% be not may process thresholding the see, can you As
noise. the with deal to operations

## Operations Morphological 23.2.9

image. binary your in noise unwanted have you image, your thresholding after Sometimes,
image. the from noise that remove help can operations Morphological

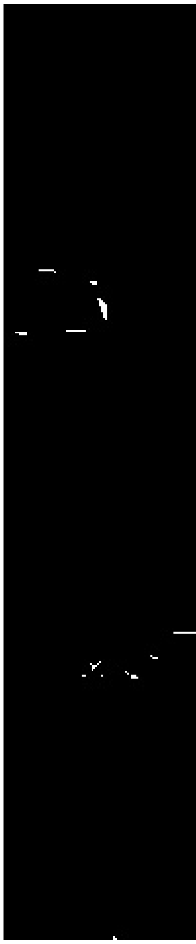
### Kernel

of 1 value of pixel each on superimposed is origin the where shape simple a is kernel The
The number. odd an is N where matrix NxN a to kernel the limits OpenCV image. binary the
is kernel common A center. the is kernel the of origin

$$kernel = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}$$

vertically. dilating or eroding only as such differently, image the affect can kernels Different

created: we image binary our is this reference, For



## Erosion

Erosion in computer vision is similar to erosion on soil. It takes away from the borders of foreground objects. This process can remove noise from the background.

Python

```
kernel = np.ones((3, 3), np.uint8)
binary_img = cv2.erode(binary_img, kernel, iterations = 1)
```

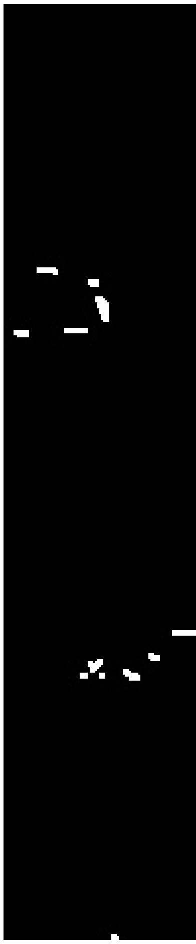
binary the by completely contained not are pixels kernel’s superimposed the if erosion, During deleted. is on superimposed was it that pixel the pixels, image’s

### Dilation

This them. to adds it borders, the from away taking of Instead erosion. of opposite is Dilation region. larger a inside holes small remove can process

Python

```
uint8).np ),3 ,3ones((.np = kernel
)1 = iterations kernel, dilate(binary_img,.cv2 = binary_img
```



dilation. the in included is kernel superimposed every of pixel every dilation, During

### Opening

the affecting without noise removes process This dilation. by followed erosion is Opening features. larger of shape

Python

```
uint8).np ),3 ,3ones((.np = kernel
kernel) MORPH_OPEN,.cv2 morphologyEx(binary_img,.cv2 = binary_img
```

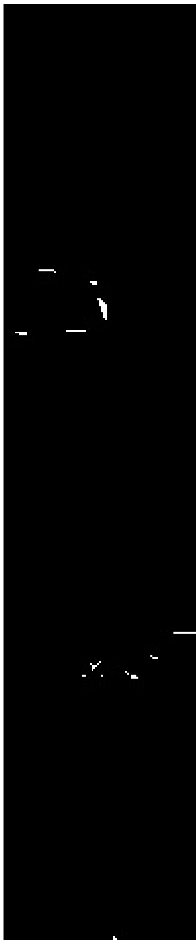
get to order in opening of iterations more do to appropriate is it case, specific this In :□□□□
right. top the in pixels the of rid

### Closing

without breaks or holes small removes process This erosion. by followed dilation is Closing
features. larger of shape the affecting

Python

```
                         uint8).np ),3 ,3ones((.np = kernel
kernel) MORPH_CLOSE,.cv2 morphologyEx(binary_img,.cv2 = binary_img
```



## Contours with Working 23.2.10

to ready now are you operations, morphological with noise removing and thresholding After on based contours generate to you allows method This method. `findContours` OpenCV’s use image. binary your

### Contours Filtering and Finding

Python

```
    CHAIN_APPROX_.cv2 RETR_EXTERNAL,.cv2 findContours(binary_img,.cv2 = _ contours, ,_
                                                                          SIMPLE) ↪
```

and contour largest the take just can you target, vision one only is there where cases In you target, vision one than more is there When for. looking are you target the is that assume out. contours unwanted filter to properties other and fullness, shape, size, use can

Python

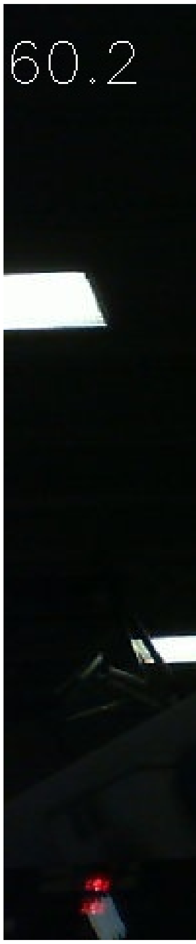
```
                                                :0 > (contours)len if
                                             ]0contours[ = largest
                                        contours: in contour for
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                        contourArea(largest):.cv2 > contourArea(contour).cv2 if
                                                         contour = largest

                                                                          #
                                                       code processing Contour #
                                                                          #
```

this: like something look should it found, just you contour the draw you If



## Contours from Information Extracting

about information get to want now you want, you that contour(s) the found you’ve that Now rotation. and corners, center, the as such it,

### Center

Python

```
minAreaRect(contour).cv2 = rect
rect = _ ,_ center,
center = center_y center_x,
```

### Corners

Python

```
convexHull(contour).cv2 = corners
)True arcLength(contour),.cv2 * 0.1 approxPolyDP(corners,.cv2 = corners
```

### Rotation

Python

```
fitEllipse(contour).cv2 = rotation ,_ ,_
```

*Measurements* see values, these use can you how on information more For

## NetworkTables to Publishing

RoboRIO. the and Station Driver the to properties these send to NetworkTables use can You itself. RoboRIO the or Pi, Raspberry the on done be could processing Additional

Python

```
NetworkTables import networktables from

)'vision'getTable(.NetworkTables = nt

#
here code Initialization #
#

:True while

    #
    here code processing Image #
    #

    center_x) ,'center_x'putNumber(.nt
    center_y) ,'center_y'putNumber(.nt
```

## 23.2.11 Basic Vision Example

This is an example of a basic vision setup that posts the target's location in the aiming coordinate system described *here* to NetworkTables, and uses CameraServer to display a bounding rectangle of the contour detected. This example will display the framerate of the processing code on the images sent to CameraServer.

Python

```
from cscore import CameraServer
from networktables import NetworkTables

import cv2
import json
import numpy as np
import time

def main():
   with open('/boot/frc.json') as f:
      config = json.load(f)
   camera = config['cameras'][0]

   width = camera['width']
   height = camera['height']

   CameraServer.startAutomaticCapture()

   input_stream = CameraServer.getVideo()
   output_stream = CameraServer.putVideo('Processed', width, height)

   # Table for vision output information
   vision_nt = NetworkTables.getTable('Vision')

   # Allocating new images is very expensive, always try to preallocate
   img = np.zeros(shape=(240, 320, 3), dtype=np.uint8)

   # Wait for NetworkTables to start
   time.sleep(0.5)

   while True:
      start_time = time.time()

      frame_time, input_img = input_stream.grabFrame(img)
      output_img = np.copy(input_img)

      # Notify output of error and skip iteration
      if frame_time == 0:
         output_stream.notifyError(input_stream.getError())
         continue

      # Convert to HSV and threshold image
      hsv_img = cv2.cvtColor(input_img, cv2.COLOR_BGR2HSV)
      binary_img = cv2.inRange(hsv_img, (65, 65, 200), (85, 255, 255))

      _, contour_list, _ = cv2.findContours(binary_img, mode=cv2.RETR_EXTERNAL,␣
↪method=cv2.CHAIN_APPROX_SIMPLE)

      x_list = []
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                                                                     [] = y_list

                                                    contour_list: in contour for

      thresholding noise/bad of because be could that contours small Ignore #
                                            :15 < contourArea(contour).cv2 if
                                                                  continue

␣thickness ),255 ,255 ,255( = color ,1- contour, drawContours(output_img,.cv2
                                                                               )1- = ↪

                                              minAreaRect(contour).cv2 = rect
                                                   rect = angle size, center,
 draw can we so int to Convert # center]) in dim for (dim)int([tuple = center

                                                  circle and rectangle Draw #
 ␣= color ,1- )],intastype(.boxPoints(rect).[cv2 drawContours(output_img,.cv2
                                                         )2 = thickness ),255 ,0 ,0( ↪
    ␣),255 ,0 ,0( = color ,3 = radius center, = center circle(output_img,.cv2
                                                                     )1- = thickness ↪

                         ))2 / (width / )2 / width - ]0append((center[.x_list
                         ))2 / (width / )2 / width - ]1append((center[.x_list

                                    x_list) ,'target_x'putNumberArray(.vision_nt
                                    y_list) ,'target_y'putNumberArray(.vision_nt

                                      start_time - time().time = processing_time
                                                       processing_time / 1 = fps
 ␣FONT_HERSHEY_SIMPLEX,.cv2 ),40 ,0( )),1 (fps,round(str putText(output_img,.cv2
                                                                 ))255 ,255 ,255( ,1 ↪
                                              putFrame(output_img).output_stream

                                                                                main()
```

## Introduction AprilTag 23.3

### AprilTags? Are What 23.3.1

Michigan of University the at researchers by developed tags visual of system a are AprilTags applications. different many for localization accuracy high overhead, low provide to

website their on found be can creators its and system tag the about information Additional purposes. related robotics FIRST for content the summarize to attempts document This

#### FRC to Application

the on at is it where know robot your helping for useful are AprilTags FRC, of context the In position. goal some to itself align can it so field,

to years the over refined been have and 2011, since development in been have AprilTags detection. of speed and robustness the increase

each field, the throughout scattered tags, of number a providing is FIRST 2023, in Starting .*pose* known a at

family. 16h5 the from are tags the of All

---

are which family, 36h11 the from are documentation this in pictures the of Many **:□□□□** are concepts underlying the All FRC. for use in actually 16h5 the to identical) not (but similar same. the

---

be should tags of sets how on standards defines implementation library AprilTag The .here described are families tag possible the of Some designed.

of grid 4x4 a of made is tags of family This 2023. for family 16h5 the chosen has FIRST must border white and black additional An information. of bit one representing each pixels, bits. the of outside the around present be

are These  used. actually are 30 only tags, possible theoretical $2^{16} = 65536$ are there While
to: chosen

1. identified). incorrectly color its has bit a where issues (IE, flips bit some against robust Be
2. tags. not are which things on found be to likely patterns geometric ”simple“ involve Not
etc.) stripes, squares, (IE,
3. which out figure always can you that enough asymmetric is pattern geometric the Ensure
up. is way

length. in inches 6 is ”body“ main tag’s the that such printed be will tags All

Mount area. practice your around placed and off printed be may files tag usage, home For algorithm processing the as flat, stays tag the ensure to material backing rigid a to them flat. are tags the assumes

## Software Support

The main repository for the source code that detects and decodes AprilTags is located here.

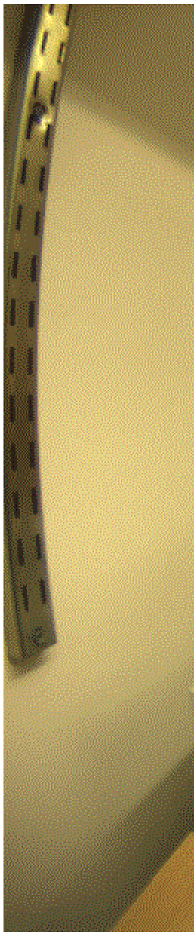
WPILib has forked the repository to add new features for FRC. These include:

1. Building the source code for common FRC targets, including the roboRIO and Raspberry Pi.
2. Adding Java Native Interface (JNI) support to allow invoking its functionality from Java
3. Gradle & Maven publishing support

## Processing Technique

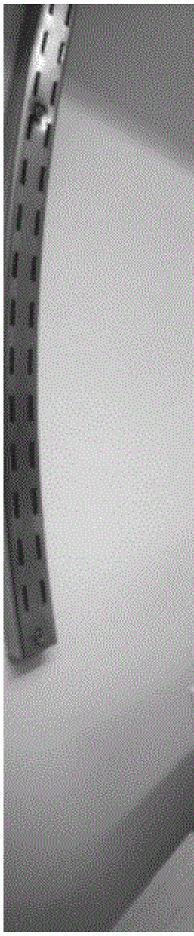
While most FRC teams should not have to implement their own code to identify AprilTags in a camera image, it is useful to know the basics of how the underlying libraries function.

Original Image



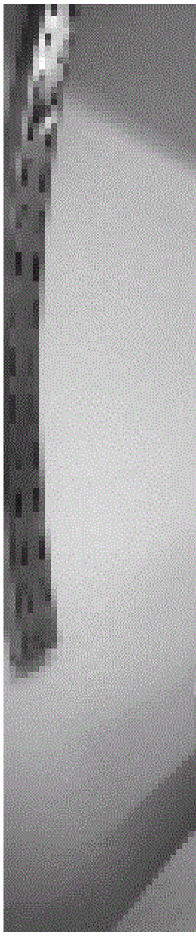
An image from a camera is simply an array of values, corresponding to the color and brightness of each pixel.

Remove Colors



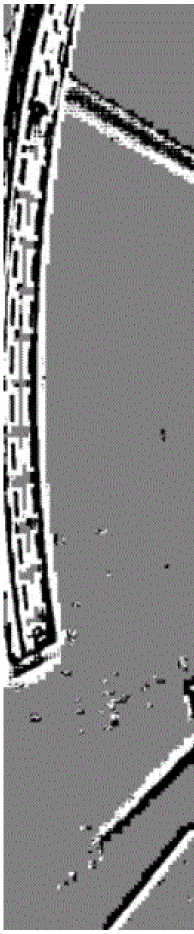
Color image. only)(brightness- scalegrey- a to image the convert to is step first The tags. whiteand-black- the detect to needed not is information

Decimate



pixels fewer with Working resolution. lower a to image the convert to is step next The early refine to later used be will image resolutionfull- The faster. work algorithm the helps estimates.

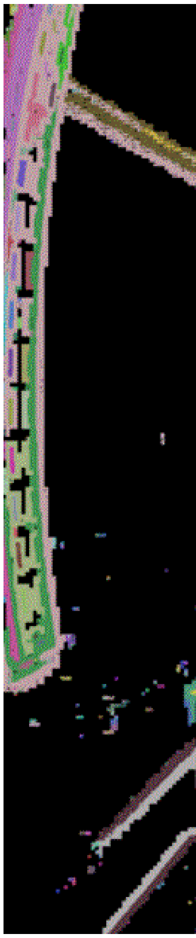
### Threshold Adaptive



”definitely light“, ”definitely as pixel each classify to run is algorithm threshold adaptive An
sure“. ”not or dark“,

small a to compared brightness, pixel’s the at looking by calculated is threshold The
it. around pixels of neighborhood

Segmentation



reasonably to small too are which clumps Any together. clumped are pixels known the Next,
discarded. are tag a of part meaningful a be

### Detection Quad

run: now is clump each to quadrilateral a fitting for algorithm An

- dimensions. both in outliers are which pixels by candidates ”corner“ likely Identify
- time each fit the evaluating corners, of combinations possible all through Iterate
- quadrilateral fitbest- the Pick

tag. a likely is which quadrilaterals of subset a Identify quadralaterals, all of set the Given

good a likely is quadrilateral interior many with quadrilateral exterior large single A candidate.

valid a likely is that pixels of region sidedfour- a with left are we far, so well gone has all If tag.

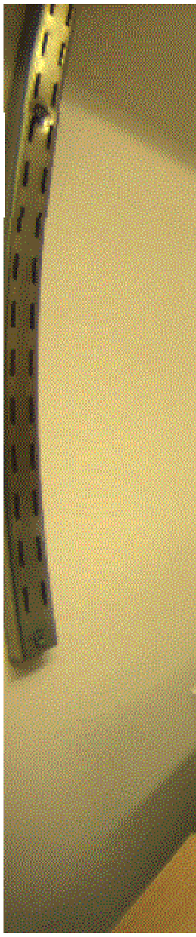
ID Decode

we AprilTag, valid a be to believe we which pixels of regions more or one have we that Now light of pattern the ”decoding“ by done is This at. looking are we tag which identify to need inside. the on squares dark and

- be should bit each of center the where coordinates pixel interior expected the Calculate
- threshold a to intensity pixel the comparing by ”0“ or ”1“ as location each Mark
- for allowing image, the in seen was what matches closely most which ID tag the Find errors. bit two or one

decoding the case, this In tag. suspect the matches which ID tag valid no is there possible is It stops. process

Quad External Fit



it. with useful something do to need we pixels, of region the for ID tag a have we that Now

the of corners the of location precise the knowing about care we applications, FRC most For the at did we operation loweringresolution- the expect we cases, both In center. its or tag, effects. those undo to want we and image, the distorted have to beginning

is: this do to algorithm The

- resolutionoriginal- the in interest of region a define to location tag detected the Use image
- the where detect to interest of region the in points definedpre- at *gradient* the Calculate white to black between transitions sharply most image
- full at quadrilateral exterior an fitre- rapidly to measurements gradient these Use resolution
- quadrilateral fitre- the of center exact the calculate to geometry Use

However, processing. image faster for skipped be can and optional, is step this that Note you how on depending behavior, robot's your into errors significant induce can it skipping outputs. tag the using are

## Usage

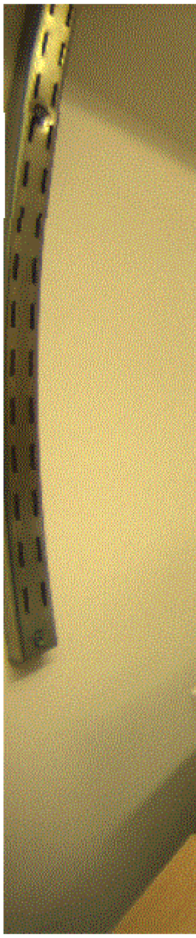
### Alignment 2D

centered is target the until robot the move to is targets using for strategy simple A gamepiece, the that such constructed are robot and field the Assuming image. the in a proved should method this aligned, all are camera and target, vision location, scoring position. scoring the to robot the align automatically to method straightforward

apply correct, is ID tag's the If view. in AprilTags the of *centroid* the identify camera, a Using camera the in centered is tag the until right or left robot the rotate to commands drivetrain image.

step. homography the performing or camera the calibrating require not does method This

### Alignment 3D



fieldon- perform help to locations corner their use to is AprilTags of usage advanced more A localization.

Using page. this on described algorithm the using AprilTags for searched is image Each pixels of array 2d the onto world 3d the distorts lense camera's the how about assumptions good A calculated. is tag the to relative position camera's the of estimate an camera, the in accurate. be to behavior lens its about assumptions the for required is calibration camera on tag the of position the ID, tag's each Given image. the from decoded. also is ID tag's The up. looked be can field the

the to relative camera the of position the and field, the on tag the of position the Knowing field. the on camera the of position the estimate to used be can classes geometry 3D the tag,

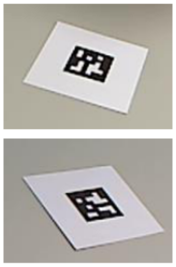
be also can field the on position robot's the known, is robot the on position camera's the If estimated.

classes. estimation pose WPILib the into incorporated be can estimates These

## Ambiguity 3D to 2D

dimensional)(two- image the in target the of corners known four the translating of process The ambiguous. inherently is dimensional)(three- camera the to relative position worldreal- a into ending corners target the in result that positions worldreal- multiple are there say, to is That image. camera the in spot same the in up

in oriented are objects how understand to clues background or lighting use often can Humans lookingsimilar- by tricked be can They benefit. this have not do computers However, space. targets:



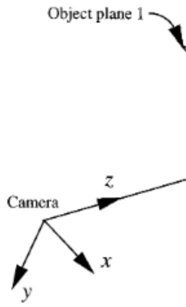


**FIG. 4.** Two object p
proximation.

ways: different few a in done be can ”correct“ is position which Resolving

1. expect you where to closest pose the pick to sensors all from history odometry your Use be. to robot the
2. air) the in up or perimeter, field the outside (ex: unlikely very are which poses Reject
3. differentiate) to hard (and together close very are which estimates pose Ignore
4. can camera one least at that such target, same the at look to cameras multiple Use estimate pose good a generate
5. Discard estimates. pose multiple generate to each using once, at targets many at Look together. clustered tightly are which ones the use estimates, outlying the

## Parameters Adjustable

processing. before sampleddown- is image the much how impacts `factor Decimation` which tags see to able being not of cost the at speed, detection increase will it Increasing away. far are

when speed increases which noise, decrease to image input the to smoothing applies `Blur` at left be may this cameras, good most For precision. of cost the at pixels, to quads fitting zero.

the process to uses algorithm the which threads parallel of number the changes `Threads` this want you general, In multithreading. allowing by up sped be may steps Certain image. of number the minus CPU, your in cores physical of number the to equal approximately be to tasks. processing other for used be will which cores

.here found be can parameters tunable the about information Detailed

### Learning Further

It’s papers. academic three in described are AprilTags of versions major three The previous: the upon builds each as order, in them read to recommended

- v1 AprilTags
- v2 AprilTags
- v3 AprilTags
- Ambiguity Pose

# GRIP עם תמונה עיבוד 23.4

## GRIP to Introduction 23.4.1

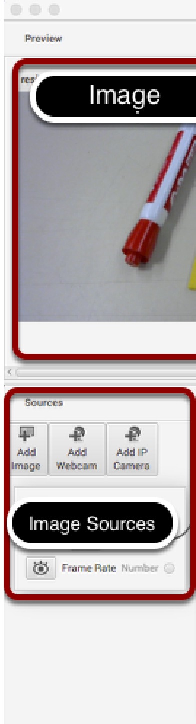
through than rather interactively algorithms vision computer developing for tool a is GRIP mode headless in GRIP run may you algorithm your developing After coding. error and trial robot your to connected coprocessor a on or Laptop, Station Driver a on roboRIO, your on represents that pipeline graphical a create to operations vision choose you Grip With network. algorithm. vision the complete to performed are that operations of sequence the

for used libraries software vision computer popular most the of one OpenCV, on based is GRIP available are that operations The implementations. algorithm vision and robotics, research, the coding hand were you if available operations the with match 1 to 1 a almost are GRIP in language. programming basedtext- some with algorithm same

### interface user GRIP The

parts: 4 of consists interface user GRIP The

- provide can You pipeline. GRIP the into images getting of ways the are **Sources Image** of beginning the always almost are Sources files. or cameras attached through images algorithm. processing image the
- that library OpenCV the from steps processing image the contains **Palette Operation** operation an on Clicking algorithm. your form to pipeline the in together chain can you arrows right and left the use then can You pipeline. the of end the to it adds palette the in pipeline. the within operation the move to
- in (operation) step Each algorithm. the up make that steps of sequence the is **Pipeline** to input an to step one of output the from step previous a to connected is pipeline the connections the through right to left from generally from flows data The step. next the create. you that
- button preview it’s has that step each of result the of previews shows are **Preview Image** of outputs the preview to able being by algorithms debug to easy it makes This pressed. step. intermediate each



### square yellow the Finding

position. it’s display and image the in square yellow the find to try will we application this In at down looking computer the to connected camera web USB a just simple, pretty is setup The locating in interested we’re that thing the is square plastic yellow The objects. colorful some image. the in

### source image the Enable

and button Webcam“ ”Add the on click source, the use To image. an acquire to is step first The Webcam as appeared that camera USB Logitech the case this In number. camera the select case this in selected is camera web The 1. Webcam was camera monitor computer the and 0 preview image the select Then setup. the in shown as computer the behind image the grab to area. preview the in shown be will stream camera the of display timereal- the and button

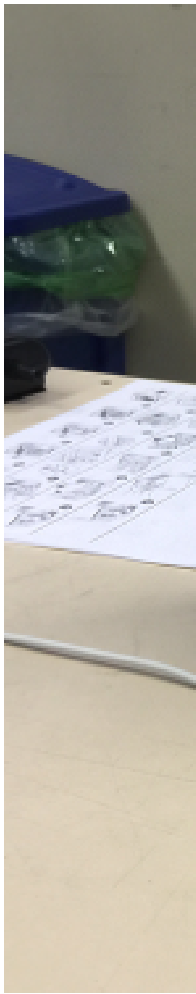
### image the Resize

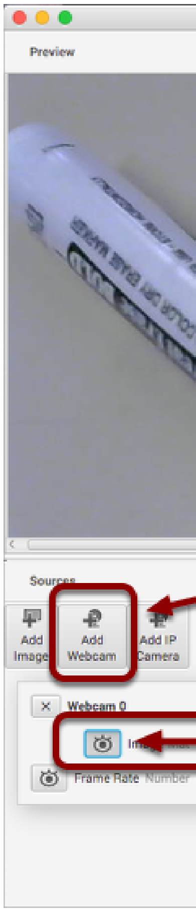
image entire the fact in and purposes, our for high too is resolution camera the case this In the from clicked is operation ”Resize“ The window. preview the in viewed be even cannot operation, Resize the locate help To pipeline. the of end the to it add to Palette Operation are: steps The palette. the of top the at box search the into ”Resize“ type

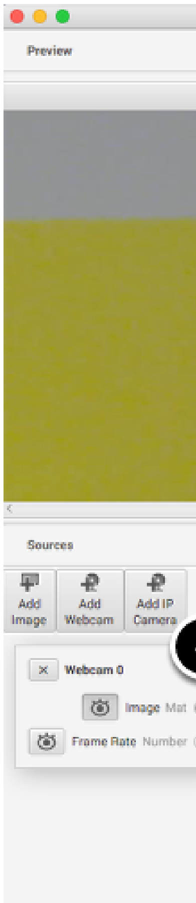
palette the on box search the into ”Resize“ Type 1.

pipeline. the in appear will It palette. the from operation Resize the Click 2.

case this In pipeline. the in operation resize the into factor scale resize y and x the Enter 3.
both. for chosen was 0.25




Preview
Sources
Add Image
Add Webcam
Add IP Camera
Webcam 0
Frame Rate Number

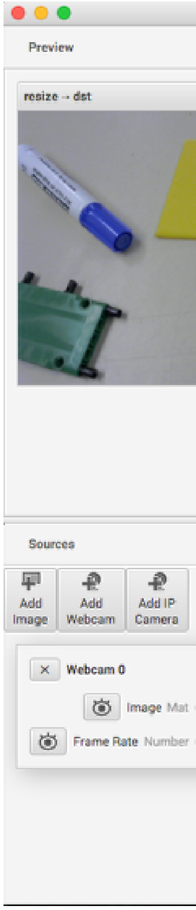

Preview
Sources
Add Image
Add Webcam
Add IP Camera
Webcam 0
Image Mat
Frame Rate Number

socket. mat source image Resize the to socket mat output image Webcam the from Drag 4. resize the to sent being is output camera the that indicating shown be will connection A input.

The pipeline. the in operation ”Resize“ the on button preview destination the on Click 5. to need might You image. original larger the alongside displayed be will image smaller shown. as both see to horizontally scroll

both at look to reason no is there since button preview source Webcam the click Lastly, 6. time. same the at image smaller the and image large the

### image the of parts yellow the only Find



of color yellow the match doesn’t that image the from everything remove to is step next The operation Threshold HSV a that do To detected. being object the is that plastic of piece the be should pixels which indicate to values HSV of limits lower and upper set to chosen is everything while white is area target the that Notice image. binary resultant the in included before: as Again, black. in shown are values threshold the within wasn’t that

operation. Threshold HSV the find to box search the into HSV Type 1.

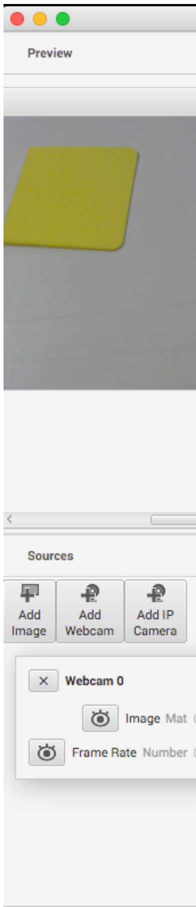
pipeline. the of end the at appear will it and palette the in operation the on Click 2.

Threshold. HSV the of input the to operation resize the on socket (output) dst the Connect 3.

is operation the of result the so operation Threshold HSV the of preview the Enable 4.
window. preview the in displayed

the in shown is object target the only parameters Value and Saturation, Hue, the Adjust 5.
window. preview

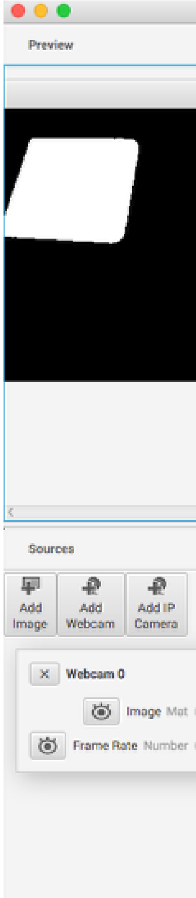
## hits extraneous and noise the of rid Get



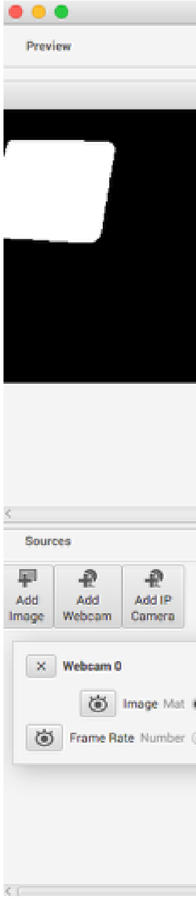
couldn’t that things other from noise is there sometimes but far, so good pretty looks This pixels occasional those reduce to technique possible one illustrate To out. filtered be quite of groups small remove will Erosion chosen. is operation Erosion an detected, were that interest. of area the of part not are that pixels

## image original the from area yellow the just Mask

it operation) (and masking and image original the taking by generated is image new a Here image original the in seen as card yellow the just leaves This erosion. the of results the with found being was what exactly visualize to easy it makes it And shown. else nothing with filters. of series the through


Preview
Sources
Add Image
Add Webcam
Add IP Camera
Webcam 0
Image Mat
Frame Rate Number

### (blob) area yellow the Find



looks operation This Detector. Blob a using card yellow the detecting actually is step last The
pixels blacknon- only the case, this In area. minimum some have that pixels of grouping a for
around drawn is circle a that see can You done. is filtering the after card yellow the from are
updates more for (watch GRIP of version release the In image. the of portion detected the
your to blob detected the about parameters send to able be will you kickoff) and now between
.*NetworkTables* using program robot

### GRIP of Status

object simple do to able be to fast and easy very is it example, this from see can you As
principles basic the illustrates it example, simple very a is this While GRIP. using recognition
will team project the weeks coming the Over general. in extraction feature and GRIP using of
(Axis cameras supports it Currently added. are features more as GRIP to updates posting be
yet output for provision no is There inputs. image and cameras) web and camera ethernet
planned. are System) Operating (Robot ROS and NetworkTables although

page GitHub the from code the of release builtpre- a download either can You
the clone can you or )https://github.com/WPIRoboticsProjects/GRIP( section ”Releases“
page. project the on are GRIP building on Directions yourself. it built and repository source
wiki. project the on documentation additional also is There

can you bugs, find you If forum. the on here feedback us give and GRiP with play please So,
page. project the on issue project GitHub a as or here them post either

## GRIP from Code Generating 23.4.2

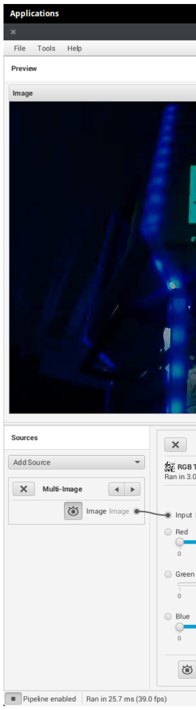
### Generation Code GRIP

Raspberry or roboRIO a as such processor small a on algorithm vision your running When
GRIP. of overhead the without processor the on directly OpenCV run to encouraged is it PI
you that pipeline the for Python and Java, C++, in code generate can GRIP this, facilitate To
directly called and project robot your to added be can code generated This created. have
code. robot existing your from

NetworkTables as such steps output and directories image or cameras as such sources Input
the roboRIO, the On mats. OpenCV as images supply must code Your generated. not are
use just can you results getting For format. that in images supplies class CameraServer
values. y and x contour as such values resultant the retrieving for methods getter generated

### Code Generating

lets that dialog save a up bring will This .`Code Generate > Tools` to go code, generate To
pipeline. GRIP the in steps the performs that class Python or Java, C++, a create you



the save to directory relevant a choose project, existingpre- a in used be to code generating If
to. pipeline

- file implementation and header a into split is class pipeline the :**Users C++**
- be should declaration a so declaration, package a lacks class generated the :**Users Java**
saved. was file the where directory the match to added

- statement import the so class, the to identical be will name module the :**Users Python**
  `Pipeline import Pipeline from` like something be will

### Code Generated the of Structure

```
                                                   Pipeline:
                          pipeline the run will this -- Process //
                                                source) process(Mat

                                                accessors Output //
                                                     getFooOutput()
                                                    getBar0Output()
                                                    getBar1Output()
                                                                ...
```

### Pipeline the Running

image camera, IP (webcams, sources the with method process the call Pipeline, the run To with pipeline the in operation every of outputs the expose will This arguments. as etc) file, methods. `getFooOutput` the

### Results the Getting

operations these of outputs The pipeline. the in step every of outputs the to able are Users example: For accessors. respective their through accessible be would

| Operation | getter Java/C++ | variable Python |
|---|---|---|
| Threshold RGB | `getRgbThresholdOutput` | `rgb_threshold_output` |
| Blur | `getBlurOutput` | `blur_output` |
| Erode CV | `getCvErodeOutput` | `mcv_erode_output` |
| Contours Find | `getFindContoursOutput` | `find_contours_output` |
| Contours Filter | `getFilterContoursOutput` | `filter_contours_output` |

have operations those for accessors the pipeline, the in times multiple appears operation an If operation: that of number the

| Operation | appearance Which | Accessor |
|---|---|---|
| Blur | First | `getBlur0Output` |
| Blur | Second | `getBlur1Output` |
| Blur | Third | `getBlur2Output` |

### Program Robot a in Code Generated Using 23.4.3

and roboRIO a on runs that program FRC® an to added be can that class a generates GRIP
output. the on based robot the drive code, additional of lot a without

robot a drives that pipeline GRIP a uses that program sample complete a is here Included
material. retroreflective of piece a towards

necessarily not does and works code vision the how illustrate to designed is program This
program own your writing When program. robot your writing for technique best the represent
considerations: following the of aware be

1. camera The .**problematic be could robot the steering for output camera the Using**
that rate slower much a at runs images processes and captures that example this in code
more slightly only and better, A robot. the steering for loop control a for desirable is
have then rate, processing it's and camera the from headings get to is solution, complex
sensor. gyro a using headings those to steering loop control faster much a

2. writing of way better A .**pipeline the wraps that class the in code vision the Keep**
process and class pipeline generated the instantiate or subclass to is code oriented object
robot the example, this In program. robot the in than rather there results OpenCV the
By contours. OpenCV resultant the manipulating by drive to direction the extracts code
to difficult it makes it program robot the throughout exposed code OpenCV the having
one. better a have you should algorithm vision the change

#### definitions program Iterative

Java

```
;org.usfirst.frc.team190.robot package

;org.usfirst.frc.team190.grip.MyVisionPipeline import

;org.opencv.core.Rect import
;org.opencv.imgproc.Imgproc import

;edu.wpi.cscore.UsbCamera import
;edu.wpi.first.cameraserver.CameraServer import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
;edu.wpi.first.wpilibj.PWMSparkMax import
;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.vision.VisionRunner import
;edu.wpi.first.vision.VisionThread import

{ TimedRobot extends Robot class public

;320 = IMG_WIDTH int final static private
;240 = IMG_HEIGHT int final static private

visionThread; VisionThread private
;0.0 = centerX double private
drive; DifferentialDrive private
left; PWMSparkMax private
right; PWMSparkMax private

Object(); new = imgLock Object final private
```

classes WPILib the for statements import the all see can you program the of part first this In program. this for used

- pixels. 320x240 as defined are **height and width image** The
- a in processing camera your do to easy it makes class WPILib a is **VisionThread** The program. robot the of rest the from thread separate
- target. detected the of value X center computed the be will value **centerX**
- simplified allows and robot this on motors drive the encapsulates **DifferentialDrive** driving.
- updated simultaneously being data the to access synchronize to variable a is **imgLock** and coordinates the processing that’s code the and pass acquisition image each with robot. the steering

Java

```
                                                                               @Override
                                                               { ()robotInit void public
                            ();startAutomaticCaptureCameraServer. = camera UsbCamera
                                        IMG_HEIGHT); (IMG_WIDTH,setResolutioncamera.

       { >- pipeline MyVisionPipeline(), new VisionThread(camera, new = visionThread
                               { ())isEmpty().filterContoursOutputpipeline.!( if
      ));0(get().filterContoursOutput(pipeline.boundingRectImgproc. = r Rect
                                                    { (imgLock) synchronized
                                          );2 / width(r. + xr. = centerX
                                                                           }
                                                                               }
                                                                                 );}
                                                               ();startvisionThread.

                                                          );0PWMSparkMax( new = left
                                                         );1PWMSparkMax( new = right
                                         right); DifferentialDrive(left, new = drive
                                                                                       }
```

creates It up. starts program the when once called is method **robotInit()** The resolution requested the at images capturing begins that instance **CameraServer** a IMG_HEIGHT). by (IMG_WIDTH

images capturing begins VisionThread created. is **VisionThread** class the of instance an Next the image, each processing After thread. separate a in asynchronously camera the from is value **X center** it’s and retrieved is target the around **box bounding** computed pipeline the in rectangle the of center the of value pixel x the be will value centerX This computed. image.

subclass a have we (here, instance **VisionPipeline** a takes also VisionThread The output the handle to use we that callback a as well as GRIP) by generated **MyVisionPipeline** an in areas of (outlines contours of list a outputs pipeline the example, this In pipeline. the of the of box bounding the finds callback The kind. some of targets or goals mark that image) Note centerX. variable the in value that saves then center, its find to order in contour first will thread robot main the sure makes this assignment: the around block synchronized the **synchronized** uses also it as long as variable, the of value dateto-up- most the have always variable. the read to blocks

Java

```
@Override
public void autonomousPeriodic() {
    double centerX;
    synchronized (imgLock) {
        centerX = this.centerX;
    }
    double turn = centerX - (IMG_WIDTH / 2);
    drive.arcadeDrive(-0.6, turn * 0.005);
}
```

This, the final part of the program, is called repeatedly during the **autonomous period** of the match. It gets the **centerX** pixel value of the target and **subtracts half the image width** to change it to a value that **is zero when the rectangle is centered** in the image and **positive** or **negative when the target center is on the left or right side of the frame.** That value is used to steer the robot towards the target.

Note the **synchronized** block at the beginning. This takes a snapshot of the most recent centerX value found by the VisionThread.

## 23.4.4 Using GRIP with a Kangaroo Computer

A recently available computer called the Kangaroo looks like a great platform for running GRIP on FRC® robots. Some of the specs for this processor include:

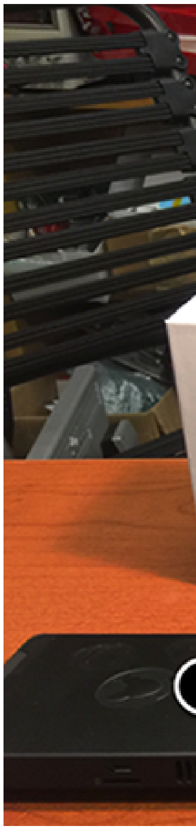
- Quad core 1.4Ghz Atom processor
- HDMI port
- 2 USB ports (1 USB2 and 1 USB3)
- 2GB RAM
- 32GB Flash
- Flash card slot
- WiFi
- Battery with 4 hours running time
- Power supply
- Windows 10
- and a fingerprint reader

The advantage of this setup is that it offloads the roboRIO from doing image processing and it is a normal Windows system so all of our software should work without modification. Be sure to read the caveats at the end of this page before jumping in.

**More detailed instructions** for using a Kangaroo for running GRIP can be found in the following PDF document created by Scott Taylor and FRC 1735. His explanation goes beyond what is shown here, detailing how to get the GRIP program to auto-start on boot and many other details.

Grip Plus Kangaroo

### Setup

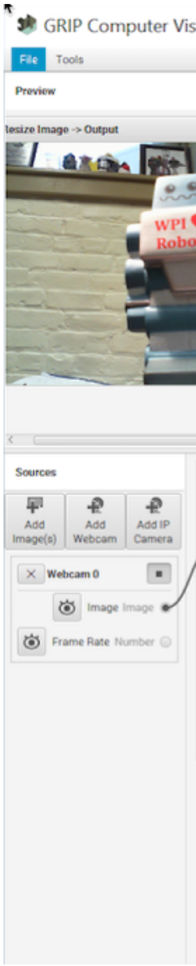


mouse keyboard, monitor, a in plug to need just you that is setup this about thing nice The the programming with go to good are you and camera web Microsoft the case) this (in and put and monitor and mouse keyboard, the disconnect finished, are you When pipeline. GRIP connect and Kangaroo the on WiFi the disable to need will You robot. your on Kangaroo the radio. robot the on port ethernet extra the to dongle ethernet USB a with robot the to it

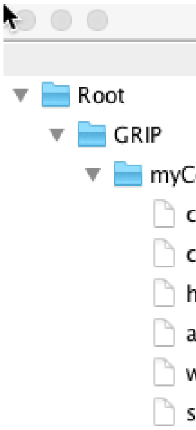
keyboard, (3), hub USB a to connected (1) computer Kangaroo the see can you example this In mouse. and camera the to connected is hub USB The programming. for monitor HDMI an and

### program GRIP Sample

little the on heart red the detecting Kangaroo the on running program sample the is Attached color red that get only to threshold HSV a doing is It panel). (left image the in robot foam end the At solidity. and size the using contours the filtering then and contours, finding then NetworkTables. to published being are values the pipeline, the of


GRIP Computer Vis
File
Tools
Preview
esize Image -> Output
WPI
Robo
Sources
Add Image(s)
Add Webcam
Add IP Camera
Webcam 0
Image Image
Frame Rate Number

### NetworkTables in Report Contours Viewing



(<username>/WPILib/tools/OutlineViewer.jar), OutlineViewer the from output the is This in network the on roboRIO no is there (since server a as computer different a on running program the that contour single the for back reported being values the and example) this operation. Contours Filter the of requirements the met that detected

### Considerations

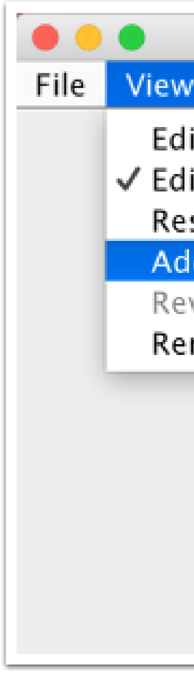
running keep will GRIP sure make to taken be to must care so 10, Windows runs Kangaroo The Windows a do to try not should it example, For testing. or match a during robot the on being of advantage the has it configured, Once etc. sleep, to go refresh, scan Virus Update, only running is it since performance predictable give should and Architecture Intel normal a application. one

# RoboRIO the on Vision 23.5

## roboRIO the on CameraServer the Using 23.5.1

### Program CameraServer Simple

LifeCam Microsoft the like camera USB a of capture automatic starts program following The send and frames capture will camera the mode, this In roboRIO. the to connected is that widget Viewer Stream CameraServer a create images, the view To dashboard. the to them just and unprocessed are images The dashboard. the in menu ”Add“ then ”View“, the using dashboard. the to camera the from forwarded



Java

```
                    ;edu.wpi.first.cameraserver.CameraServer import
                           ;edu.wpi.first.wpilibj.TimedRobot import

                                                                 **/
 ␣and webcam USB a from video capture automatically to class CameraServer the Uses *
                                                       the to it send ↩
␣get to way easiest the is This processing. vision any doing without dashboard FRC *
                                                       images camera ↩
        program. your in method robotInit() the to this add Just dashboard. the to *
                                                                 */
                            { TimedRobot extends Robot class public
                                                          @Override
                                         { ()robotInit void public
                         ();startAutomaticCaptureCameraServer.
                                                                 }
                                                                  }
```

C++

```
                         cameraserver/CameraServer.h>< include#
                                 frc/TimedRobot.h>< include#
                         { TimedRobot::frc public : Robot class
                                                         :public
                                 { override RobotInit() void
                 StartAutomaticCapture();::CameraServer::frc
                                                              }
                                                               ;}

                                     RUNNING_FRC_TESTS ifndef#
                                                { ()main int
                           ();>Robot<StartRobot::frc return
                                                               }
```

### Program Server Camera Advanced

instance. Server Camera the gets robotInit() in created thread a example following the In the on rectangle a drawing case this in processed, individually is video the of frame Each the to passed then are images resultant The method. `rectangle()` OpenCV the using image with operation `rectangle` the replace can You dashboard. the to sent and stream output the annotate even can You application. your for necessary is that code processing image any the to sent being image the onto information targeting write to methods OpenCV using image dashboard.

Java

```
;edu.wpi.first.cameraserver.CameraServer import
;edu.wpi.first.cscore.CvSink import
;edu.wpi.first.cscore.CvSource import
;edu.wpi.first.cscore.UsbCamera import
;edu.wpi.first.wpilibj.TimedRobot import
;org.opencv.core.Mat import
;org.opencv.core.Point import
;org.opencv.core.Scalar import
;org.opencv.imgproc.Imgproc import

**/
␣The processing. vision do to OpenCV of use the showing program demo a is This *
acquired is image ↪
␣the to sent and image the on put is rectangle a then camera, USB the from *
has OpenCV dashboard. ↪
processing. of types different for methods many *
*/
{ TimedRobot extends Robot class public
m_visionThread; Thread

@Override
{ ()robotInit void public
= m_visionThread
Thread( new
{ >- ()
CameraServer from UsbCamera the Get //
();startAutomaticCaptureCameraServer. = camera UsbCamera
resolution the Set //
);480 ,640(setResolutioncamera.

camera the from Mats capture will This CvSink. a Get //
();getVideoCameraServer. = cvSink CvSink
Dashboard the to back images send will This CvSource. a Setup //
);480 ,640 ,"Rectangle"(putVideoCameraServer. = outputStream CvSource

Mat. this reuse Lets expensive. memory very are Mats //
Mat(); new = mat Mat

This is. it if exit never will program The .'true' be cannot This //
or code robot restarting when thread this stop robot the lets //
deploying. //
{ ())interruptedThread.!( while
it put and camera the from frame a grab to CvSink the Tell //
output. the notify error an is there If  mat. source the in //
{ )0 == (mat)grabFrame(cvSink. if
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   error. the output the Send //
                          ());getError(cvSink.notifyErroroutputStream.
                                 iteration current the of rest the skip //
                                                              ;continue
                                                                        }
                                   image the on rectangle a Put //
                                                   (rectangleImgproc.
   ␣,255Scalar( new ),400 ,400Point( new ),100 ,100Point( new mat,
                                                                 );5 ),255 ,255 ↪
                         display to image new a stream output the Give //
                                               (mat);putFrameoutputStream.
                                                                         }
                                                                         );}
                                              );true(setDaemonm_visionThread.
                                                    ();startm_visionThread.
                                                                               }
                                                                                 }
```

C++

```
                                                           cstdio>< include#
                                                           thread>< include#

                                      cameraserver/CameraServer.h>< include#
                                                  frc/TimedRobot.h>< include#
                                            opencv2/core/core.hpp>< include#
                                           opencv2/core/types.hpp>< include#
                                      opencv2/imgproc/imgproc.hpp>< include#

                                                                         **/
    The processing. vision do to OpenCV of use the showing program demo a is This *
      image the on put is rectangle a then camera, USB the from acquired is image *
        of types different for methods many has OpenCV dashboard. the to sent and *
                                                               processing. *
                                                                          */
                                      { TimedRobot::frc public : Robot class
                                                                   :private
                                                { VisionThread() void static
                                       CameraServer from camera USB the Get //
                 StartAutomaticCapture();::CameraServer::frc = camera UsbCamera::cs
                                                      resolution the Set //
                                               );480 ,640camera.SetResolution(

                             Camera the from Mats capture will This CvSink. a Get //
                                     GetVideo();::CameraServer::frc = cvSink CvSink::cs
                      Dashboard the to back images send will This CvSource. a Setup //
                                                      = outputStream CvSource::cs
                             );480 ,640 ,"Rectangle"PutVideo(::CameraServer::frc

                             Mat. this reuse Lets expensive. memory very are Mats //
                                                                   mat; Mat::cv

                                                                 { )true( while
                            and camera the from frame a grab to CvSink the Tell //
                                                                     it put //
                            the notify error an is there If  mat. source the in //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                    output. //
                      { )0 == (cvSink.GrabFrame(mat) if
                            error. the output the Send //
             outputStream.NotifyError(cvSink.GetError());
               iteration current the of rest the skip //
                                               ;continue
                                                       }
                       image the on rectangle a Put //
),400 ,400Point(::cv ),100 ,100Point(::cv rectangle(mat,
             );5 ),255 ,255 ,255Scalar(::cv
    display to image new a stream output the Give //
                   outputStream.PutFrame(mat);
                                             }
                                               }

                           { override RobotInit() void
robot our not, If thread. separate a in program vision our run to need We //
                                  run. not will program //
               (VisionThread);visionThread thread::std
                                 visionThread.detach();
                                                     }
                                                      ;}

                                RUNNING_FRC_TESTS ifndef#
                                           { ()main int
               ();>Robot<StartRobot::frc return
                                                      }
                                                  endif#
```

stream. named a to video the writes method `PutVideo()` the examples, these in that Notice this In stream. named that select Shuffleboard, or SmartDashboard on stream that view To ”Rectangle“. is that case

## Cameras Multiple Using 23.5.2

### Views Driver the Switching

the SmartDashboard, using are and sees, driver the what switching just in interested you’re If that Path“) Camera (”Selected option an has Viewer Stream CameraServer SmartDashboard (displaying value that to Choice“ ”Camera the changes and key *NetworkTables* given the reads correct the to key *NetworkTables* the set to needs just then code robot The camera). that following the ”CameraSelection“, to set is Path“ Camera ”Selected Assuming name. camera camera2. and camera1 show to state button trigger 1 joystick the uses code

Java

```
                                  camera1; UsbCamera
                                  camera2; UsbCamera
                      );0Joystick( new = joy1 Joystick
                     cameraSelection; NetworkTableEntry

                                              @Override
                               { ()robotInit void public
        );0(startAutomaticCaptureCameraServer. = camera1
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   );1(startAutomaticCaptureCameraServer. = camera2

         (getEntry).""(getTable().getDefaultNetworkTableInstance. = cameraSelection
                                                                  );"CameraSelection" ↪
                                                                                      }

                                                                              @Override
                                                         { ()teleopPeriodic void public
                                                    { ())getTriggerPressed(joy1. if
                                        );"2 camera Setting"(println.outSystem.
                                  ());getName(camera2.setStringcameraSelection.
                                            { ())getTriggerReleased(joy1. if else }
                                        );"1 camera Setting"(println.outSystem.
                                  ());getName(camera1.setStringcameraSelection.
                                                                                  }
                                                                                      }
```

C++

```
                                                                 camera1; UsbCamera::cs
                                                                 camera2; UsbCamera::cs
                                                                 ;}0joy1{ Joystick::frc

                                                 cameraSelection; NetworkTableEntry::nt

                                                            { override ()RobotInit void
                               );0StartAutomaticCapture(::CameraServer::frc = camera1
                               );1StartAutomaticCapture(::CameraServer::frc = camera2

     GetEntry(>-)""GetDefault().GetTable(::NetworkTableInstance::nt = cameraSelection
                                                                  );"CameraSelection" ↪
                                                                                      }

                                                       { override ()TeleopPeriodic void
                                                      { (joy1.GetTriggerPressed()) if
                                      endl;::std << "2 Camera Setting" << cout::std
                                      cameraSelection.SetString(camera2.GetName());
                                              { (joy1.GetTriggerReleased()) if else }
                                      endl;::std << "1 Camera Setting" << cout::std
                                      cameraSelection.SetString(camera1.GetName());
                                                                                    }
                                                                                      }
```

server camera the by used camera the change can you dashboard, other some using you're If change will code robot the camera1, to nominally viewer stream a open you If dynamically. trigger. joystick the on based camera2 or camera1 either to contents stream the

Java

```
                                                                     camera1; UsbCamera
                                                                     camera2; UsbCamera
                                                                      server; VideoSink
                                                       );0Joystick( new = joy1 Joystick

                                                                              @Override
                                                              { ()robotInit void public
                                   );0(startAutomaticCaptureCameraServer. = camera1
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   );1(startAutomaticCaptureCameraServer. = camera2
                                                  ();getServerCameraServer. = server
                                                                                      }

                                                                              @Override
                                                         { ()teleopPeriodic void public
                                                    { ())getTriggerPressed(joy1. if
                                        );"2 camera Setting"(println.outSystem.
                                                     (camera2);setSourceserver.
                                            { ())getTriggerReleased(joy1. if else }
                                        );"1 camera Setting"(println.outSystem.
                                                     (camera1);setSourceserver.
                                                                                  }
                                                                                      }
```

C++

```
                                                                 camera1; UsbCamera::cs
                                                                 camera2; UsbCamera::cs
                                                                  server; VideoSink::cs
                                                                 ;}0joy1{ Joystick::frc
                                                              ;false = prevTrigger bool

                                                            { override ()RobotInit void
                               );0StartAutomaticCapture(::CameraServer::frc = camera1
                               );1StartAutomaticCapture(::CameraServer::frc = camera2
                                             GetServer();::CameraServer::frc = server
                                                                                      }

                                                       { override ()TeleopPeriodic void
                                             { prevTrigger)! && (joy1.GetTrigger() if
                                      endl;::std << "2 Camera Setting" << cout::std
                                                         server.SetSource(camera2);
                                      { prevTrigger) && joy1.GetTrigger()!( if else }
                                      endl;::std << "1 Camera Setting" << cout::std
                                                         server.SetSource(camera1);
                                                                                    }
                                                     joy1.GetTrigger(); = prevTrigger
                                                                                      }
```

## Open Streams Keeping

What use. in not cameras off turning in aggressive pretty is library cscore the default, By use, in not camera the from disconnect may it cameras, switch you when that is means this camera both keep To camera. the to reconnects it as delay some have will back switching so the keep to library the tell to method `SetConnectionStrategy()` the use open, connections them. using aren't you if even open, streams

Java

```
                                                                     camera1; UsbCamera
                                                                     camera2; UsbCamera
                                                                      server; VideoSink
                                                       );0Joystick( new = joy1 Joystick
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                              @Override
                                                              { ()robotInit void public
                                   );0(startAutomaticCaptureCameraServer. = camera1
                                   );1(startAutomaticCaptureCameraServer. = camera2
                                                 ();getServerCameraServer. = server

                       );kKeepOpen(ConnectionStrategy.setConnectionStrategycamera1.
                       );kKeepOpen(ConnectionStrategy.setConnectionStrategycamera2.
                                                                                      }

                                                                              @Override
                                                         { ()teleopPeriodic void public
                                                    { ())getTriggerPressed(joy1. if
                                        );"2 camera Setting"(println.outSystem.
                                                     (camera2);setSourceserver.
                                            { ())getTriggerReleased(joy1. if else }
                                        );"1 camera Setting"(println.outSystem.
                                                     (camera1);setSourceserver.
                                                                                  }
                                                                                      }
```

C++

```
                                                                 camera1; UsbCamera::cs
                                                                 camera2; UsbCamera::cs
                                                                  server; VideoSink::cs
                                                                 ;}0joy1{ Joystick::frc
                                                              ;false = prevTrigger bool
                                                            { override ()RobotInit void
                               );0StartAutomaticCapture(::CameraServer::frc = camera1
                               );1StartAutomaticCapture(::CameraServer::frc = camera2
                                             GetServer();::CameraServer::frc = server
                                                                             camera1.
     kConnectionKeepOpen);::ConnectionStrategy::VideoSource::SetConnectionStrategy(cs ↪
                                                                             camera2.
     kConnectionKeepOpen);::ConnectionStrategy::VideoSource::SetConnectionStrategy(cs ↪
                                                                                      }

                                                       { override ()TeleopPeriodic void
                                             { prevTrigger)! && (joy1.GetTrigger() if
                                      endl;::std << "2 Camera Setting" << cout::std
                                                         server.SetSource(camera2);
                                      { prevTrigger) && joy1.GetTrigger()!( if else }
                                      endl;::std << "1 Camera Setting" << cout::std
                                                         server.SetSource(camera1);
                                                                                    }
                                                     joy1.GetTrigger(); = prevTrigger
                                                                                      }
```

higher with limitations bandwidth USB into run may you USB, are cameras both If :□□□□ both from data streaming be to going is roboRIO the cases these of all in as resolutions, continuously and 2, and 1 options in period short a (for simultaneously roboRIO the to cameras option the in simultaneity this avoid to library the for possible theoretically is It 3). option in implemented. currently not is this but (only), case 2

hitting you're if you tell will library The differently. usage bandwidth report cameras Different message: error this get you’ll limit; the

```
                     limitations; bandwidth USB to due streaming start not could
                              format pixel different a or resolution lower a try
                                      device) on left space No (VIDIOC_STREAMON:
```

just should you Thus .`RobotInit()` during error this you give will it 3 Option using you’re If and error that get don’t both you until necessary as adjusting and resolution desired your try limitations. bandwidth radio the exceed don’t

---

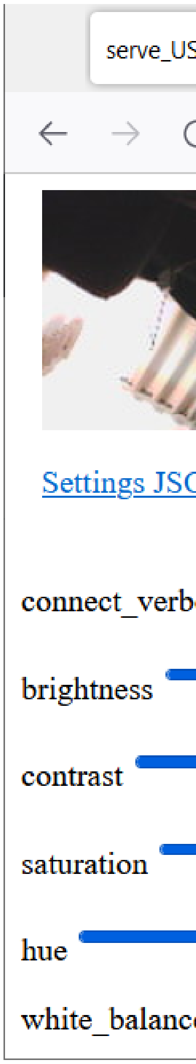
## Interface Web CameraServer 23.5.3

the view to use can you that webpage a creates it camera, a opens CameraServer When web the to connect To settings. camera various of effects the view and stream camera There .`frc.local:1181-TEAM-http://roboRIO` to navigate to browser web a use interface, .*Program CameraServer Simple* then other needed code additional no is

---

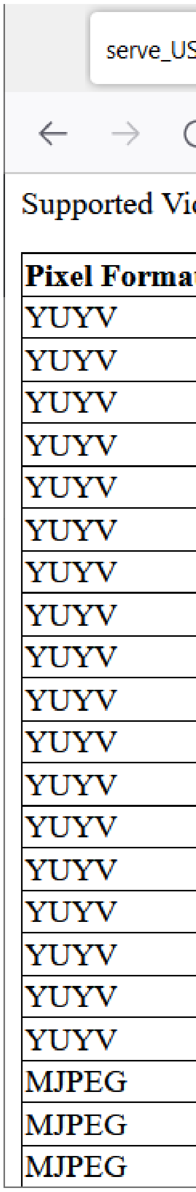
camera, additional for increments port The camera. first the for used is 1181 port The **:□□□□** so if you have two cameras, the replace 1181 above with 1182.

## Settings Camera



camera various adjust to sliders has and image camera live a show will server web The adjust can You  options. other many and sharpness contrast, brightness, as such settings, your in those set to class `VideoCamera` the use then and live, results the see and values the code. robot

## Modes Video Camera



Supported Vi

| Pixel Forma |
|---|
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| YUYV |
| MJPEG |
| MJPEG |
| MJPEG |

This page. web the of bottom the at modes video supported of list the is feature useful One that one the choose to you enable to supports camera the that modes supported the all shows requirements. your for rate frame and resolution of combination best the is

[redacted]

migrate should Users 2023. in available longer no is basedcommand- 2020)(pre- Old :□□□□ is basedcommand- old for Documentation below. framework basedcommand- new the to .here available

command- WPILib the for reference and to introduction an as serves articles of sequence This framework. based

*Command-* see framework, basedcommand- the using projects example of collection a For *.Examples Based*

## 24.1 מהו ״תכנות מבוסס פקודות?״

programming. based“”command- called methodology programming robot a supports WPILib the to and paradigm, programming general the both refer can based“”command- general, In it. facilitate to included resources library WPILib of set

not is It software. robot for *pattern design* possible one is programming based“”Command- robot basedCommand- one. effective very a is it but program, robot a write to way only the year. to year from usere- to easy tricks) some (with and extensible, clean, be to tends code

command- The *.programming declarative* of example an also is paradigm basedcommand- The of amount the minimizing while behaviors robot desired define to users allow library based basedcommand- the in example, For write. must they that logic robot iterationby-iteration- is condition a when action an perform should robot ”the that specify can user a program, ):*lambda* a of use the (note true“

Java

```
(DoubleSolenoid.setpiston. >- (()runOnce(Commands.onTrueTrigger(condition::get). new
                                                        )));kForward.Value ↪
```

C++

```
␣{ piston]&RunOnce([::cmd::condition.Get()).OnTrue(frc2 return { condition]&Trigger([
                                  kForward)));::DoubleSolenoid::piston.Set(frc ↪
```

state button the check to need would user the based,command- using without contrast, In button. the of state the on based action appropriate the perform and iteration, every

Java

```
                         { ())get(condition.if
                              { pressed)!(if
);kForward.Value(DoubleSolenoid.setpiston.
                           ;true = pressed
                                           }
                                      { else }
                            ;false = pressed
                                             }
```

C++

```
                         { (condition.Get())if
                              { pressed)!(if
kForward);::DoubleSolenoid::piston.Set(frc
                           ;true = pressed
                                           }
                                      { else }
                            ;false = pressed
                                             }
```

### Commands and Subsystems 24.1.1

### Run Are Commands How 24.1.2

---

.*Scheduler Command The* see explanation, detailed more a For :□□□□

---

triggers polls which singleton, )C++ ,Java( `CommandScheduler` the by run are Commands
executing and conflicts, resource preventing schedule, to commands for buttons) as (such
generally is it called; be must method `run()` scheduler's The commands. scheduled
at run is which class, `Robot` the of method `robotPeriodic()` the from it call to recommended
20ms). every (once 50Hz of frequency default a

resources same the require not do they as long as concurrently, run can commands Multiple
specify commands basis: subsystemper- a on handled is management Resource robot. the on
than more more no that ensure will scheduler the and with, interact they subsystems which
for that, ensures This time. a at scheduled is subsystem given a requiring command one
same the set to attempting code of pieces different two with up end not will users example,
values. output different to controller motor

### Compositions Command 24.1.3

by achievable is This pieces. simple from commands complex build to desirable often is It
types several provides library basedcommand- The commands. of *composition* a creating
command As own. their write may users and use, to teams for *compositions command* of
That .*composition recursive* a in used be may they themselves, commands are compositions
compositions. command multiple from compositions command a create can one - say to is
simple from actions robot complex building of way powerful extremely an provides This
components.

## Commands 24.2

they until scheduled, when run Commands take. can robot the actions represent **Commands**
command- the in represented are Commands met. is condition end their or interrupted are
).C++ ,Java( interface `Command` the by library based

### Command a of Structure The 24.2.1

by done is This states. possible its of each in do will command the what specify Commands
must command a Additionally, methods. `end()` and ,`execute()` ,`initialize()` the overriding
overriding by done is this - execution finished has it ever) (if when scheduler the tell to able be
code: user in clutter reduce to defaulted are methods these of All method. `isFinished()` the
`isFinished()` while nothing, do simply to defaulted are `end()` and ,`execute()` ,`initialize()`
run will and naturally, finishes never that command a in (resulting false return to defaulted is
interrupted). until

### Initialization

once exactly called is and start, command the marks )C++ ,Java( method `initialize()` The the place to used be should method `initialize()` The scheduled. is command a time per and reused be may objects Command execution. for state starting known a in command functionality command's the for needed resources or state any so times, multiple scheduled use) each of start the at called be will (which `initialize` in opened or initialized be should useful also is It allocation). object on once only invoked is (which constructor the than rather setting as such scheduled, time per once performed be to need only that tasks performing for actuator. solenoid a of state the setting or speed constant a at run to motors

### Execution

scheduled; is command the while repeatedly called is )C++ ,Java( method `execute()` The robot main the in done generally is (this called is method `run()` scheduler's the when is this for used be should block execute The default). by 20ms every runs which method, periodic updating as such scheduled, is command the while continually done be to needs that task any loop. control a of output the using or inputs, joystick match to outputs motor

### Ending

ends, command the when once called is )C++ ,Java( method `interrupted)` `end(bool` The (either interrupted was it or true) returned `isFinished()` (i.e. normally finishes it whether the specifies argument method The canceled). explicitly being by or command another by their of behavior the differentiate to this use can users ended; command the which in manner a in state command up" "wrap to used be should block end The accordingly. end command "default" a to actuator solenoid a reverting or zero to back motors setting as such way, neat .`end()` in closed be should `initialize()` in initialized resources or state Any state.

### conditions end Specifying

scheduled, is command the while repeatedly called is )C++ ,Java( method `isFinished()` The command's the true, returns it as soon As called. is method `run()` scheduler's the whenever `execute()` the after called is method `isFinished()` The ends. it and called is method `end()` ends. it that iteration same the on once execute will command the so method,

## Properties Command 24.2.2

three has also `Command` each above, described methods lifecycle four the to addition In side no with value same the return always should that methods getter by defined properties, affects.

### getRequirements

the backs This requirements. as controls it subsystems any declare should command Each
command one than more no that ensuring mechanism, management resource scheduler's
different two as such situations prevents This time. same the at subsystem given a requires
values. output different to controller motor same the set to attempting code of pieces

relevant the in method `getRequirements()` the overriding by done is requirements Declaring
/ (Java) vararg `requirements` the using by or ,`addRequirements()` calling by class, command
constructors command most of list parameter the of end the at parameter (C++) list initializer
library: the in factories and

Java

```
intake); (intake::activate,runCommands.
```

C++

```
intake});&{ ,} intake.Activate(); { intake]&Run([::cmd::frc2
```

require. components their subsystems all require compositions command rule, a As

### runsWhenDisabled

whether specifying `bool`/`boolean` a returns )C++ ,Java( method `runsWhenDisabled()` The
the ,`false` returning of default the With disabled. is robot the when run may command the
do will it schedule to attempts and disabled is robot the when canceled be will command
is robot the when scheduled be and run to command the allow will `true` Returning nothing.
disabled.

---

may controllers motor CAN and disabled are outputs PWM disabled, is robot the When :□□□□
!`runsWhenDisabled` of regardless voltage, apply not

---

relevant the in method `runsWhenDisabled()` the overriding by either set be can property This
):C++ ,Java( decorator `ignoringDisable` the using by or class, command

Java

```
updateTelemetry()). >- (()runCommands. = mayRunDuringDisabled CommandBase
                                                    );true(ignoringDisable ↪
```

C++

```
).} UpdateTelemetry(); { Run([]::cmd::frc2 = mayRunDuringDisabled CommandPtr::frc2
                                                    );trueIgnoringDisable( ↪
```

commands component their all if disabled when run may compositions command rule, a As
.`true` as `runsWhenDisabled` set

### getInterruptionBehavior

another if happens what defines )C++ ,Java( method `getInterruptionBehavior()` The the In running. is one this while scheduled is requirement a sharing command incoming the and canceled be will command current the ,`kCancelSelf` behavior, default incoming the returned, is `kCancelIncoming` If successfully. scheduled be will command that Note running. continue will command this and aborted be will scheduling command’s commands all conflicts: requirement of resolution affects only `getInterruptionBehavior` .`getInterruptionBehavior` of regardless canceled, be can

when passed parameter `interruptible` the by controlled previously was This :□□□□ object. command the of property a now is and command, a scheduling

the in method `getInterruptionBehavior` the overriding by either set be can property This ):C++ ,Java( decorator *withInterruptBehavior()* the using by or class, command relevant

Java

```
                    intake). (intake::activate,runCommands. = noninteruptible CommandBase
                      );kCancelIncoming.InterruptBehavior(Command.withInterruptBehavior ↪
```

C++

```
  ,} intake.Activate(); { intake]&Run([::cmd::frc2 = noninterruptible CommandPtr::frc2
     kCancelIncoming);::InterruptBehavior::intake}).WithInterruptBehavior(Command&{ ↪
```

are components their all if `kCancelIncoming` are compositions command rule, a As well. as `kCancelIncoming`

## Types Command Included 24.2.3

of use the Through types. command writtenpre- many includes library basedcommand- The to need rarely should teams and cases use all almost cover can commands these ,*lambdas* factory static via provided are commands these of Many classes. command custom write the in defined namespace `frc2::cmd` the in or (Java) class utility `Commands` the in functions methods instance have also `Subsystem` from inheriting Classes (C++). header `Commands.h` .this require implicitly that

### Actions Running

changing motor, a to voltage setting takes: robot the actions are commands basic most The or call method a of consist typically which commands, these For etc. direction, solenoid’s a with inline commands construct be to factories several offers library basedcommand- the two, executed. be to lambdas more or one

command a creates class, )C++ ,Java( `InstantCommand` the by backed factory, `runOnce` The finishes. then and once, lambda a calls that

Java

```
                                      */ hatch. the Grabs **/
                     { ()grabHatchCommand CommandBase public
                                `this` require implicitly //
(kForward));setm_hatchSolenoid. >- (()runOnce.this return
                                                           }

                                   */ hatch. the Releases **/
                 { ()releaseHatchCommand CommandBase public
                                `this` require implicitly //
(kReverse));setm_hatchSolenoid. >- (()runOnce.this return
                                                           }
```

(Header) C++

```
                                        **/
                          hatch. the Grabs *
                                         */
         ();GrabHatchCommand CommandPtr::frc2

                                        **/
                       hatch. the Releases *
                                         */
      ();ReleaseHatchCommand CommandPtr::frc2
```

(Source) C++

```
                 { ()HatchSubsystem::GrabHatchCommand CommandPtr::frc2
                                             `this` require implicitly //
                                                      RunOnce(>-this return
);} kForward);::DoubleSolenoid::m_hatchSolenoid.Set(frc { ]this[
                                                                    }

              { ()HatchSubsystem::ReleaseHatchCommand CommandPtr::frc2
                                             `this` require implicitly //
                                                      RunOnce(>-this return
);} kReverse);::DoubleSolenoid::m_hatchSolenoid.Set(frc { ]this[
                                                                    }
```

calls that command a creates class, )C++ ,Java( RunCommand the by backed factory, run The interrupted. until repeatedly, lambda a

Java

```
left the by controlled forward/backward with command, arcade split-stick A //
                          right. the by controlled turning and hand, //
                     (arcadeDrivem_robotDrive. >- RunCommand(() new
                                     (),getLeftYdriverController.-
                                    ()),getRightXdriverController.
                                                    m_robotDrive)
```

C++

```
left the by controlled forward/backward with command, arcade split-stick A //
                          right. the by controlled turning and hand, //
                                                     RunCommand(::frc2
                                                              { ]this[
                                               m_drive.ArcadeDrive(
```

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(□□□□ □□□□□ □□□□)

```
                    m_driverController.GetLeftY(),-
                   m_driverController.GetRightX());
                                                 ,}
                                       m_drive}))&{
```

lambda one calls class, )C++ ,Java( StartEndCommand the by backed factory, startEnd The interrupted. when lambda second a then and scheduled, when

Java

```
                                          (StartEndCommands.
                      power 50% at spinning flywheel a Start //
                         ),0.5(shooterSpeedm_shooter. >- ()
              command the of end the at flywheel the Stop //
                         ),0.0(shooterSpeedm_shooter. >- ()
                          subsystem shooter the Requires //
                                                m_shooter
                                                          )
```

C++

```
                                      StartEnd(::cmd::frc2
                      power 50% at spinning flywheel a Start //
                    ,} );0.5m_shooter.shooterSpeed( { ]this[
              command the of end the at flywheel the Stop //
                    ,} );0.0m_shooter.shooterSpeed( { ]this[
                          subsystem shooter the Requires //
                                                m_shooter}&{
                                                          )
```

command four the constitute that lambdas four accepts )C++ ,Java( FunctionalCommand initialize() of each for ><void()std::function/Runnable a methods: lifecycle a and ,end() for ><void(bool)std::function/BooleanConsumer a ,execute() and .isFinished() for ><bool()std::function/BooleanSupplier

Java

```
                                       FunctionalCommand( new
                              start command on encoders Reset //
                                  m_robotDrive::resetEncoders,
                command the of start the at forward driving Start //
                   ),0 (kAutoDriveSpeed,arcadeDrivem_robotDrive. >- ()
                            command the of end the at driving Stop //
                          ),0 ,0(arcadeDrivem_robotDrive. >- interrupted
 value desired the exceeds distance driven s'robot the when command the End //
   kAutoDriveDistanceInches, => ()getAverageEncoderDistancem_robotDrive. >- ()
                                      subsystem drive the Require //
                                                      m_robotDrive
                                                                  )
```

C++

```
                                     FunctionalCommand(::frc2
                               start command on encoders Reset //
                               ,} m_drive.ResetEncoders(); { ]this[
                 command the of start the at forward driving Start //
           ,} );0 kAutoDriveSpeed,::m_drive.ArcadeDrive(ac { ]this[
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                      command the of end the at driving Stop //
                    ,} );0 ,0m_drive.ArcadeDrive( { interrupted) bool( ]this[
      value desired the exceeds distance driven s'robot the when command the End //
 ,} kAutoDriveDistanceInches; => m_drive.GetAverageEncoderDistance() return { ]this[
                                                subsystem drive the Requires //
                                                                  m_drive}&{
                                                                           )
```

Commands. the offers library the immediately, ending and string a print To the by backed factory, `frc2::cmd::Print(std::string_view)/print(String)` .InstantCommand of subclass )C++ ,Java( `PrintCommand`

### Waiting

synchronize to useful be can delay a adding or happen to condition certain a for Waiting actions. robot other between or composition command a in commands different between

the offers library the elapses, time of period specified a after end and wait To by backed factory, `frc2::cmd::Wait(units::second_t)/Commands.waitSeconds(double)` class. )C++ ,Java( `WaitCommand` the

Java

```
scheduled being after seconds 5 Ends //
                   )5.0WaitCommand( new
```

C++

```
scheduled being after seconds 5 Ends //
                  s)_5.0WaitCommand(::frc2
```

Commands. the offers library the ,true becomes condition certain a until wait To factory, `>)<bool()frc2::cmd::WaitUntil(std::function/waitUntil(BooleanSupplier)` ).C++ ,Java( class `WaitUntilCommand` the by backed

Java

```
true returns m_limitSwitch.get() after Ends //
   WaitUntilCommand(m_limitSwitch::get) new
```

C++

```
             true returns m_limitSwitch.Get() after Ends //
)} m_limitSwitch.Get(); return { m_limitSwitch]&WaitUntilCommand([::frc2
```

### Commands Algorithm Control

setups: control various for commands are There

- .*PIDCommand* see info, more For controller. PID a uses `PIDCommand`
- see info, more For profile. motion trapezoid a tracks `TrapezoidProfileCommand` .*TrapezoidProfileCommand*
- more For profiles. motion trapezoid with control PID combines `ProfiledPIDCommand` .*ProfiledPIDCommand* see info,
- drivetrains. mecanum controlling for useful is )C++ ,Java( `MecanumControllerCommand` for project example )C++ ,Java( **MecanumControllerCommand** the and docs API See info. more
- See drivetrains. swerve controlling for useful is )C++ ,Java( `SwerveControllerCommand` more for project example )C++ ,Java( **SwerveControllerCommand** the and docs API info.
- drivetrains differential with following path for useful is )C++ ,Java( `RamseteCommand` info. more for *Tutorial Trajectory* the and docs API See drive“). (”tank

## Classes Command Custom 24.2.4

it’s verbose, more significantly is this As classes. command custom write also may Users above. mentioned factories concise more the use to recommended

---

the with work to methods Command certain allow to used is *CRTP* a API, C++ the In **:□□□□** defining when class `CommandHelper` the extend always should Users model. ownership object below. shown is as classes, command own their

---

as ),C++ ,Java( class `CommandBase` abstract the subclass class, command custom a write To ):C++ ,Java( template basedcommand- the in seen

Java

```
;edu.wpi.first.wpilibj.templates.commandbased.subsystems.ExampleSubsystem import
;edu.wpi.first.wpilibj2.command.CommandBase import

*/ subsystem. example an uses that command example An **/
{ CommandBase extends ExampleCommand class public
)}"PMD.SingularField" ,"PMD.UnusedPrivateField"({@SuppressWarnings
m_subsystem; ExampleSubsystem final private

**/
ExampleCommand. new a Creates *
*
command. this by used subsystem The subsystem @param *
*/
{ subsystem) (ExampleSubsystemExampleCommand public
subsystem; = m_subsystem
dependencies. subsystem declare to here addRequirements() Use //
addRequirements(subsystem);
}
```

C++

```
once pragma#

frc2/command/CommandBase.h>< include#
frc2/command/CommandHelper.h>< include#

subsystems/ExampleSubsystem.h"" include#

**/
subsystem. example an uses that command example An *
*
CommandBase extending rather CommandHelper, extends this that p>Note< *
in functions decorator the else or important, crucially is this directly; *
work! *not* will Command *
*/
ExampleCommand class
{ >ExampleCommand CommandBase,::frc2<CommandHelper::frc2 public :
:public
**/
ExampleCommand. new a Creates *
*
command. this by used subsystem The subsystem @param *
*/
subsystem); *ExampleCommand(ExampleSubsystem explicit

:private
m_subsystem; *ExampleSubsystem
;}
```

features. convenience several provides Command than rather CommandBase from Inheriting of list a returning users, for method getRequirements() the overrides automatically It addRequirements() the with to added be can but default, by empty is that requirements - dashboard the to sent be can so and interface, Sendable the implements also It method. dashboard) the on button a (via testing for commands scheduling for way handy a provides this controller. a on buttons to them bind to needing without

## Example Command Simple 24.2.5

command simple a is below before, As practice? in like look command functional a might What :HatchSubsystem the uses that )C++ ,Java( project example HatchBot the from

Java

```
;edu.wpi.first.wpilibj.examples.hatchbottraditional.commands package

;edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems.HatchSubsystem import
;edu.wpi.first.wpilibj2.command.CommandBase import

**/
␣Written HatchSubsystem}. @link{ the with hatch a grabs that command simple A *
for explicitly ↪
@link{ with simple this command a inline should code Actual purposes. pedagogical *
edu.wpi.first.wpilibj2.command.InstantCommand}. *
*/
{ CommandBase extends GrabHatch class public
on runs command the subsystem The //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
m_hatchSubsystem; HatchSubsystem final private

  { subsystem) (HatchSubsystemGrabHatch public
               subsystem; = m_hatchSubsystem
          addRequirements(m_hatchSubsystem);
                                             }

                                     @Override
                    { ()initialize void public
               ();grabHatchm_hatchSubsystem.
                                             }

                                     @Override
                 { ()isFinished boolean public
                                ;true return
                                             }
                                               }
```

(Header) C++

```
                                                                once pragma#

                                       frc2/command/CommandBase.h>< include#
                                     frc2/command/CommandHelper.h>< include#

                                      subsystems/HatchSubsystem.h"" include#

                                                                        **/
    Written  HatchSubsystem. the with hatch a grabs that command simple A *
command a inline should code Actual  purposes. pedagogical for explicitly *
                                         InstantCommand. with simple this *
                                                                          *
                                                      InstantCommand @see *
                                                                         */
{ >GrabHatch CommandBase,::frc2<CommandHelper::frc2 public : GrabHatch class
                                                                    :public
                            subsystem); *GrabHatch(HatchSubsystem explicit

                                               ;override ()Initialize void

                                               ;override ()IsFinished bool

                                                                   :private
                                                  m_hatch; *HatchSubsystem
                                                                          ;}
```

(Source) C++

```
                                             commands/GrabHatch.h"" include#

      { m_hatch(subsystem) : subsystem) *GrabHatch(HatchSubsystem::GrabHatch
                                               AddRequirements(subsystem);
                                                                           }

                                              { Initialize()::GrabHatch void
                                                     GrabHatch();>-m_hatch
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                          }

                                  { IsFinished()::GrabHatch bool
                                                   ;true return
                                                          }
```

through command the into passed is command the by used subsystem hatch the that Notice users allows and ,*injection dependency* called pattern a is This constructor. command's the best- a as accepted widely is This variables. global as subsystems their declaring avoid to .*section later* a in discussed is this behind reasoning the - practice

then and initialize, from once method subsystem the calls command above the that also Notice that commands for typical is This true). returns simply `isFinished()` (as ends immediately command this write to succinct more be would it such as and subsystems, of states the toggle above. described factories the using

example same the from command, drive a is Below case? complicated more a about What project:

Java

```
                 ;edu.wpi.first.wpilibj.examples.hatchbottraditional.commands package

  ;edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems.DriveSubsystem import
                                      ;edu.wpi.first.wpilibj2.command.CommandBase import
                                               ;java.util.function.DoubleSupplier import

                                                                                  **/
                     ␣@link{ as in (passed input joystick with robot the drive to command A *
                                                                  Written DoubleSupplier}s). ↪
          ␣this command a inline should code actual - purposes pedagogical for explicitly *
                                                                           @link{ with simple ↪
                                                    edu.wpi.first.wpilibj2.command.RunCommand}. *
                                                                                  */
                                                 { CommandBase extends DefaultDrive class public
                                                           m_drive; DriveSubsystem final private
                                                       m_forward; DoubleSupplier final private
                                                      m_rotation; DoubleSupplier final private

                                                                                **/
                                                             DefaultDrive. new a Creates *
                                                                                *
                                    on. run wil command this subsystem drive The subsystem @param *
                                  forwards/backwards driving for input control The forward @param *
                                                  turning for input control The rotation @param *
                                                                                */
                 ␣forward, DoubleSupplier subsystem, (DriveSubsystemDefaultDrive public
                                                               { rotation) DoubleSupplier ↪
                                                                   subsystem; = m_drive
                                                                   forward; = m_forward
                                                                 rotation; = m_rotation
                                                               addRequirements(m_drive);
                                                                                  }

                                                                         @Override
                                                                  { ()execute void public
                ());getAsDoublem_rotation. (),getAsDouble(m_forward.arcadeDrivem_drive.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
}
 }
```

(Header) C++

```
once pragma#

frc2/command/CommandBase.h>< include#
frc2/command/CommandHelper.h>< include#

subsystems/DriveSubsystem.h"" include#

**/
lambdas. through in passed input joystick with robot the drive to command A *
a inline should code actual - purposes pedagogical for explicitly Written *
RunCommand. with simple this command *
*
RunCommand @see *
*/
DefaultDrive class
{ >DefaultDrive CommandBase,::frc2<CommandHelper::frc2 public :
:public
**/
DefaultDrive. new a Creates *
*
on. run wil command this subsystem drive The subsystem @param *
forwards/backwards driving for input control The forward @param *
turning for input control The rotation @param *
*/
forward, >()double<function::std subsystem, *DefaultDrive(DriveSubsystem
rotation); >()double<function::std

;override ()Execute void

:private
m_drive; *DriveSubsystem
m_forward; >()double<function::std
m_rotation; >()double<function::std
;}
```

(Source) C++

```
commands/DefaultDrive.h"" include#

utility>< include#

subsystem, *DefaultDrive(DriveSubsystem::DefaultDrive
forward, >()double<function::std
rotation) >()double<function::std
m_drive{subsystem}, :
move(forward)},::m_forward{std
{ move(rotation)}::m_rotation{std
AddRequirements({subsystem});
}

{ Execute()::DefaultDrive void
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                      m_rotation()); ArcadeDrive(m_forward(),>-m_drive
                                                                                     }
```

usage: then And

Java

```
                                                      commands default Configure //
                               drive arcade split-stick to command drive default the Set //
                                                          (setDefaultCommandm_robotDrive.
  left the by controlled forward/backward with command, arcade split-stick A //
                                          right. the by controlled turning and hand, //
                                                                     DefaultDrive( new
                                                                     m_robotDrive,
                                           (),getLeftYm_driverController.- >- ()
                                         ()));getRightXm_driverController.- >- ()
```

C++

```
                                                        command drive default up Set //
                                                 m_drive.SetDefaultCommand(DefaultDrive(
                        ,} m_driverController.GetLeftY();- return { ]this[ m_drive,&
                               ));} m_driverController.GetRightX();- return { ]this[
```

is this end; never will thus and ,`isFinished()` override not does command this that Notice this more, Once commands. default as used be to intended are that commands for norm the such, as and place, one from only method subsystem the calls and simple rather is command factories: using written concisely more be could

Java

```
                                                      commands default Configure //
                               drive arcade split-stick to command drive default the Set //
                                                          (setDefaultCommandm_robotDrive.
  left the by controlled forward/backward with command, arcade split-stick A //
                                          right. the by controlled turning and hand, //
                                                                     (runCommands.
                                                                        >- ()
                                                     (arcadeDrivem_robotDrive.
  ()),getRightXm_driverController.- (),getLeftYm_driverController.-
                                                                  m_robotDrive));
```

C++

```
                                                        command drive default up Set //
                                               Run(::cmd::m_drive.SetDefaultCommand(frc2
                                                                             { ]this[
                                m_driverController.GetLeftY(),-m_drive.ArcadeDrive(
                              m_driverController.GetRightX());-
                                                                                  ,}
                                                                       m_drive}));&{
```

## Compositions Command 24.3

the but tasks, robot of variety large a accomplishing of capable are commands Individual functionality advanced more when cumbersome become quickly can format statethree- simple is subsystems robot multiple of coordination or tasks robot of sequences extended requiring command powerful the use to encouraged are users this, accomplish to order In required. library. basedcommand- the in included functionality composition

commands. more or one of *composition* a is composition command a suggests, name the As commands component individual the as simpler, and cleaner much kept be to code allows This amount the reducing greatly them, combines that code the of independently written be may process. the of step given any at complexity of

they - commands themselves are compositions command however, importantly, Most composed further be to compositions command allows This interface. `Command` the implement command other contain may composition command a is, that - *composition recursive* a as expressions: inline concise and powerful very allows This components. as compositions

Java

```
bazCommand and barCommand between race a then and fooCommand, run Will //
(bazCommand)));raceWith(barCommand.andThen(fooCommand.onTruebutton.
```

C++

```
bazCommand and barCommand between race a then and fooCommand, run Will //
move(barCommand).::move(fooCommand).AndThen(std::button.OnTrue(std
move(bazCommand))));::RaceWith(std ↪
```

require, components their subsystems all require compositions command rule, a As are and ,`true` as `runsWhenDisabled` set component their all if disabled when run may well. as `kCancelIncoming` are components their all if `kCancelIncoming`

be cannot composition command a to passed been have that instances Command so do to Attempting composition. command second a to passed or scheduled independently will throw an exception and crash the user program. This is because composition members are run through their encapsulating command composition, and errors could occur if those same command instances were independently scheduled at the same time as the group - the command would be being run from multiple places at once, and thus could end up with inconsistent internal state, causing unexpected and hard-to-diagnose behavior. The C++ command-based library uses `CommandPtr`, a class with move-only semantics, so this type of mistake is easier to avoid.

### Types Composition 24.3.1

be can them of All types. composition various includes library basedcommand- The be also can some and commands, member the accept that factories using constructed is which object, command a on called be can that methods decorators: using constructed returned. is that object new a into transformed

cannot object command the composition, a to passed being or decorator a calling After :□□□□ decorator. the from returned object command the only Use reused! be

### Repeating

)C++ ,Java( class `RepeatCommand` the by backed ),C++ ,Java( decorator `repeatedly()` The interrupted. until runs it that so ends, it time each command the restarts

Java

```
command. time every restarting interrupted, externally unless forever run Will //
                                                     true returns isFinished() ↪
                                               ();repeatedlycommand. = repeats Command
```

C++

```
command. time every restarting interrupted, externally unless forever run Will //
                                                     true returns IsFinished() ↪
                          move(command).Repeatedly();::std = repeats CommandPtr::frc2
```

### Sequence

),C++ ,Java( class `SequentialCommandGroup` the by backed ),C++ ,Java( factory `Sequence` The second, the then executed, be will command first the sequence: in commands of list a runs last the after finishes group sequential The finishes. list the until on so and third, the then each that ensure to important usually therefore is It finishes. sequence the in command next the finish, not does command given a (if finish actually does sequence the in command start!). never will command

to used be can decorators )C++ ,Java( `beforeStarting()` and )C++ ,Java( `andThen()` The syntax. infix with composition sequence a construct

Java

```
(barCommand)andThenfooCommand.
```

C++

```
move(barCommand))::move(fooCommand).AndThen(std::std
```

### Sequence Repeating

a creates )C++ ,Java( factory `RepeatingSequence` the combination, common fairly a it's As time each command first the from restarting interrupted, until runs that *Sequence Repeating* finishes. command last the

### Parallel

composition the when on based differing compositions, parallel of types three are There finishes:

- ,Java( class `ParallelCommandGroup` the by backed ),C++ ,Java( factory `Parallel` The The finish. members all when finishes that composition parallel a constructs ),C++ notation. infix in same the does )C++ ,Java( decorator `alongWith`

- ),C++ ,Java( class ParallelRaceGroup the by backed ),C++ ,Java( factory Race The other all finishes; member any as soon as finishes that composition parallel a constructs the does )C++ ,Java( decorator raceWith The point. that at interrupted are members notation. infix in same
- a when finishes )C++ ,Java( ParallelDeadlineGroup ),C++ ,Java( factory Deadline The are point that at running still members other all ends; ”deadline“) (the command specific notation; infix in same the does )C++ ,Java( decorator deadlineWith The interrupted. deadline. the is on called was decorator the comand the

Java

```
     ␣three all with seconds three after ends that group command parallel a be Will //
                                            duration. full their running commands ↪
     threeSecCommand)); oneSecCommand, (twoSecCommand,parallel(Commands.onTruebutton.

    ␣three and two the with second one after ends that group race parallel a be Will //
                                             interrupted. getting commands second ↪
         threeSecCommand)); oneSecCommand, (twoSecCommand,race(Commands.onTruebutton.

  ␣with deadline) (the seconds two after ends that group deadline parallel a be Will //
 finished). already command second (one interrupted getting command second three the ↪
     threeSecCommand)); oneSecCommand, (twoSecCommand,deadline(Commands.onTruebutton.
```

C++

```
     ␣three all with seconds three after ends that group command parallel a be Will //
                                            duration. full their running commands ↪
␣move(oneSecCommand),::std move(twoSecCommand),::Parallel(std::cmd::button.OnTrue(frc2
                                                       move(threeSecCommand)));::std ↪

    ␣three and two the with second one after ends that group race parallel a be Will //
                                             interrupted. getting commands second ↪
    ␣move(oneSecCommand),::std move(twoSecCommand),::Race(std::cmd::button.OnTrue(frc2
                                                       move(threeSecCommand)));::std ↪

  ␣with deadline) (the seconds two after ends that group deadline parallel a be Will //
 finished). already command second (one interrupted getting command second three the ↪
␣move(oneSecCommand),::std move(twoSecCommand),::Deadline(std::cmd::button.OnTrue(frc2
                                                       move(threeSecCommand)));::std ↪
```

### Conditions End Command Adding

condition. end additional an with command the composes decorator )C++ ,Java( until() The an as condition end this see will on called was decorator the command the that Note interruption.

Java

```
                                 true returns m_limitSwitch.get() if interrupted be Will //
                                           (m_limitSwitch::get));until(command.onTruebutton.
```

C++

```
                                 true returns m_limitSwitch.get() if interrupted be Will //
    ));} m_limitSwitch.Get(); return { m_limitSwitch]&button.OnTrue(command.Until([
```

as timeout a uses that `until` of specialization a is )C++ ,Java( decorator `withTimeout()` The condition. end additional the

Java

```
interrupted be and scheduled, being after seconds 5 out time Will //
));5(withTimeout(command.onTruebutton.
```

C++

```
interrupted be and scheduled, being after seconds 5 out time Will //
s));_5.0button.OnTrue(command.WithTimeout(
```

### Behavior End Adding

will that lambda a an with command the composes decorator )C++ ,Java( `finallyDo()` The indicating parameter boolean same the with method, `end()` command's the after called be interrupted. was or finished command the whether

lambda a an with command the composes decorator )C++ ,Java( `handleInterrupt()` The interrupted. is command the when only called be will that

### Compositions Selecting

or feedback sensor on based options few a of out command a run to desired it's Sometimes or routine, auto an determining for useful be can This runtime. at only known data other on. so and not, or present is piece game a whether on based command different a running

executes ),C++ ,Java( class `SelectCommand` the by backed ),C++ ,Java( factory `Select` The scheduled. when called function selector a on based map, a from command one

Java

```
                                              { RobotContainer class public
                     run. to command the selecting for keys as used enum The //
                                            { CommandSelector enum private
                                                                  ONE,
                                                                  TWO,
                                                                 THREE
                                                                      }

     ␣that selector the Returns  selectcommand. the for method selector example An //
                                                              select will ↪
  ␣at evaluated conditions logical on choice this base Can  run. to command which //
                                                                 runtime. ↪
                                       { ()select CommandSelector private
                                           ;ONECommandSelector. return
                                                                      }

      ␣the on based commands three the from select Will  selectcommand. example An //
                                                           returned value ↪
  ␣Object(), on works selectcommand that Note  runtime. at method selector the by //
                                                                   the so ↪
      ␣(string, type desired any be could it enum; an be to have not does selector //
                                                                 integer, ↪
```

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```
                                          double...) boolean, //
                    = m_exampleSelectCommand Command final private
                                              SelectCommand( new
                               commands to values selector Maps //
                                                    (ofEntriesMap.
     ␣was one Command"PrintCommand( new ,ONE(CommandSelector.entryMap.
                                                   )),"selected! ↪
     ␣was two Command"PrintCommand( new ,TWO(CommandSelector.entryMap.
                                                   )),"selected! ↪
   ␣was three Command"PrintCommand( new ,THREE(CommandSelector.entryMap.
                                                  ))),"selected! ↪
                                                    ::select);this
```

(Header) C++

```
                  run. to command the selecting for keys as used enum The //
                                 ;} THREE TWO, ONE, { CommandSelector enum

        selector the Returns  selectcommand. the for method selector example An //
        logical on choice this base Can  run. to command which select will that //
                                         runtime. at evaluated conditions //
                                  } ONE; return { ()Select CommandSelector

                  here... defined are commands and subsystems s'robot The //

      the on based commands three the from select Will  selectcommand. example An //
       selectcommand that Note  runtime. at method selector the by returned value //
      could it enum; an be to have not does selector the so type, generic a takes //
                        double...) boolean, integer, (string, type desired any be //
     (>CommandSelector<Select::cmd::frc2 = m_exampleSelectCommand CommandPtr::frc2
                                                   ,} Select(); return { ]this[
                                                commands to values selector Maps //
               )},"selected! was one Command"Print(::cmd::frc2 pair{ONE,::std
               )},"selected! was two Command"Print(::cmd::frc2 pair{TWO,::std
           )});"selected! was three Command"Print(::cmd::frc2 pair{THREE,::std
```

a is ),C++ ,Java( class `ConditionalCommand` the by backed ),C++ ,Java( factory `Either` The function. selector boolean a and commands two accepting specialization

Java

```
       m_ of value the on depending commandOnFalse or commandOnTrue either Runs //
                                                         limitSwitch.get() ↪
          m_limitSwitch::get) commandOnFalse, ConditionalCommand(commandOnTrue, new
```

C++

```
       m_ of value the on depending commandOnFalse or commandOnTrue either Runs //
                                                         limitSwitch.get() ↪
  m_ return { m_limitSwitch]&[ commandOnFalse, ConditionalCommand(commandOnTrue,::frc2
                                                    )} limitSwitch.Get(); ↪
```

prevent will that condition a with command a composes )C++ ,Java( decorator `unless()` The running. from it

Java

```
␣while deployed gets intake the If deployed. is intake the if run only will Command //
                   running stop not will command the running, is command the ↪
                    ()));isDeployedintake.! >- (()unless(command.onTruebutton.
```

C++

```
␣while deployed gets intake the If deployed. is intake the if run only will Command //
                   running stop not will command the running, is command the ↪
           ));} intake.IsDeployed();! return { intake]&button.OnTrue(command.Unless([
```

a calls that )C++ ,Java( overload constructor a has also below described `ProxyCommand` proxy. by command returned the runs and timeschedule- at lambda returningcommand-

### Commands Other Scheduling

never are and composition, command the through run are members composition default, By group's the to added are requirements their Accordingly, scheduler. the by seen themselves command entire the for undesirable is it sometimes fine, usually is this While requirements. off" "fork to is solution good A command. single a of requirements the gain to group requires this However, separately. command that schedule and group command the from command. scheduledindividually- the and composition the between synchronization

),C++ ,Java( decorator `asProxy()`. the using creatable also ),C++ ,Java( `ProxyCommand` scheduled, is proxy the when scheduled is command the proxy": "by command a schedules a from off" "forking of case the In finishes. command the when finishes proxy the and it without progress command's the track to group the allows this composition, command composition. the in being

Java

```
                  ends command proxied the after only continues sequence The //
                                            ()asProxy).5.0(waitSecondsCommands.
   ␣delay 5-second the after printed be only will This"(print(Commands.andThen.
                                                                 ))"elapses! ↪
```

C++

```
                  ends command proxied the after only continues sequence The //
                                                 s).AsProxy()_5.0Wait(::cmd::frc2
  ␣delay 5-second the after printed be only will This"Print(::cmd::AndThen(frc2.
                                                                 ))"elapses! ↪
```

)C++ ,Java( `ScheduleCommand` command, proxied the track to need don't that cases For instantly. ends and command specified a schedules

Java

```
                 continues sequence the so immediately, ends ScheduleCommand //
                           ))5.0(waitSecondsScheduleCommand(Commands. new
                  ))"immediately! printed be will This"(print(Commands.andThen.
```

C++

```
                 continues sequence the so immediately, ends ScheduleCommand //
                                  s))_5.0Wait(::cmd::ScheduleCommand(frc2::frc2
                 ))"immediately! printed be will This"Print(::cmd::AndThen(frc2.
```

### Compositions Subclassing 24.3.2

exterior most the of subclass onlyconstructor- a as written be also can compositions Command
Consider constructor. superclass the to members composition the passing type, composition
):C++ ,Java( project example Bot Hatch the from following the

Java

```
;edu.wpi.first.wpilibj.examples.hatchbottraditional.commands package

;edu.wpi.first.wpilibj.examples.hatchbottraditional.Constants.AutoConstants import
;edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems.DriveSubsystem import
;edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems.HatchSubsystem import
;edu.wpi.first.wpilibj2.command.SequentialCommandGroup import

␣drives then and hatch, a releases forward, drives that command auto complex A **/
*/ backward. ↪
{ SequentialCommandGroup extends ComplexAuto class public
**/
ComplexAuto. new a Creates *
*
on run will command this subsystem drive The drive @param *
on run will command this subsystem hatch The hatch @param *
*/
{ hatch) HatchSubsystem drive, (DriveSubsystemComplexAuto public
addCommands(
distance specified the forward Drive //
DriveDistance( new
␣,kAutoDriveSpeedAutoConstants. ,kAutoDriveDistanceInchesAutoConstants.
drive), ↪

hatch the Release //
ReleaseHatch(hatch), new

distance specified the backward Drive //
DriveDistance( new
␣,kAutoDriveSpeedAutoConstants.- ,kAutoBackupDistanceInchesAutoConstants.
drive)); ↪
}
}
```

(Header) C++

```
once pragma#

frc2/command/CommandHelper.h>< include#
frc2/command/SequentialCommandGroup.h>< include#

Constants.h"" include#
commands/DriveDistance.h"" include#
commands/ReleaseHatch.h"" include#

**/
drives then and hatch, a releases forward, drives that command auto complex A *
backward. *
*/
ComplexAuto class
{ >ComplexAuto SequentialCommandGroup,::frc2<CommandHelper::frc2 public :
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                          :public
                                            **/
                           ComplexAuto. new a Creates *
                                              *
   on run will command this subsystem drive The drive @param *
   on run will command this subsystem hatch The hatch @param *
                                             */
     hatch); *HatchSubsystem drive, *ComplexAuto(DriveSubsystem
                                                ;}
```

(Source) C++

```
                        commands/ComplexAuto.h"" include#

                         ;AutoConstants namespace using

 { hatch) *HatchSubsystem drive, *ComplexAuto(DriveSubsystem::ComplexAuto
                                                         AddCommands(
                          distance specified the forward Drive //
   drive), kAutoDriveSpeed, DriveDistance(kAutoDriveDistanceInches,
                                              hatch the Release //
                                              ReleaseHatch(hatch),
                         distance specified the backward Drive //
drive)); kAutoDriveSpeed,- DriveDistance(kAutoBackupDistanceInches,
                                                                  }
```

are others to comparison in approach subclassing this of disadvantages and advantages The .*Groups Command Subclassing* in discussed

## מערכות 24.4

A  paradigm. basedcommand- the in organization robot of unit basic the are Subsystems .*unit a as together operates* that hardware robot of collection a for abstraction an is subsystem robot the of rest the from it ”hiding“ hardware, this for *encapsulation* an form Subsystems Restricting methods. public subsystem’s the through except it to access restricting and code be otherwise might that code for place convenient single a provides way this in access the the if switches) limit checking or outputs motor scaling as (such places multiple in duplicated the how of details specific the to changes allows also It exposed. were internals subsystem it making code, robot of rest the from isolated be to ”implementation“) (the works subsystem change. constraints design the if/when changes substantial make to easier far

management resource ’s`CommandScheduler` the of backbone the as serve also Subsystems they subsystems which specifying by requirements resource declare may Commands system. that command one than more schedule concurrently never will scheduler the with; interact subsystem a requires that command a schedule to attempt An subsystem. given a requires ignored, be or command runningcurrently- the interrupt either will usein-already- is that .*Behavior Interruption* command’s running the on based

scheduled automatically be will that commands“ ”default with associated be can Subsystems ”background“ for useful is This subsystem. the using currently is command other no when stopping or setpoint, a at held arm an keeping drive, robot the controlling as such actions the in achieved be can functionality Similar  used. isn’t subsystem the when motors try should teams scheduler; the of run per once run is which method, `periodic()` subsystem’s of either through achieved is functionality which about codebase their within consistent be to

`Subsystem` the by library basedcommand- the in represented are Subsystems methods. these ).C++ ,Java( interface

## Subsystem a Creating 24.4.1

abstract the subclass to is users most for subsystem a create to method recommended The ):C++ ,Java( template basedcommand- the in seen as ),C++ ,Java( class `SubsystemBase`

Java

```
;edu.wpi.first.wpilibj2.command.CommandBase import
;edu.wpi.first.wpilibj2.command.SubsystemBase import

{ SubsystemBase extends ExampleSubsystem class public
 */ ExampleSubsystem. new a Creates **/
 }{ ()ExampleSubsystem public

 **/
 method. factory command Example *
 *
 command a @return *
 */
 { ()exampleMethodCommand CommandBase public
 here. goes command of construction Inline //
 subsystem. `this` requires implicitly Subsystem::RunOnce //
 runOnce( return
 { >- ()
 */ here goes action one-time */
 );}
 }

 **/
␣a example, (for subsystem the of state boolean a querying method example An *
 sensor). digital ↪
 *
 sensor. digital a as such state, subsystem boolean some of value @return *
 */
 { ()exampleCondition boolean public
 sensor. digital a as such state, boolean some Query //
 ;false return
 }

 @Override
 { ()periodic void public
 run scheduler per once called be will method This //
 }

 @Override
 { ()simulationPeriodic void public
 simulation during run scheduler per once called be will method This //
 }
}
```

C++

```
                                                    once pragma#

                           frc2/command/CommandPtr.h>< include#
                        frc2/command/SubsystemBase.h>< include#

        { SubsystemBase::frc2 public : ExampleSubsystem class
                                                          :public
                                               ExampleSubsystem();

                                                             **/
                                   method. factory command Example *
                                                              */
                      ();ExampleMethodCommand CommandPtr::frc2

                                                             **/
 a example, (for subsystem the of state boolean a querying method example An *
                                                 sensor). digital *
                                                                 *
   sensor. digital a as such state, subsystem boolean some of value @return *
                                                              */
                                          ();ExampleCondition bool

                                                             **/
           runs. CommandScheduler the whenever periodically called be Will *
                                                              */
                                         ;override ()Periodic void

                                                             **/
     during runs CommandScheduler the whenever periodically called be Will *
                                                       simulation. *
                                                              */
                              ;override ()SimulationPeriodic void

                                                         :private
      be generally should sensors) and controllers motor (e.g. Components //
                  methods. public through only exposed and private declared //
                                                                ;}
```

it interface: `Subsystem` basic the of top on features convenience few a contains class This with subsystem the register to constructor its in method `register()` the calls automatically scheduler the when called be to method `periodic()` the for necessary is (this scheduler the to dashboard the to sent be can it that so interface `Sendable` the implements also and runs), information. status relevant display/log

the implements that class a create simply may flexibility more seeking users Advanced interface. `Subsystem`

### Example Subsystem Simple 24.4.2

pneumatically- simple a is Below practice? in like look subsystem functional a might What ):C++ ,Java( project example HatchBotTraditional the from mechanism hatch actuated

Java

```
                 ;edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems package

                     ;edu.wpi.first.wpilibj.DoubleSolenoid.Value.kForward static import
                     ;edu.wpi.first.wpilibj.DoubleSolenoid.Value.kReverse static import

                                    ;edu.wpi.first.util.sendable.SendableBuilder import
                                           ;edu.wpi.first.wpilibj.DoubleSolenoid import
                                     ;edu.wpi.first.wpilibj.PneumaticsModuleType import
    ;edu.wpi.first.wpilibj.examples.hatchbottraditional.Constants.HatchConstants import
                                   ;edu.wpi.first.wpilibj2.command.SubsystemBase import

                  */ DoubleSolenoid}. @link{ single a by actuated mechanism hatch A **/
                                    { SubsystemBase extends HatchSubsystem class public
                                       = m_hatchSolenoid DoubleSolenoid final private
                                                              DoubleSolenoid( new
                                                ,CTREPCMPneumaticsModuleType.
                                       ,]0[kHatchSolenoidPortsHatchConstants.
                                      );]1[kHatchSolenoidPortsHatchConstants.

                                                              */ hatch. the Grabs **/
                                                            { ()grabHatch void public
                                                     (kForward);setm_hatchSolenoid.
                                                                                     }

                                                           */ hatch. the Releases **/
                                                         { ()releaseHatch void public
                                                     (kReverse);setm_hatchSolenoid.
                                                                                     }

                                                                            @Override
                                  { builder) (SendableBuilderinitSendable void public
                                                       (builder);initSendable.super
                                        telemetry. to state solenoid the Publish //
   ␣kForward, == ()getm_hatchSolenoid. >- () ,"extended"(addBooleanPropertybuilder.
                                                                                );null ↪
                                                                                     }
                                                                                       }
```

(Header) C++

```
                                                                           once pragma#

                                                        frc/DoubleSolenoid.h>< include#
                                               frc/PneumaticsControlModule.h>< include#
                                                frc2/command/SubsystemBase.h>< include#

                                                                 Constants.h"" include#

                                    { SubsystemBase::frc2 public : HatchSubsystem class
                                                                                :public
                                                                    HatchSubsystem();
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                   here. go methods Subsystem //

                                                                             **/
                                                               hatch. the Grabs *
                                                                             */
                                                              ();GrabHatch void

                                                                             **/
                                                            hatch. the Releases *
                                                                             */
                                                           ();ReleaseHatch void

                         ;override builder) &SendableBuilder::(wpiInitSendable void

                                                                        :private
              be generally should sensors) and controllers motor (e.g. Components //
                         methods. public through only exposed and private declared //
                                             m_hatchSolenoid; DoubleSolenoid::frc
                                                                              ;}
```

(Source) C++

```
                                         subsystems/HatchSubsystem.h"" include#

                                        wpi/sendable/SendableBuilder.h>< include#

                                                  ;HatchConstants namespace using

                                                 HatchSubsystem()::HatchSubsystem
                    CTREPCM,::PneumaticsModuleType::m_hatchSolenoid{frc :
          }{ ]}1kHatchSolenoidPorts[ ],0kHatchSolenoidPorts[

                                              { GrabHatch()::HatchSubsystem void
                        kForward);::DoubleSolenoid::m_hatchSolenoid.Set(frc
                                                                               }

                                            { ReleaseHatch()::HatchSubsystem void
                        kReverse);::DoubleSolenoid::m_hatchSolenoid.Set(frc
                                                                               }

             { builder) &SendableBuilder::InitSendable(wpi::HatchSubsystem void
                                               InitSendable(builder);::SubsystemBase

                                     telemetry. to state solenoid the Publish //
                                                         builder.AddBooleanProperty(
                                                                     ,"extended"
     ,} kForward;::DoubleSolenoid::frc == m_hatchSolenoid.Get() return { ]this[
                                                                      );nullptr
                                                                               }
```

is (it code outside from DoubleSolenoid the of presence the hides subsystem the that Notice actions: robot descriptive level,higher- two exposes publicly instead and ),private declared details" "implementation that important extremely is It .releaseHatch() and grabHatch() the outside code that ensures this manner; this in "hidden" be solenoid double the as such user the allows also It state. unexpected an in be to solenoid the cause never will subsystem pneumatic) a of instead used be could motor a instance, (for implementation the change to without any of the code outside of the subsystem having to change with it.

Alternatively, instead of writing void public methods that are called from commands, we can define the public methods as factories that return a command. Consider the following from the HatchBotInlined example project (Java, C++):

Java

```java
package edu.wpi.first.wpilibj.examples.hatchbotinlined.subsystems;

import static edu.wpi.first.wpilibj.DoubleSolenoid.Value.kForward;
import static edu.wpi.first.wpilibj.DoubleSolenoid.Value.kReverse;

import edu.wpi.first.util.sendable.SendableBuilder;
import edu.wpi.first.wpilibj.DoubleSolenoid;
import edu.wpi.first.wpilibj.PneumaticsModuleType;
import edu.wpi.first.wpilibj.examples.hatchbotinlined.Constants.HatchConstants;
import edu.wpi.first.wpilibj2.command.CommandBase;
import edu.wpi.first.wpilibj2.command.SubsystemBase;

/** A hatch mechanism actuated by a single {@link edu.wpi.first.wpilibj.DoubleSolenoid}. */
public class HatchSubsystem extends SubsystemBase {
  private final DoubleSolenoid m_hatchSolenoid =
      new DoubleSolenoid(
          PneumaticsModuleType.CTREPCM,
          HatchConstants.kHatchSolenoidPorts[0],
          HatchConstants.kHatchSolenoidPorts[1]);

  /** Grabs the hatch. */
  public CommandBase grabHatchCommand() {
    // implicitly require `this`
    return this.runOnce(() -> m_hatchSolenoid.set(kForward));
  }

  /** Releases the hatch. */
  public CommandBase releaseHatchCommand() {
    // implicitly require `this`
    return this.runOnce(() -> m_hatchSolenoid.set(kReverse));
  }

  @Override
  public void initSendable(SendableBuilder builder) {
    super.initSendable(builder);
    // Publish the solenoid state to telemetry.
    builder.addBooleanProperty("extended", () -> m_hatchSolenoid.get() == kForward, null);
  }
}
```

C++ (Header)

```cpp
#pragma once

#include <frc/DoubleSolenoid.h>
#include <frc/PneumaticsControlModule.h>
#include <frc2/command/CommandPtr.h>
#include <frc2/command/SubsystemBase.h>
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
Constants.h"" include#

{ SubsystemBase::frc2 public : HatchSubsystem class
:public
HatchSubsystem();

here. go methods Subsystem //

**/
hatch. the Grabs *
*/
();GrabHatchCommand CommandPtr::frc2

**/
hatch. the Releases *
*/
();ReleaseHatchCommand CommandPtr::frc2

;override builder) &SendableBuilder::(wpiInitSendable void

:private
be generally should sensors) and controllers motor (e.g. Components //
methods. public through only exposed and private declared //
m_hatchSolenoid; DoubleSolenoid::frc
;}
```

(Source) C++

```
subsystems/HatchSubsystem.h"" include#

wpi/sendable/SendableBuilder.h>< include#

;HatchConstants namespace using

HatchSubsystem()::HatchSubsystem
CTREPCM,::PneumaticsModuleType::m_hatchSolenoid{frc :
}{ ]}1kHatchSolenoidPorts[ ],0kHatchSolenoidPorts[

{ GrabHatchCommand()::HatchSubsystem CommandPtr::frc2
`this` require implicitly //
RunOnce(>-this return
);} kForward);::DoubleSolenoid::m_hatchSolenoid.Set(frc { ]this[
}

{ ReleaseHatchCommand()::HatchSubsystem CommandPtr::frc2
`this` require implicitly //
RunOnce(>-this return
);} kReverse);::DoubleSolenoid::m_hatchSolenoid.Set(frc { ]this[
}

{ builder) &SendableBuilder::InitSendable(wpi::HatchSubsystem void
InitSendable(builder);::SubsystemBase

telemetry. to state solenoid the Publish //
builder.AddBooleanProperty(
```

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```
                                                      ,"extended"
       ,} kForward;::DoubleSolenoid::frc == m_hatchSolenoid.Get() return { ]this[
                                                          );nullptr
                                                                  }
```

in factory static the isn't this here: used factory `RunOnce` the of qualification the Note this requiring commands return that factories instance similar have Subsystems !Commands used. is )C++ ,Java( factory `Subsystem.runOnce(Runnable)` the Here, subsystem.

.*Methods Factory Command Instance* see options, these between comparison a For

## Periodic 24.4.3

(usually, iteration scheduler every once called is that method `periodic` a have Subsystems that actions periodic other and telemetry for used typically is method This ms). 20 every once subsystem. the requiring is command whatever with interfere not do

Java

```
                                                        @Override
                                        { ()periodic void public
                         block periodic the in odometry the Update //
                                                  (updatem_odometry.
                            (getHeading()),fromDegreesRotation2d.
                                        (),getDistancem_leftEncoder.
                                      ());getDistancem_rightEncoder.
                                    (getPose());setRobotPosem_fieldSim.
                                                                  }
```

(Header) C++

```
                                          ;override ()Periodic void
```

(Source) C++

```
                                     { ()DriveSubsystem::Periodic void
                   here. goes method periodic subsystem of Implementation //
                             m_odometry.Update(m_gyro.GetRotation2d(),
                  meter_t{m_leftEncoder.GetDistance()},::units
                 meter_t{m_rightEncoder.GetDistance()});::units
                          m_fieldSim.SetRobotPose(m_odometry.GetPose());
                                                                     }
```

is it that except `periodic()` to similar is that method `simulationPeriodic()` a also is There robot. the of state the update to used be can and *Simulation* during run only

### Commands Default 24.4.4

default the *owns* CommandScheduler the library, basedcommand- C++ the In :□□□□ object. command

being not is subsystem a whenever automatically run that commands are commands“ ”Default controlling as such actions ”background“ for useful be can This command. another by used setpoint. a at held arm an keeping or drive, robot the

Setting a default command for a subsystem is very easy; one simply calls `CommandScheduler.` `getInstance().setDefaultCommand()`, or, more simply, the `setDefaultCommand()` method of the `Subsystem` interface:

Java

```
    exampleCommand); (exampleSubsystem,setDefaultCommand().getInstanceCommandScheduler.
```

C++

```
                        ␣CommandScheduler.GetInstance().SetDefaultCommand(exampleSubsystem,
                                                               move(exampleCommand));::std ↪
```

Java

```
                                  (exampleCommand);setDefaultCommandexampleSubsystem.
```

C++

```
                        move(exampleCommand));::exampleSubsystem.SetDefaultCommand(std
```

require must subsystem a for command default the as assigned is that command A :□□□□ subsystem. that

## Triggers-ל Commands קישור 24.5

□□□□□□ □□□□□□□□ □□□□□□ ,□□□□□□□□□□ □□□□□ □□□□ □□□□□□□ □□□□□□□□□ □□□□ ,□□□□□□□□□□□ □□□□□□□□ □□□□□ □□□□□□ □□□□□□ □□□□□□ □□□□□□□ □□□□□ ,□□□□□□□ □□ □□□□□ subsystem-□□ □□□□ □□□□ □□□□□□□□□ □□□□ ,□□□□□ □□□□□□□ □□□□□□□□□ .□□□□□□ □□□□□□ □□□□ □□ □□□□□□ □□□□□□ □□□□□ ,□□□□□□ □□□□□□□ □□□□ □□□□□□ □□□□□□ □□□□ .□□□□ □□□□ □□ □□□□□□□ □□□□□ □□□□□ □□□□□□□□-□□□□□□□

Accordingly, paradigm. *programming declarative* a is basedcommand- earlier, mentioned As command a and button a of association the declaratively; done is commands to buttons binding of work hard the all does then library The initialization. robot during once, ”declared“ is behind- needed, as command the canceling) (or scheduling and state button the checking about not - setup UI desired their designing about worry to need only Users scenes.the- it! implementing

).C++ ,Java( class `Trigger` the through done is binding Command

## Instance Trigger a Getting 24.5.1

a get to ways three are There object. `Trigger` a need we conditions, to commands bind To object: Trigger

### Factories HID

given a for `Trigger` a returning methods factory contain classes HID basedcommand- The its and ),C++ ,Java( factory `button(int)` basedindex- an has `CommandGenericHID` button. and ),C++ ,Java( `CommandPS4Controller` ),C++ ,Java( `CommandXboxController` subclasses button. each for methods factory named have )C++ ,Java( `CommandJoystick`

Java

```
␣// );1CommandXboxController( new = exampleCommandController CommandXboxController
                                          1. port on CommandXboxController a Creates ↪
␣for object Trigger new a Creates // ();xexampleCommandController. = xButton Trigger
                                      exampleCommandController on button `X` the ↪
```

C++

```
              ␣a Creates // }1exampleCommandController{ CommandXboxController::frc2
                                                   1 port on CommandXboxController ↪
␣object Trigger new a Creates // exampleCommandController.X() = xButton Trigger::frc2
                                          exampleCommandController on button `X` the for ↪
```

### JoystickButton

of instance an create to passed and used be can *regular HID classes* the Alternatively, :Trigger of subclass onlyconstructor- a ),C++ ,Java( `JoystickButton`

Java

```
          ␣an Creates // );2XboxController( new = exampleController XboxController
                                                          2. port on XboxController ↪
.kY.ButtonXboxController. JoystickButton(exampleController, new = yButton Trigger
           ␣on button `Y` the for object JoystickButton new a Creates // );value ↪
                                                               exampleController ↪
```

C++

```
  2 port on XboxController an Creates // }2exampleController{ XboxController::frc
␣// kY);::Button::XboxController::frc exampleStick,&yButton( JoystickButton::frc2
     exampleController on button `Y` the for object JoystickButton new a Creates ↪
```

### Triggers Arbitrary

bind to want may users case, use common most the far by is buttons HID to binding While the to lambda a passing by inline done be can This events. triggering arbitrary to commands :`Trigger` of constructor

Java

```
3 DIO on switch Limit // );3DigitalInput( new = limitSwitch DigitalInput

Trigger(limitSwitch::get); new = exampleTrigger Trigger
```

C++

```
3 DIO on switch Limit // ;}3limitSwitch{ DigitalInput::frc

);} limitSwitch.Get(); return { limitSwitch]&([exampleTrigger Trigger::frc2
```

## Bindings Trigger 24.5.2

---

binding button each of overloads two offers library basedcommand- C++ The :□□□□ raw a takes that one and ),`CommandPtr&&`( reference rvalue an takes that one - method raw the while scheduler, the to ownership moves overload rvalue The ).`Command*`( pointer is It object. command the of lifespan the for responsible user the leaves overload pointer a is there unless overload reference rvalue the use preferentially users that recommended code. calling the in command the to handle a retain to need specific

---

will bindings these of All class. `Trigger` the for available bindings of number a are There however, - occurs event activation trigger certain a when command a schedule automatically behavior. specific different has binding each

binding the so *,method binding a to call the past survive to need not do* objects `Trigger` :*declarative* is binding button that Remember temp. a on called simply be may methods The initialization. robot during time some ideally once, declared be to need only bindings else. everything handles library

---

be should methods binding its of usage and deprecated, is subclass `Button` The :□□□□ docs. API the in messages deprecation respective the to according replaced

---

### onTrue

(or, `true` to `false` from changes trigger a when command a schedules binding This scheduled be will command The pressed). initially is changes button a when accordingly, trigger the unless again scheduled be not will and changes, state the when iteration the on pressed).re- then and released is button the (or again `true` then and `false` becomes

Java

```
pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
));2(setArmGoalCommand(m_robotArm.onTrue().am_driverController.
```

C++

```
        pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
                         rad));_2m_driverController.A().OnTrue(m_arm.SetArmGoalCommand(
```

.true on of instead false on schedules it that only identical, is binding onFalse The

### whileTrue

(or, true to false from changes trigger a when command a schedules binding This false becomes trigger the when it cancels and pressed) initially is button a when accordingly, while finishes it if scheduledre- be *not* will command The released). is button the (or again ,true is trigger the while finishes it if restart to command the For .true still is trigger the .InstantCommand an of instead RunCommand a use or ,RepeatCommand a in command the wrap

Java

```
                   speed half at drive button, shoulder the holding While //
          )value.kRightBumperButton. JoystickButton(m_driverController, new
                          HalveDriveSpeed(m_robotDrive)); new(whileTrue.
```

C++

```
                    speed half at drive button, shoulder the holding While //
                                      m_driverController,&JoystickButton(::frc2
          kRightBumper)::Button::XboxController::frc
                  m_drive).ToPtr());&WhileTrue(HalveDriveSpeed(.
```

.true on cancels and false on schedules it that only identical, is binding whileFalse The

### toggleOnTrue

true to false from changes trigger a when it scheduling command, a toggles binding This command the if condition same the under it canceling and pressed), initially is button a (or highly- a not are toggles supported, is functionality this while that Note running. currently is robot the of track keep to driver the require they as control, user for option recommended off. turn to another and on turn to one buttons; two use to is method preferred The state. commands the specify to way good a is ConditionalCommand a or StartEndCommand a Using between. toggled be to want be to want you that

Java

```
                   (mySubsystem::onMethod,startEnd(Commands.toggleOnTruemyButton.
                                              mySubsystem::offMethod,
                                                      mySubsystem));
```

C++

```
         ,} mySubsystem.OnMethod(); { ]&StartEnd([::cmd::myButton.ToggleOnTrue(frc2
                              ,} mySubsystem.OffMethod(); { ]&[
                                          mySubsystem}));&{
```

.true on of instead false on toggles it that only identical, is binding toggleOnFalse The

### Calls Chaining 24.5.3

were they that trigger the return all methods binding command the that note to useful is It same the of states different to commands multiple bind to chained be can thus and on, called example: For trigger.

Java

```
                                                                  exampleButton
                        pressed is button the when scheduled be to FooCommand a Binds //
                                                                FooCommand()) new(onTrue.
                   released is button same that when scheduled be to BarCommand a Binds //
                                                              BarCommand()); new(onFalse.
```

C++

```
                                                                  exampleButton
                        pressed is button the when scheduled be to FooCommand a Binds //
                                                              OnTrue(FooCommand().ToPtr()).
                   released is button same that when scheduled be to BarCommand a Binds //
                                                            OnFalse(BarCommand().ToPtr());.
```

### Triggers Composing 24.5.4

,`or()` ,`and()` the through triggers composite create to composed be can class `Trigger` The example: For operators). ! and ,|| ,&& the C++, in (or, methods `negate()` and

Java

```
  ␣the of buttons 'Y' and 'X' the both when scheduled be to ExampleCommand an Binds //
                                                               pressed are gamepad driver ↪
                                                                ()xexampleCommandController.
                                                     ())y(exampleCommandController.and.
                                                            ExampleCommand()); new(onTrue.
```

C++

```
  ␣the of buttons 'Y' and 'X' the both when scheduled be to ExampleCommand an Binds //
                                                               pressed are gamepad driver ↪
                                                              (exampleCommandController.X()
                                                  exampleCommandController.Y()) &&
                                                 OnTrue(ExampleCommand().ToPtr());.
```

### Triggers Debouncing 24.5.5

inputs) digital from originating those (especially triggers activation, repeated rapid avoid To method: *debounce* the using *class Debouncer WPILib* the with debounced be can

Java

```
                        only edges rising time, debounce 0.1s a with exampleButton debounces //
                                      ExampleCommand()); new(onTrue).0.1(debounceexampleButton.

          edges falling and rising both time, debounce 0.1s a with exampleButton debounces //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
␣new(onTrue).kBoth.DebounceTypeDebouncer. ,0.1(debounceexampleButton.
                                              ExampleCommand()); ↪
```

C++

```
only edges rising time, debounce 100ms a with exampleButton debounces //
        ms).OnTrue(ExampleCommand().ToPtr());_100exampleButton.Debounce(

edges falling and rising both time, debounce 100ms a with exampleButton debounces //
Both).OnTrue(ExampleCommand().::DebounceType::Debouncer ms,_100exampleButton.Debounce(
                                                                    ToPtr()); ↪
```

## Project Robot BasedCommand- a Structuring 24.6

advanced (and like they however libraries basedcommand- the use to free are users While a structure to how on guidance some want may users new so), do to encouraged are users project. robot basedcommand- basic

examples WPILib the in included is project robot basedcommand- a for template standard A template. this of structure the through users walk will section This ).C++ ,Java( repository

classes: four contain will generally package/directory root The

class. this touch *not should* users New only). (Java application robot main the is which ,`Main` ,`RobotContainer` code. robot the of flow control main the for responsible is which ,`Robot` robot declarative the of most where is and commands, and subsystems robot holds which accessibleglobally- holds which ,`Constants` performed. is bindings) button (e.g. setup robot. the throughout used be to constants

contains `Subsystems` directories:packages/sub-sub- two contain also will directory root The classes. command defineduser- all contains `Commands` classes. subsystem defineduser- all

### Robot 24.6.1

flow, control program's the for responsible is )(Source) C++ ,(Header) C++ ,Java( `Robot` As attention of amount the minimize to designed paradigm declarative an is basedcommand- and basedcommand- a of class `Robot` the flow, control program explicit to pay to has user the be must that things important few a are there However, empty. mostly be should project included

Java

```
                                                                    **/
  ␣for used be should and up started first is robot the when run is function This *
                                                                     any ↪
                                                   code. initialization *
                                                                    */
                                                               @Override
                                                 { ()robotInit void public
   ␣bindings, button our all perform will This  RobotContainer. our Instantiate //
                                                                our put and ↪
                                      dashboard. the on chooser autonomous //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
RobotContainer(); new = m_robotContainer
                                       }
```

robotInit() the during constructed be should RobotContainer of instance an Java, In the from called be will setup robot declarative the of most as important, is this - method constructor. RobotContainer

constructed be will and member value a is RobotContainer as needed not is this C++, In .Robot of construction the during

Java

```
                                                        **/
␣like items for this Use mode. the matter no ms, 20 every called is function This *
                                                  diagnostics ↪
           test. and teleoperated autonomous, disabled, during ran want you that *
                                                              *
 ␣LiveWindow before but functions, periodic specific mode the after runs p>This< *
                                                          and ↪
                              updating. integrated SmartDashboard *
                                                                */
                                                        @Override
                                  { ()robotPeriodic void public
  newly- adding buttons, polling for responsible is This  Scheduler. the Runs //
                                                    scheduled ↪
␣interrupted or finished removing commands, already-scheduled running commands, //
                                                     commands, ↪
 robot the from called be must This  methods. periodic() subsystem running and //
                                                   periodic s' ↪
          work. to framework Command-based the in anything for order in block //
                              ();run().getInstanceCommandScheduler.
                                                               }
```

(Source) C++

```
                                                         **/
                  Use mode. the matter no ms, 20 every called is function This *
             disabled, during run to want you that diagnostics like items for this *
                                      test. and teleoperated autonomous, *
                                                                         *
               before but functions, periodic specific mode the after runs This p>< *
                              updating. integrated SmartDashboard and LiveWindow *
                                                                        */
                                            { ()Robot::RobotPeriodic void
                          GetInstance().Run();::CommandScheduler::frc2
                                                                       }
```

robotPeriodic() the in call CommandScheduler.getInstance().run() the of inclusion The commands. scheduled any execute not will scheduler the call, this without essential; is method with frequency the is this 50Hz, of frequency loop main default a with runs TimedRobot Since for recommended not is It called. be will methods subsystem and command periodic which code. their in else anywhere from method this call to users new

Java

```
  ␣@link{ your by selected command autonomous the runs autonomous This **/
                                            */ class. RobotContainer} ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                      @Override
                                   { ()autonomousInit void public
        ();getAutonomousCommandm_robotContainer. = m_autonomousCommand

                       (example) command autonomous the schedule //
                                 { )null =! (m_autonomousCommand if
                                  ();schedulem_autonomousCommand.
                                                                 }
                                                                   }
```

(Source) C++

```
                                                                   **/
        @link{ your by selected command autonomous the runs autonomous This *
                                                   class. RobotContainer} *
                                                                    */
                                         { ()Robot::AutonomousInit void
              m_container.GetAutonomousCommand(); = m_autonomousCommand

                                            { (m_autonomousCommand) if
                                   Schedule();>-m_autonomousCommand
                                                                   }
                                                                     }
```

the by returned command autonomous an schedules method `autonomousInit()` The can run to command autonomous which selecting for logic The instance. `RobotContainer` be handled inside of `RobotContainer`.

Java

```
                                                      @Override
                                       { ()teleopInit void public
               when running stops autonomous the that sure makes This //
                 to autonomous the want you If running. starts teleop //
                remove command, another by interrupted until continue //
                                     out. it comment or line this //
                                 { )null =! (m_autonomousCommand if
                                    ();cancelm_autonomousCommand.
                                                                 }
                                                                   }
```

(Source) C++

```
                                           { ()Robot::TeleopInit void
               when running stops autonomous the that sure makes This //
                 to autonomous the want you If running. starts teleop //
                remove command, another by interrupted until continue //
                                     out. it comment or line this //
                                            { (m_autonomousCommand) if
                                      Cancel();>-m_autonomousCommand
                                                                   }
                                                                     }
```

generally is This commands. autonomous runningstill- any cancels method `teleopInit()` The practice. good

as methods periodic and init various the to code additional add to free are users Advanced robot imperative of amounts large including that noted be should it however, fit; see they basedcommand- the of philosophy design declarative the to contrary is Robot.java in code code. structured/disorganizedconfusingly- in result can and paradigm,

### RobotContainer 24.6.2

command- your for setup the of most where is )(Source) C++ ,(Header) C++ ,Java( class This and subsystems robot's your define will you class, this In place. take will robot based which specify and buttons), as (such events triggering to commands those bind commands, new class this of aspects few a are There routine. autonomous your in run will you command for: explanations want may users

Java

```
ExampleSubsystem(); new = m_exampleSubsystem ExampleSubsystem final private
```

(Header) C++

```
m_subsystem; ExampleSubsystem
```

stark in is This .RobotContainer in fields private as declared are subsystems that Notice more- much is but framework, basedcommand- the of incarnation previous the to contrast global as declared are subsystems If practices.best- orientedobject- uponagreed- with aligned make can this While code. the in anywhere from them access to user the allows it variables, commands to subsystems pass to need no be would there example, (for easier things certain much program the of flow control the makes it them), access to commands those for order in or change can code the of parts which obvious immediately not is it as of track keep to harder resource- the of ability the circumvents also This code. the of parts other which by changed be accidentally to users for easy it makes accessof-ease- as job, its do to system management commands. managedresource- the of outside methods subsystem to calls conflicting make

Java

```
(m_exampleSubsystem);exampleAutoAutos. return
```

(Source) C++

```
m_subsystem);&ExampleAuto(::autos return
```

to passed explicitly be must they members, private as declared are subsystems Since call to commands those for order in injection“) ”dependency called pattern (a commands an to pointer a passed is which ,ExampleCommand with here done is This them. on methods .ExampleSubsystem

Java

```
                                                                      **/
     ␣be can Triggers mappings. trigger->command your define to method this Use *
                                                                 the via created ↪
 ␣an with constructor Trigger#Trigger(java.util.function.BooleanSupplier)} @link{ *
                                                                       arbitrary ↪
                                @link{ in factories named the via or predicate, *
 @link{ for subclasses s'edu.wpi.first.wpilibj2.command.button.CommandGenericHID} *
      edu.wpi.first.wpilibj2.command.button. Xbox}/{@link CommandXboxController *
                                                            CommandPS4Controller ↪
␣edu.wpi.first.wpilibj2.command.button.CommandJoystick @link{ or controllers PS4} *
                                                                          Flight ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   joysticks}. *
                                        */
                         { ()configureBindings void private
      `true` to changes `exampleCondition` when `ExampleCommand` Schedule //
                Trigger(m_exampleSubsystem::exampleCondition) new
               ExampleCommand(m_exampleSubsystem)); new(onTrue.

pressed, is button B s'controller Xbox the when `exampleMethodCommand` Schedule //
                            release. on cancelling //
   ());exampleMethodCommand(m_exampleSubsystem.whileTrue().bm_driverController.
                                         }
```

(Source) C++

```
                      { ()RobotContainer::ConfigureBindings void
                      here bindings trigger your Configure //

       `true` to changes `exampleCondition` when `ExampleCommand` Schedule //
                               { ]thisTrigger([::frc2
                      m_subsystem.ExampleCondition(); return
                  m_subsystem).ToPtr());&).OnTrue(ExampleCommand(}

      is button B s'controller Xbox the when `ExampleMethodCommand` Schedule //
                         release. on cancelling pressed, //
        m_driverController.B().WhileTrue(m_subsystem.ExampleMethodCommand());
                                          }
```

declarative the of most where is constructor `RobotContainer()` the before, mentioned As autonomous configuring bindings, button including place, take should robot the for setup into code migrate to encouraged are users ”busy,“ too gets constructor the If etc. selectors, which default) by included method `configureBindings()` the as (such subroutines separate constructor. the from called are

Java

```
                                        **/
     class. Robot} @link{ main the to command autonomous the pass to this Use *
                                         *
                     autonomous in run to command the @return *
                                        */
                      { ()getAutonomousCommand Command public
                 autonomous in run be will command example An //
                  (m_exampleSubsystem);exampleAutoAutos. return
                                         }
                                          }
```

(Source) C++

```
              { ()RobotContainer::GetAutonomousCommand CommandPtr::frc2
                  autonomous in run be will command example An //
                      m_subsystem);&ExampleAuto(::autos return
                                          }
```

send to users for way convenient a provides method `getAutonomousCommand()` the Finally, to it to access needs (which class `Robot` main the to command autonomous selected their starts). autonomous when it schedule

### Constants 24.6.3

file header a simply but class, a not is this C++ (in )(Header) C++ ,Java( class `Constants` The (such constants robot accessibleglobally- where is defined) are namespaces several which in is It stored. be can ports) sensor/motor and gains, PID factors, conversion unit speeds, as corresponding classes inner individual into constants these separate users that recommended shorter. names variable keep to modes, robot or subsystems to

globally are they that so `final static public` declared be should constants all Java, In .`constexpr` be should constants all C++, In changed. be cannot and accessible

see practice, in like look should class `constants` a what of examples illustrative more For projects: example basedcommand- various the of those

- )C++ ,Java( FrisbeeBot
- )C++ ,Java( GyroDriveCommands
- )C++ ,Java( Hatchbot
- )C++ ,Java( RapidReactCommandBot

statically by classes other from used be constants the that recommended is it Java, In static the imports statement `static import` An class. inner necessary the importing constants `static` any that so working, are you which in class the into class a of namespace effect same the C++, In class. that in defined been had they if as directly referenced be can :`namespace using` with attained be can

Java

```
;edu.wpi.first.wpilibj.templates.commandbased.Constants.OIConstants.* static import
```

C++

```
;OIConstants namespace using
```

### מערכות 24.6.4

package/directory. this in go should subsystems definedUser-

### Commands 24.6.5

package/directory. this in go should commands definedUser-

## Projects Robot BasedCommand- Organizing 24.7

the maintaining and understanding, navigating, complicated, more becomes code robot As becomes often code the to changes Making energy. and time more and more up takes code complexity actual the with do to little very have that reasons for sometimes difficult, more of the underlying logic. For a simplified example: putting the logic for many unrelated robot within code of piece specific a find to difficult it makes file line1000- single a into functions logic related closely out spreading But competition. a at stress under particularly file, that navigate. to difficult as just often is files tiny of dozens across more becomes only organization good fact, in and FRC, to unique problem a not is This organization ”best“ The bigger. and bigger become projects software as critical more and the in but language, programming ”best“ the like much debate, of topic perennial a is system programmer the and hand at task specific the to down comes cases) both (in choice the end, robot FRC of space small relatively the in Even task. said implementing programmers) (or the on depend will team given a for choice best The answer. right no is there programming, preference. personal pure and structure, team code, robot specific the of nature

advanced that design program robot basedcommand- of facets various discusses article This prescriptive a not is It code. writing when of aware be to want may programmers FRC seems choice of level this If practices. best recommended some presents it though tutorial, WPILib’s to closely sticking while successful highly been have teams many however, daunting, and intermediate to interest of be may discussion this However, guidelines. and code example easily flexible, but effective, only not code their make to want who programmers advanced beautiful. even sometimes and changeable,

## Organization? About Care Why 24.7.1

does it ability—but competitive team’s a break or make rarely will organization code Good programmers. happier and code, lookingnicer- modifications, faster debugging, easier mean the from like looks code the what of way by organization ”good“ define to impossible it’s While outside. the from like looks software robot’s the what of terms in define to easier it’s inside,

### Like Looks Organization Good What

intuitive is structure internal code’s the organized,well- and designedwell- is code When robot new that meaning minimized, is boilerplate Cumbersome comprehensible. easily and (such value constant a When code. of lines few a just with added be often can functionality place. one in change to needs only it changed, be to needs intake) robot’s the of speed the as others« each understand easily can they together, working are programmers multiple If (such behavior unintended introduce accidentally to difficult is it since rare, are Bugs work. more Implementing subsystems). necessary require not does that command a creating as physical the from away abstracted is code the since easier, is tests unit like functions advanced time). the of (most happy are Programmers hardware.

### Like Looks Organization Bad What

to even sense, no to little makes that structure internal has often code organized Poorly unrelated breaks often it changed, or added be to has functionality When it. wrote whoever climbing the in bug a introduce might control shooter automatic adding robot: the of parts strict so be might framework organizational the Alternatively, reasons. unclear for sequence workarounds. or hacks nasty requiring behavior, necessary implement to impossible it’s that scattered are Constants logic. robot simple for needed are code boilerplate of lines Many to change same the making requires often behavior basic changing and codebase, the across impossible. or difficult is programmers multiple among Collaboration files. different many

## Commands Defining 24.7.2

many in used be to need command same the of copies multiple codebases, robot larger In teleop, in used be might intake robot’s a runs that command a instance, For places. different autonomous an for group command complicated a of part as button; certain a to bound sequence. testself- a of part as and routine;

the runs simply that command simple a define to ways some at look let’s example, an As canceled. until power full at forward intake robot’s

### Commands Inline

:`StartEndCommand` a with is this do to way expressive most and easiest The

Java

```
␣),0(setintake. >- () ),1(setintake. >- (()startEndCommands. = runIntake Command
                                                                      intake); ↪
```

C++

```
&[ ,} );1.0intake.Set( { intake]&StartEnd([::cmd::frc2 = runIntake CommandPtr::frc2
                                        intake});&{ ,} );0intake.Set( { intake] ↪
```

that this like command a for However, once. used only are that commands for sufficient is This commands inline bindings, button and routines autonomous different many in used get might code: repetitive of lot a means everywhere

Java

```
                                                          RobotContainer.java //
␣),0(setintake. >- () ),1.0(setintake. >- (()startEnd(Commands.whileTrueintakeButton.
                                                                     intake)); ↪

),0(setintake. >- () ),1.0(setintake. >- (()startEndCommands. = intakeAndShoot Command
                                                                       intake)  ↪
                                                  RunShooter(shooter)); new(alongWith.

                                             (sequenceCommands. = autonomousCommand Command
        intake). ),0.0(setintake. >- () ),1.0(setintake. >- (()startEndCommands.
                                                                  ),5.0(withTimeout ↪
                                                            ),3.0(waitSecondsCommands.
        intake). ),0.0(setintake. >- () ),1.0(setintake. >- (()startEndCommands.
                                                                   )5.0(withTimeout ↪
                                                                                  );
```

C++

```
  intake]&[ ,} );1.0intake.Set( { intake]&StartEnd([::cmd::intakeButton.WhileTrue(frc2
                                                     intake}));&{ ,} );0intake.Set( { ↪

␣,} );1.0intake.Set( { intake]&StartEnd([::cmd::frc2 = intakeAndShoot CommandPtr::frc2
                                         intake})&{ ,} );0intake.Set( { intake]&[ ↪
                                            shooter).ToPtr());&AlongWith(RunShooter(.

                                Sequence(::cmd::frc2 = autonomousCommand CommandPtr::frc2
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
&{ ,} );0intake.Set( { intake]&[ ,} );1.0intake.Set( { intake]&StartEnd([::cmd::frc2
                                                   s),_5.0intake}).WithTimeout( ↪
                                                                s),_3.0Wait(::cmd::frc2
&{ ,} );0intake.Set( { intake]&[ ,} );1.0intake.Set( { intake]&StartEnd([::cmd::frc2
                                                    s)_5.0intake}).WithTimeout( ↪
                                                                                  );
```

since here, work won't variable a in it putting and instance `StartEndCommand` one Creating that by "owned" effectively is it group command a to added is command a of instance an once context. other any in used be cannot and group command

### Methods Factory Command Instance

function a pattern: design method" "factory the using is quandary this solve to way One *command* Using specification. some to according invocation, every object new a returns that few a merely with object command complex a construct can method factory a ,*composition* code. of lines

exactly to related conceptually is command runningintake- the like command a example, For as method `runIntakeCommand` a put to sense makes it such, As .`Intake` the subsystem: one class: `Intake` the of method instance an

---

teams but ,`lowerCamelCaseCommand` as methods factory name will we document this In :□□□□ with name method the end to recommended is it general, In conventions. other on decide may might `intake.run` (e.g. method ordinary an with confused be otherwise might it if `Command` intake). the on turns simply that method a of name the be

---

Java

```
                                            { SubsystemBase extends Intake class public
                                  etc.] configuration, controllers, motor for [code //
                                                                                ... //

                                                   { ()runIntakeCommand Command public
                                                         `this` requires implicitly //
        ));0.0(set.this >- () ),1.0(set.this >- (()startEnd.this return
                                                                                     }
                                                                                       }
```

C++

```
                                        { ()Intake::RunIntakeCommand CommandPtr::frc2
                                                       `this` requires implicitly //
      );} );0Set(>-this { ]this[ ,} );1.0Set(>-this { ]thisStartEnd([>-this return
                                                                                   }
```

use we instead, ;`intake` to refer longer no we class, `Intake` the in are we since how Notice instance. current the to refer to keyword `this` the

and variables `private` access can we technically class, `Intake` the inside are we Since intermediary needing not thus method, `runIntakeCommand` the within from directly methods motor the with interface directly can method `runIntakeCommand` the example, (For methods. methods intermediary these hand, other the On .)`set()` calling of instead objects controller in outlined choices other many Like encapsulation. increase and duplication code reduce can basis. caseby-case- a on preference personal of matter a is tradeoff this document, this

expressive: highly is bindings button and groups command in method factory new this Using

Java

```
                                    ());runIntakeCommand(intake.whileTrueintakeButton.

RunShooter(shooter)); new(alongWith().runIntakeCommandintake. = intakeAndShoot Command

                                        (sequenceCommands. = autonomousCommand Command
                                       ),5.0(withTimeout().runIntakeCommandintake.
                                                        ),3.0(waitSecondsCommands.
                                        )5.0(withTimeout().runIntakeCommandintake.
                                                                                   );
```

C++

```
                                    intakeButton.WhileTrue(intake.RunIntakeCommand());

    &intake.RunIntakeCommand().AlongWith(RunShooter( = intakeAndShoot CommandPtr::frc2
                                                                  shooter).ToPtr()); ↪

                             Sequence(::cmd::frc2 = autonomousCommand CommandPtr::frc2
                                       s),_5.0intake.RunIntakeCommand().WithTimeout(
                                                             s),_3.0Wait(::cmd::frc2
                                        s)_5.0intake.RunIntakeCommand().WithTimeout(
                                                                                   );
```

run to percentage exact the provide to method runIntakeCommand the to parameter a Adding flexibility. more even for allows and easy is intake the

Java

```
                                     { percent) double(runIntakeCommand Command public
   );this ),0.0(set.this >- () (percent),set.this >- StartEndCommand(() new return
                                                                                    }
```

C++

```
                                         { ()Intake::RunIntakeCommand CommandPtr::frc2
                                                       `this` requires implicitly //
      >-this { ]this[ ,} Set(percent);>-this { percent] ,thisStartEnd([>-this return
                                                                         );} );0Set( ↪
                                                                                    }
```

two for forwards intake the runs that group command a creates code this instance, For seconds. five for backwards intake the runs then and seconds, two for waits seconds,

Java

```
             )2.0(withTimeout).1.0(runIntakeCommandintake. = intakeRunSequence Command
                                               ))2.0(waitSeconds(Commands.andThen.
                         ));5.0(withTimeout).1.0-(runIntakeCommand(intake.andThen.
```

C++

```
  s)_2.0).WithTimeout(1.0intake.RunIntakeCommand( = intakeRunSequence CommandPtr::frc2
                                                  s))_2.0Wait(::cmd::AndThen(frc2.
                       s));_5.0).WithTimeout(1.0-AndThen(intake.RunIntakeCommand(.
```

single a only to related conceptually are that commands for recommended is approach This more to related commands with well fare doesn't it However, concise. very is and subsystem, race cause can and unintuitive is objects subsystem other in passing subsystem: one than approach this Therefore, avoided. be should thus and dependencies, circular and conditions cases. those for only used be should and commands, subsystemsingle- for suited best is

### Factories Command Static

complicated However, commands. subsystemsingle- for great work methods factory Instance to need typically period) autonomous the during required often ones the (like actions robot that command inline an define to want we When once. at subsystems multiple coordinate single any in live to factory command the for sense make doesn't it subsystems, multiple uses methods factory command the define to cleaner be can it Instead, subsystems. those of one class: external some in statically

---

parallel and sequential construct factories static `parallel` and `sequence` The :□□□□ be can but decorators, `alongWith` and `andThen` the to equivalent is this groups: command more readable. Their use is a matter of personal preference.

---

Java

```
                                                           { AutoRoutines class public

       { intake) Intake drivetrain, (DrivetraindriveAndIntake Command static public
                                                     (sequenceCommands. return
                                                        (parallelCommands.
                                    ),0.5 ,0.5(driveCommanddrivetrain.
                                          )1.0(runIntakeCommandintake.
                                                       ),5.0(withTimeout).
                                                        (parallelCommands.
                                               ();stopCommanddrivetrain.
                                                   ();stopCommandintake.
                                                                         )
                                                                            );
                                                                                 }
                                                                                     }
```

C++

```
                                                                               TODO //
```

### Factories Command StaticNon-

factory our to parameters as subsystems required adding of verbosity the avoid to want we If our inject and class `AutoRoutines` our of instance an construct instead can we methods, constructor: the through subsystems

Java

```
                              { AutoRoutines class public

                          drivetrain; Drivetrain private

                              intake; Intake private

            { intake) Intake drivetrain, (DrivetrainAutoRoutines public
                          drivetrain; = drivetrain.this
                              intake; = intake.this
                                        }

                         { ()driveAndIntake Command public
                           (sequenceCommands. return
                            (parallelCommands.
                  ),0.5 ,0.5(driveCommanddrivetrain.
                     )1.0(runIntakeCommandintake.
                            ),5.0(withTimeout).
                            (parallelCommands.
                        ();stopCommanddrivetrain.
                          ();stopCommandintake.
                                     )
                                      );
                                        }

                        { ()driveThenIntake Command public
                           (sequenceCommands. return
            ),5.0(withTimeout).0.5 ,0.5(driveCommanddrivetrain.
                         (),stopCommanddrivetrain.
              ),5.0(withTimeout).1.0(runIntakeCommandintake.
                           ()stopCommandintake.
                                      );
                                        }
                                          }
```

C++

```
                                   TODO //
```

to it use and class this of instance single an instantiate can we code, our in elsewhere Then, commands: several produce

Java

```
      );intake.this ,drivetrain.thisAutoRoutines( new = autoRoutines AutoRoutines

                ();driveAndIntakeautoRoutines. = driveAndIntake Command
               ();driveThenIntakeautoRoutines. = driveThenIntake Command

                (sequenceCommands. = drivingAndIntakingSequence Command
                           (),driveAndIntakeautoRoutines.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                        ()driveThenIntakeautoRoutines.
                                                                    );
```

C++

```
                                                              TODO //
```

### Commands Inline in State Capturing

support explicit offer not do but expressive, and concise extremely are commands Inline
following trajectory drivetrain a as (such state internal own their have that commands for
instead by accomplished often is This controller). entire an encapsulate may which command,
article. this in later covered be will which class, Command a writing

using composition command stateful a write ergonomically to possible still is it However,
state the declare we so, do To method. factory a within working are we as long so syntax, inline
following the consider example, For definition. inline our in it ”capture“ and local method a as
controller: PID a with angle specific a to drivetrain a turn to factory command instance

---

a of creation the sugar methods factory `Subsystem.runOnce` and `Subsystem.run` The :□□□□
subsystem. this requiring `InstantCommand` an and `RunCommand`

---

Java

```
                              { targetDegrees) double(turnToAngle Command public
                        capture to command inline the for controller a Create //
    );0 ,0 ,kTurnToAnglePPIDController(Constants. new = controller PIDController
␣returning before state created the on want we configuration whatever do can We //
                                                                factory the from ↪
                   );kTurnToAngleTolerance(Constants.setPositionTolerancecontroller.

  ␣the at re'we until error heading the to proportional rate a at turn to Try //
                                                               stop then setpoint, ↪
         ␣(),getHeading(gyro.calculatecontroller.-,0arcadeDrive( >- run(() return
                                                                targetDegrees))) ↪
                                              (controller::atSetpoint)until.
                               )));0 ,0arcadeDrive( >- (runOnce(()andThen.
                                                                           }
```

C++

```
                                                              TODO //
```

is it i.e., - final“ ”effectively is state captured the as long so Java in well very works pattern This
(e.g. types primitive capture and define directly cannot we that means This reassigned. never
mutable a in primitives state any wrap to need we this, circumvent to - )*boolean* ,*double* ,*int*
values). *kD* and ,*kI* ,*kP* internal its wraps *PIDController* way same (the type container

## Classes Command Writing

represents that class a write to is commands reusable define to way possible Another the of one or `CommandBase` either subclassing by done typically is This command. the classes. `CommandGroup`

### CommandBase Subclassing

new a creating by this do could we earlier, from command intake simple our to Returning methods. end and `initialize` necessary the implements that `CommandBase` of subclass

Java

```
{ CommandBase extends RunIntakeCommand class public
  m_intake; Intake private

  { intake) (IntakeRunIntakeCommand public
    intake; = m_intake.this
    addRequirements(intake);
  }

  @Override
  { ()initialize void public
    );1.0(setm_intake.
  }

  @Override
  { interrupted) boolean(end void public
    );0.0(setm_intake.
  }

  nothing do to defaults execute() //
  false return to defaults isFinished() //
}
```

C++

```
TODO //
```

The verbose. more not if code, repetitive original the as cumbersome as just is however, This, there yet ,`intake.set()` to calls two the are file entire this in matter really that lines two only actions robot of lot a for this doing mention, to Not code! boilerplate of lines 20 over are feel might this Nevertheless, files. small of dozens with project robot a up clutters quickly orientedobject- an to closely stick to prefer who programmers for particularly ”natural,“ more model.

state!), subsystem (not state internal with commands for used be should approach This write to intuitive more be also may It state. said manage to fields have can class the as command with experienced less those for especially classes, as logic complex with commands the and class subsystem specific any from detached is command the As composition. well deals approach this constructor, the through injected are objects subsystem required subsystems. multiple involving commands with

### Groups Command Subclassing

constructor- a write may we classes, own their as commands composite write to wish we If sequence outtakethen-intake- an example, For type. group exterior most the of subclass only this: like look can methods) factory instance as defined commands subsystemsingle- (with

Java

```
                    { SequentialCommandGroup extends IntakeThenOuttake class public
                                        { intake) (IntakeIntakeThenOuttake public
                                                                        (super
                         ),2.0(withTimeout).1.0(runIntakeCommandintake.
                                                 ),2.0WaitCommand( new
                          )5.0(withTimeout).1-(runIntakeCommandintake.
                                                                           );
                                                                              }
                                                                                }
```

C++

```
                                                                          TODO //
```

purely a in use to comfortable also is It boilerplate. minimizes and short relatively is This However, programmers. novice to acceptable more be may and paradigm orientedobject- command of type what exactly clear immediately not is it one, For downsides. some has it and inline more a in this define to better is it definition: constructor the from is this group it Additionally, up. showing start groups command nested when particularly way, expressive conceptually are groups the when even group, command single every for file new a requires related.

group command the within captured and defined be can state methods, factory with As necessary. if constructor, subclass

### Summary

| Approach | Use Primary Case | Single-subsystem Commands | Multi-subsystem Commands | Stateful Commands | Logic Complex Commands |
|---|---|---|---|---|---|
| Instance Factory Methods | Single-subsystem commands | at Excels them | No | but Yes, obey must capture rules | Yes |
| Subclassing CommandBase | Stateful commands | Very verbose | Relatively verbose | at Excels them | more be may Yes; than natural approaches other |
| and Static Instance Command Factories | Multi-subsystem commands | Yes | Yes | but Yes, obey must capture rules | Yes |
| Subclassing Command Groups | Multi-subsystem command groups | Yes | Yes | but Yes, obey must capture rules | Yes |

# Scheduler Command The 24.8

commands. running actually for responsible class the is )C++ ,Java( `CommandScheduler` The buttons, registered all polls scheduler the 20ms), per once (ordinarily iteration Each scheduled all of bodies command the runs accordingly, execution for commands schedules interrupted. are or finished have that commands those ends and commands,

.`Subsystem` registered each of method `periodic()` the runs also `CommandScheduler` The

## Scheduler Command the Using 24.8.1

with class accessibleglobally- a is it that meaning ,*singleton* a is `CommandScheduler` The the call must users scheduler, the access to order in Accordingly, instance. one only command. `CommandScheduler.getInstance()`

important all almost - directly methods scheduler call to have not do users part, most the For `Subsystem` and `Command` the in (e.g. elsewhere wrappers convenience have methods scheduler interfaces).

`CommandScheduler.getInstance().run()` call *must* users exception: one is there However, will scheduler the done, not is this If class. `Robot` their of method `robotPeriodic()` the from project basedcommand- provided The work. not will framework command the and run, never included. already call this has template

## Method `schedule()` The 24.8.2

a takes method This ).C++ ,Java( method `schedule()` the call users command, a schedule To it whether pending commands, runningcurrently- of list to it add to attempts and command, `initialize()` its added, is it If available. are requirements its whether or running already is called. is method

steps: following the through walks method This

composition. a in isn't command the that Verifies 1.

and disabled is robot or scheduled, already is command disabled, is scheduler if opNo- 2.
<commands:runsWhenDisabled>. doesn't command

them. cancel interruptible, are commands conflicting all If * use: in are requirements If 3.
command. new the schedule don't not, If *

.`initialize()` Call 4.

Java

```
                                            { command) (Commandschedule void private
                                                            { )null == (command if
           );true ,"command null a schedule to Tried"(reportWarningDriverStation.
                                                                         ;return
                                                                                 }
                                                                { (m_inRunLoop) if
                                                      (command);addm_toSchedule.
                                                                         ;return
                                                                                 }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
requireNotComposed(command);

␣command the and disabled is robot the disabled, is scheduler the if nothing Do //
t'doesn ↪
scheduled. already is command the or disabled, when run //
(m_disabled if
isScheduled(command) ||
{ ())runsWhenDisabledcommand.! && ()isDisabledRobotState. ||
;return
}

();getRequirementscommand. = requirements >Subsystem<Set

in-use. currently not are requirements the if command the Schedule //
{ requirements)) (),keySet(m_requirements.disjoint(Collections. if
requirements); initCommand(command,
{ else }
␣interruptible have all have use in are that requirements the if check Else //
commands, ↪
command. new the schedule and commands those interrupt so, if and //
{ requirements) : requirement (Subsystem for
requiring(requirement); = requiring Command
null =! (requiring if
InterruptionBehavior. == ()getInterruptionBehaviorrequiring. &&
{ )kCancelIncoming ↪
;return
}
}
{ requirements) : requirement (Subsystem for
requiring(requirement); = requiring Command
{ )null =! (requiring if
cancel(requiring);
}
}
requirements); initCommand(command,
}
}
```

```
{ requirements) >Subsystem<Set command, (CommandinitCommand void private
(command);addm_scheduledCommands.
{ requirements) : requirement (Subsystem for
command); (requirement,putm_requirements.
}
();initializecommand.
{ m_initActions) : action >Command<(Consumer for
(command);acceptaction.
}

);"initialize()." + ()getName(command.addEpochm_watchdog.
```

(Source) C++

```
{ command) *(CommandCommandScheduler::Schedule void
{ inRunLoop)>-(m_impl if
toSchedule.emplace_back(command);>-m_impl
;return
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                                    }

                                                           RequireUngrouped(command);

               || scheduledCommands.contains(command)>-m_impl || disabled>-(m_impl if
               { RunsWhenDisabled()))>-command! && IsDisabled()::RobotState::(frc
                                                                            ;return
                                                                                    }

                               GetRequirements();>-command = requirements &auto const

                                          intersection; >8 ,*Command<SmallVector::wpi

                                                              ;true = isDisjoint bool
                                                        ;true = allInterruptible bool
                                             { requirements)>-m_impl : i1 &&auto( for
                           { requirements.end()) =! (requirements.find(i1.first) if
                                                              ;false = isDisjoint
                     == GetInterruptionBehavior()>-(i1.second =& allInterruptible
                kCancelSelf);::InterruptionBehavior::Command
                                            intersection.emplace_back(i1.second);
                                                                                  }
                                                                                    }

                                                { allInterruptible) || (isDisjoint if
                                                            { (allInterruptible) if
                                        { intersection) : cmdToCancel &&auto( for
                                                           Cancel(cmdToCancel);
                                                                                }
                                                                                  }
                                         scheduledCommands.insert(command);>-m_impl
                                          { requirements) : requirement &&auto( for
                                     command; = requirements[requirement]>-m_impl
                                                                                  }
                                                             Initialize();>-command
                                        { initActions)>-m_impl : action &&auto( for
                                                                command);*action(
                                                                                  }
                         );"Initialize()." + GetName()>-m_watchdog.AddEpoch(command
                                                                                    }
                                                                                      }
```

### Sequence Run Scheduler The 24.8.3

scheduled, is command the when called is Command each of method `initialize()` The :□□□□
button). a to bound is command that (unless runs scheduler the when necessarily not is which

The do? actually )C++ ,Java( method `run()` scheduler's the of iteration single a does What implementation, full the For iteration. scheduler a of logic the through walks section following ).C++ ,Java( code source the see

### Methods Periodic Subsystem Run :1 Step

simulation, In .`Subsystem` registered each of method `periodic()` the runs scheduler the First, well. as called is method `simulationPeriodic()` subsystem’s each

Java

```
                      subsystems. registered all of method periodic the Run //
                           { ())keySetm_subsystems. : subsystem (Subsystem for
                                                        ();periodicsubsystem.
                                              { ())isSimulation(RobotBase. if
                                              ();simulationPeriodicsubsystem.
                                                                            }
);"periodic()." + ()getSimpleName().getClass(subsystem.addEpochm_watchdog.
                                                                            }
```

(Source) C++

```
                      subsystems. registered all of method periodic the Run //
                           { subsystems)>-m_impl : subsystem &&auto( for
                                                   Periodic();>-subsystem.getFirst()
                             { IsSimulation())::RobotBase::(frc constexpr if
                               SimulationPeriodic();>-subsystem.getFirst()
                                                                            }
                               );"Periodic() Subsystem"m_watchdog.AddEpoch(
                                                                            }
```

### Triggers Scheduling Command Poll :2 Step

---

*Triggers-□ Commands* □□□□□ see work, bindings trigger how on information more For :□□□□

---

commands new any if see to triggers registered all of state the polls scheduler the Secondly, scheduling for conditions the If scheduled. be should triggers those to bound been have that run. is method `Initialize()` its and scheduled is command the met, are command bound a

Java

```
                      add. to commands new for buttons Poll //
                                               ();pollloopCache.
                           );"buttons.run()"(addEpochm_watchdog.
```

(Source) C++

```
                      add. to commands new for buttons Poll //
                                               Poll();>-loopCache
                             );"buttons.Run()"m_watchdog.AddEpoch(
```

### Commands Scheduled Run/Finish :3 Step

and command, scheduledcurrently- each of method `execute()` the calls scheduler the Thirdly, the If method. `isFinished()` the calling by finished has command the whether checks then scheduledde- is command the and called, also is method `end()` the finished, has command freed. are subsystems required its and

may command one thus, - command each for order in done is calls of sequence this that Note Commands called. method `execute()` its has another before called method `end()` its have scheduled. were they order the in handled are

Java

```
                        commands. finished remove commands, scheduled Run //
     iterator. ();iteratorm_scheduledCommands. = iterator >Command<(Iterator for
                                                               { ) ();hasNext ↪
                                      ();nextiterator. = command Command

                      { ())isDisabledRobotState. && ()runsWhenDisabledcommand.!( if
                                                      );true(endcommand.
                          { m_interruptActions) : action >Command<(Consumer for
                                                   (command);acceptaction.
                                                                          }
                 ());getRequirements(command.removeAll().keySetm_requirements.
                                                      ();removeiterator.
                        );"end(true)." + ()getName(command.addEpochm_watchdog.
                                                               ;continue
                                                                          }

[redacted]
                             { m_executeActions) : action >Command<(Consumer for
                                                   (command);acceptaction.
                                                                          }
                         );"execute()." + ()getName(command.addEpochm_watchdog.
[redacted]
                            { m_finishActions) : action >Command<(Consumer for
                                                   (command);acceptaction.
                                                                          }
                                                      ();removeiterator.

                 ());getRequirements(command.removeAll().keySetm_requirements.
                       );"end(false)." + ()getName(command.addEpochm_watchdog.
                                                                          }
                                                                            }
```

(Source) C++

```
                              { scheduledCommands)>-m_impl : command *(Command for
           { IsDisabled())::RobotState::frc && RunsWhenDisabled()>-command!( if
                                                          Cancel(command);
                                                                 ;continue
                                                                          }

[redacted]
                                   { executeActions)>-m_impl : action &&auto( for
                                                          command);*action(
                                                                          }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                          );"Execute()." + GetName()>-m_watchdog.AddEpoch(command

[redacted]
                                { finishActions)>-m_impl : action &&auto( for
                                                command);*action(
                                                               }

                     { GetRequirements())>-command : requirement &&auto( for
                                 requirements.erase(requirement);>-m_impl
                                                               }

                                  scheduledCommands.erase(command);>-m_impl
                    );"End(false)." + GetName()>-m_watchdog.AddEpoch(command
                                                                 }
                                                                   }
```

### Commands Default Schedule :4 Step

Note  one). has it (if scheduled command default its has `Subsystem` registered any Finally, time. this at called be will command default the of method `initialize()` the that

Java

```
                  subsystems. registered un-required for commands default Add //
  { ())entrySetm_subsystems. : subsystemCommand >Command Subsystem,<Entry(Map. for
                      ())getKey(subsystemCommand.containsKeym_requirements.!( if
                                      { )null =! ()getValuesubsystemCommand. &&
                                           ());getValueschedule(subsystemCommand.
                                                                          }
                                                                            }
```

(Source) C++

```
                   subsystems. registered un-required for commands default Add //
                                   { subsystems)>-m_impl : subsystem &&auto( for
                        requirements.find(subsystem.getFirst());>-m_impl = s auto
                 { subsystem.getSecond()) && requirements.end()>-m_impl == (s if
                                       Schedule({subsystem.getSecond().get()});
                                                                            }
                                                                              }
```

### Scheduler the Disabling 24.8.4

`.CommandScheduler.getInstance().disable()` calling by disabled be can scheduler The anything. do not will commands `run()` and `schedule()` scheduler’s the disabled, When

`.CommandScheduler.getInstance().enable()` calling by enabledre- be may scheduler The

### 24.8.5 Command Event Methods

Occasionally, it is desirable to have the scheduler execute a custom action whenever a certain command event (initialization, execution, or ending) occurs. This can be done with the following methods:

- `onCommandInitialize` (Java, C++) runs a specified action whenever a command is initialized.
- `onCommandExecute` (Java, C++) runs a specified action whenever a command is executed.
- `onCommandFinish` (Java, C++) runs a specified action whenever a command finishes normally (i.e. the `isFinished()` method returned true).
- `onCommandInterrupt` (Java, C++) runs a specified action whenever a command is interrupted (i.e. by being explicitly canceled or by another command that shares one of its requirements).

A typical use-case for these methods is adding markers in an event log whenever a command scheduling event takes place, as demonstrated in the following code from the HatchbotInlined example project (Java, C++):

Java

```java
// Set the scheduler to log Shuffleboard events for command initialize, interrupt,
↪ finish
CommandScheduler.getInstance()
    .onCommandInitialize(
        command ->
            Shuffleboard.addEventMarker(
                "Command initialized", command.getName(), EventImportance.
↪ kNormal));
CommandScheduler.getInstance()
    .onCommandInterrupt(
        command ->
            Shuffleboard.addEventMarker(
                "Command interrupted", command.getName(), EventImportance.
↪ kNormal));
CommandScheduler.getInstance()
    .onCommandFinish(
        command ->
            Shuffleboard.addEventMarker(
                "Command finished", command.getName(), EventImportance.kNormal));
```

C++ (Source)

```cpp
// Log Shuffleboard events for command initialize, execute, finish, interrupt
frc2::CommandScheduler::GetInstance().OnCommandInitialize(
    [](const frc2::Command& command) {
      frc::Shuffleboard::AddEventMarker(
          "Command initialized", command.GetName(),
          frc::ShuffleboardEventImportance::kNormal);
    });
frc2::CommandScheduler::GetInstance().OnCommandExecute(
    [](const frc2::Command& command) {
      frc::Shuffleboard::AddEventMarker(
          "Command executed", command.GetName(),
          frc::ShuffleboardEventImportance::kNormal);
    });
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                              GetInstance().OnCommandFinish(::CommandScheduler::frc2
                                              { command) &Command::frc2 const[](
                                            AddEventMarker(::Shuffleboard::frc
                                    command.GetName(), ,"finished Command"
                               kNormal);::ShuffleboardEventImportance::frc
                                                                             );}
                           GetInstance().OnCommandInterrupt(::CommandScheduler::frc2
                                              { command) &Command::frc2 const[](
                                            AddEventMarker(::Shuffleboard::frc
                                 command.GetName(), ,"interrupted Command"
                               kNormal);::ShuffleboardEventImportance::frc
                                                                             );}
```

## Commands C++ on Discussion Technical A 24.9

---

concepts, C++ advanced of understanding fair a have you that assumes article This :□□□□ move semantics, copy references, rvalue inheritance, pointers, smart templates, including use to article this within information the understand to need not do You CRTP. and semantics, code. robot your in framework basedcommand- the

---

the in made decisions the of some behind reasoning the understand you help will article This of form the in CRTP ,`std::unique_ptr` of use the as (such framework basedcommand- 2020 within information the understand to need not do You etc.). ,`>Derived <Base,CommandHelper` code. robot your in framework basedcommand- the use to article this

---

.*below* described as 2023, in changed further was model The :□□□□

---

### Model Ownership 24.9.1

users that meaning pointers, raw of use the employed framework basedcommand- old The no was there Since code. robot their in allocations) heap manual in (resulting `new` use to had the or groups, command the scheduler, (the commands the owned who on indication clear memory. the freeing of care take to supposed was who apparent not was it themselves), user

this: like code involved framework basedcommand- old the in examples Several

```
                                                                PlaceSoda.h"" include#
                                                                 Elevator.h"" include#
                                                                    Wrist.h"" include#

                                                              { PlaceSoda()::PlaceSoda
                     TABLE_HEIGHT));::SetElevatorSetpoint(Elevator newAddSequential(
                                 PICKUP));::SetWristSetpoint(Wrist newAddSequential(
                                                      OpenClaw()); newAddSequential(
                                                                                     }
```

being were group command the of commands component the above, groupcommand- the In had user that meant This line. same the in all `AddSequential` into passed and allocated heap

allocated the freeing of means no had therefore and memory in object that to reference no
memory the freed never itself group command The ended. group command the once memory
(i.e. programs robot in leaks memory to led This scheduler. command the did neither and
freed). never but heap the on allocated was memory

A framework. the of rewrite the for reasons the of one was problem glaring This
of usage the with along rewrite, this with introduced was model ownership comprehensive
scope. of out go they when memory free automatically will which pointers smart

commands component whereas scheduler command the by owned are commands Default
are commands Other composition. command the by owned are compositions command of
or instance subsystem a (e.g. by owned be should they decides user the whatever by owned
any by allocated memory the of ownership the that means This instance). `RobotContainer` a
defined. clearly is compositions command or commands

### `std::shared_ptr` vs. `std::unique_ptr`

object. the owns who determine clearly to us allows `std::unique_ptr` Using
than more be never will there copied, be cannot `std::unique_ptr` an Because
on memory of block same the to points that `std::unique_ptr` a of instance one
a in takes `SequentialCommandGroup` for constructor a example, For heap. the
rvalue an requires it that means This `.>&&>Command<std::unique_ptrstd::vector`
code example some through go Let's `.>Command<std::unique_ptr` of vector a to reference
better: this understand to stepby-step-

```
        sequentially. run to want we that commands our store to vector a create s'Let //
                                         commands; >>Command<unique_ptr::std<vector::std

                                console. the to prints that command instant an Add //
  ␣,} ;"Hello" << cout::std ([]{>InstantCommand<make_unique::commands.emplace_back(std
                                                                   requirements)); ↪

                    created. has user a that something be can this command: other some Add //
 command)); ,this ,for needed, (args,>MyCommand<make_unique::commands.emplace_back(std

␣vector the when state, current its In commands. these of all owns"" vector the Now //
                                                                  (i.e. destroyed is ↪
           added. just we commands the of all destroy will it scope), of out goes it //

                ␣commands two these run will that SequentialCommandGroup a create s'Let //
                                                                       sequentially. ↪
                              move(commands));::SequentialCommandGroup(std = group auto

          ␣group, command sequential the into commands of vector the MOVED we that Note //
                                                                      the that meaning ↪
        ␣the on std::move call we When commands. our of ownership has now group command //
                                                                     its of all vector, ↪
               group. command the into moved are instances) unique_ptr the (i.e. contents //

          ␣running, was group command the while destroyed be to were vector the if Even //
                                                                    OK be would everything ↪
                             anymore. commands our own not does vector the since //
```

multiple be can there because model ownership clear no is there ,`std::shared_ptr` With
commands If memory. of block same the to point that `std::shared_ptr` a of instances
cannot scheduler command the or group command a instances, `std::shared_ptr` in were

the because executing finished has command the once memory the free and ownership take of block that to pointing instance `std::shared_ptr` a have still unknowingly still might user scope. in somewhere memory

## CRTP of Use 24.9.2

extend must you command, new a create to order in that noticed have may You you that class the and )`frc2::CommandBase` (usually class base the providing ,`CommandHelper` this: behind reasoning the at look a take Let's created. just

### Decorators Command

decorators", "command as known feature a includes framework basedcommand- new The this: like something to user the allows which

```
    ␣command my after printed This" << cout::std { MyCommand().AndThen([] = task auto
                                                                    ,} ;"ended. ↪
                                                                 requirements);
```

finished has command that once and `MyCommand()` execute first will it scheduled, is `task` When by is internally achieved is this way The console. the to message the print will it executing, group. command sequential a using

we group, command sequential a construct to order in that section previous the from Recall print the for pointer unique the Creating command. each to pointers unique of vector a need trivial: pretty is function

```
                                                             temp.emplace_back(
              requirements)); move(toRun),::(std>InstantCommand<make_unique::std
```

the into pass to need we that commands of vector the storing is `temp` Here need we ,`InstantCommand` that add we before But constructor. `SequentialCommandGroup` that? do we do How .`SequentialCommandGroup` the to `MyCommand()` add to

```
                   ));this*move(::(std>MyCommand<make_unique::temp.emplace_back(std
```

this Because case. the not is that but straightforward, this be would it think might You that subclass the in `Command` the to refers `*this` interface, `Command` the in is code decorator trying be will you Effectively, .`Command` of type the has and from decorator the calling are you and `MyCommand*` a to pointer `this` the cast could We .`MyCommand` of instead `Command` a move to time.compile- at to cast to subclass the about information no have we but it dereference then

### Problem the to Solutions

called `Command` in method virtual a create to was this to solution initial Our override an Such override. to had `Command` of subclass every that `TransferOwnership()` this: like looked have would

```
                      { override && TransferOwnership() >Command<unique_ptr::std
                         ));this*move(::(std>MyCommand<make_unique::std return
                                                                                 }
```

desired the to point actually would *this subclass, derived the in be would code the Because unique the make to class derived the of info type the has user the and instance subclass pointer.

derived intermediary an Here, proposed. was method CRTP a deliberation, of days few a After template two have would `CommandHelper` exist. would `CommandHelper` called `Command` of class a at look a take Let's subclass. derived desired the and class base original the arguments, this: understand to `CommandHelper` of implementation basic

```
         a actually is Base that check to SFINAE use we implementation, real the In //
                                               Command. of subclass a or Command //
                                           >Derived typename ,Base typename<template
                                                { Base public : CommandHelper class
    constructors. class) (base superclass the of all inheriting just are we Here, //
                                                               Base;::Base using

           above. mentioned method TransferOwnership() the override will we Here, //
                         { override && TransferOwnership() >Command<unique_ptr::std
    class derived the about information no had we that mentioned we Previously, //
template our of one s'It do! we CRTP of because but compile-time, at to cast to //
                                                                 arguments! //
        )));this(>*Derived<static_cast*move(::(std>Derived<make_unique::std return
                                                                               }
                                                                                ;}
```

will `Command` of instead `CommandHelper` extend commands custom your making Thus, teams asking behind reasoning the is this and you for boilerplate this implement automatically things. doing of way obscure rather a be to seem may what use to

following: the do now can we example, `AndThen()` our to back Going

```
            TransferOwnership() the call will we works, inheritance how of Because //
          only can TransferOwnership() because *this moving are We subclass. the of //
                                                 references. rvalue on called be //
                             ).TransferOwnership());this*move(::temp.emplace_back(std
```

## Decorators Advanced of Lack 24.9.3

commands actual of instead `><void()std::function` in take decorators C++ the of Most `,AndThen()` as such decorators in commands actual in taking of idea The themselves. reasons. of variety a to due abandoned then but considered was etc. `,BeforeStarting()`

### Decorators Templating

group command a to adding are we that commands the of types the know to need we Because However, commands). multiple for (variadic templates use to need will we time,compile- at anyway: this do groups command for constructors The deal. big a like seem not might this

```
                                                          Types, ...class< template
                            <conjunction_v::std<enable_if_t::std = typename
          >>>...>>Types<remove_reference_t::std Command,<is_base_of::std
                              { commands) ...&&SequentialCommandGroup(Types explicit
                                    (commands)...);>Types<forward::AddCommands(std
                                                                                }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                Types, ...class< template
                      <conjunction_v::std<enable_if_t::std = typename
          >>>...>>Types<remove_reference_t::std Command,<is_base_of::std
                                         { commands) ...&&AddCommands(Types void
                                  foo; >>Command<unique_ptr::std<vector::std
          (>>Types<remove_reference_t::std<make_unique::)foo.emplace_back(stdvoid((
                                         (commands))),>Types<forward::std
                                                                      );...
                                              move(foo));::AddCommands(std
                                                                            }
```

---

vector the to addition in `SequentialCommandGroup` for constructor secondary a is This :□□□□ above. described we that constructor

---

This inline. declared be must definition its function, templated a make we when However, header, `Command.h` the in `SequentialCommandGroup` the instantiate to need will we that means include we If .`Command.h` includes `SequentialCommandGroup.h` problem. a poses which do How dependency. circular a have we ,`Command.h` of inside `SequentialCommandGroup.h` then? now it do we

:`Command.h` of top the at declaration forward a use We

```
;SequentialCommandGroup class

;} ... { Command class
```

decorator these If .`Command.cpp` in `SequentialCommandGroup.h` include we then And resulting files, `cpp.` the in definitions write cannot we however, templated were functions dependency. circular a in

### Syntax C++ vs Java

calls) new raw requires Java (because Java in verbosity more save usually decorators These you if C++ in difference syntantic a of much make not does it general, in so C++, in than code. user in manually group command the create

## Updates 2023 24.9.4

create to way recommended the framework, basedcommand- new the in years few a After methods. factory and decorators, commands, inline towards shifted increasingly commands 2020 in introduced model commands C++ the that evident became it shift, paradigm this With recommendations. new the to according used when points pain some has above described and

a in value by passed being commands was points pain most of cause root significant A in changes and easy, rather mistakes slicing object made This way. polymorphicnon- if example, for codebase: the throughout changes type propagate could structure composition would changes type those ,`ParallelDeadlineGroup` a to changed were `ParallelRaceGroup` a Java) in done (as `Command` a as object the around Passing codebase. the through propagate slicing. object in result would

.*above* described reasons to due C++ in supported weren't decorators various Additionally,
was Java (where verbosity reduce to mainly were and used rarely were decorators as long As
was decorators of usage heavy Once problem. a of less was this C++), than verbose more
issue. an of more became this recommended,

### CommandPtr

move only with type value a above: far `std::unique_ptr` of mention the recall Let's
want! we model ownership the is This semantics.

Primarily, drawbacks. some had `><Commandstd::unique_ptr` using plainly However,
library standard the in defined is `unique_ptr` impossible: be would decorators implementing
access have wouldn't `Command` on defined methods any and it, on methods define can't we so
.`unique_ptr` owning the to

define can we that ,`unique_ptr` wrapping class value onlymove- a :`CommandPtr` is solution The
on. methods

decorators, All .`std::move` using ,`CommandPtr` as around passed be should Commands
this.rvalue- with `CommandPtr` on defined are before, C++ in supported not those including
avoid to easy very it makes ownership clear and semantics, onlymove- rvalues, of use The
.*composition command* one than more to instance command same the adding as such mistakes

as such methods utility define also instances `CommandPtr` decorators, to addition In
way every almost nearly in used be can instances `CommandPtr` .`IsScheduled()` ,`Schedule()`
default bindings, trigger into moved be can they Java: in used be can objects command
trigger owningnon- as (such `Command*` a require that things few the For on. so and commands,
.`get()` using retrieved be can command owned the to pointer raw a bindings),

instance: `CommandPtr` a get to ways multiple are There

- the in namespace `frc2::cmd` the in present are factories returning-`CommandPtr`
compositions, commandmulti- For types. command all almost for header `Commands.h`
multiple for overload templatedvariadic- a as well as overload takingvector- a is there
instances. `CommandPtr`
- allowed has This .`CommandPtr` return ,`Command` on defined those including decorators, All
.`Command` a from start can chain decorator a so ,`Command` on decorators all almost defining
- is This .`TransferOwnership` to akin CRTP, the to added been has method `ToPtr()` A
classes command other as well as classes, command defineduser- for especially useful
factories. have don't that

project example *HatchbotInlined* the from following the consider instance, For
:<*https://github.com/wpilibsuite/allwpilib/blob/v2023.2.1/wpilibcExamples/src/main/cpp/examples/Hatchbo*

```
                    drive, *(DriveSubsystemautos::ComplexAuto CommandPtr::frc2
                  { hatch) *HatchSubsystem
                                               Sequence(::cmd::frc2 return
                                 distance specified the forward Drive //
                                            FunctionalCommand(::frc2
                                  start command on encoders Reset //
                                ,} ResetEncoders();>-drive { [drive]
                      executing is command the while forward Drive //
                  ,} );0 ArcadeDrive(kAutoDriveSpeed,>-drive { [drive]
                            command the of end the at driving Stop //
               ,} );0 ,0ArcadeDrive(>-drive { interrupted) bool[drive](
          the exceeds distance driven s'robot the when command the End //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
value desired //
{ [drive]
=> GetAverageEncoderDistance()>-drive return
kAutoDriveDistanceInches;
,}
subsystem drive the Requires //
drive}){
ToPtr(),.
hatch the Release //
ReleaseHatchCommand(),>-hatch
distance specified the backward Drive //
distance specified the forward Drive //
FunctionalCommand(::frc2
start command on encoders Reset //
,} ResetEncoders();>-drive { [drive]
executing is command the while backward Drive //
,} );0 kAutoDriveSpeed,-ArcadeDrive(>-drive { [drive]
command the of end the at driving Stop //
,} );0 ,0ArcadeDrive(>-drive { interrupted) bool[drive](
the exceeds distance driven s'robot the when command the End //
value desired //
{ [drive]
=< GetAverageEncoderDistance()>-drive return
kAutoBackupDistanceInches;
,}
subsystem drive the Requires //
drive}){
ToPtr());.
}
```

CommandPtr so ,><Commandunique_ptr use still compositions command breakage, avoid To thisrvalue- Unwrap() the using ><Commandunique_ptr a into destructured be can instances function >)<CommandPtrCommandPtr::UnwrapVector(vector static the vectors, For method. exists.

## and PIDSubsystems through Control PID 24.10 PIDCommands

---

basedcommand- these by used features control PID WPILib the of description a For :□□□□ .*WPILib* □□ *PID* □□□□ see wrappers,

---

WPILib controller. *PID* the is FRC® in used algorithms control common most the of One their on functionality this implement teams help to class *PIDController* own its offers project, robot basedcommand- a into control PID integrate teams help further To robots. class: `PIDController` the for wrappers convenience two includes library basedcommand- the which ,`PIDCommand` and subsystem, a into controller PID the integrates which ,`PIDSubsystem` command. a into controller PID the integrates

## PIDSubsystems 24.10.1

a with subsystem a create conveniently to users allows )C++ ,Java( class `PIDSubsystem` The subclass a create must users class, `PIDSubsystem` the use to order In .`PIDController` inbuilt-it. of

### PIDSubsystem a Creating

---

call to sure make ,`PIDSubsystem` from inheriting when overridden is `periodic` If :□□□□ properly. work not will functionality PID Otherwise, !`super.periodic()`

---

provide to methods abstract two override must users ,`PIDSubsystem` subclassing When operation: ordinary its in use will class the that functionality

#### getMeasurement()

Java

```
();getMeasurement double abstract protected
```

C++

```
;0 = ()GetMeasurement double virtual
```

The variable. process the of measurement current the returns method `getMeasurement` The its pass and block, `periodic()` its from method this call automatically will `PIDSubsystem` loop. control the to value

their as use to wish they reading sensor whatever return to method this override should Users measurement. variable process

#### useOutput()

Java

```
setpoint); double output, double(useOutput void abstract protected
```

C++

```
;0 = setpoint) double output, double(UseOutput void virtual
```

setpoint current the and controller, PID the of output the consumes method `useOutput()` The automatically will `PIDSubsystem` The feedforward). a computing for useful often is (which control the of output computed the it pass and block, `periodic()` its from method this call loop.

their to output control computed final the pass to method this override should Users motors. subsystem’s

### Controller the In Passing

the through class base `PIDSubsystem` the to `PIDController` a in pass also must Users well as gains, PID the specify to serves This subclass. their of call constructor superclass period). loop robot main standardnon- a using is user the (if period the as

the in controller the to made be can input) continuous enabling (e.g. modifications Additional .`getController()` calling by body constructor

### PIDSubsystem a Using

commands by used be can it created, been has subclass `PIDSubsystem` a of instance an Once methods: following the through

### setSetpoint()

The .`PIDSubsystem` the of setpoint the set to used be can method `setSetpoint()` The output: defined the using setpoint the to track automatically will subsystem

Java

```
5. of setpoint a to track will subsystem The //
);5(setSetpointexamplePIDSubsystem.
```

C++

```
5. of setpoint a to track will subsystem The //
);5examplePIDSubsystem.SetSetpoint(
```

### disable() and enable()

the of control PID the disable and enable methods `disable()` and `enable()` The loop control the run automatically will it enabled, is subsystem the When .`PIDSubsystem` performed. is control no disabled, is it When setpoint. the track and

`disable()` the and ,`PIDController` internal the resets method `enable()` the Additionally, .`0` to set setpoint and output both with method *useOutput()* defineduser- the calls method

### Example PIDSubsystem Full

taken are examples following The practice? in used when like look `PIDSubsystem` a does What ):C++ ,Java( project example FrisbeeBot the from

Java

```
;edu.wpi.first.wpilibj.examples.frisbeebot.subsystems package

;edu.wpi.first.math.controller.PIDController import
;edu.wpi.first.math.controller.SimpleMotorFeedforward import
;edu.wpi.first.wpilibj.Encoder import
;edu.wpi.first.wpilibj.examples.frisbeebot.Constants.ShooterConstants import
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                          ;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import
                              ;edu.wpi.first.wpilibj2.command.PIDSubsystem import

                               { PIDSubsystem extends ShooterSubsystem class public
  PWMSparkMax(ShooterConstants. new = m_shooterMotor PWMSparkMax final private
                                                            );kShooterMotorPort ↪
   PWMSparkMax(ShooterConstants. new = m_feederMotor PWMSparkMax final private
                                                             );kFeederMotorPort ↪
                                  = m_shooterEncoder Encoder final private
                                                              Encoder( new
                                    ,]0[kEncoderPortsShooterConstants.
                                    ,]1[kEncoderPortsShooterConstants.
                                   );kEncoderReversedShooterConstants.
                  = m_shooterFeedforward SimpleMotorFeedforward final private
                                               SimpleMotorFeedforward( new
    );kVVoltSecondsPerRotationShooterConstants. ,kSVoltsShooterConstants.

                                */ robot. the for subsystem shooter The **/
                                             { ()ShooterSubsystem public
             ␣,kIShooterConstants. ,kPPIDController(ShooterConstants. new(super
                                                      ));kDShooterConstants. ↪
            );kShooterToleranceRPS(ShooterConstants.setTolerancegetController().
 );kEncoderDistancePerPulse(ShooterConstants.setDistancePerPulsem_shooterEncoder.
                              );kShooterTargetRPSsetSetpoint(ShooterConstants.
                                                                          }

                                                                  @Override
                           { setpoint) double output, double(useOutput void public
    (setpoint));calculatem_shooterFeedforward. + (outputsetVoltagem_shooterMotor.
                                                                          }

                                                                  @Override
                                          { ()getMeasurement double public
                                         ();getRatem_shooterEncoder. return
                                                                          }

                                            { ()atSetpoint boolean public
                                         ();atSetpointm_controller. return
                                                                          }

                                                { ()runFeeder void public
                             );kFeederSpeed(ShooterConstants.setm_feederMotor.
                                                                          }

                                               { ()stopFeeder void public
                                                   );0(setm_feederMotor.
                                                                          }
                                                                            }
```

(Header) C++

```
                                                               once pragma#

                                                  frc/Encoder.h>< include#
                            frc/controller/SimpleMotorFeedforward.h>< include#
                                   frc/motorcontrol/PWMSparkMax.h>< include#
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
frc2/command/PIDSubsystem.h>< include#
units/angle.h>< include#

{ PIDSubsystem::frc2 public : ShooterSubsystem class
:public
ShooterSubsystem();

;override setpoint) double output, double(UseOutput void

;override ()GetMeasurement double

();AtSetpoint bool

();RunFeeder void

();StopFeeder void

:private
m_shooterMotor; PWMSparkMax::frc
m_feederMotor; PWMSparkMax::frc
m_shooterEncoder; Encoder::frc
m_shooterFeedforward; >turns::units<SimpleMotorFeedforward::frc
;}
```

(Source) C++

```
subsystems/ShooterSubsystem.h"" include#

frc/controller/PIDController.h>< include#

Constants.h"" include#

;ShooterConstants namespace using

ShooterSubsystem()::ShooterSubsystem
kD}}, kI, PIDController{kP,::PIDSubsystem{frc2 :
m_shooterMotor(kShooterMotorPort),
m_feederMotor(kFeederMotorPort),
]),1kEncoderPorts[ ],0m_shooterEncoder(kEncoderPorts[
{ kV) m_shooterFeedforward(kS,
m_controller.SetTolerance(kShooterToleranceRPS.value());
m_shooterEncoder.SetDistancePerPulse(kEncoderDistancePerPulse);
SetSetpoint(kShooterTargetRPS.value());
}

{ setpoint) double output, doubleUseOutput(::ShooterSubsystem void
+ volt_t{output}::m_shooterMotor.SetVoltage(units
m_shooterFeedforward.Calculate(kShooterTargetRPS));
}

{ AtSetpoint()::ShooterSubsystem bool
m_controller.AtSetpoint(); return
}

{ GetMeasurement()::ShooterSubsystem double
m_shooterEncoder.GetRate(); return
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                   }

                         { RunFeeder()::ShooterSubsystem void
                           m_feederMotor.Set(kFeederSpeed);
                                                   }

                        { StopFeeder()::ShooterSubsystem void
                                       );0m_feederMotor.Set(
                                                   }
```

simple: very be can commands with PIDSubsystem a Using

Java

```
  m_ (m_shooter::enable,runOnceCommands. = m_spinUpShooter Command final private
                                                                       shooter); ↪
   m_ (m_shooter::disable,runOnceCommands. = m_stopShooter Command final private
                                                                       shooter); ↪

  RobotContainer in them to references retaining while commands bind can We //

                          pressed is button 'A' the when shooter the up Spin //
                                (m_spinUpShooter);onTrue().am_driverController.

                         pressed is button 'B' the when shooter the off Turn //
                                  (m_stopShooter);onTrue().bm_driverController.
```

(Header) C++

```
                                       = m_spinUpShooter CommandPtr::frc2
        m_shooter});&{ ,} m_shooter.Enable(); { ]thisRunOnce([::cmd::frc2

                                         = m_stopShooter CommandPtr::frc2
       m_shooter});&{ ,} m_shooter.Disable(); { ]thisRunOnce([::cmd::frc2
```

(Source) C++

```
        RobotContainer in ownership their keeping while commands bind can We //

                            pressed is button 'A' the when shooter the up Spin //
                            m_driverController.A().OnTrue(m_spinUpShooter.get());

                           pressed is button 'B' the when shooter the off Turn //
                              m_driverController.B().OnTrue(m_stopShooter.get());
```

### PIDCommand 24.10.2

PIDController. inbuilt- a with commands create easily to users allows class `PIDCommand` The

## Creating a PIDCommand

A PIDCommand can be created two ways - by subclassing the PIDCommand class, or by defining the command *inline*. Both methods ultimately extremely similar, and ultimately the choice of which to use comes down to where the user desires that the relevant code be located.

---

**□□□□:** If subclassing PIDCommand and overriding any methods, make sure to call the `super` version of those methods! Otherwise, PID functionality will not work properly.

---

In either case, a PIDCommand is created by passing the necessary parameters to its constructor (if defining a subclass, this can be done with a *super()* call):

Java

```java
/**
 * Creates a new PIDCommand, which controls the given output with a PIDController.
 *
 * @param controller the controller that controls the output.
 * @param measurementSource the measurement of the process variable
 * @param setpointSource the controller's setpoint
 * @param useOutput the controller's output
 * @param requirements the subsystems required by this command
 */
public PIDCommand(
    PIDController controller,
    DoubleSupplier measurementSource,
    DoubleSupplier setpointSource,
    DoubleConsumer useOutput,
    Subsystem... requirements) {
```

C++

```cpp
/**
 * Creates a new PIDCommand, which controls the given output with a
 * PIDController.
 *
 * @param controller        the controller that controls the output.
 * @param measurementSource the measurement of the process variable
 * @param setpointSource    the controller's reference (aka setpoint)
 * @param useOutput         the controller's output
 * @param requirements      the subsystems required by this command
 */
PIDCommand(PIDController controller,
           std::function<double()> measurementSource,
           std::function<double()> setpointSource,
           std::function<void(double)> useOutput,
           std::initializer_list<Subsystem*> requirements);
```

### controller

command. the by used be will that object `PIDController` the is parameter `controller` The the (if controller the for period the and gains PID the specify can users in, this passing By period). loop robot main nonstandard a using is user

can input) continuous enabling (e.g. modifications additional ,`PIDCommand` subclassing When .`getController()` calling by body constructor the in controller the to made be

### measurementSource

returns that )*lambda* a as passed (usually function a is parameter `measurementSource` The function `measurementSource` the in Passing variable. process the of measurement the in function *getMeasurement()* the overriding to analogous functionally is `PIDCommand` in .`PIDSubsystem`

supplier measurement the modify further may users advanced ,`PIDCommand` subclassing When field. `m_measurement` class's the modifying by

### setpointSource

the returns that )*lambda* a as passed (usually function a is parameter `setpointSource` The exists overload an needed, is setpoint constant a only If loop. control the for setpoint current supplier. a than rather setpoint constant a takes that

by supplier setpoint the modify further may users advanced ,`PIDCommand` subclassing When field. `m_setpoint` class's the modifying

### useOutput

the consumes that )*lambda* a as passed (usually function a is parameter `useOutput` The `PIDCommand` in function `useOutput` the in Passing loop. control the of setpoint and output .`PIDSubsystem` in function *useOutput()* the overriding to analogous functionally is

by consumer output the modify further may users advanced ,`PIDCommand` subclassing When field. `m_useOutput` class's the modifying

### דרישות

subsystem its specify to user the allows `PIDCommand` commands, inlineable all Like parameter. constructor a as requirements

## Example PIDCommand Full

from are examples following The practice? in used when like look `PIDCommand` a does What ):C++ ,Java( project example GyroDriveCommands the

Java

```
;edu.wpi.first.wpilibj.examples.gyrodrivecommands.commands package

;edu.wpi.first.math.controller.PIDController import
;edu.wpi.first.wpilibj.examples.gyrodrivecommands.Constants.DriveConstants import
;edu.wpi.first.wpilibj.examples.gyrodrivecommands.subsystems.DriveSubsystem import
;edu.wpi.first.wpilibj2.command.PIDCommand import

*/ angle. specified the to robot the turn will that command A **/
{ PIDCommand extends TurnToAngle class public
  **/
  angle. specified the to robot to Turns *
  *
  to turn to angle The targetAngleDegrees @param *
  use to subsystem drive The drive @param *
  */
  { drive) DriveSubsystem targetAngleDegrees, double(TurnToAngle public
    (super
      ␣,kTurnIDriveConstants. ,kTurnPPIDController(DriveConstants. new
),kTurnDDriveConstants. ↪
        heading on loop Close //
        drive::getHeading,
        target to reference Set //
        targetAngleDegrees,
        robot turn to output Pipe //
        output), ,0(arcadeDrivedrive. >- output
        drive the Require //
        drive);

    controller) angle an is it (because continuous be to controller the Set //
    );180 ,180-(enableContinuousInputgetController().
    ␣is robot the ensures tolerance delta the - tolerance controller the Set //
the at stationary ↪
    reference the reached having as considered is it before setpoint //
    getController()
    DriveConstants. ,kTurnToleranceDeg(DriveConstants.setTolerance.
);kTurnRateToleranceDegPerS ↪
  }

  @Override
  { ()isFinished boolean public
    reference. the at is controller the when End //
    ();atSetpointgetController(). return
  }
}
```

(Header) C++

```
once pragma#

frc2/command/CommandHelper.h>< include#
frc2/command/PIDCommand.h>< include#
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```

                                        subsystems/DriveSubsystem.h"" include#

                                                                          **/
                       angle. specified the to robot the turn will that command A *
                                                                          */
     { >TurnToAngle PIDCommand,::frc2<CommandHelper::frc2 public : TurnToAngle class
                                                                        :public
                                                                         **/
                                    angle. specified the to robot to Turns *
                                                                         *
                               to turn to angle The targetAngleDegrees @param *
                      use to subsystem drive The                drive @param *
                                                                         */
                        drive); *DriveSubsystem target, degree_t::TurnToAngle(units

                                                   ;override ()IsFinished bool
                                                                          ;}
```

(Source) C++

```
                                           commands/TurnToAngle.h"" include#

                                      frc/controller/PIDController.h>< include#

                                                ;DriveConstants namespace using

             drive) *DriveSubsystem target, degree_t::TurnToAngle(units::TurnToAngle
                    kTurnD}, kTurnI, PIDController{kTurnP,::CommandHelper{frc2 :
                                          heading on loop Close //
                    ,} GetHeading().value();>-drive return { [drive]
                                         target to reference Set //
                                                     target.value(),
                                        robot turn to output Pipe //
          ,} output); ,0ArcadeDrive(>-drive { output) double[drive](
                                              drive the Require //
                                                            { drive}}{
        controller) angle an is it (because continuous be to controller the Set //
                                 );180 ,180-m_controller.EnableContinuousInput(
        is robot the ensures tolerance delta the - tolerance controller the Set //
       the reached having as considered is it before setpoint the at stationary //
                                                                  reference //
      kTurnRateTolerance.value()); m_controller.SetTolerance(kTurnTolerance.value(),

                                                      AddRequirements({drive});
                                                                              }

                                                 { IsFinished()::TurnToAngle bool
                                           GetController().AtSetpoint(); return
                                                                              }
```

example: *inlined* an for And,

Java

```
          held is bumper left when gyro with straight drive to robot Stabilize //
                          )value.kL1Button. JoystickButton(m_driverController, new
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                  (whileTrue.
                                           PIDCommand( new
                                       PIDController( new
                          ,kStabilizationPDriveConstants.
                          ,kStabilizationIDriveConstants.
                         ),kStabilizationDDriveConstants.
                          rate turn the on loop the Close //
                               m_robotDrive::getTurnRate,
                                         0 is Setpoint //
                                                      ,0
                      controls turning the to output the Pipe //
  ␣(),getLeftYm_driverController.-(arcadeDrivem_robotDrive. >- output
                                                         output), ↪
                              drive robot the Require //
                                        m_robotDrive));
```

C++

```
              held is L1 when gyro with straight drive to robot Stabilize //
        kL1)::Button::PS4Controller::frc m_driverController,&JoystickButton(::frc2
                                                           WhileTrue(.
                                                     PIDCommand(::frc2
    kStabilizationI,::dc kStabilizationP,::PIDController{dc::frc2
                        kStabilizationD},::dc
                               rate turn the on loop the Close //
                        ,} m_drive.GetTurnRate(); return { ]this[
                                              0 is Setpoint //
                                                          ,0
                      controls turning the to output the Pipe //
                                      { output) double](this[
    output); m_drive.ArcadeDrive(m_driverController.GetLeftY(),
                                                          ,}
                                   drive robot the Require //
                                                m_drive})&{
```

## TrapezoidProfileSubsystems through Profiling Motion 24.11
## TrapezoidProfileCommands and

---

:□□□□ command- these by used features profiling motion WPILib the of description a For .*WPILib in Profiles Motion Trapezoidal* see wrappers, based

---

:□□□□ composition for intended generally are wrappers command `TrapezoidProfile` The WPILib's with profiling motion trapezoidal combining For controllers. external or custom with .*BasedCommand- in PID and Profiling Motion Combining* see ,`PIDController`

---

positions, two between smoothly it move to desirable often is mechanism, a controlling When supported is and profiling,“”motion- called is This setpoint. its change abruptly to than rather ).C++ ,Java( class `TrapezoidProfile` the through WPILib in

robot basedcommand- their into profiling motion integrate teams help further To class: `TrapezoidProfile` the for wrappers convenience two includes WPILib projects, profiles motion executes and generates automatically which ,`TrapezoidProfileSubsystem` user- single a executes which ,`TrapezoidProfileCommand` the and method, `periodic()` its in .`TrapezoidProfile` provided

## TrapezoidProfileSubsystem 24.11.1

---

used type unit the on templated is class `TrapezoidProfileSubsystem` the C++, In :□□□□ have *must* values inpassed- The linear. or angular be may which measurements, distance for more For thrown. be will error timecompile- a or units, distance the with consistent units .*Library Units C++ The* see units, C++ on information

---

execute and create automatically will )C++ ,Java( class `TrapezoidProfileSubsystem` The the use To state. goal provideduser- the reach to profiles motion trapezoidal it. of subclass a create must users class, `TrapezoidProfileSubsystem`

### TrapezoidProfileSubsystem a Creating

---

make ,`TrapezoidProfileSubsystem` from inheriting when overridden is `periodic` If :□□□□ work not will functionality profiling motion Otherwise, !`super.periodic()` call to sure properly.

---

abstract single a override must users ,`TrapezoidProfileSubsystem` subclassing When operation: ordinary its in use will class the that functionality provide to method

#### useState()

Java

```
state); State(TrapezoidProfile.useState void abstract protected
```

C++

```
;0 = state) (StateUseState void virtual
```

The profile. motion the of state current the consumes method `useState()` The block, `periodic()` its from method this call automatically will `TrapezoidProfileSubsystem` progress current subsystem’s the to corresponding state profile motion the it pass and profile. motion the through

*Full* the in shown (as case use typical a state; this with want they whatever do may Users feedforward a and setpoint a obtain to state the use to is )*Example TrapezoidProfileSubsystem* controller. motor ”smart“ external an for

### Parameters Constructor

the to `TrapezoidProfile.Constraints` of set a in pass must Users their of call constructor superclass the through class base `TrapezoidProfileSubsystem` maximum given a to profiles generatedautomatically- the constrain to serves This subclass. acceleration. and velocity

mechanism. the for position initial an in pass also must Users

main standardnon- a if period, loop the for value alternate an in pass may users Advanced used. being is period loop

### TrapezoidProfileSubsystem a Using

used be can it created, been has subclass `TrapezoidProfileSubsystem` a of instance an Once methods: following the through commands by

#### setGoal()

---

zero, of velocity target implicit an with distance simple a to goal the set to wish you If **:□□□□** motion full a than rather value, distance single a takes that exists `setGoal()` of overload an state. profile

---

.`TrapezoidProfileSubsystem` the of state goal the set to used be can method `setGoal()` The at state current the passing goal, the to profile a execute automatically will subsystem The method. *useState()* provided the to iteration each

Java

```
3. of velocity a and 5 of position a to profile a execute will subsystem The //
);3 ,5(StateTrapezoidProfile. new(setGoalexamplePIDSubsystem.
```

C++

```
␣3 of velocity a and meters 5 of position a to profile a execute will subsystem The //
                                                                              mps. ↪
                                            mps});_3 m,_5examplePIDSubsyste.SetGoal({
```

#### disable() and enable()

the of control profiling motion the disable and enable methods `disable()` and `enable()` The the run automatically will it enabled, is subsystem the When .`TrapezoidProfileSubsystem` performed. is control no disabled, is it When periodically. `useState()` call and loop control

### Full TrapezoidProfileSubsystem Example

What does a `TrapezoidProfileSubsystem` look like when used in practice? The following examples are taking from the ArmbotOffobard example project (Java, C++):

Java

```java
package edu.wpi.first.wpilibj.examples.armbotoffboard.subsystems;

import edu.wpi.first.math.controller.ArmFeedforward;
import edu.wpi.first.math.trajectory.TrapezoidProfile;
import edu.wpi.first.wpilibj.examples.armbotoffboard.Constants.ArmConstants;
import edu.wpi.first.wpilibj.examples.armbotoffboard.ExampleSmartMotorController;
import edu.wpi.first.wpilibj2.command.Command;
import edu.wpi.first.wpilibj2.command.Commands;
import edu.wpi.first.wpilibj2.command.TrapezoidProfileSubsystem;

/** A robot arm subsystem that moves with a motion profile. */
public class ArmSubsystem extends TrapezoidProfileSubsystem {
  private final ExampleSmartMotorController m_motor =
      new ExampleSmartMotorController(ArmConstants.kMotorPort);
  private final ArmFeedforward m_feedforward =
      new ArmFeedforward(
          ArmConstants.kSVolts, ArmConstants.kGVolts,
          ArmConstants.kVVoltSecondPerRad, ArmConstants.kAVoltSecondSquaredPerRad);

  /** Create a new ArmSubsystem. */
  public ArmSubsystem() {
    super(
        new TrapezoidProfile.Constraints(
            ArmConstants.kMaxVelocityRadPerSecond, ArmConstants.kMaxAccelerationRadPerSecSquared),
        ArmConstants.kArmOffsetRads);
    m_motor.setPID(ArmConstants.kP, 0, 0);
  }

  @Override
  public void useState(TrapezoidProfile.State setpoint) {
    // Calculate the feedforward from the sepoint
    double feedforward = m_feedforward.calculate(setpoint.position, setpoint.velocity);
    // Add the feedforward to the PID output to get the motor output
    m_motor.setSetpoint(
        ExampleSmartMotorController.PIDMode.kPosition, setpoint.position, feedforward / 12.0);
  }

  public Command setArmGoalCommand(double kArmOffsetRads) {
    return Commands.runOnce(() -> setGoal(kArmOffsetRads), this);
  }
}
```

C++ (Header)

```cpp
#pragma once

#include <frc/controller/ArmFeedforward.h>
#include <frc2/command/Commands.h>
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
frc2/command/TrapezoidProfileSubsystem.h>< include#
units/angle.h>< include#

ExampleSmartMotorController.h"" include#

**/
profile. motion a with moves that subsystem arm robot A *
*/
{ >radians::units<TrapezoidProfileSubsystem::frc2 public : ArmSubsystem class
State;::>radians::units<TrapezoidProfile::frc = State using

:public
ArmSubsystem();

;override setpoint) (StateUseState void

goal); radian_t::(unitsSetArmGoalCommand CommandPtr::frc2

:private
m_motor; ExampleSmartMotorController
m_feedforward; ArmFeedforward::frc
;}
```

(Source) C++

```
subsystems/ArmSubsystem.h"" include#

Constants.h"" include#

;ArmConstants namespace using
State;::>radians::units<TrapezoidProfile::frc = State using

ArmSubsystem()::ArmSubsystem
(>radians::units<TrapezoidProfileSubsystem::frc2 :
kArmOffset), kMaxAcceleration}, kMaxVelocity,{
m_motor(kMotorPort),
{ kA) kV, kG, m_feedforward(kS,
);0 ,0 m_motor.SetPID(kP,
}

{ setpoint) UseState(State::ArmSubsystem void
sepoint the from feedforward the Calculate //
= feedforward volt_t::units
setpoint.velocity); m_feedforward.Calculate(setpoint.position,
output motor the get to output PID the to feedforward the Add //
kPosition,::PIDMode::m_motor.SetSetpoint(ExampleSmartMotorController
V);_12 / feedforward setpoint.position.value(),
}

{ goal) radian_t::SetArmGoalCommand(units::ArmSubsystem CommandPtr::frc2
);}this{ ,} SetGoal(goal);>-this { goal] ,thisRunOnce([::cmd::frc2 return
}
```

simple: quite be can commands with TrapezoidProfileSubsystem a Using

Java

```
      pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
                       ));2(setArmGoalCommand(m_robotArm.onTrue().am_driverController.

                 pressed. is button 'B' the when position neutral to arm the Move //
                                                                  m_driverController
                                                                            ()b.
  ));kArmOffsetRads.ArmConstants(Constants.setArmGoalCommand(m_robotArm.onTrue.
```

C++

```
      pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
                       rad));_2m_driverController.A().OnTrue(m_arm.SetArmGoalCommand(

                 pressed. is button 'B' the when position neutral to arm the Move //
                                                       m_driverController.B().OnTrue(
                       kArmOffset));::m_arm.SetArmGoalCommand(ArmConstants
```

## TrapezoidProfileCommand 24.11.2

---

for used type unit the on templated is class `TrapezoidProfileCommand` the C++, In :□□□□ have *must* values inpassed- The linear. or angular be may which measurements, distance more For thrown. be will error timecompile- a or units, distance the with consistent units .*Library Units C++ The* see units, C++ on information

---

will that command a create to users allows )C++ ,Java( class `TrapezoidProfileCommand` The user- a to iteration each at state current its passing ,`TrapezoidProfile` single a execute function. defined

### TrapezoidProfileCommand a Creating

the subclassing by - ways two created be can `TrapezoidProfileCommand` A methods Both .*inline* command the defining by or class, `TrapezoidProfileCommand` where to down comes use to which of choice the ultimately and similar, extremely ultimately located. be code relevant the that desires user the

---

to sure make methods, any overriding and `TrapezoidProfileCommand` subclassing If :□□□□ not will functionality profiling motion Otherwise, methods! those of version `super` the call properly. work

---

parameters necessary the passing by created is `TrapezoidProfileCommand` a case, either In call): *super()* a with done be can this subclass, a defining (if constructor its to

Java

```
                                                                      **/
    ␣@link{ given the execute will that TrapezoidProfileCommand new a Creates *
                                                      TrapezoidProfile}. ↩
                   function. consumer provided the to piped be will Output *
                                                                          *
                               execute. to profile motion The profile @param *
```

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(□□□□ □□□□□ □□□□)

```
                                    output. profile the for consumer The output @param *
                          command. this by required subsystems The requirements @param *
                                                                                     */
                                                        (TrapezoidProfileCommand public
  { requirements) Subsystem... output, >State<Consumer profile, TrapezoidProfile
```

C++

```
                                                                                :public
                                                                                   **/
                 given the execute will that TrapezoidProfileCommand new a Creates *
       function. consumer provided the to piped be will Output TrapezoidalProfile. *
                                                                                     *
                                 execute. to profile motion The      profile @param *
                            output. profile the for consumer The       output @param *
                                      requirements. of list The requirements @param *
                                                                                    */
                    profile, >Distance<TrapezoidProfile::TrapezoidProfileCommand(frc
                         output, >(State)void<function::std
```

### profile

the by executed be will that object `TrapezoidProfile` the is parameter `profile` The constraints motion and state, end state, start the specify users in, this passing By command. use. will command the that profile the of

### output

and output the consumes that )*lambda* a as passed (usually function a is parameter `output` The functionally is `PIDCommand` in function `useOutput` the in Passing loop. control the of setpoint .`PIDSubsystem` in function *useState()* the overriding to analogous

### דרישות

its specify to user the allows `TrapezoidProfileCommand` commands, inlineable all Like parameter. constructor a as requirements subsystem

### Example TrapezoidProfileCommand Full

following The practice? in used when like look `TrapezoidProfileSubsystem` a does What ):C++ ,Java( project example DriveDistanceOffboard the from taking are examples

Java

```
              ;edu.wpi.first.wpilibj.examples.drivedistanceoffboard.commands package

                                   ;edu.wpi.first.math.trajectory.TrapezoidProfile import
   ;edu.wpi.first.wpilibj.examples.drivedistanceoffboard.Constants.DriveConstants import
  ;edu.wpi.first.wpilibj.examples.drivedistanceoffboard.subsystems.DriveSubsystem import
```

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```
                    ;edu.wpi.first.wpilibj2.command.TrapezoidProfileCommand import

                             */ profile. motion a using distance set a Drives **/
                  { TrapezoidProfileCommand extends DriveDistanceProfiled class public
                                                                             **/
                                        command. DriveDistanceProfiled new a Creates *
                                                                               *
                                                drive. to distance The meters @param *
                                            use. to subsystem drive The drive @param *
                                                                             */
               { drive) DriveSubsystem meters, double(DriveDistanceProfiled public
                                                                          (super
                                                           TrapezoidProfile( new
                                    velocity and acceleration max the Limit //
                                                  (ConstraintsTrapezoidProfile. new
                                     ,kMaxSpeedMetersPerSecondDriveConstants.
                        ),kMaxAccelerationMetersPerSecondSquaredDriveConstants.
                       0 at starts implicitly meters; in position desired at End //
                                          )),0 (meters,StateTrapezoidProfile. new
                                                drive the to state profile the Pipe //
          setpointState), (setpointState,setDriveStatesdrive. >- setpointState
                                                              drive the Require //
                                                                        drive);
                               0 at starting re'we since encoders drive Reset //
                                                           ();resetEncodersdrive.
                                                                               }
                                                                                 }
```

(Header) C++

```
                                                                 once pragma#

                                        frc2/command/CommandHelper.h>< include#
                                 frc2/command/TrapezoidProfileCommand.h>< include#

                                             subsystems/DriveSubsystem.h"" include#

                                                       DriveDistanceProfiled class
   ,>meters::units<TrapezoidProfileCommand::frc2<CommandHelper::frc2 public :
                               { >DriveDistanceProfiled
                                                                         :public
       drive); *DriveSubsystem distance, meter_t::DriveDistanceProfiled(units
                                                                             ;}
```

(Source) C++

```
                                     commands/DriveDistanceProfiled.h"" include#

                                                             Constants.h"" include#

                                                ;DriveConstants namespace using

            distance, meter_t::DriveDistanceProfiled(units::DriveDistanceProfiled
              drive) *DriveSubsystem
                                                              CommandHelper{ :
                                       {>meters::units<TrapezoidProfile::frc
```

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```
                               velocity and acceleration max the Limit //
                                           kMaxAcceleration}, kMaxSpeed,{
             0 at starts implicitly meters; in position desired at End //
                                                      mps}},_0 distance,{
                                       drive the to state profile the Pipe //
                                                { setpointState) auto[drive](
                       setpointState); SetDriveStates(setpointState,>-drive
                                                                           ,}
                                                         drive the Require //
                                                                   { drive}}{
                                    0 at starting re'we since encoders drive Reset //
                                                              ResetEncoders();>-drive
                                                                                      }
```

example: *inlined* an for And,

Java

```
   inline defined but pressed, is button 'B' the when above as thing same the Do //
                                                                 m_driverController
                                                                           ()b.
                                                                       (onTrue.
                                               TrapezoidProfileCommand(  new
                                              TrapezoidProfile( new
                     velocity and acceleration max the Limit //
                              (ConstraintsTrapezoidProfile. new
                   ,kMaxSpeedMetersPerSecondDriveConstants.
    ),kMaxAccelerationMetersPerSecondSquaredDriveConstants.
   0 at starts implicitly meters; in position desired at End //
                             )),0 ,3(StateTrapezoidProfile. new
                             drive the to state profile the Pipe //
       ␣(setpointState,setDriveStatesm_robotDrive. >- setpointState
                                                                      setpointState), ↪
                                               drive the Require //
                                                      m_robotDrive)
                           (m_robotDrive::resetEncoders)beforeStarting.
                                                     ));10(withTimeout.
```

C++

```
            defined but pressed, is button 'B' the when above as thing same the Do //
                                                                            inline //
                                                       m_driverController.B().OnTrue(
                                    (>meters::units<TrapezoidProfileCommand::frc2
                                        (>meters::units<TrapezoidProfile::frc
                               velocity and acceleration max the Limit //
           kMaxAcceleration},::DriveConstants kMaxSpeed,::DriveConstants{
             0 at starts implicitly meters; in position desired at End //
                                                           mps}),_0 m,_3{
                                       drive the to state profile the Pipe //
                                                 { setpointState) auto](this[
                      setpointState); m_drive.SetDriveStates(setpointState,
                                                                           ,}
                                                         drive the Require //
                                                                  m_drive})&{
                                                     CommandPtr to Convert //
                                                                     ToPtr().
```

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```
                                                BeforeStarting(.
       ))}{ ,} m_drive.ResetEncoders(); { ]()thisRunOnce([::cmd::frc2
                                                s));_10WithTimeout(.
```

## Command- in PID and Profiling Motion Combining 24.12 Based

---

basedcommand- these by used features control PID WPILib the of description a For :□□□□ .*WPILib □□ PID □□□□* see wrappers,

---

setpoint for profile motion trapezoidal a pair to is solution controls FRC® common A includes WPILib this, facilitate To tracking. setpoint for controller PID a with generation functionality this integrating in teams aid further To class. *ProfiledPIDController* own its the for wrappers convenience two contains framework basedcommand- the robots, their into into controller the integrates which ,`ProfiledPIDSubsystem` class: `ProfiledPIDController` command. a into controller the integrates which ,`ProfiledPIDCommand` and subsystem, a

### ProfiledPIDSubsystem 24.12.1

---

for used type unit the on templated is class `ProfiledPIDSubsystem` the C++, In :□□□□ have *must* values inpassed- The linear. or angular be may which measurements, distance more For thrown. be will error timecompile- a or units, distance the with consistent units .*Library Units C++ The* see units, C++ on information

---

a create conveniently to users allows )C++ ,Java( class `ProfiledPIDSubsystem` The class, `ProfiledPIDSubsystem` the use to order In PIDController. inbuilt- a with subsystem it. of subclass a create must users

#### ProfiledPIDSubsystem a Creating

---

to sure make ,`ProfiledPIDSubsystem` from inheriting when overridden is `periodic` If :□□□□ properly. work not will functionality control Otherwise, !`super.periodic()` call

---

to methods abstract two override must users ,`ProfiledPIDSubsystem` subclassing When operation: ordinary its in use will class the that functionality provide

### getMeasurement()

Java

```
();getMeasurement double abstract protected
```

C++

```
;0 = ()GetMeasurement Distance_t virtual
```

The variable. process the of measurement current the returns method `getMeasurement` The its pass and block, `periodic()` its from method this call automatically will `PIDSubsystem` loop. control the to value

their as use to wish they reading sensor whatever return to method this override should Users measurement. variable process

### useOutput()

Java

```
setpoint); State output, double(useOutput void abstract protected
```

C++

```
;0 = setpoint) State output, double(UseOutput void virtual
```

current the and controller, PID Profiled the of output the consumes method `useOutput()` The will `PIDSubsystem` The feedforward). a computing for useful often is (which state setpoint of output computed the it pass and block, `periodic()` its from method this call automatically loop. control the

their to output control computed final the pass to method this override should Users motors. subsystem's

### Controller the In Passing

class base `ProfiledPIDSubsystem` the to `ProfiledPIDController` a in pass also must Users gains, PID the specify to serves This subclass. their of call constructor superclass the through robot main standardnon- a using is user the (if period the and constraints, profile motion the period). loop

the in controller the to made be can input) continuous enabling (e.g. modifications Additional .`getController()` calling by body constructor

## ProfiledPIDSubsystem a Using

commands by used be can it created, been has subclass `PIDSubsystem` a of instance an Once
methods: following the through

### setGoal()

---

zero, of velocity target implicit an with distance simple a to goal the set to wish you If :□□□□
motion full a than rather value, distance single a takes that exists `setGoal()` of overload an
state. profile

---

subsystem The .`PIDSubsystem` the of setpoint the set to used be can method `setGoal()` The
output: defined the using setpoint the to track automatically will

Java

```
second. per meters 3 of velocity and meters 5 of goal a to track will subsystem The //
);3 ,5(setGoalexamplePIDSubsystem.
```

C++

```
second. per meters 3 of velocity and meters 5 of goal a to track will subsystem The //
mps});_3 m,_5examplePIDSubsystem.SetGoal({
```

### disable() and enable()

the of control automatic the disable and enable methods `disable()` and `enable()` The
motion the run automatically will it enabled, is subsystem the When .`ProfiledPIDSubsystem`
performed. is control no disabled, is it When goal. the to track and loop control the and profile

the and ,`ProfiledPIDController` internal the resets method `enable()` the Additionally,
setpoint and output both with method *useOutput()* defineduser- the calls method `disable()`
.`0` to set

### Example ProfiledPIDSubsystem Full

taken are examples following The practice? in used when like look PIDSubsystem a does What
):C++ ,Java( project example ArmBot the from

Java

```
;edu.wpi.first.wpilibj.examples.armbot.subsystems package

;edu.wpi.first.math.controller.ArmFeedforward import
;edu.wpi.first.math.controller.ProfiledPIDController import
;edu.wpi.first.math.trajectory.TrapezoidProfile import
;edu.wpi.first.wpilibj.Encoder import
;edu.wpi.first.wpilibj.examples.armbot.Constants.ArmConstants import
;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import
;edu.wpi.first.wpilibj2.command.ProfiledPIDSubsystem import

```

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```
*/ profile. motion a with moves that subsystem arm robot A **/
{ ProfiledPIDSubsystem extends ArmSubsystem class public
);kMotorPortPWMSparkMax(ArmConstants. new = m_motor PWMSparkMax final private
= m_encoder Encoder final private
);]1[kEncoderPortsArmConstants. ,]0[kEncoderPortsEncoder(ArmConstants. new
= m_feedforward ArmFeedforward final private
ArmFeedforward( new
,kGVoltsArmConstants. ,kSVoltsArmConstants.
);kAVoltSecondSquaredPerRadArmConstants. ,kVVoltSecondPerRadArmConstants.

*/ ArmSubsystem. new a Create **/
{ ()ArmSubsystem public
(super
ProfiledPIDController( new
,kPArmConstants.
,0
,0
(ConstraintsTrapezoidProfile. new
,kMaxVelocityRadPerSecondArmConstants.
)),kMaxAccelerationRadPerSecSquaredArmConstants.
);0
);kEncoderDistancePerPulse(ArmConstants.setDistancePerPulsem_encoder.
position neutral in rest at arm Start //
);kArmOffsetRadssetGoal(ArmConstants.
}

@Override
{ setpoint) StateTrapezoidProfile. output, double(useOutput void public
sepoint the from feedforward the Calculate //
setpoint. ,position(setpoint.calculatem_feedforward. = feedforward double
);velocity ↪
output motor the get to output PID the to feedforward the Add //
feedforward); + (outputsetVoltagem_motor.
}

@Override
{ ()getMeasurement double public
;kArmOffsetRadsArmConstants. + ()getDistancem_encoder. return
}
}
```

(Header) C++

```
once pragma#

frc/Encoder.h>< include#
frc/controller/ArmFeedforward.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#
frc2/command/ProfiledPIDSubsystem.h>< include#
units/angle.h>< include#

**/
profile. motion a with moves that subsystem arm robot A *
*/
{ >radians::units<ProfiledPIDSubsystem::frc2 public : ArmSubsystem class
State;::>radians::units<TrapezoidProfile::frc = State using
```

page) next on (continues

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```
                                                              :public
                                                       ArmSubsystem();

                          ;override setpoint) State output, double(UseOutput void

                                          ;override ()GetMeasurement radian_t::units

                                                              :private
                                              m_motor; PWMSparkMax::frc
                                                m_encoder; Encoder::frc
                                     m_feedforward; ArmFeedforward::frc
                                                                     ;}
```

(Source) C++

```
                                 subsystems/ArmSubsystem.h"" include#

                                                 Constants.h"" include#

                                          ;ArmConstants namespace using
       State;::>radians::units<TrapezoidProfile::frc = State using

                                             ArmSubsystem()::ArmSubsystem
                    (>radians::units<ProfiledPIDSubsystem::frc2 :
                (>radians::units<ProfiledPIDController::frc
      kMaxAcceleration})), kMaxVelocity,{ ,0 ,0 kP,
                                              m_motor(kMotorPort),
                 ]),1kEncoderPorts[ ],0m_encoder(kEncoderPorts[
                                     { kA) kV, kG, m_feedforward(kS,
  m_encoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
                                      position neutral in arm Start //
                           rad_per_s});_0 SetGoal(State{kArmOffset,
                                                                      }

           { setpoint) State output, doubleUseOutput(::ArmSubsystem void
                              sepoint the from feedforward the Calculate //
                                               = feedforward volt_t::units
 setpoint.velocity); m_feedforward.Calculate(setpoint.position,
  output motor the get to output PID the to feedforward the Add //
          feedforward); + volt_t{output}::m_motor.SetVoltage(units
                                                                      }

                 { GetMeasurement()::ArmSubsystem radian_t::units
    kArmOffset; + radian_t{m_encoder.GetDistance()}::units return
                                                                      }
```

simple: very be can commands with ProfiledPIDSubsystem a Using

Java

```
 pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
                                                       m_driverController
                                                                    ()a.
                                                              (onTrue.
                                                  (runOnceCommands.
                                                         { >- ()
```

page) next on (continues

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```
                                                  );2(setGoalm_robotArm.
                                                    ();enablem_robotArm.
                                                                      ,}
                                                          m_robotArm));
```

C++

```
          pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
                                              RunOnce(::cmd::m_driverController.A().OnTrue(frc2
                                                                             { ]this[
                                                        rad);_2m_arm.SetGoal(
                                                             m_arm.Enable();
                                                                           ,}
                                                                m_arm}));&{
```

## ProfiledPIDCommand 24.12.2

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for used type unit the on templated is class `ProfiledPIDCommand` the C++, In :□□□□ have *must* values inpassed- The linear. or angular be may which measurements, distance more For thrown. be will error timecompile- a or units, distance the with consistent units .*Library Units C++ The* see units, C++ on information

---

a with commands create easily to users allows )C++ ,Java( class `ProfiledPIDCommand` The ProfiledPIDController. inbuilt-

### PIDCommand a Creating

`ProfiledPIDCommand` the subclassing by - ways two created be can `ProfiledPIDCommand` A and similar, extremely ultimately methods Both .*inline* command the defining by or class, relevant the that desires user the where to down comes use to which of choice the ultimately located. be code

---

the call to sure make methods, any overriding and `ProfiledPIDCommand` subclassing If :□□□□ properly. work not will functionality control Otherwise, methods! those of version `super`

---

its to parameters necessary the passing by created is `ProfiledPIDCommand` a case, either In call): *super()* a with done be can this subclass, a defining (if constructor

Java

```
                                                                          **/
                 ␣a with output given the controls which PIDCommand, new a Creates *
                                                    Goal ProfiledPIDController. ↪
                                                         specified. is velocity *
                                                                                *
                     output. the controls that controller the controller @param *
                variable process the of measurement the measurementSource @param *
                                      goal s'controller the goalSource @param *
                                     output s'controller the useOutput @param *
```

page) next on (continues

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```
                   command this by required subsystems the requirements @param *
                                                                              */
                                                       (ProfiledPIDCommand public
                                          controller, ProfiledPIDController
                                          measurementSource, DoubleSupplier
                                               goalSource, >State<Supplier
                                     useOutput, >State Double,<BiConsumer
                                                { requirements) Subsystem...
```

C++

```
                                                                            **/
               a with output given the controls which PIDCommand, new a Creates *
                                                        ProfiledPIDController. *
                                                                               *
              output. the controls that controller the        controller @param *
               variable process the of measurement the measurementSource @param *
                                           goal s'controller the   goalSource @param *
                                     output s'controller the         useOutput @param *
               command this by required subsystems the      requirements @param *
                                                                              */
               controller, >Distance<ProfiledPIDController::ProfiledPIDCommand(frc
                 measurementSource, >Distance_t()<function::std
                             goalSource, >State()<function::std
                  useOutput, >State) ,double(void<function::std
                requirements) >*Subsystem<initializer_list::std
```

### controller

the by used be will that object `ProfiledPIDController` the is parameter `controller` The constraints, profile motion the gains, PID the specify can users in, this passing By command. period). loop robot main nonstandard a using is user the (if controller the for period the and

continuous enabling (e.g. modifications additional ,`ProfiledPIDCommand` subclassing When .`getController()` calling by body constructor the in controller the to made be can input)

### measurementSource

returns that )*lambda* a as passed (usually function a is parameter `measurementSource` The in function `measurementSource` the in Passing variable. process the of measurement the function *getMeasurement()* the overriding to analogous functionally is `ProfiledPIDCommand` .`ProfiledPIDSubsystem` in

the modify further may users advanced ,`ProfiledPIDCommand` subclassing When field. `m_measurement` class's the modifying by supplier measurement

### goalSource

current the returns that )*lambda* a as passed (usually function a is parameter `goalSource` The takes that exists overload an needed, is goal constant a only If mechanism. the for state goal zero, be to desired are velocities goal if Additionally, supplier. a than rather goal constant a state. profile full a than rather distance constant a take that exist overloads

setpoint the modify further may users advanced ,`ProfiledPIDCommand` subclassing When field. `m_goal` class's the modifying by supplier

### useOutput

the consumes that )*lambda* a as passed (usually function a is parameter `useOutput` The in function `useOutput` the in Passing loop. control the of state setpoint and output in function *useOutput()* the overriding to analogous functionally is `ProfiledPIDCommand` .`ProfiledPIDSubsystem`

output the modify further may users advanced ,`ProfiledPIDCommand` subclassing When field. `m_useOutput` class's the modifying by consumer

### דרישות

subsystem its specify to user the allows `ProfiledPIDCommand` commands, inlineable all Like parameter. constructor a as requirements

### Example ProfiledPIDCommand Full

examples following The practice? in used when like look `ProfiledPIDCommand` a does What ):C++ ,Java( project example GyroDriveCommands the from are

Java

```
                    ;edu.wpi.first.wpilibj.examples.gyrodrivecommands.commands package

                             ;edu.wpi.first.math.controller.ProfiledPIDController import
                                   ;edu.wpi.first.math.trajectory.TrapezoidProfile import
      ;edu.wpi.first.wpilibj.examples.gyrodrivecommands.Constants.DriveConstants import
     ;edu.wpi.first.wpilibj.examples.gyrodrivecommands.subsystems.DriveSubsystem import
                                ;edu.wpi.first.wpilibj2.command.ProfiledPIDCommand import

␣profile. motion a using angle specified the to robot the turn will that command A **/
                                                                                  */ ↪
                         { ProfiledPIDCommand extends TurnToAngleProfiled class public
                                                                               **/
                  profile. motion a using angle specified the to robot to Turns *
                                                                                *
                                 to turn to angle The targetAngleDegrees @param *
                                       use to subsystem drive The drive @param *
                                                                               */
       { drive) DriveSubsystem targetAngleDegrees, double(TurnToAngleProfiled public
                                                                          (super
                                                      ProfiledPIDController( new
                                                       ,kTurnPDriveConstants.
```

page) next on (continues

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```
,kTurnIDriveConstants.
,kTurnDDriveConstants.
(ConstraintsTrapezoidProfile. new
,kMaxTurnRateDegPerSDriveConstants.
)),kMaxTurnAccelerationDegPerSSquaredDriveConstants.
heading on loop Close //
drive::getHeading,
target to reference Set //
targetAngleDegrees,
robot turn to output Pipe //
output), ,0(arcadeDrivedrive. >- setpoint) (output,
drive the Require //
drive);

controller) angle an is it (because continuous be to controller the Set //
);180 ,180-(enableContinuousInputgetController().
␣is robot the ensures tolerance delta the - tolerance controller the Set //
the at stationary ↪
reference the reached having as considered is it before setpoint //
getController()
DriveConstants. ,kTurnToleranceDeg(DriveConstants.setTolerance.
);kTurnRateToleranceDegPerS ↪
}

@Override
{ ()isFinished boolean public
reference. the at is controller the when End //
();atGoalgetController(). return
}
}
```

(Header) C++

```
once pragma#

frc2/command/CommandHelper.h>< include#
frc2/command/ProfiledPIDCommand.h>< include#

subsystems/DriveSubsystem.h"" include#

**/
motion a using angle specified the to robot the turn will that command A *
profile. *
*/
TurnToAngleProfiled class
,>radians::units<ProfiledPIDCommand::frc2<CommandHelper::frc2 public :
{ >TurnToAngleProfiled
:public
**/
profile. motion a using angle specified the to robot to Turns *
*
to turn to angle The targetAngleDegrees @param *
use to subsystem drive The drive @param *
*/
targetAngleDegrees, degree_t::TurnToAngleProfiled(units
drive); *DriveSubsystem
```

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```
                                          ;override ()IsFinished bool
                                                                   ;}
```

(Source) C++

```
                          commands/TurnToAngleProfiled.h"" include#

                  frc/controller/ProfiledPIDController.h>< include#

                                    ;DriveConstants namespace using

  target, degree_t::TurnToAngleProfiled(units::TurnToAngleProfiled
   drive) *DriveSubsystem
                                                 CommandHelper{ :
           {>radians::units<ProfiledPIDController::frc
kMaxTurnAcceleration}}, kMaxTurnRate,{ kTurnD, kTurnI, kTurnP,
                                         heading on loop Close //
             ,} GetHeading();>-drive return { [drive]
                                      target to reference Set //
                                                          target,
                                       robot turn to output Pipe //
         { setpointState) auto output, double[drive](
                    output); ,0ArcadeDrive(>-drive
                                                               ,}
                                              drive the Require //
                                                       { drive}}{
controller) angle an is it (because continuous be to controller the Set //
                deg);_180 deg,_180-GetController().EnableContinuousInput(
is robot the ensures tolerance delta the - tolerance controller the Set //
the reached having as considered is it before setpoint the at stationary //
                                                          reference //
       kTurnRateTolerance); GetController().SetTolerance(kTurnTolerance,

                                           AddRequirements({drive});
                                                                    }

                          { IsFinished()::TurnToAngleProfiled bool
                              GetController().AtGoal(); return
                                                                    }
```

## 24.13 כתיבה מחדש של תכנות מבוסס פקודות 2020: מה השתנה?

framework basedcommand- original the from changes of summary a provides article This rigorous for - comprehensive necessarily not is summary This rewrite. 2020 the to ).C++ ,Java( docs API the to refer always, as documentation,

## Location Package 24.13.1

in and Java, for package `wpilibj2` the in located is framework basedcommand- new The instructions: the using installed be must framework new The C++. for namespace `frc2` the .*Libraries Command WPILib*

## Changes Architectural Major 24.13.2

same. the largely remained has framework basedcommand- the of structure overall The aware be should users that changes architectural major few a still some are there However, of:

### Interfaces as Subsystems and Commands

to opposed as interfaces now both are )C++ ,Java( `Subsystem` and )C++ ,Java( `Command` and `CommandBase` flexibility. potential more users advanced allowing classes, abstract required. not are but convenience, for provided still are classes base abstract `SubsystemBase` .□□□□□□□ and *Commands* see information, more For

### Classes Group Command Multiple

narrower of number a by replaced been has and exists, longer no class `CommandGroup` The For structures. group complicatedmore- create to composed recursively be can that classes .*Compositions Command* see information more

### Definitions Command Inline

a where cases all almost in `Command` of subclass a write to required were users Previously, definition inline allow to designed are commands new the of Many needed. was command For subclass. explicit an for need the without used be can so and functionality, command of .*Types Command Included* see information, more

### Dependencies Command of Injection

the for pattern use recommended the library, the of coding the to change actual an not While commands, into dependencies subsystem of injection utilizes framework basedcommand- new and maintainable, more cleaner, a is This globals. as declared not are subsystems that so more For previously. promoted pattern subsystem global the than pattern reusable more .*Project Robot BasedCommand- a Structuring* see information,

### Only) (C++ Ownership Command

commands, all for pointers raw use to users required framework command previous The
well as projects, basedcommand- C++ all in leaks memory unavoidablenearly- in resulting
command- within commands allocatingdouble- as such errors common for room leaving as
groups.

Default commands. all for management ownership offers framework command new The
and scheduler, the by owned typically are buttons to bound commands and commands
users result, a As groups. command encapsulating their by owned are commands component
reason good very a is there unless `new` with command a allocateheap- never generally should
so. do to

and *moved* be will rvalues meaning ,forwarding perfect using done is ownership of Transfer
).explanation rvalue/lvalue( *copied* be will lvalues

## Scheduler the to Changes 24.13.3

- ).C++ ,Java( `CommandScheduler` to renamed been has `Scheduler`
- the not scheduler, the of responsibility the now is commands of Interruptibility
  .`schedule` to call the during specified be can and commands,
- is command a whenever taken are which scheduler the to actions pass now can Users
  event as such cases for useful highly is This normally. ends or interrupted, scheduled,
  logging.

## Subsystem to Changes 24.13.4

---

.□□□□□□□ see subsystems, on information more For :□□□□

---

- equivalent closest the );C++ ,Java( interface an now is `Subsystem` earlier, noted As
  relatedSendable- the of Many class. `SubsystemBase` new the is `Subsystem` old the of
  setters the call can users clutter; reduce to removed been have overloads constructor
  needed. if constructor, own their from directly
- ”know to need longer no subsystems removed; been has `initDefaultCommand`
  the with directly registered instead are which commands, default their about“
  the wraps simply method `setDefaultCommand` new The .`CommandScheduler`
  call. `CommandScheduler`
- this them; requiring currently commands the about“ ”know longer no Subsystems
  the on wrapper convenience A .`CommandScheduler` the by exclusively handled is
  however. provided, is method `CommandScheduler`

### Command to Changes 24.13.5

.*Commands* see commands, on information more For :□□□□

- the of equivalent closest the );C++ ,Java( interface an now is `Command` earlier, noted As constructor relatedSendable- the of Many class. `CommandBase` new the is `Command` old from directly setters the call can users clutter; reduce to removed been have overloads needed. if constructor, own their
- of responsibility the now is this state; scheduling own their handle longer no Commands scheduler. the
- takes now which method, `end()` the into rolled been has method `interrupted()` The ended it if `false`( interrupted was command the whether specifying parameter a normally).
- .`addRequirement()` to renamed been has method `requires()` The
- overridable an by replaced been has `disabled) setRunsWhenDisabled(boolean void` method. *runsWhenDisabled*
- overridable an by replaced been has `interruptible) setInterruptible(boolean void` method. *getInterruptionBehavior*
- of modification inline easy allow to added been have *methods ”decorator“* Several timeout). a adding (e.g. commands
- model, ownership command the with work to decorators the allow to order In only) (C++ `Foo` subclass Command defineduser- Any .class `CommandHelper` the via used is *CRTP* a class. base desired the is `Base` where `>Base <Foo,CommandHelper` extend *must*

### PIDSubsystem/PIDCommand to Changes 24.13.6

,*PIDCommands and PIDSubsystems through Control PID* see information, more For :□□□□ *WPILib □□ PID □□□□* and

- the from synchronously run now classes these PIDController, to changes the Following loop. robot main
- the of many removing constructor, the through injected now is `PIDController` The .`getController()` with construction after modified be can It methods. forwarding
- GyroDriveCommands the in shown as use, inline for largely intended is `PIDCommand` ).C++ ,Java( example
- protected the overriding ”traditionally,“ more PIDCommand use to wish users If by replaced been has methods `output) usePIDOutput(double` and `returnPIDInput()` than rather Similarly, fields. `m_useOutput` and `m_measurement` protected the modifying field. `m_setpoint` protected the modify can users ,`setSetpoint` calling

# Parameters As Functions Passing 24.14

functions accepts often library basedcommand- the syntax, inline concise a provide to order In C++ and Java both Fortunately, decorators. and factories, constructors, of parameters as :*objects as functions pass* to ability the users offer

## (Java) References Method 24.14.1

method a called is parameter a as passed be can that function a to reference a Java, In no that Note .`object::method` is reference method a for syntax general The reference. being not is method The passed. is *itself* method the since included, are parameters method *that* that so command) a case, this (in code of piece another to passed being is it - called code can call it when needed. For further information on method references, see *Method .References*

## (Java) Expressions Lambda 24.14.2

often written, been already has that function a passing for well work references method While method a as sending of purpose the for solely function a write to inconvenient/wasteful is it a supports also Java this, avoid To elsewhere. used be never will function that if reference, it - definition method inline an is expression lambda A expressions.“ ”lambda called feature Java write to how on specifics For .*list parameter a of inside* defined be to function a allows .*Java in Expressions Lambda* see expressions, lambda

## (C++) Expressions Lambda 24.14.3

> lambda C++ a in `this` capturing semantics, C++ in complications to Due :□□□□□ command a of command component a from done if exception pointer null a cause can members command relevant capture should users C++ possible, Whenever composition. .here see details, more For value. by and explicitly

functions member to pointers - references method Java to equivalent close a lacks C++ `this` implicit the of presence the to due parameters as usable directly not generally are lambda the addition, in - expressions lambda offer does C++ However, parameter. specifics For Java. in those than powerful more ways many in are C++ by offered expressions on how to write C++ lambda expressions, see *C++ in Expressions Lambda*.

[redacted]

## Speeds Chassis The and Kinematics to Introduction 25.1 Class

### kinematics? is What 25.1.1

and drive, swerve drive, differential for classes contains suite kinematics new brand The a between convert help classes kinematics The odometry. and kinematics drive mecanum usable to robot a for velocities angular and linear containing object, `ChassisSpeeds` universal differential a for speeds wheel right and left i.e. drivetrain of type individual each for speeds angle) and (speed states module individual or drive, mecanum a for speeds wheel four drive, drive. swerve a for

### odometry? is What 25.1.2

the of position the of estimate an create to robot the on sensors using involves Odometry number exact (the encoders several typically are sensors these FRC, In field. the on robot classes odometry The angle. robot measure to gyroscope a and type) drive the on depends the in angles (and speeds about inputs user periodic with along classes kinematics the utilize field. the on location robot's the of estimate an create to swerve) of case

### Class Speeds Chassis The 25.1.3

suite. odometry and kinematics WPILib new the to essential is object `ChassisSpeeds` The three has struct This chassis. robot a of speeds the represents object `ChassisSpeeds` The components:

- direction. (forward) x the in robot the of velocity The :`vx`
- the mean values (Positive direction. (sideways) y the in robot the of velocity The :`vy` left). the to moving is robot
- second. per radians in robot the of velocity angular The :`omega`

---

a ex: sideways, move cannot that drivetrain a (i.e. drivetrain holonomicnon- A :□□□□
sideways. move to inability its of because zero of component vy a have will drive) differential

---

## object ChassisSpeeds a Constructing 25.1.4

three accepting straightforward, very is object `ChassisSpeeds` the for constructor The
C++, In second. per meters in be must vy and vx Java, In .omega and ,vy ,vx for arguments
unit. velocity linear any using velocity linear a provide to used be may library units the

Java

```
 meters 2 forward, second per meters 3 at moving is robot The //
per rotation a half at rotating and right, the to second per //
                                   counterclockwise. second //
          );PIMath. ,2.0- ,3.0ChassisSpeeds( new = speeds var
```

C++

```
 meters 2 forward, second per meters 3 at moving is robot The //
per rotation a half at rotating and right, the to second per //
                                   counterclockwise. second //
                  mps,_2.0- mps,_3.0speeds{ ChassisSpeeds::frc
             pi)};::numbers::radians_per_second_t(std::units
```

## Speeds RelativeField- from Object ChassisSpeeds a Creating 25.1.5

robot the when speeds relativefield- of set a from created be also can object `ChassisSpeeds` A
example, (for field the to relative velocities desired of set a converts This given. is angle
`ChassisSpeeds` a to boundary) field right the toward and station alliance opposite the toward
for useful is This frame. robot the to relative are that speeds represents which object
robot. drive mecanum or swerve a for controls orientedfield- implementing

/ (Java) `ChassisSpeeds.fromFieldRelativeSpeeds` static The
generate to used be can method (C++) `ChassisSpeeds::FromFieldRelativeSpeeds`
to (relative `vx` the accepts method This speeds. relativefield- from object `ChassisSpeeds` the
angle. robot the and ,`omega` field), the to (relative `vy` field), the

Java

```
 second per meters 2 is here speed relative field desired The //
 per meters 2 and wall, station alliance s'opponent the toward //
   rotation desired The boundary. field left the toward second //
current The counterclockwise. second per rotation a of quarter a is //
                                    degrees. 45 is angle robot //
     (fromFieldRelativeSpeedsChassisSpeeds. = speeds ChassisSpeeds
       ));45.0(fromDegreesRotation2d. ,2.0 / PIMath. ,2.0 ,2.0
```

C++

```
 second per meters 2 is here speed relative field desired The //
 per meters 2 and wall, station alliance s'opponent the toward //
   rotation desired The boundary. field left the toward second //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                   current The counterclockwise. second per rotation a of quarter a is //
                                                         degrees. 45 is angle robot //
              FromFieldRelativeSpeeds(::ChassisSpeeds::frc = speeds ChassisSpeeds::frc
   _45Rotation2d( ),2.0 / pi::numbers::radians_per_second_t(std::units mps,_2 mps,_2
                                                                        deg)); ↪
```

the because field“ the to ”relative be to stated explicitly not is velocity angular The :□□□□
perspective. robot a or perspective field a from measured as same the is velocity angular

## Kinematics Drive Differential 25.2

a between converts that tool useful a is class `DifferentialDriveKinematics` The contains which object, `DifferentialDriveWheelSpeeds` a and object `ChassisSpeeds` robot. drive differential a of sides right and left the for velocities

### Object Kinematics the Constructing 25.2.1

the is which argument, constructor one accepts object `DifferentialDriveKinematics` The a on wheels of sets two the between distance the represents This robot. the of width track drive. differential

to used be can library units the C++, In meters. in be must width track the Java, In :□□□□
unit. length any using width track the in pass

### Speeds Wheel to Speeds Chassis Converting 25.2.2

`ToWheelSpeeds(ChassisSpeeds` / (Java) `speeds)` `toWheelSpeeds(ChassisSpeeds` The a to object `ChassisSpeeds` a convert to used be should method (C++) `speeds)` to have you where situations in useful is This object. `DifferentialDriveWheelSpeeds` velocities. wheel right and left to )omega( velocity angular an and )vx( velocity linear a convert

Java

```
                              inches 27 of width track object: kinematics my Creating //
                                            = kinematics DifferentialDriveKinematics
                         ));27.0(inchesToMetersDifferentialDriveKinematics(Units. new

                           velocity, linear second per meters 2 speeds: chassis Example //
                                            velocity. angular second per radian 1 //
                                 );1.0 ,0 ,2.0ChassisSpeeds( new = chassisSpeeds var

                                                               speeds wheel to Convert //
   (chassisSpeeds);toWheelSpeedskinematics. = wheelSpeeds DifferentialDriveWheelSpeeds

                                                                        velocity Left //
                              ;leftMetersPerSecondwheelSpeeds. = leftVelocity double
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                             velocity Right //
;rightMetersPerSecondwheelSpeeds. = rightVelocity double
```

C++

```
inches 27 of width track object: kinematics my Creating //
          in};_27kinematics{ DifferentialDriveKinematics::frc

velocity, linear second per meters 2 speeds: chassis Example //
                          velocity. angular second per radian 1 //
      rad_per_s};_1 mps,_0 mps,_2chassisSpeeds{ ChassisSpeeds::frc

bindings structured s'C++17 use can we Here, speeds. wheel to Convert //
      DifferentialDriveWheelSpeeds the split automatically to feature //
                         velocities. right and left into struct //
        kinematics.ToWheelSpeeds(chassisSpeeds); = right] [left, auto
```

## Speeds Chassis to Speeds Wheel Converting 25.2.3

to right) and (left speeds wheel individual convert to object kinematics the use also can One `toChassisSpeeds(DifferentialDriveWheelSpeeds` The object. `ChassisSpeeds` singular a method (C++) `speeds)` `ToChassisSpeeds(DifferentialDriveWheelSpeeds` / (Java) `speeds)` this. achieve to used be should

Java

```
inches 27 of width track object: kinematics my Creating //
                     = kinematics DifferentialDriveKinematics
  ));27.0(inchesToMetersDifferentialDriveKinematics(Units. new

second per meters 2 speeds: wheel drive differential Example //
  side. right the for second per meters 3 side, left the for //
  );3.0 ,2.0DifferentialDriveWheelSpeeds( new = wheelSpeeds var

                                       speeds. chassis to Convert //
(wheelSpeeds);toChassisSpeedskinematics. = chassisSpeeds ChassisSpeeds

                                                 velocity Linear //
       ;vxMetersPerSecondchassisSpeeds. = linearVelocity double

                                                velocity Angular //
  ;omegaRadiansPerSecondchassisSpeeds. = angularVelocity double
```

C++

```
inches 27 of width track object: kinematics my Creating //
          in};_27kinematics{ DifferentialDriveKinematics::frc

second per meters 2 speeds: wheel drive differential Example //
  side. right the for second per meters 3 side, left the for //
  mps};_3 mps,_2wheelSpeeds{ DifferentialDriveWheelSpeeds::frc

bindings structured s'C++17 use can we Here speeds. chassis to Convert //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
     components. 3 its into struct ChassisSpeeds the split automatically to feature //
           variable vy the non-holonomic, is drive differential a because that Note //
                                                                  zero. to equal be will //
  kinematics.ToChassisSpeeds(wheelSpeeds); = angularVelocity] vy, [linearVelocity, auto
```

## Odometry Drive Differential 25.3

WPILib .*odometry* perform to order in classes kinematics drive differential the use can user A a of position the track to used be can that class `DifferentialDriveOdometry` a contains field. the on robot drive differential

---

position robot's the of estimate the gyro, a and encoders uses only method this Because :□□□□ robots other with contact into comes robot your as especially time, over drift will field the on period. autonomous the during accurate very usually is odometry However, gameplay. during

---

### Object Odometry the Creating 25.3.1

and arguments mandatory three requires constructor class `DifferentialDriveOdometry` The are: arguments mandatory The argument. optional one

- )`Rotation2d` a (as gyroscope your by reported angle The
- must and ,`double` a each are these Java, In readings. encoder right and left initial The must *library units* the C++, In meters. in side each by traveled distance the represent positions. wheel your represent to used be

default, By ).`Pose2d` a (as field the on robot your of pose starting the is argument optional The .`0 = theta 0, = y 0, = x` at start will robot the

---

toward directly facing is robot the when angle robot the represents radians / degrees 0 :□□□□ should angle gyroscope your left, the to turns robot your As station. alliance opponent's your this for use can you that `GetRotation2d/getRotation2d` supplies interface `Gyro` The increase. system. coordinate the about information more for *System Coordinate Field* See purpose.

---

Java

```
                                           Here, object. odometry my Creating //
           the in and field the of end long the along meters 5 is pose starting our //
                        forward. facing end, short the along field the of center //
                      DifferentialDriveOdometry( new = m_odometry DifferentialDriveOdometry
                                                                  (),getRotation2dm_gyro.
                    (),getDistancem_rightEncoder. (),getDistancem_leftEncoder.
                                              Rotation2d())); new ,13.5 ,5.0Pose2d( new
```

C++

```
                                           Here, object. odometry my Creating //
           the in and field the of end long the along meters 5 is pose starting our //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                     forward. facing end, short the along field the of center //
                                          m_odometry{ DifferentialDriveOdometry::frc
                                                              m_gyro.GetRotation2d(),
                                            meter_t{m_leftEncoder.GetDistance()},::units
                                           meter_t{m_rightEncoder.GetDistance()},::units
                                                       rad}};_0 m,_13.5 m,_5Pose2d{::frc
```

## Pose Robot the Updating 25.3.2

must method This field. the on position robot's the update to used be can method `update` The `update` The .*Subsystem* a of method `periodic()` the in preferably periodically, called be of angle gyro the in takes method This robot. the of pose updated new the returns method distance. encoder right and distance encoder left the with along robot, the

---

must right) and (left distances **both** line, straight a in forward moving is robot the If :□□□□ positive. be must change of rate the – positively increasing be

---

Java

```
                                                                          @Override
                                                        { ()periodic void public
                                    gyro. the from robot the of rotation the Get //
                                         ();getRotation2dm_gyro. = gyroAngle var

                                                                  pose the Update //
                                          (gyroAngle,updatem_odometry. = m_pose
                                                     (),getDistancem_leftEncoder.
                                                   ());getDistancem_rightEncoder.
                                                                                  }
```

C++

```
                                                          { override ()Periodic void
                                    gyro. the from robot the of rotation the Get //
                           m_gyro.GetRotation2d(); = gyroAngle Rotation2d::frc

                                                                  pose the Update //
                                           m_odometry.Update(gyroAngle, = m_pose
                                     meter_t{m_leftEncoder.GetDistance()},::units
                                   meter_t{m_rightEncoder.GetDistance()});::units
                                                                                  }
```

### Pose Robot the Resetting 25.3.3

four accepts method This method. `resetPosition` the via reset be can pose robot The field- new the and positions, wheel right and left the angle, gyro current the arguments: pose. relative

`resetPosition` the encoders, or gyroscope your reset to decide you time, any at If :□□□□ distances. wheel and angle gyro new the with called be MUST method

.Java / C++ here: available is odometry with robot drive differential a of example full A :□□□□

the retrieve to used be can methods (Java) `getPoseMeters` / (C++) `GetPose` the addition, In update. an without pose robot current

## Kinematics Drive Swerve 25.4

`ChassisSpeeds` a between converts that tool useful a is class `SwerveDriveKinematics` The each for angles and velocities contains which objects, `SwerveModuleState` several and object robot. drive swerve a of module swerve

### class state module swerve The 25.4.1

singular a of angle and velocity the about information contains class `SwerveModuleState` The arguments, two in takes `SwerveModuleState` a for constructor The drive. swerve a of module module. the of angle the and module, the on wheel the of velocity the

units the C++, In second. per meters in be must wheel the of velocity the Java, In :□□□□ unit. velocity linear any using velocity the provide to used be can library

forward. facing modules the to corresponds 0 of angle An :□□□□

### object kinematics the Constructing 25.4.2

with arguments, constructor of number variable a accepts class `SwerveDriveKinematics` The a (as center robot the to relative module swerve a of location the being argument each swerve of number the to corresponds arguments constructor of number The .`Translation2d` modules.

modules. more or 2 have must drive swerve A :□□□□

when Therefore, modules. of number the on templated is class the C++, In :□□□□ number the class, a of variable member a as object `SwerveDriveKinematics` a constructing typical a for example, For argument. template a as in passed be must modules of follows: as constructed be must object kinematics the modules, four with drive swerve `.m_kinematics{...} ><4frc::SwerveDriveKinematics`

---

values x Positive robot. the of center the to relative be must modules the for locations The moving represent values y positive whereas robot the of front the toward moving represent robot. the of left the toward

Java

```
center. robot the to relative modules drive swerve the for Locations //
);0.381 ,0.381Translation2d( new = m_frontLeftLocation Translation2d
);0.381- ,0.381Translation2d( new = m_frontRightLocation Translation2d
);0.381 ,0.381-Translation2d( new = m_backLeftLocation Translation2d
);0.381- ,0.381-Translation2d( new = m_backRightLocation Translation2d

locations module the using object kinematics my Creating //
SwerveDriveKinematics( new = m_kinematics SwerveDriveKinematics
m_backRightLocation m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
);
```

C++

```
center. robot the to relative modules drive swerve the for Locations //
m};_0.381 m,_0.381m_frontLeftLocation{ Translation2d::frc
m};_0.381- m,_0.381m_frontRightLocation{ Translation2d::frc
m};_0.381 m,_0.381-m_backLeftLocation{ Translation2d::frc
m};_0.381- m,_0.381-m_backRightLocation{ Translation2d::frc

locations. module the using object kinematics my Creating //
m_kinematics{ >4<SwerveDriveKinematics::frc
m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
m_backRightLocation};
```

### states module to speeds chassis Converting 25.4.3

/ (Java) `speeds) toSwerveModuleStates(ChassisSpeeds` The convert to used be should method (C++) `speeds) ToSwerveModuleStates(ChassisSpeeds` in useful is This objects. `SwerveModuleState` of array an a to object `ChassisSpeeds` a angular an and velocity, sideways velocity, forward a convert to have you where situations states. module individual into velocity

the which in order same the are method this by returned is that array the in elements The constructed was object kinematics the if example, For constructed. was object kinematics location, module left back location, module right front location, module left front the with front the be would array the in elements the order, that in location module right back the and module right back and state, module left back state, module right front state, module left order. that in state

Java

```
meters 3 forward, second per meter 1 speeds: chassis Example //
second per radians 1.5 at rotation and left, the to second per //
counterclockwise. //
);1.5 ,3.0 ,1.0ChassisSpeeds( new = speeds ChassisSpeeds
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                             states module to Convert //
      (speeds);toSwerveModuleStateskinematics. = moduleStates ][SwerveModuleState

                                               state module left Front //
                                 ;]0[moduleStates = frontLeft SwerveModuleState

                                              state module right Front //
                                ;]1[moduleStates = frontRight SwerveModuleState

                                                state module left Back //
                                  ;]2[moduleStates = backLeft SwerveModuleState

                                               state module right Back //
                                 ;]3[moduleStates = backRight SwerveModuleState
```

C++

```
               meters 3 forward, second per meter 1 speeds: chassis Example //
              second per radians 1.5 at rotation and left, the to second per //
                                                        counterclockwise. //
                          rad_per_s};_1.5 mps,_3 mps,_1speeds{ ChassisSpeeds::frc

               structured s'C++17 use can we Here, states. module to Convert //
               its into array the up split automatically to feature bindings //
                                components. SwerveModuleState individual //
               kinematics.ToSwerveModuleStates(speeds); = br] bl, fr, [fl, auto
```

### optimization angle Module

(C++) `Optimize()` / (Java) `optimize()` static a contains class `SwerveModuleState` The `SwerveModuleState` given a of setpoint angle and speed the ”optimize“ to used is that method module certain a of setpoint angular the if example, For heading. in change the minimize to method this degrees, 89- is angle current your but degrees, 90 is kinematics inverse from 90- setpoint angular the make and setpoint module the of speed the negate automatically will travel. to has module the distance the reduce to degrees

the from (usually state desired the parameters: two takes method This optimized new the return will It angle. current the and method) `toSwerveModuleStates` loop. control feedback your in setpoint the as use can you which state

Java

```
                (frontLeft,optimizeSwerveModuleState. = frontLeftOptimized var
                          ()));getDistanceRotation2d(m_turningEncoder. new
```

C++

```
                     Optimize(fl,::SwerveModuleState::frc = flOptimized auto
                         radian_t(m_turningEncoder.GetDistance()));::units
```

### drive orientedField-

speeds. orientedfield- desired of set a from created be can object `ChassisSpeeds` a that *Recall* speeds. orientedfield- desired of set a from states module get to used be can feature This

Java

```
        second per meters 2 is here speed relative field desired The //
    per meters 2 and wall, station alliance s'opponent the toward //
      rotation desired The boundary. field left the toward second //
current The counterclockwise. second per rotation a of quarter a is //
                                        degrees. 45 is angle robot //
        (fromFieldRelativeSpeedsChassisSpeeds. = speeds ChassisSpeeds
            ));45.0(fromDegreesRotation2d. ,2.0 / PIMath. ,2.0 ,2.0 

                                    kinematics our in this use Now //
  (speeds);toSwerveModuleStateskinematics. = moduleStates ][SwerveModuleState
```

C++

```
        second per meters 2 is here speed relative field desired The //
    per meters 2 and wall, station alliance s'opponent the toward //
      rotation desired The boundary. field left the toward second //
current The counterclockwise. second per rotation a of quarter a is //
                                        degrees. 45 is angle robot //
     FromFieldRelativeSpeeds(::ChassisSpeeds::frc = speeds ChassisSpeeds::frc
_45Rotation2d( ),2.0 / pi::numbers::radians_per_second_t(std::units mps,_2 mps,_2 
                                                               deg)); ↪

                                    kinematics our in this use Now //
             kinematics.ToSwerveModuleStates(speeds); = br] bl, fr, [fl, auto
```

### rotation of centers custom Using

evasive certain for desirable be might corner specific one around rotating Sometimes, same The classes. WPILib the by supported also is behavior of type This maneuvers. (as rotation of center the for parameter second a accepts method `ToSwerveModuleStates()` center the representing `Translation2d` the locations, wheel the like Just ).`Translation2d` a center. robot the to relative be should rotation of

---

the from velocities vy and vx provided the frame, rigid a are robots all Because :□□□□ from `omega` the However, robot. the of entirety the for apply still will object `ChassisSpeeds` the object `ChassisSpeeds` the will be measured from the center of rotation.

---

provided the if and module certain a on rotation of center the set can one example, For to appear will robot the ,`omega` zeronon- a and zero of vy and vx a has object `ChassisSpeeds` module. swerve particular that around rotate

### speeds chassis to states module Converting 25.4.4

to objects `SwerveModuleState` of array an convert to object kinematics the use also can One `states) toChassisSpeeds(SwerveModuleState...` The object. `ChassisSpeeds` singular a to used be can method (C++) `states) ToChassisSpeeds(SwerveModuleState...` / (Java) this. achieve

Java

```
                                                              states module Example //
   ));140.19-(fromDegreesRotation2d. ,23.43SwerveModuleState( new = frontLeftState var
   ));39.81-(fromDegreesRotation2d. ,23.43SwerveModuleState( new = frontRightState var
    ));109.44-(fromDegreesRotation2d. ,54.08SwerveModuleState( new = backLeftState var
    ));70.56-(fromDegreesRotation2d. ,54.08SwerveModuleState( new = backRightState var

                                                            speeds chassis to Convert //
                            (toChassisSpeedskinematics. = chassisSpeeds ChassisSpeeds
                     backRightState); backLeftState, frontRightState, frontLeftState,

                                                         speeds individual Getting //
                                        ;vxMetersPerSecondchassisSpeeds. = forward double
                                       ;vyMetersPerSecondchassisSpeeds. = sideways double
                                   ;omegaRadiansPerSecondchassisSpeeds. = angular double
```

C++

```
                                                              States module Example //
             deg)};_140.19-Rotation2d( mps,_23.43frontLeftState{ SwerveModuleState::frc
             deg)};_39.81-Rotation2d( mps,_23.43frontRightState{ SwerveModuleState::frc
              deg)};_109.44-Rotation2d( mps,_54.08backLeftState{ SwerveModuleState::frc
              deg)};_70.56-Rotation2d( mps,_54.08backRightState{ SwerveModuleState::frc

             bindings structured s'C++17 use can we Here, speeds. chassis to Convert //
                 its into struct ChassisSpeeds the up break automatically to feature //
                                                                 components. three //
                        kinematics.ToChassisSpeeds( = angular] sideways, [forward, auto
                     backRightState); backLeftState, frontRightState, frontLeftState,
```

## Odometry Drive Swerve 25.5

WPILib *.odometry* perform to order in classes kinematics drive swerve the use can user A drive swerve a of position the track to used be can that class `SwerveDriveOdometry` a contains field. the on robot

---

position robot's the of estimate the gyro, a and encoders uses only method this Because :□□□□ robots other with contact into comes robot your as especially time, over drift will field the on period. autonomous the during accurate very usually is odometry However, gameplay. during

---

## object odometry the Creating 25.5.1

template one requires constructor class `>NumModules <intSwerveDriveOdometry` The template The argument. optional one and arguments, mandatory three C++), (only argument modules. swerve of number the representing integer an is C++) (only argument

are: arguments mandatory The

- `SwerveDriveKinematics` a (as drive swerve your represents that object kinematics The instance)
- `)Rotation2d` a (as gyroscope your by reported angle The
- In `).SwerveModulePosition` of array an (as modules swerve the of positions initial The *units* the C++, In meters. in position wheel each with constructed be must this Java, order the that important is It positions. wheel your represent to used be must *library* which in order the as same the is objects `SwerveModulePosition` the pass you which in object. kinematics the created you

By `).Pose2d` a (as field the on robot your of pose starting the is argument optional fourth The `.0 = theta 0, = y 0, = x` at start will robot the default,

---

toward directly facing is robot the when angle robot the represents radians / degrees 0 :□□□□ should angle gyroscope your left, the to turns robot your As station. alliance opponent's your this for use can you that `GetRotation2d/getRotation2d` supplies interface `Gyro` The increase. system. coordinate the about information more for *System Coordinate Field* See purpose.

---

Java

```
                      center. robot the to relative modules drive swerve the for Locations //
                         );0.381 ,0.381Translation2d( new = m_frontLeftLocation Translation2d
                       );0.381- ,0.381Translation2d( new = m_frontRightLocation Translation2d
                         );0.381 ,0.381-Translation2d( new = m_backLeftLocation Translation2d
                       );0.381- ,0.381-Translation2d( new = m_backRightLocation Translation2d

                                  locations module the using object kinematics my Creating //
                              SwerveDriveKinematics( new = m_kinematics SwerveDriveKinematics
  m_backRightLocation m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
                                                                                           );

        ␣wheel initial the and object kinematics the from object odometry my Creating //
                                                                             positions. ↪
         the in and field the of end long the along meters 5 is pose starting our Here, //
            wall. alliance opposing the facing end, short the along field the of center //
                                    SwerveDriveOdometry( new = m_odometry SwerveDriveOdometry
                                                       (),getRotation2dm_gyro. m_kinematics,
                                                              { ][SwerveModulePosition new
                                                          (),getPositionm_frontLeftModule.
                                                         (),getPositionm_frontRightModule.
                                                           (),getPositionm_backLeftModule.
                                                           ()getPositionm_backRightModule.
                                             Rotation2d())); new ,13.5 ,5.0Pose2d( new ,}
```

C++

```
                      center. robot the to relative modules drive swerve the for Locations //
                            m};_0.381 m,_0.381m_frontLeftLocation{ Translation2d::frc
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                           m};_0.381- m,_0.381m_frontRightLocation{ Translation2d::frc
                             m};_0.381 m,_0.381-m_backLeftLocation{ Translation2d::frc
                           m};_0.381- m,_0.381-m_backRightLocation{ Translation2d::frc

                          locations. module the using object kinematics my Creating //
                                           m_kinematics{ >4<SwerveDriveKinematics::frc
                                          m_frontRightLocation, m_frontLeftLocation,
                                             m_backRightLocation m_backLeftLocation,
                                                                                    ;}

                      Here, object. kinematics the from object odometry my Creating //
            the in and field the of end long the along meters 5 is pose starting our //
                           forward. facing end, short the along field the of center //
           m_gyro.GetRotation2d(), m_odometry{m_kinematics, >4<SwerveDriveOdometry::frc
                             m_frontRight.GetPosition(), m_frontLeft.GetPosition(),{
                               m_backRight.GetPosition()}, m_backLeft.GetPosition(),
                                                   rad}};_0 m,_13.5 m,_5Pose2d{::frc
```

## pose robot the Updating 25.5.2

update The field. the on position robot the updates class odometry the of method `update` The `SwerveModulePosition` of array an with along robot, the of angle gyro the in takes method objects `SwerveModulePosition` the pass you which in order the that important is It objects. object. kinematics the created you which in order the as same the is

a of method `periodic()` the in preferably periodically, called be must method `update` This robot. the of pose updated new the returns method `update` The .*Subsystem*

Java

```
                                                                             @Override
                                                              { ()periodic void public
                                     gyro. the from robot the of rotation the Get //
                                             ();getRotation2dm_gyro. = gyroAngle var

                                                                  pose the Update //
                                               (gyroAngle,updatem_odometry. = m_pose
                                                      { ][SwerveModulePosition new
               (),getPositionm_frontRightModule. (),getPositionm_frontLeftModule.
                  ()getPositionm_backRightModule. (),getPositionm_backLeftModule.
                                                                               );}
                                                                                      }
```

C++

```
                                                            { override ()Periodic void
                                     gyro. the from robot the of rotation the Get //
                                 m_gyro.GetRotation2d(); = gyroAngle Rotation2d::frc

                                                                  pose the Update //
                                               m_odometry.Update(gyroAngle, = m_pose
                                                                                  {
               m_frontRightModule.GetPosition(), m_frontLeftModule.GetPosition(),
                  m_backRightModule.GetPosition() m_backLeftModule.GetPosition(),
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                      ;}
                                                                        }
```

### Pose Robot the Resetting 25.5.3

three accepts method This method. `resetPosition` the via reset be can pose robot The the in (as positions module current the of array an angle, gyro current the arguments: pose. relativefield- new the and method), update and constructor

---

the encoders, wheel or gyroscope your reset to decide you time, any at If :□□□□ positions. encoder wheel and angle gyro new the with called be MUST method `resetPosition`

---

The user. the to left is above `GetPosition() / getPosition()` of implementation The :□□□□ example, full a For module. each from angle) and (distance position module the get to is idea .Java / C++ here: see

---

the retrieve to used be can methods (Java) `getPoseMeters` / (C++) `GetPose` the addition, In update. an without pose robot current

## Kinematics Drive Mecanum 25.6

`ChassisSpeeds` a between converts that tool useful a is class `MecanumDriveKinematics` The four the of each for velocities contains which object, `MecanumDriveWheelSpeeds` a and object drive. mecanum a on wheels

### Object Kinematics the Constructing 25.6.1

argument each with arguments, constructor four accepts class `MecanumDriveKinematics` The for order The ).`Translation2d` a (as center robot the to relative wheel a of location the being wheels the for locations The right. back and left, back right, front left, front is arguments the the toward moving represent values x Positive robot. the of center the to relative be must robot. the of left the toward moving represent values y positive whereas robot the of front

Java

```
                              center. robot the to relative wheels the of Locations //
                  );0.381 ,0.381Translation2d( new = m_frontLeftLocation Translation2d
                );0.381- ,0.381Translation2d( new = m_frontRightLocation Translation2d
                  );0.381 ,0.381-Translation2d( new = m_backLeftLocation Translation2d
                );0.381- ,0.381-Translation2d( new = m_backRightLocation Translation2d

                           locations. wheel the using object kinematics my Creating //
                        MecanumDriveKinematics( new = m_kinematics MecanumDriveKinematics
   m_backRightLocation m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
                                                                                    );
```

C++

```
                          center. robot the to relative wheels the of Locations //
                    m};_0.381 m,_0.381m_frontLeftLocation{ Translation2d::frc
                  m};_0.381- m,_0.381m_frontRightLocation{ Translation2d::frc
                    m};_0.381 m,_0.381-m_backLeftLocation{ Translation2d::frc
                  m};_0.381- m,_0.381-m_backRightLocation{ Translation2d::frc

                      locations. wheel the using object kinematics my Creating //
                                     m_kinematics{ MecanumDriveKinematics::frc
       m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
                                                    m_backRightLocation};
```

## Speeds Wheel to Speeds Chassis Converting 25.6.2

`ToWheelSpeeds(ChassisSpeeds` / (Java) `speeds)` `toWheelSpeeds(ChassisSpeeds` The a to object `ChassisSpeeds` a convert to used be should method (C++) `speeds)` convert to have you where situations in useful is This object. `MecanumDriveWheelSpeeds` speeds. wheel individual into velocity angular an and velocity, sideways velocity, forward a

Java

```
                   meters 3 forward, second per meter 1 speeds: chassis Example //
                 second per radians 1.5 at rotation and left, the to second per //
                                                           counterclockwise. //
                          );1.5 ,3.0 ,1.0ChassisSpeeds( new = speeds ChassisSpeeds

                                                       speeds wheel to Convert //
         (speeds);toWheelSpeedskinematics. = wheelSpeeds MecanumDriveWheelSpeeds

                                            speeds wheel individual the Get //
                          frontLeftMetersPerSecondwheelSpeeds. = frontLeft double
                        frontRightMetersPerSecondwheelSpeeds. = frontRight double
                            rearLeftMetersPerSecondwheelSpeeds. = backLeft double
                          rearRightMetersPerSecondwheelSpeeds. = backRight double
```

C++

```
                   meters 3 forward, second per meter 1 speeds: chassis Example //
                 second per radians 1.5 at rotation and left, the to second per //
                                                           counterclockwise. //
                          rad_per_s};_1.5 mps,_3 mps,_1speeds{ ChassisSpeeds::frc

                   structured s'C++17 use can we Here, speeds. wheel to Convert //
             MecanumDriveWheelSpeeds the up split automatically to feature bindings //
                                     components individual s'it into struct //
                        kinematics.ToWheelSpeeds(speeds); = br] bl, fr, [fl, auto
```

### Field-oriented drive

*Recall* that a `ChassisSpeeds` object can be created from a set of desired field-oriented speeds. This feature can be used to get wheel speeds from a set of desired field-oriented speeds.

Java

```java
// The desired field relative speed here is 2 meters per second
// toward the opponent's alliance station wall, and 2 meters per
// second toward the left field boundary. The desired rotation
// is a quarter of a rotation per second counterclockwise. The current
// robot angle is 45 degrees.
ChassisSpeeds speeds = ChassisSpeeds.fromFieldRelativeSpeeds(
  2.0, 2.0, Math.PI / 2.0, Rotation2d.fromDegrees(45.0));

// Now use this in our kinematics
MecanumDriveWheelSpeeds wheelSpeeds = kinematics.toWheelSpeeds(speeds);
```

C++

```cpp
// The desired field relative speed here is 2 meters per second
// toward the opponent's alliance station wall, and 2 meters per
// second toward the left field boundary. The desired rotation
// is a quarter of a rotation per second counterclockwise. The current
// robot angle is 45 degrees.
frc::ChassisSpeeds speeds = frc::ChassisSpeeds::FromFieldRelativeSpeeds(
  2_mps, 2_mps, units::radians_per_second_t(std::numbers::pi / 2.0), Rotation2d(45_deg));

// Now use this in our kinematics
auto [fl, fr, bl, br] = kinematics.ToWheelSpeeds(speeds);
```

### Using custom centers of rotation

Sometimes, rotating around one specific corner might be desirable for certain evasive maneuvers. This type of behavior is also supported by the WPILib classes. The same `ToWheelSpeeds()` method accepts a second parameter for the center of rotation (as a `Translation2d`). Just like the wheel locations, the `Translation2d` representing the center of rotation should be relative to the robot center.

---

□□□□: Because all robots are a rigid frame, the provided vx and vy velocities from the `ChassisSpeeds` object will still apply for the entirety of the robot. However, the `omega` from the `ChassisSpeeds` object will be measured from the center of rotation.

---

For example, one can set the center of rotation on a certain wheel and if the provided `ChassisSpeeds` object has a vx and vy of zero and a non-zero `omega`, the robot will appear to rotate around that particular wheel.

### speeds chassis to speeds wheel Converting 25.6.3

a to object `MecanumDriveWheelSpeeds` a convert to object kinematics the use also can One `speeds) toChassisSpeeds(MecanumDriveWheelSpeeds` The object. `ChassisSpeeds` singular used be can method (C++) `speeds) ToChassisSpeeds(MecanumDriveWheelSpeeds` / (Java) this. achieve to

Java

```
speeds wheel Example //
);16.26 ,13.44- ,20.51 ,17.67-MecanumDriveWheelSpeeds( new = wheelSpeeds var

speeds chassis to Convert //
(wheelSpeeds);toChassisSpeedskinematics. = chassisSpeeds ChassisSpeeds

speeds individual Getting //
;vxMetersPerSecondchassisSpeeds. = forward double
;vyMetersPerSecondchassisSpeeds. = sideways double
;omegaRadiansPerSecondchassisSpeeds. = angular double
```

C++

```
speeds wheel Example //
mps}_16.26 mps,_13.44- mps,_20.51 mps,_17.67-wheelSpeeds{ MecanumDriveWheelSpeeds::frc
; ↪

bindings structured s'C++17 use can we Here, speeds. chassis to Convert //
its into struct ChassisSpeeds the up break automatically to feature //
components. three //
kinematics.ToChassisSpeeds(wheelSpeeds); = angular] sideways, [forward, auto
```

## Odometry Drive Mecanum 25.7

WPILib .*odometry* perform to order in classes kinematics drive mecanum the use can user A mecanum a of position the track to used be can that class `MecanumDriveOdometry` a contains field. the on robot drive

---

position robot's the of estimate the gyro, a and encoders uses only method this Because :□□□□ robots other with contact into comes robot your as especially time, over drift will field the on period. autonomous the during accurate very usually is odometry However, gameplay. during

---

### object odometry the Creating 25.7.1

one and arguments mandatory three requires constructor class `MecanumDriveOdometry` The argument. optional

are: arguments mandatory The

- a (as drive mecanum your represents that object kinematics The instance) `MecanumDriveKinematics`
- )`Rotation2d` a (as gyroscope your by reported angle The

must this Java, In ).`MecanumDriveWheelPositions` (as wheels the of positions initial The •
be must *library units* the C++, In meters. in position wheel each with constructed be
positions. wheel your represent to used

By ).`Pose2d` a (as field the on robot your of pose starting the is argument optional fourth The
`.0 = theta 0, = y 0, = x` at start will robot the default,

toward directly facing is robot the when angle robot the represents radians / degrees 0 :□□□□
should angle gyroscope your left, the to turns robot your As station. alliance opponent's your
this for use can you that `GetRotation2d/getRotation2d` supplies interface `Gyro` The increase.
system. coordinate the about information more for *System Coordinate Field* See purpose.

Java

```
                        center. robot the to relative wheels the of Locations //
              );0.381 ,0.381Translation2d( new = m_frontLeftLocation Translation2d
           );0.381- ,0.381Translation2d( new = m_frontRightLocation Translation2d
             );0.381 ,0.381-Translation2d( new = m_backLeftLocation Translation2d
           );0.381- ,0.381-Translation2d( new = m_backRightLocation Translation2d

                   locations. wheel the using object kinematics my Creating //
                     MecanumDriveKinematics( new = m_kinematics MecanumDriveKinematics
  m_backRightLocation m_backLeftLocation, m_frontRightLocation, m_frontLeftLocation,
                                                                                 );

     ␣wheel initial the and object kinematics the from object odometry my Creating //
                                                                      positions. ↪
the in and field the of end long the along meters 5 is pose starting our Here, //
   wall. alliance opposing the facing end, short the along field the of center //
                               MecanumDriveOdometry( new = m_odometry MecanumDriveOdometry
                                                                       m_kinematics,
                                                             (),getRotation2dm_gyro.
                                                   MecanumDriveWheelPositions( new
         (),getDistancem_frontRightEncoder. (),getDistancem_frontLeftEncoder.
            ()getDistancem_backRightEncoder. (),getDistancem_backLeftEncoder.
                                                                                ),
                                        Rotation2d()) new ,13.5 ,5.0Pose2d( new
                                                                                 );
```

C++

```
                        center. robot the to relative wheels the of Locations //
                  m};_0.381 m,_0.381m_frontLeftLocation{ Translation2d::frc
                m};_0.381- m,_0.381m_frontRightLocation{ Translation2d::frc
                  m};_0.381 m,_0.381-m_backLeftLocation{ Translation2d::frc
                m};_0.381- m,_0.381-m_backRightLocation{ Translation2d::frc

                      locations. wheel the using object kinematics my Creating //
                                   m_kinematics{ MecanumDriveKinematics::frc
                              m_frontRightLocation, m_frontLeftLocation,
                                 m_backRightLocation m_backLeftLocation,
                                                                     ;}

                  Here, object. kinematics the from object odometry my Creating //
            the in and field the of end long the along meters 5 is pose starting our //
                        forward. facing end, short the along field the of center //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
m_odometry{ MecanumDriveOdometry::frc
            m_kinematics,
      m_gyro.GetRotation2d(),
 MecanumDriveWheelPositions{::frc
meter_t{m_frontLeftEncoder.GetDistance()},::units
meter_t{m_frontRightEncoder.GetDistance()},::units
meter_t{m_backLeftEncoder.GetDistance()},::units
meter_t{m_backRightEncoder.GetDistance()}::units
                                        ,}
          rad}};_0 m,_13.5 m,_5Pose2d{::frc
```

## pose robot the Updating 25.7.2

update The field. the on position robot the updates class odometry the of method `update` The
`MecanumDriveWheelPositions` a with along robot, the of angle gyro the in takes method
method `update` This robot. the on wheels 4 the of each of position the representing object
`update` The .*Subsystem* a of method `periodic()` the in preferably periodically, called be must
robot. the of pose updated new the returns method

Java

```
@Override
{ ()periodic void public
positions wheel my Get //
MecanumDriveWheelPositions( new = wheelPositions var
(),getDistancem_frontRightEncoder. (),getDistancem_frontLeftEncoder.
());getDistancem_backRightEncoder. (),getDistancem_backLeftEncoder.

gyro. the from robot the of rotation the Get //
();getRotation2dm_gyro. = gyroAngle var

pose the Update //
wheelPositions); (gyroAngle,updatem_odometry. = m_pose
}
```

C++

```
{ override ()Periodic void
positions wheel my Get //
wheelPositions{ MecanumDriveWheelPositions::frc
meter_t{m_frontLeftEncoder.GetDistance()},::units
meter_t{m_frontRightEncoder.GetDistance()},::units
meter_t{m_backLeftEncoder.GetDistance()},::units
meter_t{m_backRightEncoder.GetDistance()}};::units

gyro. the from robot the of rotation the Get //
m_gyro.GetRotation2d(); = gyroAngle Rotation2d::frc

pose the Update //
wheelPositions); m_odometry.Update(gyroAngle, = m_pose
}
```

### Pose Robot the Resetting 25.7.3

three accepts method This method. `resetPosition` the via reset be can pose robot The
relativefield- new the and positions, wheel current the angle, gyro current the arguments:
pose.

---

`resetPosition` the encoders, or gyroscope your reset to decide you time, any at If **:□□□□**
positions. wheel and angle gyro new the with called be MUST method

---

.Java / C++ here: available is odometry with robot drive mecanum a of example full A **:□□□□**

---

the retrieve to used be can methods (Java) `getPoseMeters` / (C++) `GetPose` the addition, In
update. an without pose robot current

# [redacted]

communicate to API (v4) NetworkTables the using of details the outlines section This network. robot the across information

Ensure paste.copy- to user the for intended not are section this in examples code The :□□□□ is )Python ,C++ ,Java( API the and read thoroughly is documentation following the that necessary. when consulted

## NetworkTables is What 26.1

are Values .system messaging subscribepublish- a of implementation an is *NetworkTables* attached an potentially or station, driver robot, the on either ”topics“ named to published For topic. the to subscribers all to distributed automatically are values the and coprocessor, perform network, the over images camera receive might laptop station driver a example, robot. the to back sent to values some with up come and algorithm, processing vision some topics NetworkTables to results these writing By Distance. and Y, X, an be might values The Then written. being after shortly robot the by read be can they ”Distance“ and ”Y“, ”X“, called topics to values sensor write can program robot the Similarly, them. upon act can robot the and those can be read and plotted in real time on a dashboard application.

built is and LabVIEW, or C++, Java, in robot the on programs by used be can NetworkTables WPILib. of version each into

### Concepts NetworkTables 26.1.1

terms: some define let’s First,

- topic) the of lifetime the (for type data fixed a have Topics channel. data named a :**Topic** properties. *mutable* and
- values. data timestamped sends and creates and topic the defines :**Publisher**
- topics. more or one to updates value data timestamped receives :**Subscriber**

- the but active, always is subscriber The subscriber. and publisher combined a :**Entry** ”set“, is value a (e.g. performed is operation publish a until created not is publisher separate a maintaining than convenient more be may This entry). the on published, aka subscriber. and publisher
- separately updated and stored topic a about (metadata) information named :**Property** value property’s A properties. of number any have may topic A data. topic’s the from JSON. in represented be can that type data any be can

arrays and string, numeric, ,*boolean* including types, data of range a supports NetworkTables ,*point floating* precision double or single are types data numeric Supported types. those of which bytes), of array (an data raw storing of option the also is There integer. bit64- or as represented are Types data. structured encoded binary representing for used be can the in types common most the for *enumeration* an also is There reasons. efficiency for strings API. NetworkTables

the when removed are and topic the announces publisher first the when created are Topics been yet not has that topic a to subscribe to possible It’s publishing. stops publisher last created/published.

changed be may but publisher, first the by set initially are Properties properties. have Topics subscribers all to propagated are topic a to changes property values, to Similarly time. any at key/value a simply are level top the at but (JSON), data structured are Properties topic. that to by set be can ones arbitrary but behavior, defined have properties Some map). JSON (a store application. the

single a to publishers multiple be can there while type; data topic’s the specify Publishers NetworkTables the by enforced is This type. data same the publishing be all must they topic, data what specify also subscribers topicsingle- Typically ”wins“). publisher first (the server type they’re expecting to receive on a topic and thus won’t receive value updates of other types.

## Topics Persistent and Retained 26.1.2

publishing, stops publisher last the after disappear and *transitory* are topics default by While prevent to true) to property ”retained“ the setting (via *retained* as marked be can topics the of publisher implicit an as acts server the topics, retained For disappearing. from them for useful primarily is This running. is server the as long as so doing keep will and value, last should dashboard a by published selection mode autonomous an e.g. values; configuration disconnects. dashboard the case in preserved is value its so retained as topic the set

to property ”persistent“ the setting via *persistent* as marked be can topics Additionally, are values topic persistent addition, in but topics, retained to similarly operate These true. is topic the again, up starts server the when and server the on file a to saved automatically server. the by published is value last its and created

### Propagation Value 26.1.3

initially subscriber a When topic. every for value published last the of copy a keeps server The new value, initial that After value. published last the sends server the topic, a to subscribes value. new a sends publisher the time each subscribers to communicated are updates value

rather but other, each to directly talk not do clients system; client/server a is NetworkTables pieces other and server, the is program robot the Typically, server. the via communicate that clients are coprocessor) a or station driver the (e.g. computers other on software of from first sent is value the value, a publishes (client) coprocessor a when Thus, it. to connect distributes program robot the then and (server), program robot the to (client) coprocessor the as such clients other or program, local program robot the (e.g. subscribers any to value that dashboards).

subscribed not have that clients to updates value or changes topic send not does server The topic. the to

the limit help to data the batching periodically, updates value sends NetworkTables default, By recent most the only default, by Also, network. the over sent being packets small of number transmissions network between made changes value intermediate any transmitted; is value and options–publishers publish/subscribe via changed be can behavior This discarded. are via communicated and preserved be should updates value all that indicate can subscribers current all ”flush“ to NetworkTables force to possible is it addition, In option. all“ ”send the latency. minimizing for useful is this network; the to updates

### Timestamps 26.1.4

Timestamps published. are they time the at timestamped are updates value NetworkTable All microseconds. integer in measured are NetworkTables in

Each clients. and server the between time synchronizes automatically NetworkTables a when so time, server the and time local client the between offset an maintains client equivalent the calculates and time local in timestamp a stores it value, a publishes client any to network the over communicated is what is timestamp server The timestamp. server estimation reasonable a get to program robot a for e.g. possible it makes This subscribers. time. current the to relative coprocessor a on published was value a when time the of

indicating timestamp server a API: the through visible are timestamps two this, of Because client. the on time the indicating timestamp local a and server, the on (estimated) time the the as same the is timestamp server the server, NetworkTables the is RoboRIO the When different: are units the (except `Timer.getFPGATimestamp()` by returned timestamp FPGA seconds). returns `getFPGATimestamp()` while microseconds, uses NetworkTables

### Organization NetworkTables 26.1.5

files. and folders filesystem's a like much hierarchy a in NetworkTables in organized is Data whatever in nested be may that (files) topics and (folders) subtables multiple be can There ,C++ ,Java :`NetworkTableInstance`( level top the At desired. organization data the fits way are subtables filesystem: a in paths absolute to similar handled are names topic ),Python and subtable nested the separating (”/“) slashes with name topic long a as represented subtable single a represents object )Python ,C++ ,Java( `NetworkTable` A names. value table root a for e.g. path: base NetworkTable's the to relative are names topic so (folder), via accessed be can topic same the ”xValue“, named topic a with ”SmartDashboard“ called a unlike However, ”/SmartDashboard/xValue“. named topic a as `NetworkTableInstance` to way no is there as do, folders way same the in exist really don't subtables filesystem, are there as long as only "appears" subtable network–a the on subtable empty an represent it. within published topics

show can and NetworkTables, in stored values the exploring for utility a is *OutlineViewer* topics). and (subtables view nested a or paths) absolute with (topics view flat a either

up: starts program robot a when automatically created are that tables default some are There

| Table name | השתמשו ב: |
|---|---|
| /SmartDashboard | the using Shuffleboard or SmartDashboard the to written values store to Used methods. of set `SmartDashboard.put()` |
| /LiveWindow | these Typically values. Station) Driver the on (Test mode Test store to Used actuators. and sensors associated the and Subsystems are |
| /FMSInfo | Driver the from comes that match running currently the about Information System Management Field the and Station |

### Variants API NetworkTables 26.1.6

(C++ API orientedobject- The API. NetworkTables the of variants major two are There that classes provides and use, team general and code robot for recommended is Java) and orientedobject- writing as such cases use advanced For API. the of use correct ensure help API. basedhandle- C/C++ a also there's languages, programming other for wrappers

### Management Lifetime 26.1.7

exist. objects the as long as exist only entries and subscribers, Publishers,

by it release properly not and publisher or subscriber a create to is bug common a Java, In of period unknown an for around lingering object the in result will this as ,`close()` calling programs, robot in issue an of common less is This properly. resources releasing not and time for persists that variable instance an in stored is object subscriber or publisher the as long as program. the of life the

automatically are they means which ,*RAII* are entries and subscribers, publishers, C++, In is it this; to exception an is `NetworkTableInstance` scope. of out go they when destroyed it. of instance global a maintain to necessary not it's so destroyed, explicitly be to designed

are they when released are publishers or subscribers that except Java, to similar is Python collected. garbage

## Topics and Tables NetworkTables 26.2

### Class NetworkTable the Using 26.2.1

single a represents that abstraction API an is class )Python ,C++ ,Java( `NetworkTable` The NetworkTable The .*Organization NetworkTables* in described as topics of "table") (or "folder" table, the within topics get to functions provides and table the to path base the stores class path. table the prepending automatically

### Topic a Getting 26.2.2

1:1 a has This .*topic* a represents handle) `NT_Topic` (or object )Python ,C++ ,Java( Topic A exists. instance the as long as change not will and name, topic’s the with correspondence object. Topic a store to necessary not is it subscribers, and publishers Unlike

For type. correct the of is or exists topic the mean not does handle or object Topic a Having classes Topic specifictype- are there subscribers, and publishers creating when convenience ensure to level Topic the at check no is there but ),Python ,C++ ,Java :`BooleanTopic` (e.g. to topic specifictype- a get to method preferred The matches. actually type topic’s the that generic a convert directly to possible also it’s but getter, specifictype- appropriate the call of concept a have not does API basedhandle- the Note: class. Topic specifictype- a into Topic classes. specifictype-

Java

```
();getDefaultNetworkTableInstance. = inst NetworkTableInstance
);"datatable"(getTableinst. = table NetworkTable

NetworkTableInstance a from topic a get //
name full the is case this in name topic the //
);"datatable/X/"(getDoubleTopicinst. = dblTopic DoubleTopic

NetworkTable a from topic a get //
table; the within name the is case this in name topic the //
topic same the reference above one the and line this //
);"X"(getDoubleTopictable. = dblTopic DoubleTopic

Topic generic a from topic type-specific a get //
);"datatable/X/"(getTopicinst. = genericTopic Topic
DoubleTopic(genericTopic); new = dblTopic DoubleTopic
```

C++

```
GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt
);"datatable"inst.GetTable( = table >NetworkTable::nt<shared_ptr::std

NetworkTableInstance a from topic a get //
name full the is case this in name topic the //
);"datatable/X/"inst.GetDoubleTopic( = dblTopic DoubleTopic::nt

NetworkTable a from topic a get //
table; the within name the is case this in name topic the //
topic same the reference above one the and line this //
);"X"GetDoubleTopic(>-table = dblTopic DoubleTopic::nt

Topic generic a from topic type-specific a get //
);"datatable/X/"inst.GetTopic( = genericTopic Topic::nt
dblTopic{genericTopic}; DoubleTopic::nt
```

based)(handle- C++

```
GetDefaultInstance();::nt = inst NT_Instance

NetworkTableInstance a from topic a get //
);"datatable/X/" GetTopic(inst,::nt = topic NT_Topic
```

C

```
NT_Instance inst = NT_GetDefaultInstance();

// get a topic from a NetworkTableInstance
NT_Topic topic = NT_GetTopic(inst, "/datatable/X");
```

Python

```
import ntcore

inst = ntcore.NetworkTableInstance.getDefault()
table = inst.getTable("datatable")

# get a topic from a NetworkTableInstance
# the topic name in this case is the full name
dblTopic = inst.getDoubleTopic("/datatable/X")

# get a topic from a NetworkTable
# the topic name in this case is the name within the table;
# this line and the one above reference the same topic
dblTopic = table.getDoubleTopic("X")

# get a type-specific topic from a generic Topic
genericTopic = inst.getTopic("/datatable/X")
dblTopic = new DoubleTopic(genericTopic)
```

## 26.3 Publishing and Subscribing to a Topic

### 26.3.1 Publishing to a Topic

In order to create a *topic* and publish values to it, it's necessary to create a *publisher*.

NetworkTable publishers are represented as type-specific Publisher objects (e.g. `BooleanPublisher`: Java, C++, Python). Publishers are only active as long as the Publisher object exists. Typically you want to keep publishing longer than the local scope of a function, so it's necessary to store the Publisher object somewhere longer term, e.g. in an instance variable. In Java, the `close()` method needs be called to stop publishing; in C++ this is handled by the destructor. C++ publishers are moveable and non-copyable. In Python the `close()` method should be called to stop publishing, but it will also be closed when the object is garbage collected.

In the handle-based APIs, there is only the non-type-specific `NT_Publisher` handle; the user is responsible for keeping track of the type of the publisher and using the correct type-specific set methods.

Publishing values is done via a `set()` operation. By default, this operation uses the current time, but a timestamp may optionally be specified. Specifying a timestamp can be useful when multiple values should have the same update timestamp. The timestamp units are integer microseconds (see example code for how to get a current timestamp that is consistent with the library).

Java

```
public class Example {
  // the publisher is an instance variable so its lifetime matches that of the class
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
dblPub; DoublePublisher final

{ dblTopic) (DoubleTopicExample public
via case, this (in retained be must value return the publishing; start //
variable) instance an //
();publishdblTopic. = dblPub

PubSubOption using specified be may options publish //
));true(keepDuplicates(PubSubOption.publishdblTopic. = dblPub

initial setting as such options additional provides publishEx //
for string type custom a Using string. type custom a using and properties //
string properties The recommended. not is string and raw than other types //
map. JSON a be must //
);"5} :"\myprop"\{" ,"double"(publishExdblTopic. = dblPub
}

{ ()periodic void public
value default a publish //
);0.0(setDefaultdblPub.

timestamp current with value a publish //
);1.0(setdblPub.
time current use = 0 //  );0 ,2.0(setdblPub.

can NetworkTablesJNI.now() timestamp; specific a with value a publish //
as same the is this roboRIO, the On time. current the get to used be //
RobotController.getFPGATime()) (e.g. timestamp FPGA the //
();nowNetworkTablesJNI. = time long
time); ,3.0(setdblPub.

interface; functional Consumer appropriate the implement also publishers //
exists func) myFunc(DoubleConsumer void assumes example this //
myFunc(dblPub);
}

for exist t'doesn class this unless code, robot in required not often //
be to needs close() case which in program, robot entire the of lifetime the //
publishing stop to called //
{ ()close void public
publishing stop //
();closedblPub.
}
}
```

C++

```
{ Example class
class the of that matches lifetime its so variable instance an is publisher the //
␣class the by destroyed is dblPub when stopped automatically is publishing //
destructor ↪
dblPub; DoublePublisher::nt

:public
{ dblTopic) DoubleTopic::Example(nt explicit
via case, this (in retained be must value return the publishing; start //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
variable) instance an //
dblTopic.Publish(); = dblPub

PubSubOptions using specified be may options publish //
);}true = dblTopic.Publish({.keepDuplicates = dblPub

initial setting as such options additional provides PublishEx //
for string type custom a Using string. type custom a using and properties //
must properties The recommended. not is string and raw than other types //
map. JSON a be //
);}}5 ,"myprop"{{ ,"double"dblTopic.PublishEx( = dblPub
}

{ Periodic() void
value default a publish //
);0.0dblPub.SetDefault(

timestamp current with value a publish //
);1.0dblPub.Set(
time current use = 0 //  );0 ,2.0dblPub.Set(

can nt::Now() timestamp; specific a with value a publish //
time. current the get to used be //
Now();::nt = time int64_t
time); ,3.0dblPub.Set(
}
;}
```

based)(handle- C++

```
{ Example class
s'it handle, a s'it since but variable, instance an is publisher the //
destructor a need we so released, automatically not //
dblPub; NT_Publisher

:public
{ dblTopic) Example(NT_Topic explicit
standard be string type the that recommended s'It publishing. start //
raw. and string except types all for //
);"double" NT_DOUBLE, Publish(dblTopic,::nt = dblPub

PubSubOptions using specified be may options publish //
,"double" NT_DOUBLE, Publish(dblTopic,::nt = dblPub
);}true = keepDuplicates.{

The properties. initial setting allows PublishEx //
map. JSON a be must properties //
);}}5 ,"myprop"{{ ,"double" NT_DOUBLE, PublishEx(dblTopic,::nt = dblPub
}

{ Periodic() void
value default a publish //
);0.0 SetDefaultDouble(dblPub,::nt

timestamp current with value a publish //
);1.0 SetDouble(dblPub,::nt
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                            time current use = 0 //  );0 ,2.0 SetDouble(dblPub,::nt

                        can nt::Now() timestamp; specific a with value a publish //
                                                time. current the get to used be //
                                                          Now();::nt = time int64_t
                                                  time); ,3.0 SetDouble(dblPub,::nt
                                                                                    }

                                                                         { Example()~
                                                                 publishing stop //
                                                             Unpublish(dblPub);::nt
                                                                                    }
                                                                                     ;}
```

C

```
                  exists already variable dblTopic NT_Topic a that assumes code This //

                 standard be string type the that recommended s'It publishing. start //
                                                raw. and string except types all for //
              );0 ,NULL ,"double" NT_DOUBLE, NT_Publish(dblTopic, = dblPub NT_Publisher

                                                    specified be may options publish //
                                                       options; NT_PubSubOptions struct
                                                  (options));sizeof ,0 options,&memset(
                                                  (options);sizeof = options.structSize
                                                   true //  ;1 = options.keepDuplicates
             options);& ,"double" NT_DOUBLE, NT_Publish(dblTopic, = dblPub NT_Publisher

             must string properties The properties. initial setting allows PublishEx //
                                                                      map. JSON a be //
                                                                  = dblPub NT_Publisher
           );0 ,NULL ,"5} ,"\myprop"\{" ,"double" NT_DOUBLE, NT_PublishEx(dblTopic,

                                                             value default a publish //
                                                      );0.0 NT_SetDefaultDouble(dblPub,

                                              timestamp current with value a publish //
                                                             );1.0 NT_SetDouble(dblPub,
                                 time current use = 0 //  );0 ,2.0 NT_SetDouble(dblPub,

                             can NT_Now() timestamp; specific a with value a publish //
                                                    time. current the get to used be //
                                                               NT_Now(); = time int64_t
                                                       time); ,3.0 NT_SetDouble(dblPub,

                                                                     publishing stop //
                                                                  NT_Unpublish(dblPub);
```

Python

```
                                                                         :Example class
                                  DoubleTopic):.ntcore dblTopic: ,self(init____ def

       via case, this (in retained be must value return the publishing; start #
                                                        variable) instance an #
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                          publish().dblTopic = dblPub.self

                          PubSubOption using specified be may options publish #
     ))True=PubSubOptions(keepDuplicates.publish(ntcore.dblTopic = dblPub.self

                     initial setting as such options additional provides publishEx #
  for string type custom a Using string. type custom a using and properties #
  string properties The recommended. not is string and raw than other types #
                                                        map. JSON a be must #
                         )'5} :"myprop"{' ,"double"publishEx(.dblTopic = dblPub.self

                                                          ):self(periodic def
                                                 value default a publish #
                                               )0.0setDefault(.dblPub.self

                                   timestamp current with value a publish #
                                                    )1.0set(.dblPub.self
                              time current use = 0 #  )0 ,2.0set(.dblPub.self

     resolution. microsecond with timestamp specific a with value a publish #
            (e.g. timestamp FPGA the as same the is this roboRIO, the On #
                                  RobotController.getFPGATime()) #
                              now())_.ntcore ,3.0set(.dblPub.self

         for exist t'doesn class this unless code, robot in required not often #
    be to needs close() case which in program, robot entire the of lifetime the #
                                               publishing stop to called #
                                                          ):self(close def
                                                    publishing stop #
                                                   close().dblPub.self
```

## Topic a to Subscribing 26.3.2

NetworkTable publishers, to Similar topic. a to made updates value receives *subscriber* A :`BooleanSubscriber` (e.g. classes Subscriber specifictype- as represented are subscribers subscribing. continue to somewhere stored be must that )Python ,C++ ,Java

read just to possible It's values. received read to ways different of range a have Subscribers timestamp, its with along value, recent most the read ,`get()` using value recent most the `readQueue()` using call last the since changes value all of array an get or ,`getAtomic()` using .`readQueueValues()` or

Java

```
                                                          { Example class public
  class the of that matches lifetime its so variable instance an is subscriber the //
                                                 dblSub; DoubleSubscriber final

                                     { dblTopic) (DoubleTopicExample public
                           retained. be must value return the subscribing; start //
     ␣is get() when available is value no if value default the is parameter the //
                                                                      called ↪
                                          );0.0(subscribedblTopic. = dblSub

                           PubSubOption using specified be may options subscribe //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                    = dblSub
    PubSubOption. ),true(keepDuplicatesPubSubOption. ,0.0(subscribedblTopic.
                                                         ));10(pollStorage ↪

                  string. type custom a using of options the provides subscribeEx //
           ␣not is string and raw than other types for string type custom a Using //
                                                                      recommended. ↪
                             );0.0 ,"double"(subscribeExdblTopic. = dblSub
                                                                              }

                                                    { ()periodic void public
                 published, been has value no if value; recent most of get simple //
                    function subscribe() the to passed value default the returns //
                                                    ();getdblSub. = val double

               returns published, been has value no if value; recent most the get //
                                                    value default passed-in the //
                                                    );1.0-(getdblSub. = val double

            ␣e.g. interface, Supplier appropriate the implement also subscribers //
                                                                  DoubleSupplier ↪
                                            ();getAsDoubledblSub. = val double

                            timestamp its with along value, recent most the get //
                               ();getAtomicdblSub. = tsVal TimestampedDouble

            readQueue/readQueueValues to call last the since changes value all read //
                          not. does readQueueValues() timestamps; returns readQueue() //
                                 ();readQueuedblSub. = tsUpdates ][TimestampedDouble
                                   ();readQueueValuesdblSub. = valUpdates ][double
                                                                              }

             for exist t'doesn class this unless code, robot in required not often //
        be to needs close() case which in program, robot entire the of lifetime the //
                                                          subscribing stop to called //
                                                          { ()close void public
                                                              subscribing stop //
                                                                 ();closedblSub.
                                                                              }
                                                                                }
```

C++

```
                                                                 { Example class
  class the of that matches lifetime its so variable instance an is subscriber the //
      ␣class the by destroyed is dblSub when stopped automatically is subscribing //
                                                                      destructor ↪
                                                    dblSub; DoubleSubscriber::nt

                                                                          :public
                                    { dblTopic) DoubleTopic::Example(nt explicit
                          retained. be must value return the subscribing; start //
      ␣is get() when available is value no if value default the is parameter the //
                                                                          called ↪
                                              );0.0dblTopic.Subscribe( = dblSub
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                       PubSubOptions using specified be may options subscribe //
                                                                        = dblSub
                                                       ,0.0dblTopic.subscribe(
                  );}true = keepDuplicates. ,10 = pollStorage.{

           string. type custom a using of options the provides SubscribeEx //
   ␣not is string and raw than other types for string type custom a Using //
                                                                 recommended. ↪
                     );0.0 ,"double"dblTopic.SubscribeEx( = dblSub
                                                                            }

                                                            { Periodic() void
         published, been has value no if value; recent most of get simple //
             function Subscribe() the to passed value default the returns //
                                                     dblSub.Get(); = val double

       returns published, been has value no if value; recent most the get //
                                            value default passed-in the //
                                                  );1.0-dblSub.Get( = val double

                           timestamp its with along value, recent most the get //
                              dblSub.GetAtomic(); = tsVal TimestampedDouble::nt

   ReadQueue/ReadQueueValues to call last the since changes value all read //
                   not. does ReadQueueValues() timestamps; returns ReadQueue() //
         dblSub.ReadQueue(); = tsUpdates >TimestampedDouble::nt<vector::std
                 dblSub.ReadQueueValues(); = valUpdates >double<vector::std
                                                                            }
                                                                             ;}
```

based)(handle- C++

```
                                                              { Example class
         s'it handle, a s'it since but variable, instance an is subscriber the //
                      destructor a need we so released, automatically not //
                                                          dblSub; NT_Subscriber

                                                                       :public
                                  { dblTopic) Example(NT_Topic explicit
                                                          subscribing start //
   ␣not is string and raw than other types for string type custom a Using //
                                                                 recommended. ↪
                  );"double" NT_DOUBLE, Subscribe(dblTopic,::nt = dblSub

                       PubSubOptions using specified be may options subscribe //
                                                                        = dblSub
                          ,"double" NT_DOUBLE, Subscribe(dblTopic,::nt
                  );}true = keepDuplicates. ,10 = pollStorage.{
                                                                            }

                                                            { Periodic() void
       returns published, been has value no if value; recent most the get //
                                            value default passed-in the //
                             );0.0 GetDouble(dblSub,::nt = val double

                           timestamp its with along value, recent most the get //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
    nt::TimestampedDouble tsVal = nt::GetAtomic(dblSub, 0.0);

    // read all value changes since the last call to ReadQueue/ReadQueueValues
    // ReadQueue() returns timestamps; ReadQueueValues() does not.
    std::vector<nt::TimestampedDouble> tsUpdates = nt::ReadQueueDouble(dblSub);
    std::vector<double> valUpdates = nt::ReadQueueValuesDouble(dblSub);
  }

  ~Example() {
    // stop subscribing
    nt::Unsubscribe(dblSub);
  }
```

C

```
// This code assumes that a NT_Topic dblTopic variable already exists

// start subscribing
// Using a custom type string for types other than raw and string is not recommended.
NT_Subscriber dblSub = NT_Subscribe(dblTopic, NT_DOUBLE, "double", NULL, 0);

// subscribe options may be specified using NT_PubSubOptions
struct NT_PubSubOptions options;
memset(&options, 0, sizeof(options));
options.structSize = sizeof(options);
options.keepDuplicates = 1;  // true
options.pollStorage = 10;
NT_Subscriber dblSub = NT_Subscribe(dblTopic, NT_DOUBLE, "double", &options);

// get the most recent value; if no value has been published, returns
// the passed-in default value
double val = NT_GetDouble(dblSub, 0.0);

// get the most recent value, along with its timestamp
struct NT_TimestampedDouble tsVal;
NT_GetAtomic(dblSub, 0.0, &tsVal);
NT_DisposeTimestamped(&tsVal);

// read all value changes since the last call to ReadQueue/ReadQueueValues
// ReadQueue() returns timestamps; ReadQueueValues() does not.
size_t tsUpdatesLen;
struct NT_TimestampedDouble* tsUpdates = NT_ReadQueueDouble(dblSub, &tsUpdatesLen);
NT_FreeQueueDouble(tsUpdates, tsUpdatesLen);

size_t valUpdatesLen;
double* valUpdates = NT_ReadQueueValuesDouble(dblSub, &valUpdatesLen);
NT_FreeDoubleArray(valUpdates, valUpdatesLen);

// stop subscribing
NT_Unsubscribe(dblSub);
```

Python

```
class Example:
    def __init__(self, dblTopic: ntcore.DoubleTopic):
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                       retained. be must value return the subscribing; start #
   ␣is get() when available is value no if value default the is parameter the #
                                                                        called ↪
                                          )0.0subscribe(.dblTopic = dblSub.self

                        PubSubOption using specified be may options subscribe #
                                                subscribe(.dblTopic = dblSub.self
              )10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore ,0.0
                                                                             )

                  string. type custom a using of options the provides subscribeEx #
       ␣not is string and raw than other types for string type custom a Using #
                                                                 recommended. ↪
                                     )0.0 ,"double"subscribeEx(.dblTopic = dblSub

                                                             ):self(periodic def
                   published, been has value no if value; recent most of get simple #
                      function subscribe() the to passed value default the returns #
                                                              get().dblSub.self = val

                returns published, been has value no if value; recent most the get #
                                                   value default passed-in the #
                                                        )1.0-get(.dblSub.self = val

                             timestamp its with along value, recent most the get #
                                                        getAtomic().dblSub.self = tsVal

                           readQueue to call last the since changes value all read #
                                                        timestamps returns readQueue() #
                                                     readQueue().dblSub.self = tsUpdates

                   for exist t'doesn class this unless code, robot in required not often #
              be to needs close() case which in program, robot entire the of lifetime the #
                                                               subscribing stop to called #
                                                                        ):self(close def
                                                                       subscribing stop #
                                                                    close().dblSub.self
```

## Publish and Subscribe Both to Entry Using 26.3.3

the but active, always is subscriber The subscriber. and publisher combined a is *entry* An aka "set", is value a (e.g. performed is operation publish a until created not is publisher publisher separate a maintaining than convenient more be may This entry). the on published, represented are entries NetworkTable subscribers, and publishers to Similar subscriber. and retained be must that )Python ,C++ ,Java :`BooleanEntry` (e.g. classes Entry specifictype- as publishing). (and subscribing continue to

Java

```
                                                        { Example class public
   class the of that matches lifetime its so variable instance an is entry the //
                                                  dblEntry; DoubleEntry final

                                      { dblTopic) (DoubleTopicExample public
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
             retained. be must value return the subscribing; start //
   ␣is get() when available is value no if value default the is parameter the //
                                       called ↪
                        );0.0(getEntrydblTopic. = dblEntry

       PubSubOption using specified be may options subscribe and publish //
                                    = dblEntry
    PubSubOption. ),true(keepDuplicatesPubSubOption. ,0.0(getEntrydblTopic.
                                  ));10(pollStorage ↪

         string. type custom a using of options the provides getEntryEx //
     ␣not is string and raw than other types for string type custom a Using //
                                     recommended. ↪
                  );0.0 ,"double"(getEntryExdblTopic. = dblEntry
                                          }

                              { ()periodic void public
              subscribers: as methods same the all support entries //
                            ();getdblEntry. = val double
                          );1.0-(getdblEntry. = val double
                        ();getAsDoubledblEntry. = val double
                  ();getAtomicdblEntry. = tsVal TimestampedDouble
               ();readQueuedblEntry. = tsUpdates ][TimestampedDouble
                 ();readQueueValuesdblEntry. = valUpdates ][double

    time first the publishers; as methods same the all support also entries //
     created automatically is publisher internal an called, is these of one //
                             );0.0(setDefaultdblEntry.
                                 );1.0(setdblEntry.
                  time current use = 0 //  );0 ,2.0(setdblEntry.
                        ();nowNetworkTablesJNI. = time long
                             time); ,3.0(setdblEntry.
                                 myFunc(dblEntry);
                                          }

                              { ()unpublish void public
           alive subscriber the keeping while publishing stop can you //
                               ();unpublishdblEntry.
                                          }

      for exist t'doesn class this unless code, robot in required not often //
   be to needs close() case which in program, robot entire the of lifetime the //
                            subscribing stop to called //
                                { ()close void public
                          subscribing/publishing stop //
                                 ();closedblEntry.
                                          }
                                           }
```

C++

```
                                    { Example class
   class the of that matches lifetime its so variable instance an is entry the //
  by destroyed is dblEntry when stopped automatically is subscribing/publishing //
                               destructor class the //
                              dblEntry; DoubleEntry::nt
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                               :public
                                        { dblTopic) DoubleTopic::Example(nt explicit
                          retained. be must value return the subscribing; start //
     ␣is get() when available is value no if value default the is parameter the //
                                                                               called ↪
                                                );0.0dblTopic.GetEntry( = dblEntry

             PubSubOptions using specified be may options subscribe and publish //
                                                                         = dblEntry
                                                         ,0.0dblTopic.GetEntry(
                                 );}true = keepDuplicates. ,10 = pollStorage.{

                 string. type custom a using of options the provides GetEntryEx //
         ␣not is string and raw than other types for string type custom a Using //
                                                                         recommended. ↪
                                    );0.0 ,"double"dblTopic.GetEntryEx( = dblEntry
                                                                                    }

                                                                    { Periodic() void
                           subscribers: as methods same the all support entries //
                                                       dblEntry.Get(); = val double
                                                   );1.0-dblEntry.Get( = val double
                               dblEntry.GetAtomic(); = tsVal TimestampedDouble::nt
              dblEntry.ReadQueue(); = tsUpdates >TimestampedDouble::nt<vector::std
                      dblEntry.ReadQueueValues(); = valUpdates >double<vector::std

        time first the publishers; as methods same the all support also entries //
         created automatically is publisher internal an called, is these of one //
                                                          );0.0dblEntry.SetDefault(
                                                                 );1.0dblEntry.Set(
                                    time current use = 0 //  );0 ,2.0dblEntry.Set(
                                                          Now();::nt = time int64_t
                                                           time); ,3.0dblEntry.Set(
                                                                                    }

                                                                   { Unpublish() void
                     alive subscriber the keeping while publishing stop can you //
                                                              dblEntry.Unpublish();
                                                                                    }
                                                                                     ;}
```

based)(handle- C++

```
                                                                        { Example class
                 s'it handle, a s'it since but variable, instance an is entry the //
                              destructor a need we so released, automatically not //
                                                                   dblEntry; NT_Entry

                                                                               :public
                                               { dblTopic) Example(NT_Topic explicit
                                                               subscribing start //
         ␣not is string and raw than other types for string type custom a Using //
                                                                         recommended. ↪
                            );"double" NT_DOUBLE, GetEntry(dblTopic,::nt = dblEntry
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
            PubSubOptions using specified be may options subscribe and publish //
                                                                  = dblEntry
                              ,"double" NT_DOUBLE, GetEntry(dblTopic,::nt
                            );}true = keepDuplicates. ,10 = pollStorage.{
                                                                            }

                                                          { Periodic() void
                           subscribers: as methods same the all support entries //
                                          );0.0 GetDouble(dblEntry,::nt = val double
                         );0.0 GetAtomic(dblEntry,::nt = tsVal TimestampedDouble::nt
       ReadQueueDouble(dblEntry);::nt = tsUpdates >TimestampedDouble::nt<vector::std
               ReadQueueValuesDouble(dblEntry);::nt = valUpdates >double<vector::std

         time first the publishers; as methods same the all support also entries //
          created automatically is publisher internal an called, is these of one //
                                           );0.0 SetDefaultDouble(dblPub,::nt
                                                  );1.0 SetDouble(dblPub,::nt
                           time current use = 0 //  );0 ,2.0 SetDouble(dblPub,::nt
                                                         Now();::nt = time int64_t
                                              time); ,3.0 SetDouble(dblPub,::nt
                                                                            }

                                                         { Unpublish() void
                       alive subscriber the keeping while publishing stop can you //
                                                       Unpublish(dblEntry);::nt
                                                                            }

                                                               { Example()~
                                             subscribing and publishing stop //
                                                    ReleaseEntry(dblEntry);::nt
                                                                            }
```

C

```
                    exists already variable dblTopic NT_Topic a that assumes code This //

                                                                          subscribing start //
  recommended. not is string and raw than other types for string type custom a Using //
               );0 ,NULL ,"double" NT_DOUBLE, NT_GetEntryEx(dblTopic, = dblEntry NT_Entry

                   NT_PubSubOptions using specified be may options subscribe and publish //
                                                           options; NT_PubSubOptions struct
                                                    (options));sizeof ,0 options,&memset(
                                                    (options);sizeof = options.structSize
                                                     true //  ;1 = options.keepDuplicates
                                                                 ;10 = options.pollStorage
               options);& ,"double" NT_DOUBLE, NT_GetEntryEx(dblTopic, = dblEntry NT_Entry

                                    subscribers: as methods same the all support entries //
                                                  );0.0 NT_GetDouble(dblEntry, = val double

                                                        tsVal; NT_TimestampedDouble struct
                                                       tsVal);& ,0.0 NT_GetAtomic(dblEntry,
                                                            tsVal);&NT_DisposeTimestamped(

                                                                         tsUpdatesLen; size_t
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
  tsUpdatesLen);& NT_ReadQueueDouble(dblEntry, = tsUpdates *NT_TimestampedDouble struct
                                        tsUpdatesLen); NT_FreeQueueDouble(tsUpdates,

                                                            valUpdatesLen; size_t
              valUpdatesLen);& NT_ReadQueueValuesDouble(dblEntry, = valUpdates *double
                                          valUpdatesLen); NT_FreeDoubleArray(valUpdates,

            time first the publishers; as methods same the all support also entries //
             created automatically is publisher internal an called, is these of one //
                                                  );0.0 NT_SetDefaultDouble(dblPub,
                                                         );1.0 NT_SetDouble(dblPub,
                          time current use = 0 //  );0 ,2.0 NT_SetDouble(dblPub,
                                                            NT_Now(); = time int64_t
                                                    time); ,3.0 NT_SetDouble(dblPub,

                         alive subscriber the keeping while publishing stop can you //
                           NT_ReleaseEntry() before this call to necessary not s'it //
                                                              NT_Unpublish(dblEntry);

                                                                  subscribing stop //
                                                            NT_ReleaseEntry(dblEntry);
```

Python

```
                                                                    :Example class
                             DoubleTopic):.ntcore dblTopic: ,self(init____ def

                        retained. be must value return the subscribing; start #
  ␣is get() when available is value no if value default the is parameter the #
                                                                          called ↪
                                          )0.0getEntry(.dblTopic = dblEntry.self

            PubSubOption using specified be may options subscribe and publish #
                                              getEntry(.dblTopic = dblEntry.self
            )10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore ,0.0
                                                                            )

               string. type custom a using of options the provides getEntryEx #
      ␣not is string and raw than other types for string type custom a Using #
                                                                  recommended. ↪
                               )0.0 ,"double"getEntryEx(.dblTopic = dblEntry.self

                                                              ):self(periodic def
                        subscribers: as methods same the all support entries #
                                                        get().dblEntry.self = val
                                                    )1.0-get(.dblEntry.self = val
                                                getAsDouble().dblEntry.self = val
                                                getAtomic().dblEntry.self = tsVal
                                            readQueue().dblEntry.self = tsUpdates

       time first the publishers; as methods same the all support also entries #
        created automatically is publisher internal an called, is these of one #
                                                  )0.0setDefault(.dblEntry.self
                                                         )1.0set(.dblEntry.self
                        time current use = 0 #  )0 ,2.0set(.dblEntry.self
                                                                now()_.ntcore = time
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   time) ,3.0set(.dblEntry.self

                                               ):self(unpublish def
               alive subscriber the keeping while publishing stop can you #
                                                unpublish().dblEntry.self

          for exist t'doesn class this unless code, robot in required not often #
    be to needs close() case which in program, robot entire the of lifetime the #
                                                  subscribing stop to called #
                                                           ):self(close def
                                                 subscribing/publishing stop #
                                                    close().dblEntry.self
```

### GenericSubscriber and GenericPublisher, GenericEntry, Using 26.3.4

is classes Entry and Subscriber, Publisher, specifictype- the using code, robust most the For and get specifictype- uses that code write to easier be may it cases some in but recommended, (object) class the via exposed be type NetworkTables the having of instead calls function set ),Python ,C++ ,Java( GenericSubscriber ),Python ,C++ ,Java( GenericPublisher The type. approach. this enable classes )Python ,C++ ,Java( GenericEntry and

Java

```
                                                          { Example class public
    class the of that matches lifetime its so variable instance an is entry the //
                                                     pub; GenericPublisher final
                                                    sub; GenericSubscriber final
                                                      entry; GenericEntry final

                                              { topic) (TopicExample public
                      retained. be must value return the subscribing; start //
                         provided be must string type a publishing, when //
                                     );"double"(genericPublishtopic. = pub

                         string type a include optionally can subscribing //
              provided is value default no subscribers, type-specific unlike //
                                            ();genericSubscribetopic. = sub
                                    );"double"(genericSubscribetopic. = sub

         provided not if optional; also is string type the entry, an getting when //
  call publisher-creating first the by determined be will type data publisher the //
                                           ();getGenericEntrytopic. = entry
                                   );"double"(getGenericEntrytopic. = entry

               PubSubOption using specified be may options subscribe and publish //
                                     ,"double"(genericPublishtopic. = pub
             ));10(pollStoragePubSubOption. ),true(keepDuplicatesPubSubOption.
                                                                        = sub
        PubSubOption. ),true(keepDuplicates(PubSubOption.genericSubscribetopic.
                                                         ));10(pollStorage ↪
                                                                      = entry
         PubSubOption. ),true(keepDuplicates(PubSubOption.getGenericEntrytopic.
                                                         ));10(pollStorage ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
      properties. initial setting of option the provides genericPublishEx //
          ,"true} :"\retained"\{" ,"double"(genericPublishExtopic. = pub
       ));10(pollStoragePubSubOption. ),true(keepDuplicatesPubSubOption.
                                          }

                              { ()periodic void public
 ␣be must default a operations; get typed have entries and subscribers generic //
                                      provided ↪
                         );1.0-(getDoublesub. = val double
                        );1.0-(getDoubleentry. = val double

   ␣Supplier<NetworkTableValue> meets (also get untyped an support also they //
                                     interface) ↪
                        ();getsub. = val NetworkTableValue
                       ();getentry. = val NetworkTableValue

                          readQueue support also they //
                  ();readQueuesub. = updates ][NetworkTableValue
                 ();readQueueentry. = updates ][NetworkTableValue

  the if false return these operations; set typed have entries and publishers //
                  type mismatched a with exists already topic //
                   );1.0(setDefaultDoublepub. = success boolean
                      );true(setBooleanpub. = success boolean

  interface Consumer<NetworkTableValue> and set generic a implement also they //
          (...));makeDouble(NetworkTableValue.setentry. = success boolean
        (...));makeDouble(NetworkTableValue.acceptentry. = success boolean
                                          }

                              { ()unpublish void public
      alive subscriber the keeping while entry an publishing stop can you //
                                ();unpublishentry.
                                          }

      for exist t'doesn class this unless code, robot in required not often //
   be to needs close() case which in program, robot entire the of lifetime the //
                      subscribing/publishing stop to called //
                                { ()close void public
                                   ();closepub.
                                   ();closesub.
                                  ();closeentry.
                                          }
                                           }
```

C++

```
                                    { Example class
   class the of that matches lifetime its so variable instance an is entry the //
  by destroyed is dblEntry when stopped automatically is subscribing/publishing //
                               destructor class the //
                              pub; GenericPublisher::nt
                             sub; GenericSubscriber::nt
                               entry; GenericEntry::nt

                                       :public
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                             { topic) Topic::Example(nt
             retained. be must value return the subscribing; start //
                provided be must string type a publishing, when //
                      );"double"topic.GenericPublish( = pub

               string type a include optionally can subscribing //
        provided is value default no subscribers, type-specific unlike //
                         topic.GenericSubscribe(); = sub
                     );"double"topic.GenericSubscribe( = sub

   provided not if optional; also is string type the entry, an getting when //
call publisher-creating first the by determined be will type data publisher the //
                            topic.GetEntry(); = entry
                        );"double"topic.GetEntry( = entry

      PubSubOptions using specified be may options subscribe and publish //
                       ,"double"topic.GenericPublish( = pub
                );}true = keepDuplicates. ,10 = pollStorage.{
                          topic.GenericSubscribe( = sub
                );}true = keepDuplicates. ,10 = pollStorage.{
                          topic.GetGenericEntry( = entry
                );}true = keepDuplicates. ,10 = pollStorage.{

      properties. initial setting of option the provides genericPublishEx //
             ,}}5 ,"myprop"{{ ,"double"topic.genericPublishEx( = pub
                );}true = keepDuplicates. ,10 = pollStorage.{
                                         }

                                 { Periodic() void
 ␣be must default a operations; get typed have entries and subscribers generic //
                                      provided ↪
                        );1.0-sub.GetDouble( = val double
                       );1.0-entry.GetDouble( = val double

                       get untyped an support also they //
                      sub.Get(); = val NetworkTableValue::nt
                     entry.Get(); = val NetworkTableValue::nt

                          readQueue support also they //
          sub.ReadQueue(); = updates >NetworkTableValue::nt<vector::std
         entry.ReadQueue(); = updates >NetworkTableValue::nt<vector::std

  the if false return these operations; set typed have entries and publishers //
                  type mismatched a with exists already topic //
                    );1.0pub.SetDefaultDouble( = success bool
                       );truepub.SetBoolean( = success bool

  interface Consumer<NetworkTableValue> and set generic a implement also they //
        MakeDouble(...));::NetworkTableValue::entry.Set(nt = success bool
                                         }

                                 { Unpublish() void
      alive subscriber the keeping while entry an publishing stop can you //
                                entry.Unpublish();
                                         }
                                          ;}
```

Python

```
:Example class
Topic):.ntcore topic: ,self(init____ def

retained. be must value return the subscribing; start #
provided be must string type a publishing, when #
)"double"genericPublish(.topic = pub.self

string type a include optionally can subscribing #
provided is value default no subscribers, type-specific unlike #
genericSubscribe().topic = sub.self
)"double"genericSubscribe(.topic = sub.self

provided not if optional; also is string type the entry, an getting when #
␣publisher-creating first the by determined be will type data publisher the #
call ↪
getGenericEntry().topic = entry.self
)"double"getGenericEntry(.topic = entry.self

PubSubOption using specified be may options subscribe and publish #
genericPublish(.topic = pub.self
)10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore ,"double"
)
genericSubscribe(.topic = sub.self
)10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore
)
getGenericEntry(.topic = entry.self
)10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore
)

properties. initial setting of option the provides genericPublishEx #
genericPublishEx(.topic = pub.self
,"double"
,'true} :"retained"{'
),10=pollStorage ,True=PubSubOptions(keepDuplicates.ntcore
)

):self(periodic def
␣must default a operations; get typed have entries and subscribers generic #
provided be ↪
)1.0-getDouble(.sub.self = val
)1.0-getDouble(.entry.self = val

␣Supplier<NetworkTableValue> meets (also get untyped an support also they #
interface) ↪
get().sub.self = val
get().entry.self = val

readQueue support also they #
readQueue().sub.self = updates
readQueue().entry.self = updates

the if false return these operations; set typed have entries and publishers #
type mismatched a with exists already topic #
)1.0setDefaultDouble(.pub.self = success
)TruesetBoolean(.pub.self = success
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   set generic a implement also they #
                    ))...makeDouble(.Value.set(ntcore.entry.self = success

                                                        ):self(unpublish def
      alive subscriber the keeping while entry an publishing stop can you #
                                                    unpublish().entry.self

          for exist t'doesn class this unless code, robot in required not often #
      be to needs close() case which in program, robot entire the of lifetime the #
                                         subscribing/publishing stop to called #
                                                           ):self(close def
                                                        close().pub.self
                                                        close().sub.self
                                                      close().entry.self
```

## Topics Multiple to Subscribing 26.3.5

sometimes is it topics, individual to subscribe to necessary only it’s cases most in While to changes for updates value get and subscribe to applications) dashboard in (e.g. useful a creating but directly, used be can )*Changes for Listening* (see Listeners topics. multiple same the reusing and options subscription specifying allows )C++ ,Java( `MultiSubscriber` listeners. multiple for subscriber

Java

```
                                                            { Example class public
  class the of that matches lifetime its so variable instance an is subscriber the //
                                                 multiSub; MultiSubscriber final
                                        poller; NetworkTableListenerPoller final

                                  { inst) (NetworkTableInstanceExample public
                           retained. be must value return the subscribing; start //
                                        prefixes name topic of array an provide //
     );}"table2//" ,"table1//"{ ][String new MultiSubscriber(inst, new = multiSub

                           PubSubOption using specified be may options subscribe //
      ,}"table2//" ,"table1//"{ ][String new MultiSubscriber(inst, new = multiSub
                                    ));true(keepDuplicatesPubSubOption.

      ␣a create to necessary s'it MultiSubscriber, a from updates value get to //
                                                                        listener ↪
                             details) more for documentation listener the (see //
                                NetworkTableListenerPoller(inst); new = poller
      ));kValueAll.Kind(NetworkTableEvent.ofEnumSet. (multiSub,addListenerpoller.
                                                                              }

                                                        { ()periodic void public
                                                              events value read //
                                  ();readQueuepoller. = events ][NetworkTableEvent

                                       { events) : event (NetworkTableEvent for
                             ;value.valueDataevent. = value NetworkTableValue
                                                                            }
                                                                              }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
            for exist t'doesn class this unless code, robot in required not often //
      be to needs close() case which in program, robot entire the of lifetime the //
                                                        subscribing stop to called //
                                                                { ()close void public
                                                                  listener close //
                                                                    ();closepoller.
                                                                subscribing stop //
                                                                  ();closemultiSub.
                                                                                  }
                                                                                    }
```

C++

```
                                                                      { Example class
  class the of that matches lifetime its so variable instance an is subscriber the //
    ␣class the by destroyed is multiSub when stopped automatically is subscribing //
                                                                        destructor ↪
                                                     multiSub; MultiSubscriber::nt
                                               poller; NetworkTableListenerPoller::nt

                                                                              :public
                                      { inst) NetworkTableInstance::Example(nt explicit
                                retained. be must value return the subscribing; start //
                                              prefixes name topic of array an provide //
                  ;}}}"table2//" ,"table1//"{{ MultiSubscriber{inst,::nt = multiSub

                                PubSubOption using specified be may options subscribe //
                   ,}}"table2//" ,"table1//"{{ MultiSubscriber{inst,::nt = multiSub
                                                       ;}}true = keepDuplicates.{

       ␣a create to necessary s'it MultiSubscriber, a from updates value get to //
                                                                          listener ↪
                                    details) more for documentation listener the (see //
                                         NetworkTableListenerPoller{inst};::nt = poller
                                kValueAll);::EventFlags::nt poller.AddListener(multiSub,
                                                                                  }

                                                                    { Periodic() void
                                                                   events value read //
                                   poller.ReadQueue(); = events >Event::nt<vector::std

                                                     { events) : event &&auto( for
                  value;>-event.GetValueEventData() = value NetworkTableValue::nt
                                                                                }
                                                                                  }
                                                                                   ;}
```

based)(handle- C++

```
                                                                      { Example class
            s'it handle, a s'it since but variable, instance an is subscriber the //
                              destructor a need we so released, automatically not //
                                                        multiSub; NT_MultiSubscriber
                                                           poller; NT_ListenerPoller
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                            :public
                                      { inst) Example(NT_Inst explicit
                retained. be must value return the subscribing; start //
                              prefixes name topic of array an provide //
     );}}"table2//" ,"table1//"{{ SubscribeMultiple(inst,::nt = multiSub

                PubSubOption using specified be may options subscribe //
      ,}}"table2//" ,"table1//"{{ SubscribeMultiple(inst,::nt = multiSub
                                          );}true = keepDuplicates.{

␣a create to necessary s'it MultiSubscriber, a from updates value get to //
                                                           listener ↪
                    details) more for documentation listener the (see //
                                CreateListenerPoller(inst);::nt = poller
     kValueAll);::EventFlags::nt multiSub, AddPolledListener(poller,::nt
                                                                     }

                                                    { Periodic() void
                                                    events value read //
        ReadListenerQueue(poller);::nt = events >Event::nt<vector::std

                                      { events) : event &&auto( for
       value;>-event.GetValueEventData() = value NetworkTableValue::nt
                                                                   }
                                                                     }

                                                         { Example()~
                                                     listener close //
                                DestroyListenerPoller(poller);::nt
                                                   subscribing stop //
                                UnsubscribeMultiple(multiSub);::nt
                                                                     }
```

C

```
              exists already variable inst NT_Inst a that assumes code This //

                                                           subscribing start //
                                         prefixes name topic of array an provide //
                                                       ];2prefixes[ NT_String struct
                                                       ;"table1//" = ].str0prefixes[
                                                              ;8 = ].len0prefixes[
                                                       ;"table2//" = ].str1prefixes[
                                                              ;8 = ].len1prefixes[
 );0 ,NULL ,2 prefixes, NT_SubscribeMultiple(inst, = multiSub NT_MultiSubscriber

                         NT_PubSubOptions using specified be may options subscribe //
                                                       options; NT_PubSubOptions struct
                                                 (options));sizeof ,0 options,&memset(
                                                 (options);sizeof = options.structSize
                                                    true //  ;1 = options.keepDuplicates
options);& ,2 prefixes, NT_SubscribeMultiple(inst, = multiSub NT_MultiSubscriber

  listener a create to necessary s'it MultiSubscriber, a from updates value get to //
                                  details) more for documentation listener the (see //
                                 NT_CreateListenerPoller(inst); = poller NT_ListenerPoller
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
NT_EVENT_VALUE_ALL); multiSub, NT_AddPolledListener(poller,

events value read //
eventsLen; size_t
eventsLen);& NT_ReadListenerQueue(poller, = events *NT_Event struct

{ )++i eventsLen; < i ;0 = i size_t( for
events[i].data.valueData.value;& = value *NT_Value
}

eventsLen); NT_DisposeEventArray(events,

listener close //
NT_DestroyListenerPoller(poller);
subscribing stop //
NT_UnsubscribeMultiple(multiSub);
```

Python

```
:Example class
NetworkTableInstance):.ntcore inst: ,self(init____ def

retained. be must value return the subscribing; start #
prefixes name topic of array an provide #
])"table2//" ,"table1//"[ MultiSubscriber(inst,.ntcore = multiSub.self

PubSubOption using specified be may options subscribe #
MultiSubscriber(.ntcore = multiSub.self
)True=PubSubOptions(keepDuplicates.ntcore ],"table2//" ,"table1//"[ inst,
)

␣a create to necessary s'it MultiSubscriber, a from updates value get to #
listener ↪
details) more for documentation listener the (see #
NetworkTableListenerPoller(inst).ntcore = poller.self
kValueAlls).EventFlags.ntcore multiSub,.selfaddListener(.poller.self

):self(periodic def
events value read #
readQueue().poller.self = events

events: in event for
value.data.event = Value.ntcore value:

for exist t'doesn class this unless code, robot in required not often #
be to needs close() case which in program, robot entire the of lifetime the #
subscribing stop to called #
):self(close def
listener close #
close().poller.self
subscribing stop #
close().multiSub.self
```

### Options Publish/Subscribe 26.3.6

only can Options behavior. their affect that options various have subscribers and Publishers both affect entry an on set Options entry. or subscriber, publisher, the of creation the at set be can options how show examples above The entry. the of portions subscriber and publisher the subscriber. or publisher a creating when set be

options: Subscriber

- number maximum the Specifies subscription. a for size storage Polling :`pollStorage` `readQueue()` subscriber's the to calls between store should NetworkTables updates of true. is sendAll if 20 false, is sendAll if 1 to defaults zero, If function.
- As false. to Defaults announcements. topic only changes, value send Don't :`topicsOnly` option this to, subscribed not is it topics for announcements topic get doesn't client a topic particular a for announcements topic get to `MultiSubscriber` with used be may changes. value all getting also without prefix, name
- to queued being from updates publisher's single a exclude to Used :`excludePublisher` you where scenarios in useful primarily is This function. `readQueue()` subscriber's the of Regardless subscriber. local a to back" "echoed be to updates value local want don't subscriber. this on `readQueue()` affects only updated–this is value topic the setting, this
- Defaults .`readQueue()` for queued not are updates value remote true, If :`disableRemote` affects only updated–this is value topic the setting, this of Regardless false. to subscriber. this on `readQueue()`
- to Defaults .`readQueue()` for queued not are updates value local true, If :`disableLocal` `readQueue()` affects only updated–this is value topic the setting, this of Regardless false. subscriber. this on

options: publisher and Subscriber

- seconds. in network, the over sent be will changes frequently How :`periodic` minimum combined a use (e.g. this than frequently more send may NetworkTables seconds. 0.1 is default The value. this to range restricted a apply or values) all for period network; the over sent be should changes local frequently how specifies it publishers, For rate. requested the at changes server send to server the to request a is it subscribers, for the unless sent, are changes value only option, this of setting the of regardless that Note set. is option `keepDuplicates`
- with As false. to Defaults network. the over changes value all send true, If :`sendAll` for change behavior a and subscribers for server the to request a is this ,`periodic` publishers.
- them). ignoring than (rather changes value duplicate preserves true, If :`keepDuplicates` a and subscribers for server the to request a is this ,`periodic` with As false. to Defaults publishers. for change behavior

options: Entry

- internal entry's the for `excludePublisher` as behavior same the Provides :`excludeSelf` false. to Defaults publisher.

### NetworkTableEntry 26.3.7

compatibility. backwards for exists that class a is )Python ,C++ ,Java( `NetworkTableEntry` GenericEntry or classes, Subscriber and Publisher specifictype- using prefer should code New needed. is access specifictype-non- if

a in subscribing and publishing both supports it that in `GenericEntry` to similar is It (e.g. released not is `NetworkTableEntry` ,`GenericEntry` unlike However, object. single C++); (in destroyed is object the or Java) (in called is `close()` if unsubscribes/unpublishes) each for exists `NetworkTableEntry` single a only that in ,`Topic` to similar operates it instead, instance. the of lifetime the for lasts it and topic

## Instances NetworkTables 26.4

”instances.“ multiple of operation simultaneous supports implementation NetworkTables The and subscribers, publishers, topics, of set independent completely a has instance Each program single a allows It testing. unit for useful mainly is feature This state. client/server sets unrelated) (and different contain that ”networks“ *NetworkTables* two of member a be to program. single a in instances server and client both running or topics, of

dashboard current all as instance, ”default“ the use should you usage, general most For default the Normally time. a at server NetworkTables single a to connect only can programs dashboard the with communication for used and server, a as robot the on up set is instance and SmartDashboard the what is This computer. station driver your on running program use. classes LiveWindow

NetworkTables program’s robot your of testing unit do to wanted you if However, client separate a create they that such tests unit your up set could you communications, the that instance server the to connect it have and program) same the within (still instance running. is code robot main

for abstraction API the provides class )Python ,C++ ,Java( `NetworkTableInstance` The 16 to limited is created simultaneously be can that instances of number The instances. testing unit as such cases in instances multiple using when so instance), default the (including needed. longer no are that instances destroy to important it’s code,

or classes All instance. the to related resources all frees NetworkTableInstance a Destroying invalidated are Subscribers) and Publishers, Topics, (e.g. instance the reference that handles particular, destroyed–in is instance the after used if behavior unexpected in result may and previously a from over“ ”left handle a for possible it’s so reused are handles instance instance. created newly a in resource unexpected an to refer to instance destroyed

Java

```
                              instance NetworkTable default the get //
    ();getDefaultNetworkTableInstance. = defaultInst NetworkTableInstance

                                       instance NetworkTable a create //
             ();createNetworkTableInstance. = inst NetworkTableInstance

                                      instance NetworkTable a destroy //
                                                             ();closeinst.
```

C++

```
                                            instance NetworkTable default the get //
         GetDefault();::NetworkTableInstance::nt = defaultInst NetworkTableInstance::nt

                                                   instance NetworkTable a create //
                            Create();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

                RAII not are objects NetworkTableInstance instance; NetworkTable a destroy //
                                                    Destroy(inst);::NetworkTableInstance::nt
```

based)(handle- C++

```
                                            instance NetworkTable default the get //
                                    GetDefaultInstance();::nt = defaultInst NT_Instance

                                                   instance NetworkTable a create //
                                                CreateInstance();::nt = inst NT_Instance

                                                  instance NetworkTable a destroy //
                                                              DestroyInstance(inst);::nt
```

C

```
                                            instance NetworkTable default the get //
                                     NT_GetDefaultInstance(); = defaultInst NT_Instance

                                                   instance NetworkTable a create //
                                                 NT_CreateInstance(); = inst NT_Instance

                                                  instance NetworkTable a destroy //
                                                               NT_DestroyInstance(inst);
```

Python

```
                                                                        ntcore import

                                             instance NetworkTable default the get #
                          getDefault().NetworkTableInstance.ntcore = defaultInst

                                                    instance NetworkTable a create #
                                       create().NetworkTableInstance.ntcore = inst

                                                   instance NetworkTable a destroy #
                                          destroy(inst).NetworkTableInstance.ntcore
```

## Networking NetworkTables 26.5

name network known a at it’s that is server the being program robot the of advantage The possible it’s why is This number. team the on based is that address) known a at typically (and team the provide simply to dashboards most in and API client NetworkTables the both in means this note server, the is program robot the As address. server a than rather number, simulation. in running when computer local the on running is server NetworkTables the

## Server NetworkTables a Starting 26.5.1

Java

```
();getDefaultNetworkTableInstance. = inst NetworkTableInstance
                                              ();startServerinst.
```

C++

```
GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt
                                                   inst.StartServer();
```

based)(handle- C++

```
                              GetDefaultInstance();::nt = inst NT_Inst
NT_DEFAULT_PORT4); NT_DEFAULT_PORT3, ,"" ,"networktables.json" StartServer(inst,::nt
```

C

```
                              NT_GetDefaultInstance(); = inst NT_Inst
NT_DEFAULT_PORT4); NT_DEFAULT_PORT3, ,"" ,"networktables.json" NT_StartServer(inst,
```

Python

```
                                                   ntcore import

                    getDefault().NetworkTableInstance.ntcore = inst
                                                  startServer().inst
```

## Client NetworkTables a Starting 26.5.2

Java

```
();getDefaultNetworkTableInstance. = inst NetworkTableInstance

                                                   client NT4 a start //
                                  );"client example"(startClient4inst.

                          TEAM number team with roboRIO a to connect //
                                                  (TEAM);setServerTeaminst.

application DS the from address roboRIO the get to try will client DS a starting //
                                                      ();startDSClientinst.

                                         host/port specific a to connect //
                       )kDefaultPort4NetworkTableInstance. ,"host"(setServerinst.
```

C++

```
GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

                                                   client NT4 a start //
                                  );"client example"inst.StartClient4(

                          TEAM number team with roboRIO a to connect //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                   inst.SetServerTeam(TEAM);

   application DS the from address roboRIO the get to try will client DS a starting //
                                                         inst.StartDSClient();

                                                 host/port specific a to connect //
                                         NT_DEFAULT_PORT4) ,"host"inst.SetServer(
```

based)(handle- C++

```
                                      GetDefaultInstance();::nt = inst NT_Inst

                                                              client NT4 a start //
                                     );"client example" StartClient4(inst,::nt

                                  TEAM number team with roboRIO a to connect //
                                                   TEAM); SetServerTeam(inst,::nt

   application DS the from address roboRIO the get to try will client DS a starting //
                                                         StartDSClient(inst);::nt

                                                 host/port specific a to connect //
                                  NT_DEFAULT_PORT4) ,"host" SetServer(inst,::nt
```

C

```
                                    NT_GetDefaultInstance(); = inst NT_Inst

                                                              client NT4 a start //
                                       );"client example" NT_StartClient4(inst,

                                  TEAM number team with roboRIO a to connect //
                                                     TEAM); NT_SetServerTeam(inst,

   application DS the from address roboRIO the get to try will client DS a starting //
                                                          NT_StartDSClient(inst);

                                                 host/port specific a to connect //
                                   NT_DEFAULT_PORT4) ,"host" NT_SetServer(inst,
```

Python

```
                                                                      ntcore import

                                  getDefault().NetworkTableInstance.ntcore = inst

                                                                client NT4 a start #
                                                 )"client example"startClient4(.inst

                                   TEAM number team with roboRIO a to connect #
                                                           setServerTeam(TEAM).inst

    application DS the from address roboRIO the get to try will client DS a starting #
                                                               startDSClient().inst

                                                  host/port specific a to connect #
                    kDefaultPort4).NetworkTableInstance.ntcore ,"host"setServer(.inst
```

## Changes for Listening 26.6

to need that values generates coprocessor a where is *NetworkTables* for case use common A
a on running code processing image some that imagine example, For robot. the to sent be
robot. the to values those sends and goal a to distance and heading the computes coprocessor
arrive. values new when notified be to program robot the for desirable be might it case this In

is way easiest the changed; has value topic's a that detect to ways different few a are There
from function `readQueueValues()` or ,`readQueue()` ,`get()` subscriber's a call periodically to
below: shown as loop, periodic robot's the

Java

```
                                                                { Example class public
                                                        ySub; DoubleSubscriber final
                                                                        prev; double

                                                                  { ()Example public
                                      NetworkTables of instance default the get //
                    ();getDefaultNetworkTableInstance. = inst NetworkTableInstance

                                            datatable"" called subtable the get //
                              );"datatable"(getTableinst. = datatable NetworkTable

                               Y"" called datatable"" in topic the to subscribe //
                              );0.0(subscribe)."Y"(getDoubleTopicdatatable. = ySub
                                                                                   }

                                                            { ()periodic void public
           value previous the to detection change simple with used be can get() //
                                                        ();getySub. = value double
                                                              { prev) =! (value if
                                           value previous save //  value; = prev
                                value); + " value: changed X"(println.outSystem.
                                                                                 }

              call; last the since changes value all provides readQueueValues() //
              slowly too polling by change a miss to possible not s'it way this //
                                   { ())readQueueValuesySub. : iterVal double( for
                              iterVal); + " value: changed X"(println.outSystem.
                                                                                 }

           timestamps provides but readQueueValues(), to similar is readQueue() //
                                                        well as change each for //
                              { ())readQueueySub. : tsValue (TimestampedDouble for
   ␣+ " time local at " + valuetsValue. + " value: changed X"(println.outSystem.
                                                                 );timestamptsValue. ↪
                                                                                 }
                                                                                   }

                  for lives class this if programs robot for necessary be not may //
                                                        program the of length the //
                                                               { ()close void public
                                                                     ();closeySub.
                                                                                   }
                                                                                     }
```

C++

```
{ Example class
ySub; DoubleSubscriber::nt
;0 = prev double

:public
{ Example()
NetworkTables of instance default the get //
GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

datatable"" called subtable the get //
);"datatable"inst.GetTable( = datatable auto

Y"" called datatable"" in topic the to subscribe //
);0.0).Subscribe("Y"GetDoubleTopic(>-datatable = ySub
}

{ Periodic() void
value previous the to detection change simple with used be can Get() //
ySub.Get(); = value double
{ prev) =! (value if
value previous save //  value; = prev
value);  ,"n\}{ value: changed X"print(::fmt
}

call; last the since changes value all provides ReadQueueValues() //
slowly too polling by change a miss to possible not s'it way this //
{ ySub.ReadQueueValues()) : iterVal double( for
iterVal);  ,"n\}{ value: changed X"print(::fmt
}

timestamps provides but ReadQueueValues(), to similar is ReadQueue() //
well as change each for //
{ ySub.ReadQueue()) : tsValue TimestampedDouble::(nt for
tsValue. tsValue.value,  ,"n\}{ time local at }{ value: changed X"print(::fmt
timestamp); ↩
}
}
;}
```

based)(handle- C++

```
{ Example class
ySub; NT_Subscriber
;0 = prev double

:public
{ Example()
NetworkTables of instance default the get //
GetDefaultInstance();::nt = inst NT_Inst

Y"" called datatable"" in topic the to subscribe //
);"double" NT_DOUBLE, ),"datatable/Y/" GetTopic(inst,::Subscribe(nt::nt = ySub
}

{ Periodic() void
value previous the to detection change simple with used be can Get() //
);0.0 GetDouble(ySub,::nt = value double
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                          { prev) =! (value if
                                          value previous save //  value; = prev
                                   value); ,"n\}{ value: changed X"print(::fmt
                                                                              }

                    call; last the since changes value all provides ReadQueue() //
                slowly too polling by change a miss to possible not s'it way this //
                           { ReadQueueDouble(ySub))::nt : value TimestampedDouble::(nt for
         tsValue. tsValue.value, ,"n\}{ time local at }{ value: changed X"print(::fmt
                                                                      timestamp); ↪
                                                                              }
                                                                                }
                                                                               ;}
```

Python

```
                                                                   :Example class
                                                      :None >- )self(init____ def

                                       NetworkTables of instance default the get #
                                   getDefault().NetworkTableInstance.ntcore = inst

                                                 datatable"" called subtable the get #
                                                 )"datatable"getTable(.inst = datatable

                                  Y"" called datatable"" in topic the to subscribe #
                         )0.0subscribe(.)"Y"getDoubleTopic(.datatable = ySub.self

                                                                    0 = prev.self

                                                              ):self(periodic def
             value previous the to detection change simple with used be can get() #
                                                         get().ySub.self = value
                                                          prev:.self =! value if
                                                           value = prev.self
                                                        value previous save #
                                            value) + " value: changed X"(print

                        call; last the since changes value all provides readQueue() #
                    slowly too polling by change a miss to possible not s'it way this #
                                                   readQueue():.ySub.self in tsValue for
   )"}time.tsValue{ time local at }value.tsValue{ value: changed X"f(print

                        for lives class this if programs robot for necessary be not may #
                                                              program the of length the #
                                                                     ):self(close def
                                                                  close().ySub.self
```

boolean link to `NetworkBooleanEvent` use to possible also it's robot, basedcommand- a With commands). running (e.g. actions callback to changes topic

insight provide not do they topic, single a on changes value for suffice functions these While properties topic's a when or unpublished, or published is topic a (when topics to changes into They disconnects). or connects client a when (e.g. changes connection network or change) For topics. multiple across changes value for updates orderin- get to way a provide don't also facility. listener event an provides NetworkTables needs, these

automatic more For `.NetworkTableInstance` via is listeners use to way easiest The background a without operate to and C++), in (particularly lifetime listener over control listeners polled both for classes separate provides also NetworkTables thread, be must that queue internal an into events store which ),`NetworkTableListenerPoller`( ),`NetworkTableListener`( listeners threaded and events, queued the get to read periodically thread. background a from function callback a call which

### NetworkTableEvent 26.6.1

reading similarly, and parameter, `NetworkTableEvent` single a take callbacks listener All information contains event The .`NetworkTableEvent` of array an returns poller listener a the disconnect), network a topic, new a update, value a (e.g. is it event of kind what including information detailed more and generated, be to event the caused that listener the of handle topic events, connection for information (connection event the of type the on depends that for message log the and updates, value for data value events, relatedtopic- for information events). message log

### Changes for Listen to NetworkTableInstance Using 26.6.2

The .`NetworkTableInstance` using events of kinds various to listens example below The asynchronously called be will functions addListener the of any to provided callback listener occurs. event matching a when thread background a from

> it’s thread, background separate a from called is callback listener the Because **:□□□□□**
> to atomics or mutexes as such approaches synchronization safethread- use to important
> function. callback listener the and code main the to/from data pass

be can This handle. listener a return NetworkTableInstance in functions `addListener` The later. listener the remove to used

Java

```
{ Example class public
ySub; DoubleSubscriber final
thread-safe value the updating make to AtomicReference an use //
();>Double<AtomicReference new = yValue >Double<AtomicReference final
removal later for handles listener retain //
connListenerHandle; int
valueListenerHandle; int
topicListenerHandle; int

{ ()Example public
NetworkTables of instance default the get //
();getDefaultNetworkTableInstance. = inst NetworkTableInstance

the cause will parameter first the listener; connection a add //
connections current any for immediately called be to callback //
{ >- event ,true(addConnectionListenerinst. = connListenerHandle
{ ))kConnected.Kind(NetworkTableEvent.is(event. if
);remote_id.connInfoevent. + " to Connected"(println.outSystem.
{ ))kDisconnected.Kind(NetworkTableEvent.is(event. if else }
);remote_id.connInfoevent. + " from Disconnected"(println.outSystem.
}
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                               );}

                                            datatable"" called subtable the get //
                              );"datatable"(getTableinst. = datatable NetworkTable

                               Y"" called datatable"" in topic the to subscribe //
                              );0.0(subscribe)."Y"(getDoubleTopicdatatable. = ySub

                       subscriber Y the on changes value only to listener a add //
                                           (addListenerinst. = valueListenerHandle
                                                                         ySub,
                                  ),kValueAll.Kind(NetworkTableEvent.ofEnumSet.
                                                                    { >- event
                but DoubleSubscriber, a s'it because doubles get only can //
                                    too here value.isDouble() check could //
                              ());getDouble.value.valueData(event.setyValue.
                                                                           );}

           datatable within published are topics new when see to listener a add //
                           prefixes. name topic of array an is array string the //
                                           (addListenerinst. = topicListenerHandle
                                   ,} "/" + ()getPathdatatable. { ][String new
                                    ),kTopic.Kind(NetworkTableEvent.ofEnumSet.
                                                                    { >- event
                            { ))kPublish.Kind(NetworkTableEvent.is(event. if
             datatable/X"/" e.g. name, topic full the is topicInfo.name //
            );name.topicInfoevent. + " published newly"(println.outSystem.
                                                                           }
                                                                           );}
                                                                                   }

                                                            { ()periodic void public
             null to it set AtomicReference; the reading by value latest the get //
                               changes value get only we ensure to read we when //
                                            );null(getAndSetyValue. = value Double
                                                              { )null =! (value if
                                   value); + " value new got"(println.outSystem.
                                                                                 }
                                                                                   }

                may be not needed for robot programs if this class exists for the //
                                                          program the of lifetime //
                                                               { ()close void public
                    ();getDefaultNetworkTableInstance. = inst NetworkTableInstance
                                         (topicListenerHandle);removeListenerinst.
                                         (valueListenerHandle);removeListenerinst.
                                          (connListenerHandle);removeListenerinst.
                                                                     ();closeySub.
                                                                                   }
                                                                                     }
```

C++

```
                                                                       { Example class
                                                          ySub; DoubleSubscriber::nt
                      thread-safe flag and value the updating make to mutex a use //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                  mutex; mutex::wpi
                                                                     yValue; double
                                                        ;false = yValueUpdated bool
                                       removal later for handles listener retain //
                                                    connListenerHandle; NT_Listener
                                                   valueListenerHandle; NT_Listener
                                                   topicListenerHandle; NT_Listener

                                                                             :public
                                                                        { Example()
                                     NetworkTables of instance default the get //
          GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

                 the cause will parameter first the listener; connection a add //
                 connections current any for immediately called be to callback //
event) &Event::nt const( [] ,trueinst.AddConnectionListener( = connListenerHandle
                                                                                  { ↪
                                    { kConnected))::EventFlags::(event.Is(nt if
       remote_id);>-event.GetConnectionInfo() ,"n\}{ to Connected"print(::fmt
                          { kDisconnected))::EventFlags::(event.Is(nt if else }
  remote_id);>-event.GetConnectionInfo() ,"n\}{ from Disconnected"print(::fmt
                                                                              }
                                                                              );}

                                           datatable"" called subtable the get //
                                     );"datatable"inst.GetTable( = datatable auto

                              Y"" called datatable"" in topic the to subscribe //
                             );0.0).Subscribe("Y"datatable.GetDoubleTopic( = ySub

                      subscriber Y the on changes value only to listener a add //
                                          inst.AddListener( = valueListenerHandle
                                                                        ySub,
                                                   kValueAll,::EventFlags::nt
                                            { event) &Event::nt const( ]this[
               but DoubleSubscriber, a s'it because doubles get only can //
                                   too here value.IsDouble() check could //
                                              lock{mutex}; scoped_lock::std
                          value.GetDouble();>-event.GetValueData() = yValue
                                                      ;true = yValueUpdated
                                                                          );}

          datatable within published are topics new when see to listener a add //
                          prefixes. name topic of array an is array string the //
                                          inst.AddListener( = topicListenerHandle
                                GetPath())}},>-datatable ,"/}{"format(::fmt{{
                                                      kTopic,::EventFlags::nt
                                                { event) &Event::nt const( []
                                  { kPublish))::EventFlags::(event.Is(nt if
                      datatable/X"/" e.g. name, topic full the is name //
          name);>-event.GetTopicInfo() ,"n\}{ published newly"print(::fmt
                                                                          }
                                                                          );}
                                                                                  }

                                                                  { Periodic() void
```

page) next on (continues

(□□□□□ □□□□□□ □□□□□)

```
                      false to it set value; the reading by value latest the get //
                                changes value get only we ensure to read we when //
                                                      lock{mutex}; scoped_lock::wpi
                                                               { (yValueUpdated) if
                                                           ;false = yValueUpdated
                                        yValue); ,"n\}{ value new got"print(::fmt
                                                                                  }
                                                                                    }

                                                                         { Example()~
            GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt
                                           inst.RemoveListener(connListenerHandle);
                                          inst.RemoveListener(valueListenerHandle);
                                          inst.RemoveListener(topicListenerHandle);
                                                                                    }
                                                                                     ;}
```

Python

```
                                                                          ntcore import
                                                                       threading import

                                                                         :Example class
                                                        :None >- )self(init____ def

                                    NetworkTables of instance default the get #
                                getDefault().NetworkTableInstance.ntcore = inst

                                          safety thread ensure to mutex a Use #
                                                   Lock().threading = lock.self
                                                             None = yValue.self

                the cause will parameter first the listener; connection a add #
                connections current any for immediately called be to callback #
                                          Event):.ntcore (event:connect_cb_ def
                                kConnected):.EventFlags.is_(ntcore.event if
                            remote_id).data.event ,"to Connected"(print
                           kDisconnected):.EventFlags.is_(ntcore.event elif
                       remote_id).data.event ,"from Disconnected"(print

        connect_cb)_ ,TrueaddConnectionListener(.inst = connListenerHandle.self

                                          datatable"" called subtable the get #
                                         )"datatable"getTable(.inst = datatable

                             Y"" called datatable"" in topic the to subscribe #
                       )0.0subscribe(.)"Y"getDoubleTopic(.datatable = ySub.self

                     subscriber Y the on changes value only to listener a add #
                                             Event):.ntcore (event:on_ysub_ def
                but DoubleSubscriber, a s'it because doubles get only can #
                                    too here value.isDouble() check could #
                                                            lock:.self with
                             getDouble().value.data.event = yValue.self

                                   addListener(.inst = valueListenerHandle.self
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                          on_ysub_ kValueAll,.EventFlags.ntcore ySub,.self
                                                                            )

        datatable within published are topics new when see to listener a add #
                        prefixes. name topic of array an is array string the #
                                             Event):.ntcore (event:on_pub_ def
                                 kPublish):.EventFlags.is_(ntcore.event if
          datatable/X"/" e.g. name, topic full the is topicInfo.name #
                             name).data.event ,"published newly"(print

                                  addListener(.inst = topicListenerHandle.self
            on_pub_ kTopic,.EventFlags.ntcore ],"/" + getPath().[datatable
                                                                            )

                                                              ):self(periodic def
                   null to it set value; the reading by value latest the get #
                            changes value get only we ensure to read we when #
                                                              lock:.self with
                                    None yValue,.self = yValue.self value,

                                                        :None not is value if
                                             value) ,"value new got"(print

               the for exists class this if programs robot for needed be not may #
                                                        program the of lifetime #
                                                                 ):self(close def
                               getDefault().NetworkTableInstance.ntcore = inst
                                 topicListenerHandle).selfremoveListener(.inst
                                 valueListenerHandle).selfremoveListener(.inst
                                  connListenerHandle).selfremoveListener(.inst
                                                            close().ySub.self
```

## Program Robot NetworkTables Simple a Writing 26.7

instance. default the on started automatically is server NetworkTables a program, robot a In have and subscribing or publishing start to instance default the get to necessary only it's So network. the over visible it

named table a to values Y and X incrementing publishes below program robot example The program OutlineViewer the using viewed easily be can Y and X for values The `.datatable` topic. each with associated values the all and hierarchy NetworkTables the shows that

Java

```
                                              ;edu.wpi.first.wpilibj.templates package

                                              ;edu.wpi.first.wpilibj.TimedRobot import
                                   ;edu.wpi.first.networktables.DoublePublisher import
                                      ;edu.wpi.first.networktables.NetworkTable import
                              ;edu.wpi.first.networktables.NetworkTableInstance import

                             { TimedRobot extends EasyNetworkTableExample class public
                                                              xPub; DoublePublisher
                                                              yPub; DoublePublisher
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                           { ()robotInit void public
       automatically created was that NetworkTables of instance default the Get //
                                                    starts program robot the when //
                             ();getDefaultNetworkTableInstance. = inst NetworkTableInstance

           can There data. the contains that instance that within table the Get //
         organize to easier it make to exist and like you as tables many as be //
                       datatable. called table a s'it case, this In data. your //
                                        );"datatable"(getTableinst. = table NetworkTable

values Y and X the to correspond that table that within topics publishing Start //
                                                 program. your in operation some for //
                     datatable/y"./" and datatable/x"/" actually are names topic The //
                                              ();publish)."x"(getDoubleTopictable. = xPub
                                              ();publish)."y"(getDoubleTopictable. = yPub
                                                                                        }

                                                                            ;0 = x double
                                                                            ;0 = y double

                                                          { ()teleopPeriodic void public
                                     increasing. constantly are that values Publish //
                                                                         (x);setxPub.
                                                                         (y);setyPub.
                                                                             ;0.05 =+ x
                                                                              ;1.0 =+ y
                                                                                        }
                                                                                          }
```

C++

```
                                                          frc/TimedRobot.h>< include#
                                                 networktables/DoubleTopic.h>< include#
                                                networktables/NetworkTable.h>< include#
                                        networktables/NetworkTableInstance.h>< include#

                                   { TimedRobot::frc public : EasyNetworkExample class
                                                                                :public
                                                          xPub; DoublePublisher::nt
                                                          yPub; DoublePublisher::nt

                                                                    { ()RobotInit void
       automatically created was that NetworkTables of instance default the Get //
                                                    starts program robot the when //
                                      GetDefault();::NetworkTableInstance::nt = inst auto

           can There data. the contains that instance that within table the Get //
         organize to easier it make to exist and like you as tables many as be //
                       datatable. called table a s'it case, this In data. your //
                                              );"datatable"inst.GetTable( = table auto

values Y and X the to correspond that table that within topics publishing Start //
                                                 program. your in operation some for //
                     datatable/y"./" and datatable/x"/" actually are names topic The //
                                           ).Publish();"x"GetDoubleTopic(>-table = xPub
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                       ).Publish();"y"GetDoubleTopic(>-table = yPub
                                                                                   }

                                                                       ;0 = x double
                                                                       ;0 = y double

                                                             { ()TeleopPeriodic void
                                  increasing. constantly are that values Publish //
                                                                      xPub.Set(x);
                                                                      yPub.Set(y);
                                                                        ;0.05 =+ x
                                                                        ;0.05 =+ y
                                                                                   }
                                                                                     }

                                                 START_ROBOT_CLASS(EasyNetworkExample)
```

Python

```
                                                                python3 usr/bin/env/!#

                                                                         ntcore import
                                                                         wpilib import


                                     TimedRobot):.(wpilibEasyNetworkTableExample class
                                                      :None >- )self(robotInit def
     automatically created was that NetworkTables of instance default the Get #
                                               starts program robot the when #
                               getDefault().NetworkTableInstance.ntcore = inst

         can There data. the contains that instance that within table the Get #
        organize to easier it make to exist and like you as tables many as be #
                     datatable. called table a s'it case, this In data. your #
                                             )"datatable"getTable(.inst = table

    ␣Y and X the to correspond that table that within topics publishing Start #
                                                                              values ↪
                                         program. your in operation some for #
              datatable/y"./" and datatable/x"/" actually are names topic The #
                               publish().)"x"getDoubleTopic(.table = xPub.self
                               publish().)"y"getDoubleTopic(.table = yPub.self

                                                                    0 = x.self
                                                                    0 = y.self

                                                  :None >- )self(teleopPeriodic def
                               increasing. constantly are that values Publish #
                                                         x).selfset(.xPub.self
                                                         y).selfset(.yPub.self
                                                                0.05 =+ x.self
                                                                 1.0 =+ y.self


                                                            :"main____" == name____ if
                                                run(EasyNetworkTableExample).wpilib
```

## Program sideClient- a Creating 26.8

a or coprocessor *COTS* a with communicate program robot your have is do to need you all If robot writing of examples previous the then laptop, Station Driver the on running dashboard run would that code client custom some write to like would you if But sufficient. are programs *NetworkTables* build to how know to need you then coprocessor a on or station drivers the on platforms. roboRIO)(non- those for programs

example. following the like looks program client basic A

Java

```
;edu.wpi.first.networktables.DoubleSubscriber import
    ;edu.wpi.first.networktables.NetworkTable import
;edu.wpi.first.networktables.NetworkTableInstance import
  ;edu.wpi.first.networktables.NetworkTablesJNI import
      ;edu.wpi.first.util.CombinedRuntimeLoader import

                            ;java.io.IOException import

              ;edu.wpi.first.cscore.CameraServerJNI import
                     ;edu.wpi.first.math.WPIMathJNI import
                     ;edu.wpi.first.util.WPIUtilJNI import


                                   { Program class public
  { IOException throws args) ][(Stringmain void static public
     );false(setExtractOnStaticLoad.HelperNetworkTablesJNI.
           );false(setExtractOnStaticLoad.HelperWPIUtilJNI.
           );false(setExtractOnStaticLoad.HelperWPIMathJNI.
      );false(setExtractOnStaticLoad.HelperCameraServerJNI.

,"wpimathjni" ,"wpiutiljni" ,class(Program.loadLibrariesCombinedRuntimeLoader.
                                              ,"ntcorejni" ↪
                                   );"cscorejnicvstatic"
                                          ();runProgram(). new
                                                             }

                                          { ()run void public
  ();getDefaultNetworkTableInstance. = inst NetworkTableInstance
                 );"datatable"(getTableinst. = table NetworkTable
  );0.0(subscribe)."x"(getDoubleTopictable. = xSub DoubleSubscriber
  );0.0(subscribe)."y"(getDoubleTopictable. = ySub DoubleSubscriber
                          );"client example"(startClient4inst.
  inst. use or etc, 294, TEAM=190, where // );"localhost"(setServerinst.
                            similar or setServer("hostname") ↪
␣the gets this computer; DS on running if recommended // ();startDSClientinst.
                                              DS the from IP robot ↪
                                                     { )true( while
                                                              { try
                                            );1000(sleepThread.
                        { ex) (InterruptedException catch }
                         );"interrupted"(println.outSystem.
                                                      ;return
                                                            }
                                             ();getxSub. = x double
                                             ();getySub. = y double
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                y); + " Y: " + x + " X:"(println.outSystem.
                                      }
                                        }
                                          }
```

C++

```
                                   chrono>< include#
                                   thread>< include#
                                fmt/format.h>< include#
                    networktables/NetworkTableInstance.h>< include#
                        networktables/NetworkTable.h>< include#
                        networktables/DoubleTopic.h>< include#

                                     { ()main int
                 GetDefault();::NetworkTableInstance::nt = inst auto
                      );"datatable"inst.GetTable( = table auto
               );0.0).Subscribe("x"GetDoubleTopic(>-table = xSub auto
               );0.0).Subscribe("y"GetDoubleTopic(>-table = ySub auto
                        );"client example"inst.StartClient4(
   inst.setServer( use or etc, 294, TEAM=190, where //  inst.SetServerTeam(TEAM);
                               similar or "hostname") ↩
   ␣the gets this computer; DS on running if recommended //  inst.StartDSClient();
                                DS the from IP robot ↩
                                   { )true( while
                       ;chrono_literals::std namespace using
                         s);1sleep_for(::this_thread::std
                              xSub.Get(); = x double
                              ySub.Get(); = y double
                        y); x, ,"n\}{ Y: }{ X:"print(::fmt
                                         }
                                          }
```

based)(handle- C++

```
                                   chrono>< include#
                                   thread>< include#
                                fmt/format.h>< include#
                                ntcore_cpp.h>< include#

                                     { ()main int
                      GetDefaultInstance();::nt = inst NT_Inst
                                = xSub NT_Subscriber
     );"double" NT_DOUBLE, ),"datatable/x/" GetTopic(inst,::Subscribe(nt::nt
                                = ySub NT_Subscriber
     );"double" NT_DOUBLE, ),"datatable/y/" GetTopic(inst,::Subscribe(nt::nt
                      );"client example" StartClient4(inst,::nt
    inst. use or etc, 294, TEAM=190, where //  );0 TEAM, SetServerTeam(inst,::nt
                          similar or setServer("hostname") ↩
  ␣gets this computer; DS on running if recommended //  );0 StartDSClient(inst,::nt
                              DS the from IP robot the ↩
                                   { )true( while
                       ;chrono_literals::std namespace using
                         s);1sleep_for(::this_thread::std
                       );0.0 GetDouble(xSub,::nt = x double
                       );0.0 GetDouble(ySub,::nt = y double
```

page) next on (continues

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```
                                                y); x, ,"n\}{ Y: }{ X:"print(::fmt
                                                                                   }
                                                                                     }
```

C

```
                                                                    stdio.h>< include#
                                                                  threads.h>< include#
                                                                     time.h>< include#
                                                     networktables/ntcore.h>< include#

                                                                          { ()main int
                                         NT_GetDefaultInstance(); = inst NT_Instance
                                                                = xSub NT_Subscriber
   );0 ,NULL ,"double" NT_DOUBLE, ),"datatable/x/" NT_Subscribe(NT_GetTopic(inst,
                                                                = ySub NT_Subscriber
   );0 ,NULL ,"double" NT_DOUBLE, ),"datatable/y/" NT_Subscribe(NT_GetTopic(inst,
                                            );"client example" NT_StartClient4(inst,
   inst.setServer( use or etc, 294, TEAM=190, where //  TEAM); NT_SetServerTeam(inst,
                                                              similar or "hostname") ↪
    ␣the gets this computer; DS on running if recommended //  NT_StartDSClient(inst);
                                                                DS the from IP robot ↪
                                                                      { )true( while
                                   );NULL ,}1=){.tv_sectimespec struct(&thrd_sleep(
                                               );0.0 NT_GetDouble(xSub, = x double
                                               );0.0 NT_GetDouble(ySub, = y double
                                                    y); x, ,"n\f% Y: f% X:"printf(
                                                                                   }
                                                                                     }
```

Python

```
                                                                python3 usr/bin/env/!#

                                                                         ntcore import
                                                                           time import

                                                            :"main____" == name____ if
                                   getDefault().NetworkTableInstance.ntcore = inst
                                                )"datatable"getTable(.inst = table
                                     )0subscribe(.)"x"getDoubleTopic(.table = xSub
                                     )0subscribe(.)"y"getDoubleTopic(.table = ySub
                                               )"client example"startClient4(.inst
        inst.setServer( use or etc, 294, TEAM=190, where # setServerTeam(TEAM).inst
                                                              similar or "hostname") ↪
 ␣robot the gets this computer; DS on running if recommended # startDSClient().inst
                                                                      DS the from IP ↪

                                                                       :True while
                                                                 )1sleep(.time

                                                                get().xSub = x
                                                                get().ySub = y
                                                       )"}y{ Y: }x{ X:"f(print
```

to created are subscribers and created is NetworkTables of instance an example this In ”datatable“. called table a from ”y“ and ”x“ of values the reference roboRIO (the number team the with client NetworkTables a as started is instance this Then computer, Station Driver the on running is program the if Additionally, server). the always is the from address IP robot the get will NetworkTables method, startDSClient() the using by Station. Driver

and y and x for values the gets and second a once loops simply program sample this Then or processing be might client the program, realistic more a In console. the on them prints consume. to robot the for values generating

## Gradle using Building 26.8.1

the Update Repository StandaloneAppSamples the in provided are files build.gradle Example version. WPILib desired the to correspond to version GradleRIO

Java

```
{ plugins
java"" id
'application' id
'7.1.2' version 'com.github.johnrengelman.shadow' id
[redacted]
'1.1.0' version 'edu.wpi.first.WpilibTools' id
}

'Program' = mainClassName

)(get.wpilibVersion.versions.wpi = wpilibVersion.deps.wpilibTools

'wpilibNatives' = nativeConfigName def
)nativeConfigName(create.configurations = nativeConfig def

{ createExtractionTasks.wpilibTools = nativeTasks def
nativeConfigName = configurationName
}

)main.sourceSets(addToSourceSetResources.nativeTasks
)wpimath""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
)wpinet""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
)wpiutil""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
)ntcore""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
)(cscore.deps.wpilibTools add.dependencies.nativeConfig

{ dependencies
)wpiutil""(wpilibJava.deps.wpilibTools implementation
)wpimath""(wpilibJava.deps.wpilibTools implementation
)wpinet""(wpilibJava.deps.wpilibTools implementation
)ntcore""(wpilibJava.deps.wpilibTools implementation
)cscore""(wpilibJava.deps.wpilibTools implementation

␣,jackson-annotations"" name: ,com.fasterxml.jackson.core"" group: implementation
)(get.jacksonVersion.versions.wpi version: ↪
␣,jackson-core"" name: ,com.fasterxml.jackson.core"" group: implementation
)(get.jacksonVersion.versions.wpi version: ↪
␣,jackson-databind"" name: ,com.fasterxml.jackson.core"" group: implementation
)(get.jacksonVersion.versions.wpi version: ↪
```

page) next on (continues

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```
      .versions.wpi version: ,ejml-simple"" name: ,org.ejml"" group: implementation
                                                            )(get.ejmlVersion ↪
                                                                              }

                                                                    { shadowJar
                                              TestApplication"" = archiveBaseName
                                                              "" = archiveVersion
                                                     )module-info.class""(exclude
                       )platformName.currentPlatform.wpilibTools(set.archiveClassifier
                                                                              }

                                                                      { wrapper
                                                          '7.5.1' = gradleVersion
                                                                              }
```

C++

highlighted. as platform appropriate the Uncomment

```
                                                                      { plugins
                                                                        cpp"" id
[illegible]
                                                                              }

                       necessary artifact cross the have t'won it as cache, local Disable //
                                                           false = useLocal.maven.wpi

                                    mode debug in simulation run to true to Set //
                                                       false = debugSimulation.cpp.wpi

                                                      TestApplication"" = appName def

                                                    )(withCrossLinuxArm64.nativeUtils
  ␣targetPlatform arm32. for build to Uncomment // nativeUtils.withCrossLinuxArm32()//
                                                          fixed be to needs also below ↪

                                                                        { model
                                                                  { components
                                        { )NativeExecutableSpec(appName}"{$"
[illegible]
[illegible]
                                                         { cpp.sources
                                                          { source
                                            'src/main/cpp' srcDir
                                      '**/*.cc' ,'**/*.cpp' include
                                                                  }
                                                    { exportedHeaders
                                        'src/main/include' srcDir
                                                                  }
                                                                     }

                                     component this for tasks run Enable //
                                           )it(enableExternalTasks.cpp.wpi
```

page) next on (continues

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```
                                        )it(wpilibStatic.deps.cpp.wpi
                                                                   }
                                                                      }
                                                                         }

                                                              { wrapper
                                              '7.5.1' = gradleVersion
                                                                         }
```

## Python Building 26.8.2

.documentation install pyntcore RobotPy the to refer Python, For

## NetworkTables to 3.0 NetworkTables from Migrating 26.9 4.0

from changes breaking API significant of number a has 2023) for (new 4.0 NetworkTables 2022.2016- from used NetworkTables of version the 3.0, NetworkTables

### NetworkTableEntry 26.9.1

are users compatibility), backwards (for used be still can `NetworkTableEntry` While as classes Publisher/Subscriber/Entry specifictype- of use to migrate to encouraged It's .*Topic a to Subscribing and Publishing* (see `GenericEntry` necessary, if or appropriate, appropriate have to need classes these ,`NetworkTableEntry` unlike that note to important `Topic` to moved also has settings) persistent (e.g. functionality Some management. lifetime ).*Topics and Tables NetworkTables* (see properties

(was): code NT3

Java

```
                                                     { Example class public
                                       yEntry; NetworkTableEntry final
                                  outEntry; NetworkTableEntry final

                                                        { ()Example public
                  ();getDefaultNetworkTableInstance. = inst NetworkTableInstance

                                     datatable"" called subtable the get //
                        );"datatable"(getTableinst. = datatable NetworkTable

                                 Y"" called datatable"" in entry the get //
                                      );"Y"(getEntrydatatable. = yEntry

                               Out"" called datatable"" in entry the get //
                                 );"Out"(getEntrydatatable. = outEntry
                                                                         }

                                                    { ()periodic void public
```

page) next on (continues

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```
     2 by multiplied value that to Out set and Y, from value double a read //
                         0 to default //  );0.0(getDoubleyEntry. = value double
                                          );2 * (valuesetDoubleoutEntry.
                                                                          }
                                                                            }
```

C++

```
                                                                     { Example class
                                                yEntry; NetworkTableEntry::nt
                                       outEntry; NetworkTableEntry::nt

                                                                          :public
                                                                       { Example()
       GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

                                     datatable"" called subtable the get //
                              );"datatable"inst.GetTable( = datatable auto

                                  Y"" called datatable"" in entry the get //
                                        );"Y"GetEntry(>-datatable = yEntry

                                Out"" called datatable"" in entry the get //
                                    );"Out"GetEntry(>-datatable = outEntry
                                                                          }

                                                              { Periodic() void
     2 by multiplied value that to Out set and Y, from value double a read //
                         0 to default //  );0.0yEntry.GetDouble( = value double
                                          );2 * outEntry.SetDouble(value
                                                                          }
                                                                           ;}
```

Python

```
                                                                    :Example class
                                                          ):self(init____ def
                              getDefault().NetworkTableInstance.ntcore = inst

                                       datatable"" called subtable the get #
                                     )"datatable"getTable(.inst = datatable

                                    Y"" called datatable"" in entry the get #
                                         )"Y"getEntry(.datatable = yEntry.self

                                  Out"" called datatable"" in entry the get #
                                     )"Out"getEntry(.datatable = outEntry.self

                                                         ):self(periodic def
   2 by multiplied value that to Out set and Y, from value double a read #
                         0 to default #  )0.0getDouble(.yEntry.self = value
                                         )2 * setDouble(value.outEntry.self
```

be): (should equivalent NT4 Recommended

Java

```
{ Example class public
ySub; DoubleSubscriber final
outPub; DoublePublisher final

{ ()Example public
();getDefaultNetworkTableInstance. = inst NetworkTableInstance

datatable"" called subtable the get //
);"datatable"(getTableinst. = datatable NetworkTable

Y"" called datatable"" in topic the to subscribe //
0 is value default //
);0.0(subscribe)."Y"(getDoubleTopicdatatable. = ySub

Out"" called datatable"" in topic the to publish //
();publish)."Out"(getDoubleTopicdatatable. = outPub
}

{ ()periodic void public
2 by multiplied value that to Out set and Y, from value double a read //
();getySub. = value double
);2 * (valuesetoutPub.
}

for exist t'doesn class this unless code, robot in required not often //
be to needs close() case which in program, robot entire the of lifetime the //
subscribing stop to called //
{ ()close void public
();closeySub.
();closeoutPub.
}
}
```

C++

```
{ Example class
ySub; DoubleSubscriber::nt
outPub; DoublePublisher::nt

:public
{ Example()
GetDefault();::NetworkTableInstance::nt = inst NetworkTableInstance::nt

datatable"" called subtable the get //
);"datatable"inst.GetTable( = datatable auto

Y"" called datatable"" in topic the to subscribe //
0 is value default //
);0.0).Subscribe("Y"GetDoubleTopic(>-datatable = ySub

Out"" called datatable"" in topic the to publish //
).Publish();"Out"GetDoubleTopic(>-datatable = outPub
}

{ Periodic() void
2 by multiplied value that to Out set and Y, from value double a read //
ySub.Get(); = value double
```

page) next on (continues

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```
);2 * outPub.Set(value
}
;}
```

Python

```
:Example class
:None >- )self(init____ def
getDefault().NetworkTableInstance.ntcore = inst

datatable"" called subtable the get #
)"datatable"getTable(.inst = datatable

Y"" called datatable"" in topic the to subscribe #
0 is value default #
)0.0subscribe(.)"Y"getDoubleTopic(.datatable = ySub.self

Out"" called datatable"" in topic the to publish #
publish().)"Out"getDoubleTopic(.datatable = outPub.self

):self(periodic def
2 by multiplied value that to Out set and Y, from value double a read #
get().ySub.self = value
)2 * set(value.outPub.self

for exist t'doesn class this unless code, robot in required not often #
be to needs close() case which in program, robot entire the of lifetime the #
subscribing stop to called #
):self(close def
close().ySub.self
close().outPub.self
```

## Shuffleboard 26.9.2

use with replaced been has `NetworkTableEntry` of usage classes, Shuffleboard WPILib's In a return now values return copyable,non- is `GenericEntry` since C++, In .`GenericEntry` of value. a than rather reference

### Operations Set Force 26.9.3

type topic’s a change to possible longer no it’s as removed, been have operations set Force but ,`set` with replaced be simply can `forceSet` to calls cases most In published. been it’s once different into splitting (e.g. approach design different a require may scenarios complex more topics).

### Listeners 26.9.4

single a into unified been have listeners/events log and value, connection, separate The in Listeners removed. been also have listeners levelNetworkTable- The listener/event. still are listeners if but calls, `readQueue()` subscriber with replaced be can cases many more for *Changes for Listening* (see `NetworkTableInstance` via used be can they required, information).

### Operations Client/Server 26.9.5

port. NT4 the and port NT3 the both specifying requires now server NetworkTable a Starting 0. as specified be can port NT3 the server, onlyNT4- a For

no is (there both not mode, NT4 or mode NT3 in operate only can client NetworkTable A by replaced been has call `startClient()` the such, As fallback). automatic for provision itself– for name unique a specify also must client The .`startClient4()` and `startClient3()` names. duplicate with attempts connection reject will server the

### Changes C++ 26.9.6

shared of instead )`nt::Value` (plain objects value as returned/used now are values C++ ).><`nt::Valuestd::shared_ptr`( them to pointers

## NetworkTables by Published Values Array Reading 26.10

program a using *NetworkTables* by published values read to how describes article This are images the where vision computer using when useful is This robot. the on running possibly NetworkTables into stored results the and laptop station driver your on processed a or GRIP, like robot the on tool a or pi, raspberry a like processor vision separate a using processing. image the do to program python

and pieces game or goals as such interest of areas more or one for are values the often Very areas and height, width, y, x, several below, example the In returned. are instances multiple returned the of which out sort can program robot the and processor image the by returned are processing. further through interesting are values

## Published Being Topics NetworkTables the Verify 26.10.1

by values the publishing for used topics NetworkTables the of names the verify can You
the in directory user your in program C++ a is It application. Viewer Outline the using
in menu ”WPILib“ the selecting by started is application The folder. wpilib/<YEAR>/tools
image the with example, this In ”OutlineViewer“. then Tool Start then Code Studio Visual
NetworkTables. into put being values the see can you (GRIP) running program processing

called tablesub- a and GRIP called table a in stored are values the case this In
in values 2 are there and brackets in are values the that see can You myContoursReport.
height area, centerY, centerX, are names topic NetworkTables The topic. each for case this
width. and

use the illustrate just that programs simplified extremely are examples following the of Both
program the when run only it’s so method robotInit() the in is code the All NetworkTables. of
evaluating is that code in values the get likely more would you programs, your In up. starts
or autonomous the during loop control a or command a in robot the aim to direction which
periods. teleop

## Topics the Access to Program a Writing 26.10.2

Java

```
                                               areasSub; DoubleArraySubscriber

                                                                     @Override
                                                     { ()robotInit void public
      GRIP/"(getTable().getDefaultNetworkTableInstance. = table NetworkTable
                                                         );"mycontoursReport ↪
    );}{ ][double new(subscribe)."area"(getDoubleArrayTopictable. = areasSub
                                                                             }

                                                                     @Override
                                                { ()teleopPeriodic void public
                                          ();getareasSub. = areas ][double

                                             ); " areas:"(print.outSystem.

                                               { areas) : area double( for
                                           );" " + (areaprint.outSystem.
                                                                         }

                                                     ();println.outSystem.
                                                                             }
```

C++

```
                                           areasSub; DoubleArraySubscriber::nt

                                            { override ()Robot::RobotInit void
         GRIP/"GetDefault().GetTable(::NetworkTableInstance::nt = table auto
                                                         );"myContoursReport ↪
                ).Subscribe({});"area"GetDoubleArrayTopic(>-table = areasSub
                                                                             }

                                       { override ()Robot::TeleopPeriodic void
                                                     ;" Areas:" << cout::std

                                   areasSub.Get(); = arr >double<vector::std

                                                    { arr) : val double( for
                                                  ;" " << val << cout::std
                                                                           }

                                                     endl;::std << cout::std
                                                                             }
```

Python

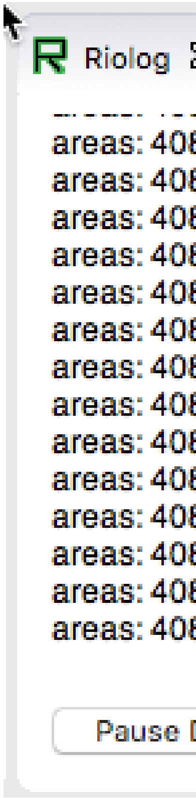
```
                                                                  ):self(robotInit def
 )"GRIP/mycontoursReport"getTable(.getDefault().NetworkTableInstance.ntcore = table
                    subscribe([]).)"area"getDoubleArrayTopic(.table = areasSub.self

                                                             ):self(teleopPeriodic def
                                                        get().areasSub.self = areas
                                                             areas) ,"Areas:"(print
```

The steps to getting the values and, in this program, printing them are:

1. Declare the table variable that will hold the instance of the subtable that have the values.
2. Initialize the subtable instance so that it can be used later for retrieving the values.
3. Read the array of values from NetworkTables. In the case of a communicating programs, it's possible that the program producing the output being read here might not yet be available when the robot program starts up. To avoid issues of the data not being ready, a default array of values is supplied. This default value will be returned if the NetworkTables topic hasn't been yet published. This code will loop over the value of areas every 20ms.

### 26.10.3 Program Output



```
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
areas: 40
```

In this case the program is only looking at the array of areas, but in a real example all the values would more likely be used. Using the Riolog in VS Code or the Driver Station log you can see the values as they are retrieved. This program is using a sample static image so they areas don't change, but you can imagine with a camera on your robot, the values would be constantly changing.

# [redacted]

Path Planning is the process of creating and following trajectories. These paths use the WPILib trajectory APIs for generation and a *Ramsete Controller* for following. This section highlights the process of characterizing your robot for system identification, trajectory following and usage of PathWeaver. Users may also want to read the *generic trajectory following documents* for additional information about the API and non-commandbased usage.

## 27.1 Notice on Swerve Support

Swerve support in path following has a couple of limitations that teams need to be aware of:

- WPILib currently does not support swerve in simulation, please see this pull request.
- SysID only supports tuning the swerve heading using a General Mechanism project and does not regularly support module velocity data. A workaround is to lock the module's heading into place. This can be done via blocking module rotation using something like a block of wood.
- Pathweaver and Trajectory following currently do not incorporate independent heading. Path following using the WPILib trajectory framework on swerve will be the same as a DifferentialDrive robot.

We are sorry for the inconvenience.

### 27.1.1 System Identification

#### Introduction to System Identification

##### What is “System Identification?”

In Control Theory, *system identification* is the process of determining a mathematical model for the behavior of a system through statistical analysis of its inputs and outputs.

This model is a rule describing how input voltage affects the way our measurements (typically encoder data) evolve in time. A “system identification” routine takes such a model and a dataset and attempts to fit parameters which would make your model most closely-match both by polluted are data worldreal- the - perfect not is model the Generally, dataset. the noise system and limitations) resolution encoder errors, timing (e.g. noise measurement model imperfect an even However, vibrations). like system, the on acting forces (unmodeled even and mechanism, the of *control feedforward* accurate us give to enough“ ”good usually is .*control feedback* for gains optimal estimate to

### Model Behavioral Assumed

WPILib the by used equations feedforward the of explanation full the read yet, haven’t you If .*Equation Feedforward Motor DC MagnetPermanent- The* in toolsuite

in coefficients the for values concrete determine to is Identification System of process The system. worldreal- *particular your* of behavior the reflectbest- that model the

(such technique fittingcurve- a model, our in coefficient each for values numeric determine To mechanism. real the from taken measurements to applied is )*regression squaresleast-* as curve- the of accuracy the improve helps experiments producingdata- the of selection Careful fitting.

and velocity desired given a take then can we determined, been have coefficients these Once This it. achieve to applied be should that voltage the calculate and motor the for acceleration mechanisms making for also but profiles, motion following say, for, only not - useful very is match closely more will inputs joystick your because control, loopopen- in controllable more motion. mechanism actual the

to equation above the into terms additional introduce toolsuite this in tools the of Some tool each for details - above described case simple the from differences known for account below: found be can

### (SysId) Tool Identification System WPILib The

PC user’s the on runs that application an of consists tool identification system WPILib The control send will application PC The robot. user’s the on runs that code robot matching and application. the to back data sends robot the while NetworkTables, over robot the to signals robot user’s the for parameters model determines and data the processes then application The for format) JSON (in saved be can Data plots. diagnostic producing as well as mechanism, desired. if use, future

### Tools Included

---

surprisingly a characterize accurately to used be can tools these ingenuity, of bit a With :□□□□ match obviously to seem not does mechanism your if Even mechanisms. robot of variety large the of one that reveals often equations system the of understanding an tools, the of any do. will routines included

---

supports: currently toolsuite Identification System The

- Setups Motor Simple
- Drivetrains
- Elevators

- Arms

routine analysis the in only differ and code, siderobot- identical use options these of Several data. the interpret to used

### Identification Motor Simple

equation: the for parameters fitbest- the determines tool identification motor simple The

$$V = kS \cdot sgn(\dot{d}) + kV \cdot \dot{d} + kA \cdot \ddot{d}$$

velocity, its is $\dot{d}$ drive, the of (position) displacement the is $d$ voltage, applied the is $V$ where loading no with motor dc magnetpermanent- a for model the is This acceleration. its is $\ddot{d}$ and flywheels, for model accurate an is and above, mentioned as inertia, and friction than other sliders. linear horizontal and turrets,

### Identification Drivetrain

equation: the for parameters fitbest- the determines tool identification drivetrain The

$$V = kS \cdot sgn(\dot{d}) + kV \cdot \dot{d} + kA \cdot \ddot{d}$$

velocity, its is $\dot{d}$ drive, the of (position) displacement the is $d$ voltage, applied the is $V$ where motor simple the in used is as equation modeling same the is This acceleration. its is $\ddot{d}$ and on run to up set specifically is tool identification drivetrain the however, - identification desired. if independently drive the of side each characterize will and drives, differential

robot your of trackwidth effective the determine also can tool identification drivetrain The *width track* the in available is identification the run to how on information More gyro. a using article. *identification*

### Identification Elevator

equation: the for parameters fitbest- the determines tool identification elevator The

$$V = kG + kS \cdot sgn(\dot{d}) + kV \cdot \dot{d} + kA \cdot \ddot{d}$$

velocity, its is $\dot{d}$ elevator, the of (position) displacement the is $d$ voltage, applied the is $V$ where effect the for account correctly to added is )$kG$( term constant The acceleration. its is $\ddot{d}$ and gravity. of

### Identification Arm

equation: the for parameters fitbest- the determines tool identification arm The

$$V = kG \cdot cos(\theta) + kS \cdot sgn(\dot{\theta}) + kV \cdot \dot{\theta} + kA \cdot \ddot{\theta}$$

its is $\dot{\theta}$ arm, the of (position) displacement angular the is $\theta$ voltage, applied the is $V$ where correctly to added is )$kG$( term cosine The acceleration. angular its is $\ddot{\theta}$ and velocity, angular gravity. of effect the for account

## Tool Identification System the Installing

Installer. WPILib the with included is )`sysid` as to referred (also tool identification system The

supported. longer no is years previous from tool characterization Python old The :□□□□

## Tool Identification System the Launching

by or Code VS in option `Tool Start` the from opened be can tool identification system The (Windows). folder desktop Tools WPILib the inside shortcut the using

## Project a Configuring

mechanism. specific your for settings the configure to need first we toolsuite, the use To

### Parameters Project Configure

is robot your how about parameters some know must tool the robot, your on run to order In up. set

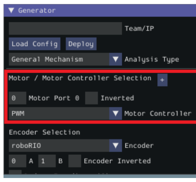
`General` config. project appropriate the select to field *Type Analysis* the use to need you First, `Drivetrain` Elevator), Arm, Motor, Simple (e.g. mechanisms drivetrainnon- for is `Mechanism` the out fill to you allows This robots. Romi the for is `Romi` and mechanisms, Drivetrain for is using. are you system of type the to specific parameters

analysis the of off based settings proper the on focused is widget Generator the of rest The type:

### Selection Controller Motor

that controller motor each for ports add to you allows *Selection Controller Motor / Motor* The
respectively. ports remove and add you let buttons - and + The used. be will

**:□□□□** motor the that sure make controllers motor into encoders your in plugging are you If
specify. you ones first the are port(s) and type controller



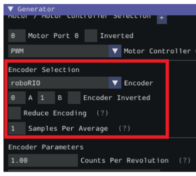
Generator
Team/IP
Load Config
Deploy
General Mechanism ▼ Analysis Type
Motor / Motor Controller Selection +
0 Motor Port 0 ☐ Inverted
PWM ▼ Motor Controller
Encoder Selection
roboRIO ▼ Encoder
0 A 1 B ☐ Encoder Inverted

parts: following the contains port motor Each

- controller specific a for number port the add you where is *Port Motor*
- inverted be should motorcontroller the if checked be should *Inverted*
- used. be will that controller motor of type the is *Controller Motor*

### Selection Encoder

of types The used. be will that encoders the configure to you allows *Selection Encoder* The
).*above* note (see specified type controller motor first the with vary will use can you encoder



Generator
Motor / Motor Controller Selection +
0 Motor Port 0 ☐ Inverted
PWM ▼ Motor Controller
Encoder Selection
roboRIO ▼ Encoder
0 A 1 B ☐ Encoder Inverted
☐ Reduce Encoding (?)
1 Samples Per Average (?)
Encoder Parameters
1.00 Counts Per Revolution (?)

### Types Encoder

- corresponds `roboRIO` selections): controller motor all across (consistent **Types General** CTRE the to corresponds `CANCoder` roboRIO, the into plugged are that encoders any to CANCoder.
- encoder the into plugged encoder quadrature any to corresponds `in-Built` :**TalonSRX** port. encoder the into plugged Tachometer CTRE the to corresponds `Tachometer` port,
- motor. TalonFX the on encoder integrated the to corresponds `in-Built` :**TalonFX**
- `Data` ,port encoder the into plugged encoder an to refers `Port Encoder` :**MAX Spark** .port data the into plugged encoder an to refers `Port`
- port. encoder Venom's the into plugged encoder an to refers `in-Built` :**Venom**

### Settings Encoder

visible are that settings the (although configured be can that settings following the are Here
type): encoder selected previously the by vary will

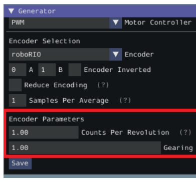
- *Port CANCoder* or *B* and *A* (either Ports
- a to correspond doesn’t power motor positive a if checked be should *Inverted Encoder*
values encoder in increase positive
- measurement. velocity per averaged be will samples many how is *Average Per Samples*
for recommended is 105- and noise encoder reduce help can one than greater value A
resulted SysId of run previous a if setting this with mess Only CPR. high with encoders
data. noisy extremely in
- Mag CTRE (e.g. encoders resolution high using if checked be should *Encoding Reduce*
uses This roboRIO. the into plugged are that Encoder) Bore Through REV or Encoders
have will you checked, is this If noise. velocity reduce to decoding 1x class `Encoder` the
encoders. the on decoding 1x use also to code robot team’s your update to
- velocity the that milliseconds in time of period the is *Window Measurement Time*
cost the at lag measurement reduce can setting This across. taken be will measurement
accurate impeding is lag data if this modify Only noise. more introducing possibly of
collection. data and control

### Parameters Encoder

generally is which encoder your for revolution per counts encoder the is *Revolution Per Counts*
include: values Common datasheet. a on specified

- 4096 Encoder: Magnetic CTRE
- 2048 Integrated: 500 Falcon
- 8192 Throughbore: REV
- 1 value): this handles already (REV Encoders Integrated 550) NEO (and NEO

magnetic an example, For shaft. output and encoder the between gearing the is *Gearing*
output the with ratio 1:1 a on is it as one of gearing a have would chassis kit a on encoder
the gearbox, the in was that motor a in encoder integrated an was is if However, shaft.
and encoder the between gearing now is there since Andymark) (per 10.71 be would gearing
shaft. output the



Generator

PWM Motor Controller

Encoder Selection

roboRIO Encoder

0 A 1 B ☐ Encoder Inverted

☐ Reduce Encoding (?)

1 Samples Per Average (?)

Encoder Parameters

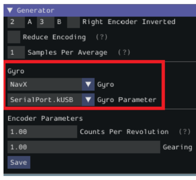
1.00 Counts Per Revolution (?)

1.00 Gearing

Save

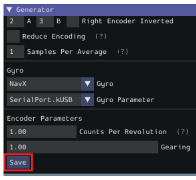
### Only) (Drivetrain Parameters Gyro

additional configure you lets *Parameter Gyro* gyro. supported of type the select you lets *Gyro* gyro. specified previously the configure to needed settings

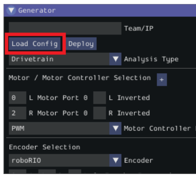


### Configurations Saving and Loading

with choice your of location/name a to it save may you set, is configuration robot your Once button: *Save* the

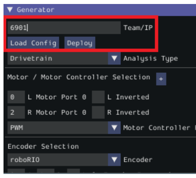


button: *Config Load* the with file config existing an load also can you Accordingly,



### Project Deploying

the run to project robot the deploy to time it's configured, been has project your Once routine. identification



the with code the deploy then can You IP. or number team your set you where is *Team/IP* label. *Deploy*

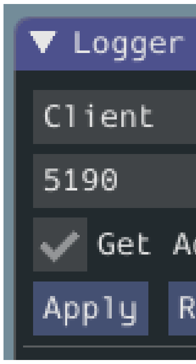
## Routine Identification the Running

and routine, identification system the run now can we deployed, been has code the Once
analysis. for data resulting the record

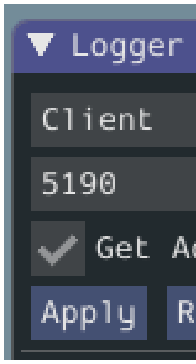
identification any running before robot the around space sufficient have you Ensure **:□□□□**
The 20«. to closer ideally space, of 10« least at requires identification drive The routine!
blocks. on while characterized accurately be not can drive robot

## Robot the to Connect

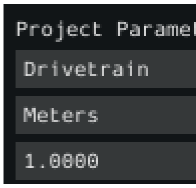
enter and window Logger the of top the at ”Client“ Select robot. the to connect must we Next,
.`localhost` in type can you program, robot simulated a characterize To number. team your
next visible be will indicator connection NetworkTables The button. *Apply* the press Finally,
button. *Apply* the to



Eventually, robot. the rebooting try connecting, successfully be to seem not does tool the If
communicating successfully is tool the indicating ,*Connected NT* to change should status the
robot. the with



### Parameters Project


Project Paramet
Drivetrain
Meters
1.0000

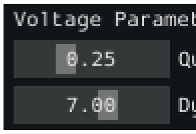
analysis. the affect to expected is gravity how and sampled is data what controls *Mechanism*

in. gains the export will SysID that units the and using are you units the is *Type Unit*

shaft output the of rotations from change the affects that anything defines *Rotation Per Units* of units and chassis KOP a using are you say example an As above. selected units the to account into take to have We generator. the in for accounted already is gearing The meters. chassis standard The rotation. per traveled have we distance the change will wheel our how by multiply to need we circumference the get to so wheels, diameter meters) (0.1524 6“ has like: looks calculation The Pi.

$$UnitsPerRotation = 0.1524 \cdot \pi$$

### Parameters Voltage


Voltage Paramet
0.25 Qu
7.00 Dy

quasistatic the during up ramp will voltage the quickly how controls *Rate Ramp Quasistatic* the If emerges. trend a that enough up ramped voltage the get to is here goal The tests. this increase slightly to need might you small is robot the run to have you space of amount rate. ramp

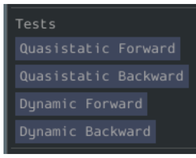
determine to start on immediately applied be will that voltage the is *Voltage Step Dynamic* the reduce slightly should you space on short is robot your If accelerates. robot your how voltage.

### Tests Running

tests: of types two of consists routine identification motor standard A

- voltage the that such upsped- gradually is mechanism the test, this In **Quasistatic:** static“). if ”as (hence, negligible is acceleration to corresponding
- the that so mechanism, the to given is voltage« »step constant a test, this In **Dynamic:** determined. be can accelerating while behavior

to corresponding total, in tests four for backwards, and forwards both run is type test Each buttons. four the



”forwards“ a after directly test ”backwards“ a running but order, any in run be can tests The
position). original its to mechanism the reset less or more will it (as advisable generally is test

button. test each pressing after windows uppop- the in instructions the Follow

## Width Track

This test. *(Angular) Drivetrain* the selecting by robot the of width track the determine can You
parameters. Ka and Kv angular provide also will

far how compares It trackwidth. empirical an determine to robot your spin will test This
best the get To gyroscope. the from rotation reported the against drove encoders wheel the
ground. the with contact maintain should wheels your results

by calculated trackwidth empirical the tires), pneumatic (like wheels frictionhigh- For **:□□□□**
The 2). of factor a by off (e.g., trackwidth real the from different significantly be may sysid
code. robot in one real the over preferred be should value empirical

this: like something look should routine entire The

file save the for location folder the select can you completed, been have tests four all After
.*Save* click and

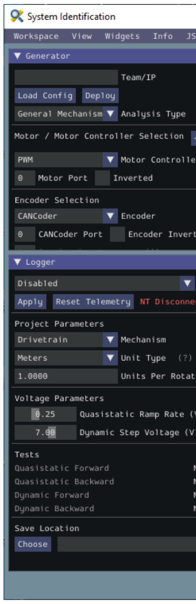
timestamp A location/name. specified the with file JSON a as data the save will This
file the of name the Additionally, filename. chosen the to appended be will `)%H%M-%Y%m%d(`
.*Log Program* the in shown be will saved

Log. Program the in displayed be will test each for collected samples of number The **:□□□□**

## Data Analyzing

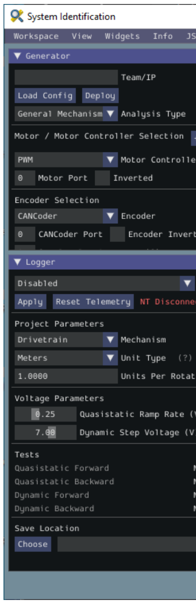
to set is option *Units* the that recommended its so units, SI on standardizes WPILib **:□□□□**
.**Meters**

and *Analyzer* the using it analyze can we routine, identification an from data have we Once
widgets. *Plots Diagnostic*



## File Data your Loading

.*Select* on Click tool. logger the from saved we file data the load to time it's Now



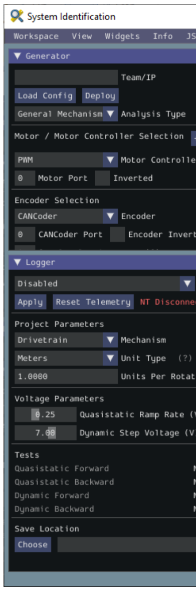
be to appears file the If analyze. to want you file JSON the select dialog, file resulting the In shown. be will error an malformed,

## Analysis Feedforward Running

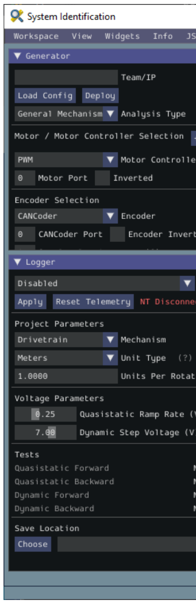
*Permanent- The* see mean, gains feedback calculated the what on information For :□□□□
feedback calculated the using on information For .*Equation Feedforward Motor DC Magnet*
.*control feedforward* see code, in gains

Section. *Feedforward* the on arrow dropdown the Click

and button *Units Override* the press to have will you units, change to like would you If :□□□□
popup. the on information the out fill



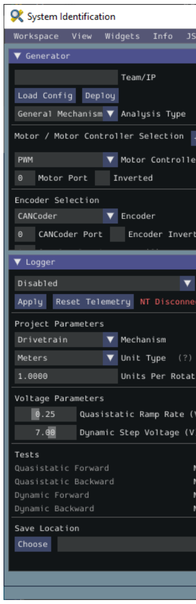
displayed. be then will parameters system mechanism computed The



## Diagnostics Viewing

### Metrics Fitof-Goodness-

acceleration tool: this with computed are that metrics accuracy numerical three are There .*RMSE* velocity simulated the and squared,r- velocity simulated ,*squaredr-*



Team/IP
General Mechanism Analysis Type
PWM Motor Controlle
0 Motor Port Inverted
CANCoder Encoder
0 CANCoder Port Encoder Invert
Disabled
Drivetrain Mechanism
Meters Unit Type (?)
1.0000 Units Per Rotat
0.25 Quasistatic Ramp Rate (V
7.00 Dynamic Step Voltage (V

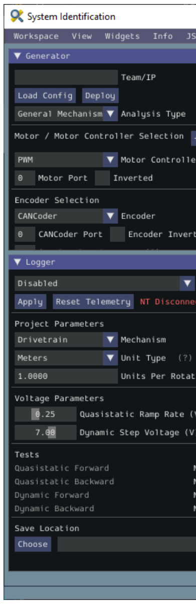
as (used acceleration measured in variance the of fraction the is squaredr- acceleration The be can This model. linear the by explained regression) SysId the in variable independent the other the Assuming noise. system to susceptible very is acceleration because variable, quite disturbances, few with mechanism ”ideal“ an indicate `1` near values acceptable, are metrics fit vibrations/losses. physical substantial with mechanism noisy a indicate `0` near values while

explained velocity measured in variance the of fraction the is squaredr- velocity simulated The constants the with forward stepped movement motor the of simulation noiseless a by fit. good a indicates `9.` of north value A regression. the from determined

simulated the from error velocity the of deviation standard the is RMSE velocity simulated The test the during present noise process of amount the of estimation good a is This model. .*control spacestate-* in term noise model the for estimate endlow- a as used be can and routine,

## Plots Diagnostic

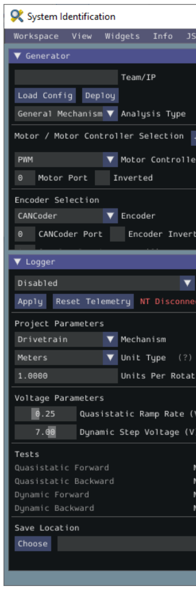
model their of quality the evaluate users help to plots diagnostic several produces also SysId fit.



## Plots DomainTime-

**:□□□□** to sure Be direction. by separated are plots diagnostic the quality, plot improve To troubleshooting! when plots backward *and* forward the both view

the of course the over time versus velocity display plots Diagnostics DomainTime- The this: like something look should These tests. analyzed



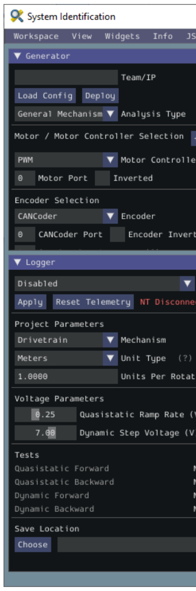
and Data, Filtered Data, Raw data: of sets three contain plots domain time velocity The the is Data Filtered the robot, your from data recorded the is Data Raw The Simulation. the represents Simulation the and data, the to applied been has filter median a after data are (these tool the from gains feedforward the of off based model a of predictions velocity above). mentioned metrics error ”sim“ the calculate to used

graph dynamic successful a while linear, nearly very be will graph quasistatic successful A speed.steady- the of approach exponential approximately an be will

settings, analysis setup, robot your in either , *error* an of sign a is behavior this from Deviation procedure. test your or

## Plot VelocityAcceleration-

of portion the versus velocity mechanism the displays plot velocityversus-acceleration- The back- only leave would this (ideally, friction than other factors to corresponding acceleration tests. the of *all* across voltage applied and EMF)



System Identification

Workspace View Widgets Info JS

▼ Generator

Team/IP

Load Config Deploy

General Mechanism ▼ Analysis Type

Motor / Motor Controller Selection

PWM ▼ Motor Controlle

0 Motor Port Inverted

Encoder Selection

CANCoder ▼ Encoder

0 CANCoder Port Encoder Invert

▼ Logger

Disabled ▼

Apply Reset Telemetry NT Disconne

Project Parameters

Drivetrain ▼ Mechanism

Meters ▼ Unit Type (?)

1.0000 Units Per Rotat

Voltage Parameters

0.25 Quasistatic Ramp Rate (V

7.00 Dynamic Step Voltage (V

Tests

Quasistatic Forward

Quasistatic Backward

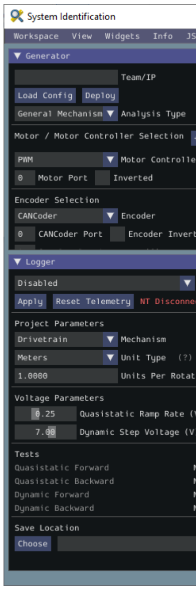
Dynamic Forward

Dynamic Backward

Save Location

Choose

intermixed data quasistatic noiseless relatively of patches with linear, quite be should plot This reduced be may plot the of sections dynamic the on noise The data. dynamic noisyquite- with setting. *Size Window* the increasing by



Team/IP

General Mechanism Analysis Type

Motor / Motor Controller Selection

PWM Motor Controlle

0 Motor Port Inverted

Encoder Selection

CANCoder Encoder

0 CANCoder Port Encoder Invert

Disabled

NT Disconne

Project Parameters

Drivetrain Mechanism

Meters Unit Type (?)

1.0000 Units Per Rotat

Voltage Parameters

0.25 Quasistatic Ramp Rate (V

7.00 Dynamic Step Voltage (V

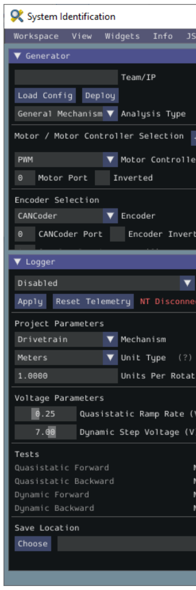
may this power, motor the to compared mass low has mechanism or robot your if However, towards tend will kA cases these In have. you data acceleration meaningful little what ”eat“ accurately be cannot kA if However, purposes. feedforward for ignored be can and zero may tuning manual and inaccurate, be to likely are gains feedback calculated the measured, required. be

### Modes Failure Common

output console and plots diagnostic identification, the with wrong gone has something When failures common some describes section This wrong. gone has *what* to as clues crucial provide their of features identifying the tool, identification system the running while encountered them. fix to taken be can that steps the and plots, diagnostic

#### Threshold Motion Set Improperly

threshold. motion the for value inappropriate an is errors commonmost- the of One



Team/IP

General Mechanism Analysis Type

Motor / Motor Controller Selection

PWM

0 Motor Port Inverted

Encoder Selection

CANCoder Encoder

0 CANCoder Port

Disabled

Project Parameters

Drivetrain Mechanism

Meters Unit Type (?)

1.0000

Voltage Parameters

0.25

7.00 Dynamic Step Voltage

Tests

Quasistatic Forward

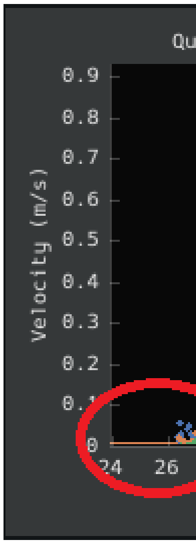
Quasistatic Backward

Dynamic Forward

Dynamic Backward

Save Location

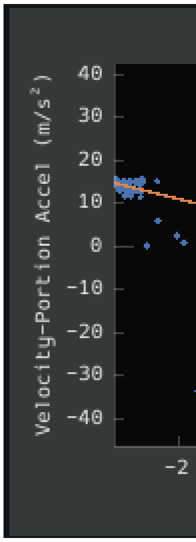
## Low Too Threshold Velocity



time- quasistatic the in circle) red added by (emphasized tail“ ”leading a of presence The from points data thus and low, too is setting *Threshold Velocity* the that indicates plot domain included. being are move to begins robot the before

data. the analyzere- and threshold velocity the increase this, solve To

### High Too Threshold Motion

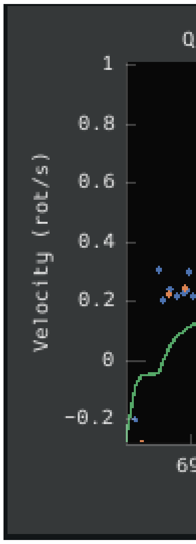


high too is that threshold velocity a threshold, lowtoo- a as problematic as nearly not While plot. velocityversus-acceleration- the in ”gap“ large a in result will

data. the analyzere- and threshold velocity the decrease this, solve To

### Signals Velocity Noisy

system and noise signal - systems mechanical affect that noise of types two are There :□□□□ to corresponds noise system while error, measurement to corresponds noise Signal noise. SysId If vibration). (e.g. model your by forunaccounted- is that motion physical actual is noise of types two the of which out figure must you noisy, is system your that suggests noise. system than eliminate to easier often is noise signal - play at



(for concentricity shaft in errors - encoders installedpoorly- from suffer setups FRC Many noisy to contribute both can encoders) magnetic (For location magnet and encoders) optical immediately be will noise Encoder settings. filtering inappropriate can as signals, velocity on common especially is noise Encoder above. seen be can as plots, diagnostic your in visible parts. of kit the in provided gearboxes mini toughbox the

by polluted data from even determined accurately be sometimes can parameters System is noise encoder of sort this However, setting. size window the increasing by noise encoder identification system the for problematic is it way same the much code robot for problematic encoder different a try to recommended is it known, not is noise the of cause root the As tool. them replacing shaft, different a to encoders the moving by either observed, is this if setup generation project in average per sample the increasing or encoder, of type different a with filtering). of layer additional an (adds

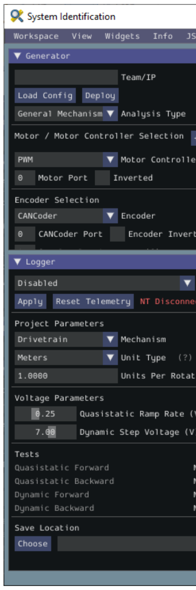
## Analysis Feedback

---

perfect, be to guaranteed not are they - guesses“ ”educated effect, in are, gains These :□□□□ tuning. further for point“ ”starting a as viewed be should and

---

section. *Feedback* the on arrow dropdown the on click constants, feedback the view To



General Mechanism Analysis Type

Motor / Motor Controller Selection

PWM Motor Controlle

0 Motor Port Inverted

Encoder Selection

CANCoder Encoder

0 CANCoder Port Encoder Invert

Disabled

Project Parameters

Drivetrain Mechanism

Meters Unit Type (?)

1.0000 Units Per Rotat

Voltage Parameters

0.25 Quasistatic Ramp Rate (V

7.00 Dynamic Step Voltage (V

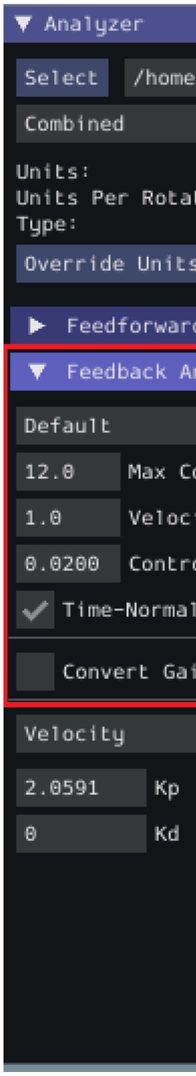
your for controller P or PD a for gains feedback optimal calculate to used be can view This ).*LQR* (via mechanism

## Parameters Controller Enter

operate to controller the configured has user the that assumes preset Max“ ”Spark The **:**
feature. factor scaling position/velocity API’s MAX SPARK the with analysis of units the in

much not Unfortunately, .*quantities dimensioned* are gains feedforward calculated The typical various the so and controls, FRC® in gains PID of units the to paid often is attention often are (which conventions unit their in differ implementations controller PID for options user). the to clear made not

options. following the use controller, PID your for settings correct the specify To



Analyzer
Select /home
Combined
Units:
Units Per Rota
Type:
Override Units
Feedforwar
Feedback A
Default
12.0 Max C
1.0 Veloc
0.0200 Contr
✓ Time-Normal
☐ Convert Ga
Velocity
2.0591 Kp
0 Kd

- with fields remaining the populateauto- will menu downdrop- This *Preset Settings Gain* some that Note setups. controller FRC common of number a of one for settings likely must motor follower a of presence the and PPR, gearing, encoderpost- as such settings, user without these knowing of way no has analyzer the (as specified manually be still setup. user on depending defaults given the from vary may others that and input),
- default The seconds. in loop, control the of period execution the is This *Period Controller*

on controllers onboard The 0.02s. of period a to corresponding 50Hz, is rate loop RIO 0.001s. of period a or 1Khz, at run controllers“ ”smart most

- respect with output, controller the of value maximum the is This *Output Controller Max* 1, of value maximum a with outputs calculate controllers Most calculation. PID the to 1023. of output maximum a have controllers Talon but
- to normalized is calculation PID the whether specifies This *Controller NormalizedTime-* gain. D the of scaling the affects which execution, of period the
- is or loop, RIO onboard an is controller the whether specifies This *Type Controller* MAX. SPARK a or Talon a as such controller motor smart a on running
- the and encoder the between gearing the specifies This *Gearing EncoderPost-* unit specifieduser- allow not do that loops control for necessary is This itself. mechanism if disabled be will This Talons). on running those (e.g. computations PID their in scaling relevant. not
- the of revolution) per cycles (not revolutionper-edges- the specifies This *EPR Encoder* Gearing. EncoderPost- as cases same the in needed is which used, encoder
- the running controller the following controller motor a is there Whether *Follower Has* the changes This device. peripheral a on run being is loop control the if loop, control period. loop effective
- default, By updated. is present) (if follower the which at rate The *Period Update Follower* be can but MAX, SPARK the and FX, Talon SRX, Talon the for 0.01s) (every 100Hz is this changed.

MAX, SPARK TalonSRX, (e.g. preset the as controller motor smart a select you If :□□□□ will tool the means This checked. automatically be will checkbox *Gains Convert* the etc.) methods. PID controller’s motor smart the through used be can they that so gains your convert box. that uncheck must you Loops, PID WPILib’s use to like would you if Therefore,

## Delays Measurement

without Control PID WPILib or settings controller motor smart default using are you If :□□□□ you. for this handles SysId filtering, additional

`SPARK` and `,FX Talon` `,Venom` `,SRX Talon` the as (such controllers“ motor ”smart Many can which measurements, velocity encoder their to filtering passlow- substantial apply `)MAX` velocity for gains calculated the cause can This lag. phase of amount significant a introduce box. *Delay Measurement* the with for accounted be can This unstable. be to loops

of settings default the for calculated been already have delays measurement the However, the selecting by handled is this users most for so controllers motor mentioned previously the .*Preset Settings Gain* in preset right

settings filtering custom own their implement to decides user the if applies only following The motorcontroller smart changing or loop PID WPILib a to filter average moving a adding (e.g. be must delay measurement the as size) window measurement and/or period measurement windows moving with filters for used be can that formula general the is Here recalculated.

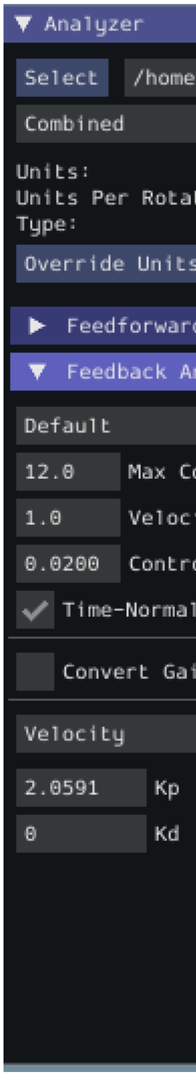
filter): average moving + filter median (e.g.

$$d = \frac{T(n-1)}{2}$$

the is n and ms) 20 is default (RIO sampled are measurements which at period the is T Where used. window moving the of size

### Criteria Optimality Specify

takes This controller. ”optimal“ an considered be will what specify must user the Finally, *not* is it that note - effort control and error system the for tolerances desired of form the times. all at tolerances these obey will system the that guaranteed



▼ Analyzer

Select /home

Combined

Units:
Units Per Rotat
Type:

Override Units

▶ Feedforward

▼ Feedback An

Default

12.0 Max Co

1.0 Veloc

0.0200 Contro

☑ Time-Normal

☐ Convert Ga

Velocity

2.0591 Kp

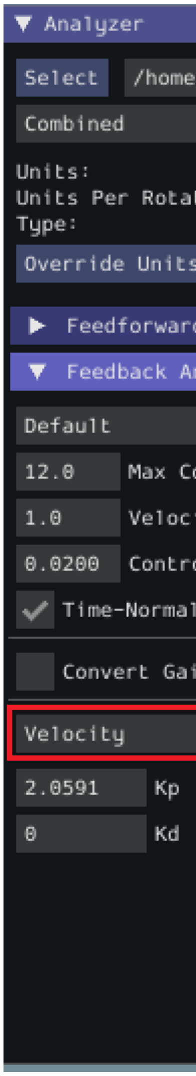
0 Kd

*Max* the for values larger and *Error Acceptable Max* the for values smaller rule, a As efforts, control larger in result will this - gains larger in result will *Effort Control Acceptable* greater and behavior violent more cause may but trackingsetpoint- better grant can which components. on wear

full to corresponds that as 12V, exceed never should *Effort Control Acceptable Max* The this. than lower somewhat be should ideally and voltage, battery

### Type Loop Select

on depending PIDs, velocity and position both with mechanisms control to typical is It menu. *Type Loop* downdrop- the using selected be can Either application.



Analyzer

Select /home

Combined

Units:
Units Per Rota
Type:

Override Units

Feedforwar

Feedback A

Default

12.0 Max C

1.0 Veloc

0.0200 Contr

Time-Norma

Convert Ga

Velocity

2.0591 Kp

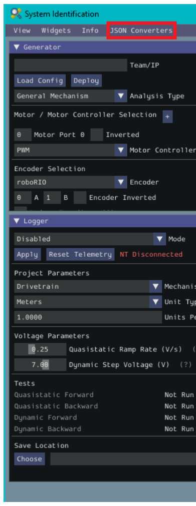
0 Kd

### Tools and Utilities Additional

tool this that functionality additional about information useful covers mainly page This provides.

## Converters JSON

CharFRC- tab: *Converters JSON* the in used be can that tools Utility JSON two a are There Converter. CSV to JSON and Converter



Team/IP
General Mechanism Analysis Type
Motor / Motor Controller Selection
0 Motor Port 0 Inverted
PWM Motor Controller
Encoder Selection
roboRIO Encoder
0 A 1 B Encoder Inverted
Disabled Mode
NT Disconnected
Project Parameters
Drivetrain Mechanis
Meters Unit Typ
1.0000 Units Pe
Voltage Parameters
0.25 Quasistatic Ramp Rate (V/s)
7.00 Dynamic Step Voltage (V) (?)
Tests
Quasistatic Forward Not Run
Quasistatic Backward Not Run
Dynamic Forward Not Run
Dynamic Backward Not Run
Save Location

that JSON SysId a into it converts and JSON CharFRC- an in reads Converter CharFRC- The read. can tool the

had JSON the If file. CSV a outputs and JSON SysId a takes Converter CSV to JSON The `Right` , `(V) Volts Left` ,`Test` ,`(s) Timestamp` are: columns the data, Mechanism Drivetrain `({units}/ Velocity Left` ,`({units}) Position Right` ,`({0}) Position Left` ,`(V) Volts` JSON the If .`(deg/s) Rate Gyro` ,`(deg) Position Gyro` ,`({units}/s) Velocity Right` ,`s)` ,`Test` ,`(s) Timestamp` columns: following the has CSV the data, Mechanism General had .`({units}/s) Velocity` ,`Position({units})` ,`(V) Volts`

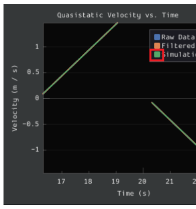
## Tips ImGui

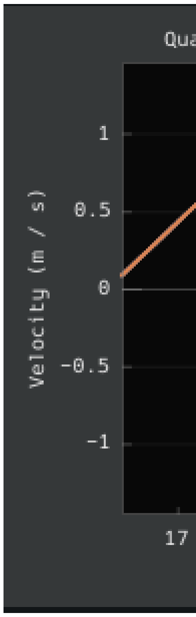
SysId that framework ImGui the with come that features handy essentially are following The uses:

### Data Plot Hiding and Showing

would you that data the of color the on click plots, the from data certain remove or add To remove. or hide to like

box. color green the click can we data, sim hide to want we if example, For

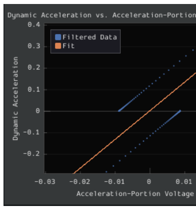




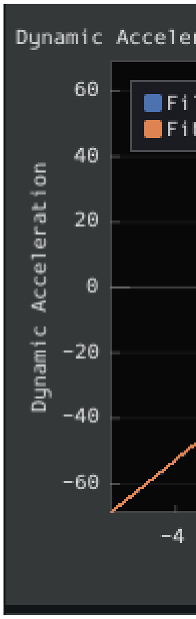
### Plots Sizing Auto

click double just plots, sized normally the to back revert to want and plots to in zoom you If it. resize automatically will it and plot the on

in: zoomed is that plot a is Here



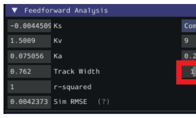
resized: automatically is it clicking, double After



### Values Slider Setting

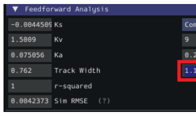
Click + CTRL can you widget, the sliding than rather number a as slider a of value the set To number. a input to you allow will it and slider the

slider: regular a is Here


Feedforward Analysis

-0.0044509 Ks
1.5009 Kv
0.075056 Ka
0.762 Track Width
1 r-squared
0.0042373 Sim RMSE (?)

slider: the clicking double after input the is Here


Feedforward Analysis

-0.0044509 Ks
1.5009 Kv
0.075056 Ka
0.762 Track Width
1 r-squared
0.0042373 Sim RMSE (?)

## Tutorial Trajectory 27.1.2

differential- a on following and generation trajectory implementing for tutorial full is This
example RamseteCommand the in found be can tutorial this in used code full The robot. drive
).C++ ,Java( project

### Overview Tutorial Trajectory

baseline a have to necessary) strictly not (but helpful is it tutorial, this following Before :□□□□
features. *trajectory* and ,*feedforward* ,*control PID* WPILib’s with familiarity

command- The framework. *basedcommand-* the uses tutorial this in code robot The :□□□□
teams. intermediate and beginning for recommended strongly is framework based

trajectory- a implementing on instruction end“to-”end- provide to is tutorial this of goal The
readers tutorial, this following By robot. drivedifferential- a for routine autonomous following
to: how learn will

feedforward accurate obtain to drivetrain robot’s their characterize Accurately 1.
gains. feedback approximate and calculations

library. odometry WPILib’s using pose robot’s the track to subsystem drive a Configure 2.

WPILib’s using waypoints of set a through trajectory simple a Generate 3.
class. `TrajectoryGenerator`

WPILib’s using routine autonomous an in trajectory generated the Follow 4.
pose. and gains feedforward/feedback calculated the with class `RamseteCommand`

programming of deal great a without teams for approachable be to intended is tutorial This
its which in manner the in flexibility significant offers library WPILib the While expertise.
outlined implementation the following closely implemented, are features followingtrajectory-
solution repeatable and clean, simple,relatively- a with teams provide should tutorial this in
movement. autonomous for

Project Example RamseteCommand the in found be can tutorial this for code robot full The
).C++ ,Java(

### Following? Trajectory Why

accurately and effectively to robot a require that tasks autonomous feature often games FRC®
most the Historically, location. scoring known a to location starting known a from move
that - approach drive“turn-”drive- a been has FRC in task of sort this for solution common
another by forward drive and angle, known a by turn distance, known a by forward drive is,
distance. known

have teams years recent in functional, certainly is approach drive“turn-”drive- the While
time. same the at turn and drive to robot the require which trajectories smooth tracking begun
in benefits: significant offers it task, technical complicatedmore- fundamentally a is this While
driven be can paths the directions, change to stop to has longer no robot the since particular,
period. autonomous the during pieces game more score to robot a allowing faster, much

for solutions code advanced working, with teams supplies now WPILib 2020, in Beginning kind this for entry“to-”barrier- the lowering significantly tracking, and generation trajectory motion. autonomous effective and advanced of

## Equipment Required

materials: following the to access ready need will you tutorial, this follow To

1. with: equipped ),AM14U5 AndyMark the as (such robot drivedifferential- A
   - drive. the of side each of rotation wheel the measuring for encoders Quadrature
   - heading. robot measuring for gyroscope A
2. with: configured computer stationdriver- A
   - .*Station Driver FRC*
   - .*WPILib*
   - .*Toolsuite Identification System The*

## Drive Robot Your Characterizing :1 Step

:□□□□ *dedicated* its see tool, Identification System the using on instructions detailed For .*documentation*

:□□□□ sure Be drive. to robot the for space ample requires process identification drive The the during drive can robot the which in 20«) to closer (ideally stretch 10« a *least at* have to routine. identification

:□□□□ 5190, Team by provided generously been has tutorial this for data identification The Carolina North 2019 the at functionality this of demonstration a of part as it generated who Workshop. P2P University State

for model accurate an have to important is it robot, a with path a following accurately Before process a is model a such Determining inputs. control its to response in moves robot the how determine accurately can tool Identification System WPILib’s identification.“ ”system called model. a such

## Data the Gathering

data. identification drive our gathering by begin We

1. .*project robot a Deploy and Configure*
2. .*Routine identification the Run*

### Data the Analyzing

to time is it saved, been has file data the and run been has routine identification the Once .*pane analysis the in it open*

### Diagnostics Checking

look data our that ensure to diagnostics the view first we ,*guide identification system* the Per reasonable:

we parameters, acceptable within are metrics fit the and linear, reasonably look data our As step. next the to proceed

## Gains Feedforward Record

gains the use *not* Do robots. across transfer general, in ,*not* do gains Feedforward :□□□□
robot. own your for tutorial this from

tool: the by calculated gains feedforward the record now We

0.52269
2.4021
0.43354
0.99985
0.074073

following the in are gains feedforward our meters, in specified was diameter wheel our Since units:

- Volts :kS
- Meters / Seconds * Volts :kV
- Meters / Seconds^2 * Volts :kA

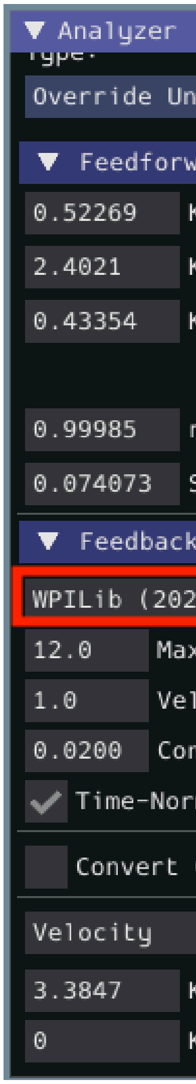
an within be likely will gains feedforward your correctly, units your specified have you If may which ,kA for exists exception possible (a here reported ones the of magnitude of order one specified you possible is it not, are they If light). is robot your if small vanishingly be for test good A project. robot your generating when incorrectly parameters drive your of theoretical the by divided volts 12 is which ,kV of value ”theoretical“ the calculate to is this wheel the times motor the of speed free the turn, in is, (which drivetrain your of speed free the with closely very agree should value This reduction). gear the by divided circumference somewhere. error an made likely have you not, does it if - tool the by measured kV

## Gains Feedback Calculate

from gains the use *not* Do robots. across transfer general, in ,*not* do gains Feedback :□□□□
robot. own your for tutorial this

path. the follow to use will we that control PID the for *gains feedback the calculate* now We
so control, loopclosed- velocity uses controller RAMSETE WPILib's with following Trajectory
tool: identification the in mode `Velocity` select first we

select furthermore we loop, velocity our for PIDController WPILib the using be will we Since
as important, *very* is This menu. "presets" downdrop- the from option `)-(2020 WPILib` the
preset: correct the select not do we if units correct the in be not will gains feedback the



0.52269
2.4021
0.43354
0.99985
0.074073
WPILib (202
12.0
1.0
0.0200
Velocity
3.3847
0

Finally, we calculate and record the feedback gains for our control loop. Since it is a velocity controller, only a P gain is required:

0.52269
2.4021
0.43354
0.99985
0.074073
WPILib (202
12.0
1.0
0.0200
3.3847
0

* Volts of units in be will gain proportional our correctly, everything done have we Assuming velocity of second per meter each for that, means gain calculated our Thus, Meters. / Seconds volts. 3.38 additional an output will controller the error,

#### Constants Calculated the Entering :2 Step

unit correct the as entered be constants feedforward the that important is it C++, In **:□□□□**
.*Library Units C++ The* see units, C++ on information more For type.

The code. our in them place to time is it constants, system our have we that Now *project basedcommand- standard* the of file `Constants` the is this for place recommended *.structure*

,Java( Project Example RamseteCommand the from file constants the of parts relevant The below. seen be can )C++

## Gains Feedforward/Feedback

the from obtained we which gains feedback and feedforward the enter must we Firstly, tool. identification

use *not* Do robots. across transfer general, in ,*not* do gains feedback and Feedforward :□□□□ robot. own your for tutorial this from gains the

Java

```
ROBOT! OWN YOUR FOR THESE USE NOT DO - only values example are These //
␣or experimentally either determined be MUST values characterization These //
                                                          theoretically ↪
                                                drive. s'robot *your* for //
␣obtaining for tool convenient a provides Toolsuite Characterization Robot The //
                                                                  these ↪
                                                  robot. your for values //
                               ;0.22 = ksVolts double final static public
                    ;1.98 = kvVoltSecondsPerMeter double final static public
             ;0.2 = kaVoltSecondsSquaredPerMeter double final static public

       drive! your for tuned be must this above, as - only value Example //
                              ;8.5 = kPDriveVel double final static public
```

(Header) C++

```
   ROBOT! OWN YOUR FOR THESE USE NOT DO - only values example are These //
or experimentally either determined be MUST values characterization These //
       Characterization Robot The drive. s'robot *your* for theoretically //
    your for values these obtaining for tool convenient a provides Toolsuite //
                                                                   robot. //
                                                   V;_0.22 = ks auto constexpr
                                    m;_1 / s_1 * V_1 * 1.98 = kv auto constexpr
                               m;_1 / s_1 * s_1 * V_1 * 0.2 = ka auto constexpr

          drive! your for tuned be must this above, as - only value Example //
                                          ;8.5 = kPDriveVel double constexpr
```

## DifferentialDriveKinematics

which class, `DifferentialDriveKinematics` the of instance an create must we Additionally, to robot the of wheels) the between distance horizontal (i.e. trackwidth the use to us allows meters. in units our keep we elsewhere, As speeds. wheel to speeds chassis from convert

Java

```
                         ;0.69 = kTrackwidthMeters double final static public
     = kDriveKinematics DifferentialDriveKinematics final static public
              DifferentialDriveKinematics(kTrackwidthMeters); new
```

(Header) C++

```
                                      m;_0.69 = kTrackwidth auto constexpr
            kDriveKinematics; DifferentialDriveKinematics::frc const extern
```

### Velocity/Acceleration Trajectory Max

during robot the for velocity max and acceleration max nominal a on decide also must We free- nominal the below somewhat set be should value velocity maximum The following.path- the ,`DifferentialDriveVoltageConstraint` the of use later the to Due robot. the of speed crucial. extremely not is value acceleration maximum

Java

```
;3 = kMaxSpeedMetersPerSecond double final static public
;1 = kMaxAccelerationMetersPerSecondSquared double final static public
```

(Header) C++

```
mps;_3 = kMaxSpeed auto constexpr
mps_sq;_1 = kMaxAcceleration auto constexpr
```

### Parameters Ramsete

shown values The controller. RAMSETE the for parameters of pair a include must we Finally, in measured correctly been have distances provided robots, most for well work should below *the Constructing* see required), is it (if values these tuning on information more for - meters .*Object Controller Ramsete*

Java

```
␣and meters of units in follower RAMSETE a for values baseline Reasonable //
seconds ↪
;2 = kRamseteB double final static public
;0.7 = kRamseteZeta double final static public
```

(Header) C++

```
and meters of units in follower RAMSETE a for values baseline Reasonable //
seconds //
m);_1 * m_1( / rad_1 * rad_1 * 2.0 = kRamseteB auto constexpr
rad;_1 / 0.7 = kRamseteZeta auto constexpr
```

### Subsystem Drive a Creating :3 Step

.*proper* code robot our writing start to time is it characterized, is drive our that Now code. robot our for framework *basedcommand-* the use will we before, mentioned As class. *subsystem* drive suitable a write to is step first our Accordingly,

seen be can )C++ ,Java( Project Example RamseteCommand the from class drive full The class. this writing in involved steps the describe will article the of rest The below.

Java

```
;edu.wpi.first.wpilibj.examples.ramsetecommand.subsystems package

;edu.wpi.first.math.geometry.Pose2d import
;edu.wpi.first.math.kinematics.DifferentialDriveOdometry import
;edu.wpi.first.math.kinematics.DifferentialDriveWheelSpeeds import
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
;edu.wpi.first.wpilibj.ADXRS450_Gyro import
;edu.wpi.first.wpilibj.Encoder import
;edu.wpi.first.wpilibj.drive.DifferentialDrive import
;edu.wpi.first.wpilibj.examples.ramsetecommand.Constants.DriveConstants import
;edu.wpi.first.wpilibj.interfaces.Gyro import
;edu.wpi.first.wpilibj.motorcontrol.MotorControllerGroup import
;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import
;edu.wpi.first.wpilibj2.command.SubsystemBase import

{ SubsystemBase extends DriveSubsystem class public
    drive. the of side left the on motors The //
    = m_leftMotors MotorControllerGroup final private
        MotorControllerGroup( new
            ),kLeftMotor1PortPWMSparkMax(DriveConstants. new
            ));kLeftMotor2PortPWMSparkMax(DriveConstants. new

    drive. the of side right the on motors The //
    = m_rightMotors MotorControllerGroup final private
        MotorControllerGroup( new
            ),kRightMotor1PortPWMSparkMax(DriveConstants. new
            ));kRightMotor2PortPWMSparkMax(DriveConstants. new

    drive s'robot The //
    m_ DifferentialDrive(m_leftMotors, new = m_drive DifferentialDrive final private
    rightMotors); ↪

    encoder drive left-side The //
    = m_leftEncoder Encoder final private
        Encoder( new
            ,]0[kLeftEncoderPortsDriveConstants.
            ,]1[kLeftEncoderPortsDriveConstants.
            );kLeftEncoderReversedDriveConstants.

    encoder drive right-side The //
    = m_rightEncoder Encoder final private
        Encoder( new
            ,]0[kRightEncoderPortsDriveConstants.
            ,]1[kRightEncoderPortsDriveConstants.
            );kRightEncoderReversedDriveConstants.

    sensor gyro The //
    ADXRS450_Gyro(); new = m_gyro Gyro final private

    pose robot tracking for class Odometry //
    m_odometry; DifferentialDriveOdometry final private

    */ DriveSubsystem. new a Creates **/
    { ()DriveSubsystem public
        voltages positive that so drivetrain the of side one invert to need We //
        s'robot your how on Depending forward. moving sides both in result //
        instead. side left the invert to have might you constructed, is gearbox //
        );true(setInvertedm_rightMotors.

        encoders the for pulse per distance the Sets //
        );kEncoderDistancePerPulse(DriveConstants.setDistancePerPulsem_leftEncoder.
        );kEncoderDistancePerPulse(DriveConstants.setDistancePerPulsem_rightEncoder.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                   resetEncoders();
                                                       = m_odometry
                                DifferentialDriveOdometry( new
    m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
                                                     ());getDistance ↪
                                                                  }

                                                         @Override
                                               { ()periodic void public
                            block periodic the in odometry the Update //
                                                   (updatem_odometry.
      m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
                                                     ());getDistance ↪
                                                                  }

                                                                **/
                     robot. the of pose currently-estimated the Returns *
                                                                  *
                                                   pose. The @return *
                                                                 */
                                              { ()getPose Pose2d public
                                     ();getPoseMetersm_odometry. return
                                                                  }

                                                                **/
                       robot. the of speeds wheel current the Returns *
                                                                  *
                                    speeds. wheel current The @return *
                                                                 */
                   { ()getWheelSpeeds DifferentialDriveWheelSpeeds public
  m_rightEncoder. (),getRateDifferentialDriveWheelSpeeds(m_leftEncoder. new return
                                                          ());getRate ↪
                                                                  }

                                                                **/
                           pose. specified the to odometry the Resets *
                                                                  *
                     odometry. the set to which to pose The pose @param *
                                                                 */
                                  { pose) (Pose2dresetOdometry void public
                                                    resetEncoders();
                                                (resetPositionm_odometry.
      m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
                                                  pose); (),getDistance ↪
                                                                  }

                                                                **/
                              controls. arcade using robot the Drives *
                                                                  *
                          movement forward commanded the fwd @param *
                                  rotation commanded the rot @param *
                                                                 */
                       { rot) double fwd, double(arcadeDrive void public
                                            rot); (fwd,arcadeDrivem_drive.
                                                                  }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                                  **/
          voltages. with directly drive the of sides right and left the Controls *
                                                                                   *
                                             output left commanded the leftVolts @param *
                                           output right commanded the rightVolts @param *
                                                                                  */
                         { rightVolts) double leftVolts, double(tankDriveVolts void public
                                                    (leftVolts);setVoltagem_leftMotors.
                                                  (rightVolts);setVoltagem_rightMotors.
                                                                       ();feedm_drive.
                                                                                    }

                */ 0. of position a read currently to encoders drive the Resets **/
                                                      { ()resetEncoders void public
                                                          ();resetm_leftEncoder.
                                                         ();resetm_rightEncoder.
                                                                                    }

                                                                                  **/
                                          encoders. two the of distance average the Gets *
                                                                                   *
                                         readings encoder two the of average the @return *
                                                                                  */
                                              { ()getAverageEncoderDistance double public
      ;2.0 / ())getDistancem_rightEncoder. + ()getDistance(m_leftEncoder. return
                                                                                    }

                                                                                  **/
                                                           encoder. drive left the Gets *
                                                                                   *
                                                         encoder drive left the @return *
                                                                                  */
                                                       { ()getLeftEncoder Encoder public
                                                                    m_leftEncoder; return
                                                                                    }

                                                                                  **/
                                                          encoder. drive right the Gets *
                                                                                   *
                                                        encoder drive right the @return *
                                                                                  */
                                                      { ()getRightEncoder Encoder public
                                                                   m_rightEncoder; return
                                                                                    }

                                                                                  **/
    ␣more drive to drive the scaling for Useful drive. the of output max the Sets *
                                                                                  slowly. ↪
                                                                                   *
       constrained be will drive the which to output maximum the maxOutput @param *
                                                                                  */
                                             { maxOutput) double(setMaxOutput void public
                                                       (maxOutput);setMaxOutputm_drive.
                                                                                    }
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
*/ robot. the of heading the Zeroes **/
{ ()zeroHeading void public
();resetm_gyro.
}

**/
robot. the of heading the Returns *
*
180 to 180- from degrees, in heading s'robot the @return *
*/
{ ()getHeading double public
();getDegrees().getRotation2dm_gyro. return
}

**/
robot. the of rate turn the Returns *
*
second per degrees in robot, the of rate turn The @return *
*/
{ ()getTurnRate double public
();getRatem_gyro.- return
}
}
```

(Header) C++

```
once pragma#

frc/ADXRS450_Gyro.h>< include#
frc/Encoder.h>< include#
frc/drive/DifferentialDrive.h>< include#
frc/geometry/Pose2d.h>< include#
frc/kinematics/DifferentialDriveOdometry.h>< include#
frc/motorcontrol/MotorControllerGroup.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#
frc2/command/SubsystemBase.h>< include#
units/voltage.h>< include#

Constants.h"" include#

{ SubsystemBase::frc2 public : DriveSubsystem class
:public
DriveSubsystem();

**/
runs. CommandScheduler the whenever periodically called be Will *
*/
;override ()Periodic void

here. go methods Subsystem //

**/
controls. arcade using robot the Drives *
*
movement forward commanded the fwd @param *
rotation commanded the rot @param *
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
*/
rot); double fwd, double(ArcadeDrive void

**/
voltage. a with directly drive the of side each Controls *
*
output left commanded the left @param *
output right commanded the right @param *
*/
right); volt_t::units left, volt_t::(unitsTankDriveVolts void

**/
0. of position a read currently to encoders drive the Resets *
*/
();ResetEncoders void

**/
encoders. TWO the of distance average the Gets *
*
readings encoder TWO the of average the @return *
*/
();GetAverageEncoderDistance double

**/
encoder. drive left the Gets *
*
encoder drive left the @return *
*/
();GetLeftEncoder &Encoder::frc

**/
encoder. drive right the Gets *
*
encoder drive right the @return *
*/
();GetRightEncoder &Encoder::frc

**/
drive to drive the scaling for Useful  drive. the of output max the Sets *
slowly. more *
*
constrained be will drive the which to output maximum the maxOutput @param *
*/
maxOutput); double(SetMaxOutput void

**/
robot. the of heading the Returns *
*
180 to 180- from degrees, in heading s'robot the @return *
*/
;const ()GetHeading degree_t::units

**/
robot. the of rate turn the Returns *
*
second per degrees in robot, the of rate turn The @return *
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
*/
();GetTurnRate double

**/
robot. the of pose currently-estimated the Returns *
*
pose. The @return *
*/
();GetPose Pose2d::frc

**/
robot. the of speeds wheel current the Returns *
*
speeds. wheel current The @return *
*/
();GetWheelSpeeds DifferentialDriveWheelSpeeds::frc

**/
pose. specified the to odometry the Resets *
*
odometry. the set to which to pose The pose @param *
*/
pose); Pose2d::(frcResetOdometry void

:private
be generally should sensors) and controllers motor (e.g. Components //
methods. public through only exposed and private declared //

controllers motor The //
m_left1; PWMSparkMax::frc
m_left2; PWMSparkMax::frc
m_right1; PWMSparkMax::frc
m_right2; PWMSparkMax::frc

drive the of side left the on motors The //
m_left2}; m_leftMotors{m_left1, MotorControllerGroup::frc

drive the of side right the on motors The //
m_right2}; m_rightMotors{m_right1, MotorControllerGroup::frc

drive s'robot The //
m_rightMotors}; m_drive{m_leftMotors, DifferentialDrive::frc

encoder drive left-side The //
m_leftEncoder; Encoder::frc

encoder drive right-side The //
m_rightEncoder; Encoder::frc

sensor gyro The //
m_gyro; ADXRS450_Gyro::frc

pose robot tracking for class Odometry //
m_odometry; DifferentialDriveOdometry::frc
;}
```

(Source) C++

```
subsystems/DriveSubsystem.h"" include#

frc/geometry/Rotation2d.h>< include#
frc/kinematics/DifferentialDriveWheelSpeeds.h>< include#

;DriveConstants namespace using

DriveSubsystem()::DriveSubsystem
  m_left1{kLeftMotor1Port}, :
  m_left2{kLeftMotor2Port},
  m_right1{kRightMotor1Port},
  m_right2{kRightMotor2Port},
  ]},1kLeftEncoderPorts[ ],0m_leftEncoder{kLeftEncoderPorts[
  ]},1kRightEncoderPorts[ ],0m_rightEncoder{kRightEncoderPorts[
  { }}0meter_t{::units ,}0meter_t{::units m_odometry{m_gyro.GetRotation2d(),
  voltages positive that so drivetrain the of side one invert to need We //
  s'robot your how on Depending forward. moving sides both in result //
  instead. side left the invert to have might you constructed, is gearbox //
  );truem_rightMotors.SetInverted(

  encoders the for pulse per distance the Set //
  m_leftEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
  m_rightEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());

  ResetEncoders();
}

{ Periodic()::DriveSubsystem void
  here. goes method periodic subsystem of Implementation //
  m_odometry.Update(m_gyro.GetRotation2d(),
                    meter_t{m_leftEncoder.GetDistance()},::units
                    meter_t{m_rightEncoder.GetDistance()});::units
}

{ rot) double fwd, doubleArcadeDrive(::DriveSubsystem void
  rot); m_drive.ArcadeDrive(fwd,
}

{ right) volt_t::units left, volt_t::TankDriveVolts(units::DriveSubsystem void
  m_leftMotors.SetVoltage(left);
  m_rightMotors.SetVoltage(right);
  m_drive.Feed();
}

{ ResetEncoders()::DriveSubsystem void
  m_leftEncoder.Reset();
  m_rightEncoder.Reset();
}

{ GetAverageEncoderDistance()::DriveSubsystem double
  ;2.0 / m_rightEncoder.GetDistance()) + (m_leftEncoder.GetDistance() return
}

{ GetLeftEncoder()::DriveSubsystem &Encoder::frc
  m_leftEncoder; return
}
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                   { GetRightEncoder()::DriveSubsystem &Encoder::frc
                               m_rightEncoder; return
                                           }

                 { maxOutput) doubleSetMaxOutput(::DriveSubsystem void
                          m_drive.SetMaxOutput(maxOutput);
                                           }

                 { const GetHeading()::DriveSubsystem degree_t::units
                      m_gyro.GetRotation2d().Degrees(); return
                                           }

                        { GetTurnRate()::DriveSubsystem double
                              m_gyro.GetRate();- return
                                           }

                        { GetPose()::DriveSubsystem Pose2d::frc
                            m_odometry.GetPose(); return
                                           }

         { GetWheelSpeeds()::DriveSubsystem DifferentialDriveWheelSpeeds::frc
            meters_per_second_t{m_leftEncoder.GetRate()},::units{ return
           meters_per_second_t{m_rightEncoder.GetRate()}};::units
                                           }

                { pose) Pose2d::ResetOdometry(frc::DriveSubsystem void
                                  ResetEncoders();
                  m_odometry.ResetPosition(m_gyro.GetRotation2d(),
        meter_t{m_leftEncoder.GetDistance()},::units
    pose); meter_t{m_rightEncoder.GetDistance()},::units
                                           }
```

## Encoders Drive the Configuring

properly To drive. the of side each on wheels the of rotation the measure encoders drive The plugged are encoders the ports the things: two specify to need we encoders, the configure to access allowing methods write to need we Then, pulse. encoder per distance the and into, subsystem. the uses that code from values encoder the

### Ports Encoder

so: like constructor, encoder's the in specified are ports encoder The

Java

```
                *encoder drive left-side The //*
                        = m_leftEncoder Encoder final private
                                  Encoder( new
                    ,]0[kLeftEncoderPortsDriveConstants.
                    ,]1[kLeftEncoderPortsDriveConstants.
                    );kLeftEncoderReversedDriveConstants.

                          encoder drive right-side The //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                     = m_rightEncoder Encoder final private
                                                          Encoder( new
                              ,]0[kRightEncoderPortsDriveConstants.
                              ,]1[kRightEncoderPortsDriveConstants.
                             );kRightEncoderReversedDriveConstants.
```

(Source) C++

```
                  ]},1kLeftEncoderPorts[ ],0m_leftEncoder{kLeftEncoderPorts[
                ]},1kRightEncoderPorts[ ],0m_rightEncoder{kRightEncoderPorts[
```

## Pulse per Distance Encoder

method. `setDistancePerPulse` encoder's the calling by specified is pulse per distance The edges), four (i.e. cycle encoder full a to refers "pulse" class, `Encoder` WPILib the for that Note that well, as Remember, config. SysId the in specified was that value the 1/4 be will thus and meters! in measured be should distance the

Java

```
        );kEncoderDistancePerPulse(DriveConstants.setDistancePerPulsem_leftEncoder.
       );kEncoderDistancePerPulse(DriveConstants.setDistancePerPulsem_rightEncoder.
```

(Source) C++

```
        m_leftEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
      m_rightEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
```

## Method Accessor Encoder

method: following the include we encoders, the by measured values the access To

---

per distance the configured we Because meters! in be **must** velocities returned The :□□□□ factor conversion the apply automatically will `getRate()` calling above, encoders the on pulse perform must you class, `Encoder` WPILib's using not are you If meters. to units encoder from a by multiplying manually by or API vendor's respective the through either conversion this factor. conversion

---

Java

```
                                                                       **/
                          robot. the of speeds wheel current the Returns *
                                                                        *
                                    speeds. wheel current The @return *
                                                                       */
                     { ()getWheelSpeeds DifferentialDriveWheelSpeeds public
  m_rightEncoder. (),getRateDifferentialDriveWheelSpeeds(m_leftEncoder. new return
                                                                  ());getRate ↪
                                                                         }
```

(Source) C++

```
{ ()DriveSubsystem::GetWheelSpeeds DifferentialDriveWheelSpeeds::frc
   meters_per_second_t{m_leftEncoder.GetRate()},::units{ return
   meters_per_second_t{m_rightEncoder.GetRate()}};::units
                                                            }
```

easier for object `DifferentialDriveWheelSpeeds` a in values encoder measured the wrap We on. later class `RamseteCommand` the with integration

## Gyroscope the Configuring

be then can (which heading robot’s the of change of rate the measures gyroscope The turned first it when to relative heading robot’s the of measurement a provide to integrated been has which ,Board Gyro FRC ADXRS450 Devices Analog the use we example, our In on). years: several for parts of kit the in included

Java

```
ADXRS450_Gyro(); new = m_gyro Gyro final private
```

(Header) C++

```
           sensor gyro The //
m_gyro; ADXRS450_Gyro::frc
```

## Method Accessor Gyroscope

method: following the include we gyroscope, the by measured heading current the access To

Java

```
                                                   **/
                          robot. the of heading the Returns *
                                                   *
180 to 180- from degrees, in heading s'robot the @return *
                                                   */
                                    { ()getHeading double public
  ();getDegrees().getRotation2dm_gyro. return
                                                    }
```

(Source) C++

```
{ const ()DriveSubsystem::GetHeading degree_t::units
   m_gyro.GetRotation2d().Degrees(); return
                                       }
```

## Odometry the Configuring

drive our up set to time is it configured, gyroscope and encoders our have we that Now readings. gyroscope and encoder the from position its compute automatically to subsystem

class: `DifferentialDriveOdometry` the of instance member a create we First,

Java

```
                    pose robot tracking for class Odometry //
m_odometry; DifferentialDriveOdometry final private
```

(Header) C++

```
          pose robot tracking for class Odometry //
m_odometry; DifferentialDriveOdometry::frc
```

## Odometry the Updating

encoder the from readings new incorporate to updated regularly be must class odometry The gyroscope. and We accomplish this inside the subsystem's `periodic` method, which is automatically called once per main loop iteration:

Java

```
                                                   @Override
                                     { ()periodic void public
                      block periodic the in odometry the Update //
                                                (updatem_odometry.
m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
                                                  ());getDistance ↪
                                                                 }
```

(Source) C++

```
                    { ()DriveSubsystem::Periodic void
   here. goes method periodic subsystem of Implementation //
              m_odometry.Update(m_gyro.GetRotation2d(),
      meter_t{m_leftEncoder.GetDistance()},::units
    meter_t{m_rightEncoder.GetDistance()});::units
                                                  }
```

## Method Accessor Odometry

method: following the include we pose, computed current robot's the access To

Java

```
                                          **/
robot. the of pose currently-estimated the Returns *
                                            *
                                pose. The @return *
                                            */
                              { ()getPose Pose2d public
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                          ();getPoseMetersm_odometry. return
                                                                           }
```

(Source) C++

```
                              { ()DriveSubsystem::GetPose Pose2d::frc
                                         m_odometry.GetPose(); return
                                                                    }
```

### Method Drive BasedVoltage-

to voltage the set to us allows that method a - method additional one include must we Finally, The interface. `MotorController` the of method `setVoltage()` the using drive the of side each ourselves: it write must we so functionality, this include not does class drive WPILib default

Java

```
                                                                       **/
       voltages. with directly drive the of sides right and left the Controls *
                                                                       *
                              output left commanded the leftVolts @param *
                            output right commanded the rightVolts @param *
                                                                       */
          { rightVolts) double leftVolts, double(tankDriveVolts void public
                                   (leftVolts);setVoltagem_leftMotors.
                                 (rightVolts);setVoltagem_rightMotors.
                                                      ();feedm_drive.
                                                                     }
```

(Source) C++

```
 { right) volt_t::units left, volt_t::(unitsDriveSubsystem::TankDriveVolts void
                                            m_leftMotors.SetVoltage(left);
                                          m_rightMotors.SetVoltage(right);
                                                          m_drive.Feed();
                                                                        }
```

method, `set()` ordinary the than rather method `setVoltage()` the use to important very is It our Since operation. during sag“ ”voltage battery for compensate automatically will this as identification measured on based are they (as meaningfulphysically- are voltages feedforward accuracy. their ensuring to essential is this data),

### שלב 4: יצירה ומעקב אחרי מסלול

an write and trajectory a generate to time now is it written, subsystem drive our With it. follow to command autonomous

the in this do will we ,*structure project basedcommand- standard* the per As the from method full The class. `RobotContainer` the of method `getAutonomousCommand` article the of rest The below. seen be can )C++ ,Java( Project Example RamseteCommand detail. more in method the of parts different the down break will

Java

```
**/
class. Robot} @link{ main the to command autonomous the pass to this Use *
*
autonomous in run to command the @return *
*/
{ ()getAutonomousCommand Command public
fast too accelerate t'don we ensure to constraint voltage a Create //
= autoVoltageConstraint var
DifferentialDriveVoltageConstraint( new
SimpleMotorFeedforward( new
,ksVoltsDriveConstants.
,kvVoltSecondsPerMeterDriveConstants.
),kaVoltSecondsSquaredPerMeterDriveConstants.
,kDriveKinematicsDriveConstants.
);10

trajectory for config Create //
= config TrajectoryConfig
TrajectoryConfig( new
,kMaxSpeedMetersPerSecondAutoConstants.
)kMaxAccelerationMetersPerSecondSquaredAutoConstants.
obeyed actually is speed max ensure to kinematics Add //
)kDriveKinematics(DriveConstants.setKinematics.
constraint voltage the Apply //
(autoVoltageConstraint);addConstraint.

meters. in units All  follow. to trajectory example An //
= exampleTrajectory Trajectory
(generateTrajectoryTrajectoryGenerator.
direction +X the facing origin the at Start //
)),0Rotation2d( new ,0 ,0Pose2d( new
path curve 's' an making waypoints, interior two these through Pass //
)),1- ,2Translation2d( new ),1 ,1Translation2d( new(ofList.
forward facing started, we where of ahead straight meters 3 End //
)),0Rotation2d( new ,0 ,3Pose2d( new
config Pass //
config);

= ramseteCommand RamseteCommand
RamseteCommand( new
exampleTrajectory,
m_robotDrive::getPose,
AutoConstants. ,kRamseteBRamseteController(AutoConstants. new
),kRamseteZeta ↪
SimpleMotorFeedforward( new
,ksVoltsDriveConstants.
,kvVoltSecondsPerMeterDriveConstants.
),kaVoltSecondsSquaredPerMeterDriveConstants.
,kDriveKinematicsDriveConstants.
m_robotDrive::getWheelSpeeds,
),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
callback the to volts passes RamseteCommand //
m_robotDrive::tankDriveVolts,
m_robotDrive);

trajectory. the of pose starting the to odometry Reset //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                    ());getInitialPose(exampleTrajectory.resetOdometrym_robotDrive.

                                  end. the at stop then command, following path Run //
             ));0 ,0(tankDriveVoltsm_robotDrive. >- (()andThenramseteCommand. return
                                                                                    }
                                                                                      }
```

(Source) C++

```
                                { ()RobotContainer::GetAutonomousCommand CommandPtr::frc2
                     fast too accelerate t'don we ensure to constraint voltage a Create //
                          autoVoltageConstraint{ DifferentialDriveVoltageConstraint::frc
                                                  {>meters::units<SimpleMotorFeedforward::frc
                   ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
                                                       V};_10 kDriveKinematics,::DriveConstants

                                                            trajectory for config up Set //
                                kMaxSpeed,::config{AutoConstants TrajectoryConfig::frc
                          kMaxAcceleration};::AutoConstants
                               obeyed actually is speed max ensure to kinematics Add //
                                kDriveKinematics);::config.SetKinematics(DriveConstants
                                                            constraint voltage the Apply //
                                           config.AddConstraint(autoVoltageConstraint);

                             meters. in units All  follow. to trajectory example An //
                  GenerateTrajectory(::TrajectoryGenerator::frc = exampleTrajectory auto
                                         direction +X the facing origin the at Start //
                                                                  deg},_0 m,_0 m,_0Pose2d{::frc
                 path curve 's' an making waypoints, interior two these through Pass //
                       m}},_1- m,_2Translation2d{::frc m},_1 m,_1Translation2d{::frc{
                    forward facing started, we where of ahead straight meters 3 End //
                                                                  deg},_0 m,_0 m,_3Pose2d{::frc
                                                                           config the Pass //
                                                                                     config);

                                 RamseteCommand(::ramseteCommand{frc2 CommandPtr::frc2
                           ,} m_drive.GetPose(); return { ]this[ exampleTrajectory,
                                      kRamseteB,::RamseteController{AutoConstants::frc
                                  kRamseteZeta},::AutoConstants
                                                  {>meters::units<SimpleMotorFeedforward::frc
                   ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
                                                           kDriveKinematics,::DriveConstants
                                            ,} m_drive.GetWheelSpeeds(); return { ]this[
                                   ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
                                   ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
                ,} right); m_drive.TankDriveVolts(left, { right) auto left, auto](this[
                                                                              m_drive})};&{

                               trajectory. the of pose starting the to odometry Reset //
                               m_drive.ResetOdometry(exampleTrajectory.InitialPose());

                                                               move(ramseteCommand)::std return
                                                                                BeforeStarting(.
              ));}{ ,} V);_0 V,_0m_drive.TankDriveVolts( { ]thisRunOnce([::cmd::frc2
                                                                                          }
```

### Constraints Trajectory the Configuring

that ensure will which trajectory the for parameters configuration some set must we First, followable. is trajectory generated the

### Constraint Voltage a Creating

the that ensure will This constraint. voltage a is need will we configuration of piece first The achieving of capable is it than faster go to robot the commands never trajectory generated supply: voltage given the with

Java

```
             fast too accelerate t'don we ensure to constraint voltage a Create //
                                                       = autoVoltageConstraint var
                                       DifferentialDriveVoltageConstraint( new
                                               SimpleMotorFeedforward( new
                                               ,ksVoltsDriveConstants.
                                 ,kvVoltSecondsPerMeterDriveConstants.
                         ),kaVoltSecondsSquaredPerMeterDriveConstants.
                                          ,kDriveKinematicsDriveConstants.
                                                                      );10
```

(Source) C++

```
               fast too accelerate t'don we ensure to constraint voltage a Create //
                      autoVoltageConstraint{ DifferentialDriveVoltageConstraint::frc
                                     {>meters::units<SimpleMotorFeedforward::frc
                ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
                                        V};_10 kDriveKinematics,::DriveConstants
```

of voltage battery nominal the than rather 10V, to voltage maximum the set we that Notice operation. during sag“ ”voltage with deal to ”headroom“ some us gives This 12V.

### Configuration the Creating

instance, `TrajectoryConfig` our create can we constraint, voltage our have we that Now constraints: path our of all together wraps which

Java

```
                                                   trajectory for config Create //
                                                         = config TrajectoryConfig
                                                         TrajectoryConfig( new
                               ,kMaxSpeedMetersPerSecondAutoConstants.
                 )kMaxAccelerationMetersPerSecondSquaredAutoConstants.
                  obeyed actually is speed max ensure to kinematics Add //
                           )kDriveKinematics(DriveConstants.setKinematics.
                                           constraint voltage the Apply //
                                    (autoVoltageConstraint);addConstraint.
```

(Source) C++

```
trajectory for config up Set //
kMaxSpeed,::config{AutoConstants TrajectoryConfig::frc
kMaxAcceleration};::AutoConstants
obeyed actually is speed max ensure to kinematics Add //
kDriveKinematics);::config.SetKinematics(DriveConstants
constraint voltage the Apply //
config.AddConstraint(autoVoltageConstraint);
```

## Trajectory the Generating

For trajectory. our generate to ready now are we hand, in configuration trajectory our With specify will we means this - trajectory cubic“ ”clamped a generating be will we example, this as known (also waypoints interior for only positions and endpoints, the at poses robot full meters. in are distances all elsewhere, As points“). ”knot

Java

```
meters. in units All  follow. to trajectory example An //
= exampleTrajectory Trajectory
(generateTrajectoryTrajectoryGenerator.
direction +X the facing origin the at Start //
)),0Rotation2d( new ,0 ,0Pose2d( new
path curve 's' an making waypoints, interior two these through Pass //
)),1- ,2Translation2d( new ),1 ,1Translation2d( new(ofList.
forward facing started, we where of ahead straight meters 3 End //
)),0Rotation2d( new ,0 ,3Pose2d( new
config Pass //
config);
```

(Source) C++

```
meters. in units All  follow. to trajectory example An //
GenerateTrajectory(::TrajectoryGenerator::frc = exampleTrajectory auto
direction +X the facing origin the at Start //
deg},_0 m,_0 m,_0Pose2d{::frc
path curve 's' an making waypoints, interior two these through Pass //
m}},_1- m,_2Translation2d{::frc m},_1 m,_1Translation2d{::frc{
forward facing started, we where of ahead straight meters 3 End //
deg},_0 m,_0 m,_3Pose2d{::frc
config the Pass //
config);
```

---

also can one above, outlined as roboRIO the on trajectory the generating of Instead :□□□□
.*JSON PathWeaver a import*

---

## RamseteCommand the Creating

the that ensures This trajectory. the of pose starting the to pose robot's our reset first will We
same. the are position starting trajectory's the and system coordinate the on location robot's

Java

```
                    trajectory. the of pose starting the to odometry Reset //
    ());getInitialPose(exampleTrajectory.resetOdometrym_robotDrive.
```

(Source) C++

```
                    trajectory. the of pose starting the to odometry Reset //
                    m_drive.ResetOdometry(exampleTrajectory.InitialPose());
```

For trajectory. the in pose first the match pose robot initial the that important very is It
with `(0,0)` of position a at starting reliably be will robot the example, our of purposes the
coordinate your base to desirable not probably is it however, use, actual In .0 of heading a
trajectory the and robot the both for position starting the so and position, robot the on system
defined been has that trajectory a use to wish you If value. other some to set be should
the to relative be to it transform can you situation, a such in coordinates centricrobot- in
about information more For ).C++ ,Java( method `transformBy` the using pose current robot's
.*Trajectories Transforming* see trajectories, transforming

follow will executed, when that, command a create can we trajectory, a have we that Now
)C++ ,Java( class `RamseteCommand` the use we this, do To trajectory. that

Java

```
                                     = ramseteCommand RamseteCommand
                                           RamseteCommand( new
                                              exampleTrajectory,
                                          m_robotDrive::getPose,
      AutoConstants. ,kRamseteBRamseteController(AutoConstants. new
                                                      ),kRamseteZeta ↪
                                 SimpleMotorFeedforward( new
                                  ,ksVoltsDriveConstants.
                   ,kvVoltSecondsPerMeterDriveConstants.
              ),kaVoltSecondsSquaredPerMeterDriveConstants.
                            ,kDriveKinematicsDriveConstants.
                                 m_robotDrive::getWheelSpeeds,
       ),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
       ),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
            callback the to volts passes RamseteCommand //
                                 m_robotDrive::tankDriveVolts,
                                         m_robotDrive);
```

(Source) C++

```
                      RamseteCommand(::ramseteCommand{frc2 CommandPtr::frc2
               ,} m_drive.GetPose(); return { ]this[ exampleTrajectory,
                       kRamseteB,::RamseteController{AutoConstants::frc
                    kRamseteZeta},::AutoConstants
                             {>meters::units<SimpleMotorFeedforward::frc
        ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
                                  kDriveKinematics,::DriveConstants
                         ,} m_drive.GetWheelSpeeds(); return { ]this[
                   ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                           ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
        ,} right); m_drive.TankDriveVolts(left, { right) auto left, auto](this[
                                                                 m_drive})};&{
```

argument:by-argument- it through go we'll so substantial, fairly is declaration This

command the pass we accordingly, followed; be to trajectory the is This trajectory: The 1.
steps. earlier our in constructed just we trajectory the

*method subsystem drive* the to lambda) (or reference method a is This supplier: pose The 2.
to measurement pose current the needs controller RAMSETE The *.pose the returns that*
outputs. wheel required the determine

will that )C++ ,Java( object `RamseteController` the is This controller: RAMSETE The 3.
and pose measured current the translates that computation followingpath- the perform
setpoint. speed chassis a into state trajectory

will that )C++ ,Java( object `SimpleMotorFeedforward` a is This feedforward: drive The 4.
gains feedforward the with calculation feedforward correct the perform automatically
tool. identification drive the from obtained we that )`kA` and ,`kV` ,`kS`(

that )C++ ,Java( object `DifferentialDriveKinematics` the is This kinematics: drive The 5.
speeds chassis convert to used be will and file, constants our in earlier constructed we
speeds. wheel to

*subsystem drive* the to lambda) (or reference method a is This supplier: speed wheel The 6.
*speeds wheel the returns that method*

track will that )C++ ,Java( object `PIDController` the is This PIDController: sideleft- The 7.
drive the from obtained we that gain P the using setpoint, speed wheel sideleft- the
tool. identification

will that )C++ ,Java( object `PIDController` the is This PIDController: sideright- The 8.
the from obtained we that gain P the using setpoint, speed wheel sideright- the track
tool. identification drive

*subsystem drive* the to lambda) (or reference method a is This consumer: output The 9.
*.motors drive the to outputs voltage the passes that method*

does command the ensure to included itself, subsystem drive the is This drive: robot The 10.
drive. the uses that command other any as time same the at drive the on operate not

followingpath- the after sequence in command "stop" final a append we that note Finally,
trajectory. the of end the at moving stops robot the that ensure to command,

## Video

this: like something look should routine autonomous robot's your well, gone has all If

## PathWeaver 27.1.3

useful. more potentially as PathPlanner project driven community a find may Users :□□□□ user intuitive an with applications pathplanning traditional upon improves PathPlanner for support no offers WPILib that Note support. following path swerve and interface projects. community

### PathWeaver to Introduction

useful. more potentially as PathPlanner project driven community a find may Users :□□□□ user intuitive an with applications pathplanning traditional upon improves PathPlanner for support no offers WPILib that Note support. following path swerve and interface projects. community

impressive do robots when exciting is it match; the of section important an is Autonomous faster The somewhere. go to need usually robot the score, to order In autonomous. in things for method traditional The points! score can it sooner the location, that at arrives robot the straight a in driving and angle, certain a to turning line, straight a in driving is autonomous time of amount negligiblenon- a spends robot the but fine, works approach This again. line turn. and line straight each after again starting and stopping

in driving of Instead planning“. ”path called is autonomous to approach advanced more A driving moves, continuously robot the complete, is line the once turning and line straight a time. stoppage turning reduce can This motion. likecurve- a with

follow and generate to teams by used be can that suite generation trajectory a contains WPILib trajectories visualize and generate to how over go will articles of series This trajectories. the visit please trajectories, following on tutorial comprehensive a For PathWeaver. using .*tutorial trajectory endto-end-*

you that recommend We PathWeaver. use to required is code *following Trajectory* :□□□□ can you there From paths. simple with working that get and following Trajectory with start PathWeaver. by generated paths complicated more testing to on continue

### Project Pathweaver a Creating

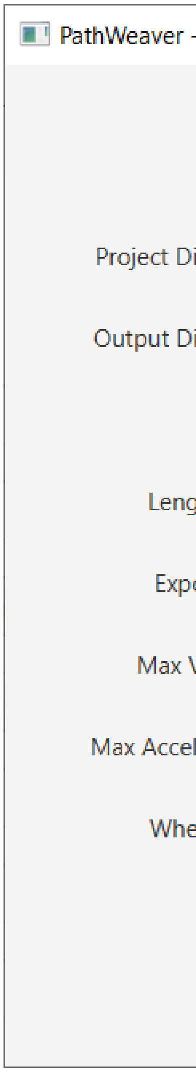
single a for paths The follow. to robot a for paths the draw to used tool the is PathWeaver project. PathWeaver a in stored are program

## PathWeaver Starting

Visual the of corner the of right top the in icon ellipsis the on clicking by started is PathWeaver icon. the see to project WPILib the from file source a select must You interface. Code Studio below. shown as ”PathWeaver“ on click then and tool“ ”Start on click Then

## Project the Creating

creation project the out fill then and project“ ”Create on click project, PathWeaver a create To information more display will form the in fields the of any over hovering that Notice form. required. is what about



the contains that directory project level top the normally is This **Directory: Project** expected the is directory this Choosing program. robot your for files src and build.gradle directories correct the in files output the all locate to it cause will and PathWeaver use to way robot. your to deployment path automatic for

robot. your to deployment for stored are paths the where directory The **directory: Output** (as step previous the in project robot our of folder project level top the specified you If optional. is directory output the in filling recommended)

overlay image field correct the cause will used) being is game FRC® (which game The **Game:** described be will procedure the and images field own your create also can You used. be to series. this in later

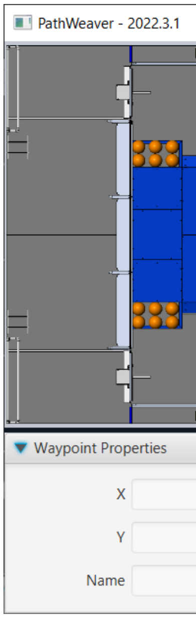
measurements field the for and robot your describing in used be to units The **Unit: Length** PathWeaver. using trajectories visualizing when are you If waypoints. and paths the exporting when used be to units The **Unit: Export** *Same* Choosing .*Meters Always* choose should you then Trajectories, WPILib use to planning above. *Unit Length* as units same the in export will *Project as*

~10 at runs kitbot The tracking. trajectory for robot the of speed max The **Velocity: Max** .$m/sec$ ~3 is which $ft/sec$

a Using tracking. trajectory for robot the of acceleration max The **Acceleration: Max** characteristics. drivetain's your know don't you if start to place good a is $m/sec^2$ 1 conservative

to used is This robot. your of wheels right and left the between distance The **Base: Wheel** around velocity max specified the over go will drive differential a on wheel no that ensure turns.

## Interface User PathWeaver

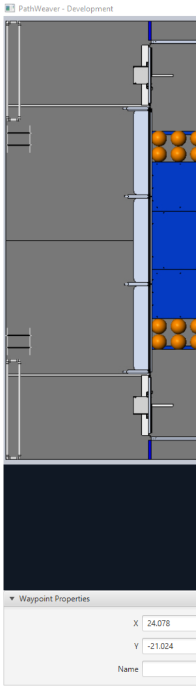


following: the of consists interface user PathWeaver The

1. window. PathWeaver the of most up takes which corner, left top the in area field The program. the of part this on drawn are Trajectories
2. pane. bottom the in displayed are waypoint selected currently the of properties The point. each at tangents the with along Y, and X the include properties These
3. the of side right upper the on displayed is mode) "autonomous" an (or paths of group A mode. auto single a in trajectories the of all seeing of way convenient a is This window.
4. the of side right lower the in displayed are follow might robot a that paths individual The window.
5. files JSON These format. JSON a in trajectories the export will button Paths" "Build The trajectory. the follow to code robot the from used be can
6. properties. project the edit to you allows button Project" "Edit The

### Trajectories PathWeaver Visualizing

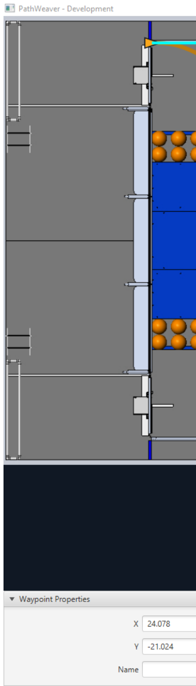
a depict images following The trajectories. visualize to is feature primary PathWeaver’s
autonomous the during take might robot a that trajectory a represents that trajectory smooth
be to driving complex more allow can that waypoints of number any have can Paths period.
the with depicted stop) and start the (including waypoints 3 are there case this In described.
heading robot a as well as field the on position Y X, a of consists waypoint Each icons. triangle
lines. tangent Y and X the as described



X 24.078
Y -21.024
Name

### Trajectory Initial the Creating

trajectory default A window. path the in button (plus) + the click trajectory, a creating start To
desire. you that points end and start proper the have not does probably that created be will
Changing points. end and start the for lines) (teal vectors tangent the shows also path The
the angle of the tangent vectors changes the shape of the trajectory.

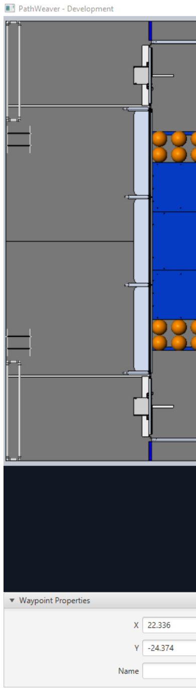


X 24.078
Y -21.024
Name

this in that Notice locations. desired the to trajectory the of points end and start the Drag the drag can We game. 2019 the for spot legal a in start not does trajectory default the case, HAB. the on start robot the make to waypoint initial

### Heading Waypoint a Changing

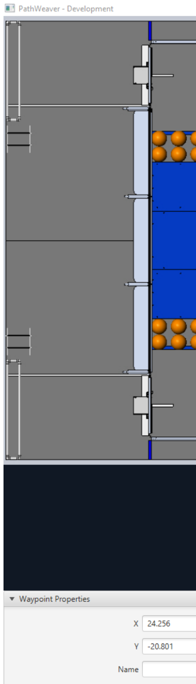
final the Here, line. (teal) vector tangent the dragging by changed be can heading robot The rocket. the face to rotated was and pose final desired the to dragged was waypoint



X 22.336
Y -24.374
Name

## Path Robot the Control to Waypoints Additional Adding

is that path the affect can vectors tangent their changing and waypoints additional Adding this In path. the of middle the in dragging by added be can waypoints Additional followed. path. the of middle the in waypoint another added we case,



▾ Waypoint Properties

X 24.256

Y -20.801

Name

## Lines Tangent the Locking

manipulated. being is trajectory the when changing from them prevents lines tangent Locking moved. is point the when locked be also will lines tangent The

## Waypoints of control Precise More

is it follow, should robot the that trajectories draw to simple it makes PathWeaver While setting case, this In placed. be should waypoints the where set precisely to hard sometimes from come might which value Y and X the entering by done be can locations waypoint the a when fields Y and X the in entered be can points The field. the of model CAD accurate an selected. is waypoint

## Routines Autonomous Creating

path one where visualizing of way a are Groups) Path as known (also Routines Autonomous does path, one drives program robot the when is example An starts. one next the and ends piece, game a obtain to location another to drives completed, has path the after something the in path each of points end and start the that important It's it. score to again back then autonomous single a to paths the all adding By points. start and end common have routine can path each Then shown. be will routine that in paths all routine, the selecting and routine paths. the all viewing while edited be

## Routine Autonomous an Creating

Paths the from Paths the drag Then Routines. Autonomous underneath button + the Press Routine. Autonomous your into section

easy it making color different a in drawn be will routine autonomous an to added path Each path. each for is name the what out figure to

follows: as works selection routine, a in paths multiple are there If

the see to easy it making routine the in paths all displays routine the Selecting 1. the while edited be can paths the of any on waypoint Any them. between relationship waypoint. the containing path the change only will it and selected is routine

to easy it making path, that display only will routine the in path single a on Selecting 2. if interface the in clutter preventing and doing are waypoints the all what see precisely other. each to close are or over cross paths multiple

## JSON PathWeaver a Importing

follow to code robot into JSON PathWeaver a import to used be can class `TrajectoryUtil` The *trajectory endto-end-* the visit Please trajectory. the importing over go will article This it. trajectory. the following on information more for *tutorial*

in methods static (C++) `FromPathweaverJson` / (Java) `fromPathweaverJson` The roboRIO the on stored file JSON a from trajectory a create to used be can `TrajectoryUtil` system. file

the for coordinates the GUI, simulator the in view `Field2d` the with compatible be To :□□□□ was coordinatey- the of range the 2021), (before Previously changed. have JSON exported feet 27 to feet 0 from is coordinatey- the of range the now, whereas feet 0 to feet 27- from affect not should This top). the at being feet 27 and screen the of bottom the at being 0 (with before *trajectory the of pose starting the to odometry their resetting* correctly are who teams following. path

be automatically will which `src/main/deploy/paths` in files JSON places PathWeaver :□□□□ using accessed be can and `home/lvuser/deploy/paths/` in system file roboRIO the on placed below. shown as getDeployDirectory

Java

```
                                ;"paths/YourPath.wpilib.json" = trajectoryJSON String
                                         Trajectory(); new = trajectory Trajectory

                                                                            @Override
                                                        { ()robotInit void public
                                                                              { try
           ().toPath().getDeployDirectoryFilesystem. = trajectoryPath Path
                                                        (trajectoryJSON);resolve ↪
           (trajectoryPath);fromPathweaverJsonTrajectoryUtil. = trajectory
                                                    { ex) (IOException catch }
   ex. trajectoryJSON, + " trajectory: open to Unable"(reportErrorDriverStation.
                                                              ());getStackTrace ↪
                                                                              }
                                                                                }
```

C++

```
                                               frc/Filesystem.h>< include#
                                     frc/trajectory/TrajectoryUtil.h>< include#
                                                       wpi/fs.h>< include#

                                               trajectory; Trajectory::frc

                                                  { ()Robot::RobotInit void
           GetDeployDirectory();::filesystem::frc = deployDirectory path::fs
         ;"YourPath.wpilib.json" / "paths" / deployDirectory = deployDirectory
    FromPathweaverJson(deployDirectory.string());::TrajectoryUtil::frc = trajectory
                                                                                }
```

path. your of name the with replaced be should `YourPath` above, examples the In

> iteration loop one than more take can Java in file from JSON PathWeaver a Loading :□□□□□
> startup. on paths these load robot the that recommended highly is it so

## PathWeaver to images field Adding

example. an as game 2019 the using image field own your adding for instructions are Here

`%USERPROFILE%/` or macOS and Linux on `~/PathWeaver/Games` the from loaded are Games `PathWeaver/Games` directory on Windows. The files can be in either a specificgame- subdirectory, or in a zip file in the Games directory. The ZIP file must follow the same layout as a game directory; the JSON file must be in the root of the ZIP file (cannot be in a subdirectory).

field Other .here definition field Space Deep Destination *FIRST* example the Download .repository GitHub allwpilib the in available are definitions

### Layout File

```
                                                                 PathWeaver/~
                                                                     Games/
                                                              Game Custom/
                                                       custom-game.json
                                                        field-image.png
                                                             OtherGame.zip
```

### Format JSON

```
                                                                            {
                                                         name", game" game":"
                                      relative/path/to/img.png"," field-image":"
                                                           { field-corners":"
                                                        y], [x, top-left":"
                                                     y] [x, bottom-right":"
                                                                          ,}
                                                length], [width, field-size":"
                                                     name" unit" field-unit":"
                                                                            }
```

should file image the simplicity, For file. JSON the to relative is image field the to path The file. JSON the as directory same the in be

defining pixels rightbottom- and lefttop- the of coordinates Y and X the are corners field The playing rectangularNon- image. field the in area playable the of boundary rectangular the supported. not are areas

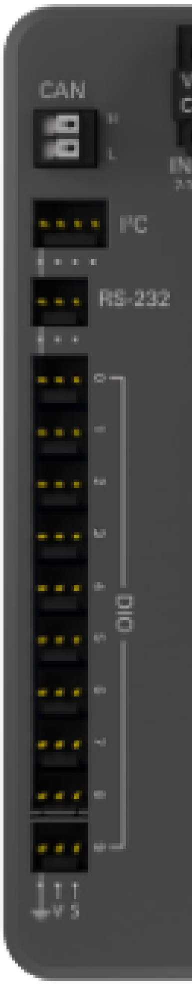
units. provided the in field the of area playable the of length and width the is size field The

or yards, feet, inches, mm, cm, meters, in be can and insensitivecase- are units field The and“m“are ”meter“,“meters“, (e.g. supported are abbreviations and plural, Singular, miles. meters) specifying for valid all

recommended) is pixels 20 of (minimum border a image, field new a making When :□□□□ should be left around the outside so that waypoints on the field edge are accessible.

[redacted]

## Introduction roboRIO 28.1



basic a has roboRIO The  mind. in FIRST with specifically designed is roboRIO The more is but array) gate programmable (field FPGA + processors TimeReal- a of architecture industry. in used systems similar some than smaller and lighter, powerful,

inter- for ports inbuilt- includes that controller robotics reconfigurable a is roboRIO The pulse Ethernet, USB, RS232, (SPI), interfaces peripheral serial (I2C), circuits integrated actuators and sensors common the connect quickly to relays and (PWM), modulation width a and accelerometer, onboard an buttons, LEDs, features controller The robotics. in used and processor Cortex-A9 timereal- ARM coredual- onboard an has It port. electronics custom FPGA. Xilinx customizable

the in and Manual User roboRIO the in found be can roboRIO the on information Detailed .specifications technical roboRIO

*1 roboRIO* roboRIO: the image first must you roboRIO, your to programs deploying Before .*2 roboRIO*

## Dashboard Web roboRIO 28.2

checking for used be can that roboRIO the into built webpage a is dashboard web roboRIO The roboRIO. the of settings updating and status

Google as such browsers Alternate (compatibility). IE using issues encounter may Users experience. best the for recommended are Firefox Mozilla or Chrome

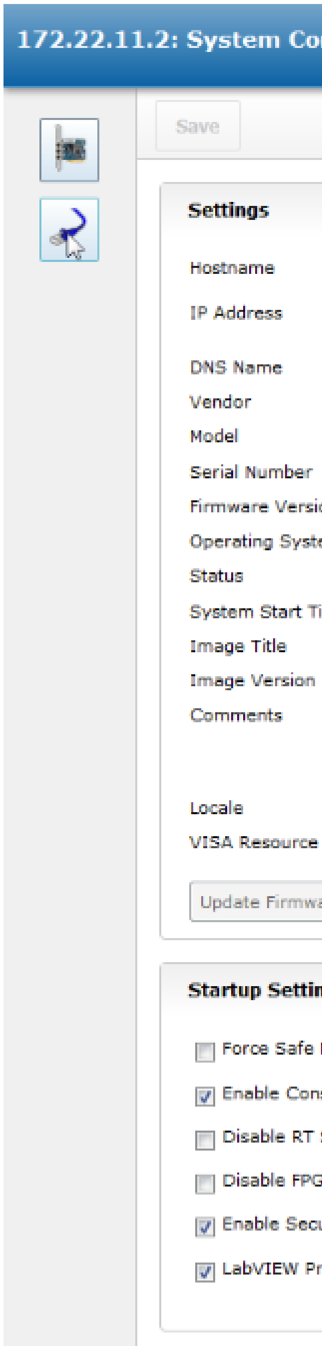
### WebDash the Opening 28.2.1

the into roboRIO the of address the enter and browser web a open dashboard, web the open To team your is #### where FRC.local####-”roboRIO- or USB, for (172.22.11.2 bar address details more for document this See interface). either for zeroes, leading no with number, *Configurations IP* networking: roboRIO and mDNS about

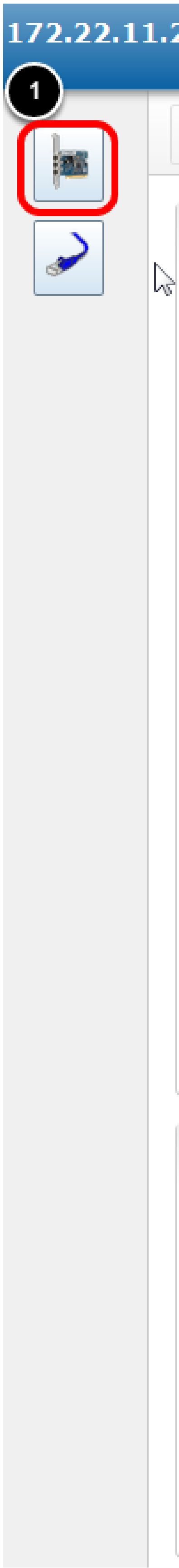
### Tab Configuration System 28.2.2

main 5 has which tab Configuration System the is dashboard web the of screen home The sections:

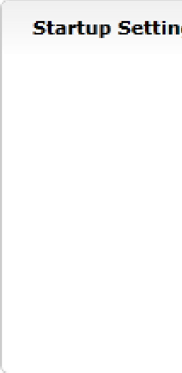
1. web the of sections different to navigate to you allows section This - Bar Navigation discussed are bar navigation this through accessible pages different The dashboard. below.
2. The Settings. System the about information contains section This - Settings System tool Imaging roboRIO the use instead manually, modified be not should field Hostname such information contains section This number. team your on based Hostname the set to version. image and version firmware IP, device the as
3. are These roboRIO. the for settings Startup contains section This - Settings Startup below stepsub- the in described
4. resources system of snapshot a provides section This - pictured) (not Resources System load. CPU and memory as such



☐ Force Safe
☑ Enable Con
☐ Disable RT
☐ Disable FPG
☑ Enable Secu
☑ LabVIEW Pr


172.22.11.2
1

### Settings Startup



- with used be can This Mode. Safe into controller the Forces - Mode Safe Force the on button Reset the use to recommended is it but issues, imaging troubleshooting the hold applied, already power (with instead Mode Safe into device the put to roboRIO **unchecked. is Default** seconds). 5 for button rest
- Console a as used be to port RS232 boardon- the enables This - Out Console Enable talk to port this using are you unless enabled this leave to recommended is It output. to connected be not should and levels RS232 uses port this that (note device serial a to **checked. is Default** levels). TTL use which microcontrollers many
- This startup. at running from code disables box this Checking - App Startup RT Disable program new to unresponsive is roboRIO the find you if troubleshooting for used be may unchecked is Default download.
- **checked. be not should box This** - App Startup FPGA Disable
- **checked. box this leave to recommended is It** - (sshd) Server Shell Secure Enable roboRIO. the on console a access remotely to way a is which SSH enables setting This the onto code loading from teams Java and C++ prevent will box this Unchecking roboRIO.
- setting This checked.** box this leave to recommended is It **- Access Project LabVIEW roboRIO. the access to projects LabVIEW allows

## Configuration Network 28.2.3

**not is It** adapters. network roboRIO's the of configuration the shows page This roboRIO on information more For **page. this on settings any change to recommended** *Configurations IP* article: this see networking


172.22.11.2:

# FTP roboRIO 28.3

how describes article This enabled. FTP anonymous and SFTP both has roboRIO The :□□□□
system. file roboRIO the access to each use to

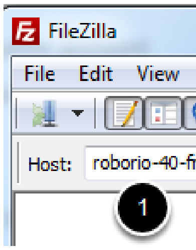
## SFTP 28.3.1

using be will you Because system. file roboRIO the access to way recommended the is SFTP
have always should over copied files under, run will program your that account same the
code. your with compatible permissions

### Software

using discuss will article This SFTP. for programs available freely of number a are There
the extrapolate or proceeding before FileZilla install and download either can You FileZilla.
choice. of client SFTP your to below directions

### roboRIO the to Connecting

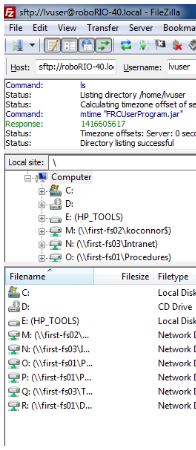


Host: roborio-40-fr

roboRIO: your to connect To

1. box ”Host“ the in frc.local)TEAM-(roboRIO- name mDNS the Enter
2. under) runs program your account the is (this box Username the in ”lvuser“ Enter
3. blank box Password the Leave
4. port) default SFTP (the box port the in ”22“ Enter
5. Quickconnect Click

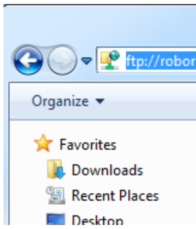
### filesystem roboRIO the Browsing



```
Command:    ls
Status:     Listing directory /home/lvuser
Status:     Calculating timezone offset of se
Command:    mtime "FRCUserProgram.jar"
Response:   1416605617
Status:     Timezone offsets: Server: 0 seco
Status:     Directory listing successful
```

right The directory. \home\lvuser the to open will Filezilla roboRIO, the to connecting After computer). (your system local the is pane left the roboRIO), (the system remote the is pane are you directory current the to hierarchy the you shows pane each of section top The click simply files, transfer To directory. the of contents shows pane bottom the browsing, and click right roboRIO, the on directories create To other. the to side one from drag and Directory“. ”Create select

### FTP 28.3.2



described as SFTP use to recommended is It enabled. FTP anonymous has also roboRIO The software additional no with pinch a in work may FTP need you what on depending but above, type bar, address the In window. Explorer Windows a open roboRIO, the to FTP To required. system file roboRIO the browse now can You enter. press and ftp://roboRIO-TEAM-frc.local computer. your on files browse would you like just

## SSH and Accounts User roboRIO 28.4

programming FRC® typical for required not topics advanced contains document This :□□□□

for used two the highlight will article this accounts, of number a contains image roboRIO The the to connect to how describe also will It purpose. their about detail some provide and FRC SSH. over roboRIO

## Accounts User roboRIO 28.4.1

interest primary of two are there but accounts, user of number a contains image roboRIO The FRC. for

### Admin

or files OS manipulate to used be can and system the to access root has account ”admin“ The modification the for allows it as account this using when caution take should Teams settings. credentials The roboRIO. the of system operating the corrupt may that files and settings of are: account this for

`admin` Username:

Password:

---

blank. intentionally is password The **:□□□□**

---

### Lvuser

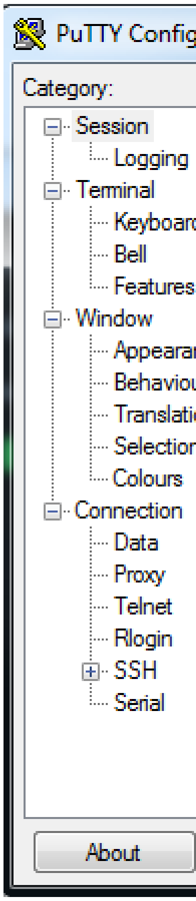
The languages. three all for code user run to used account the is account ”lvuser“ The account this use to wish may Teams changed. be not should account this for credentials changes settings or files any that ensure to roboRIO the with working when sftp) or ssh (via under. run will code their as account same the on made being are

> prevent will ”admin“ or ”lvuser“ either for passwords ssh default the Changing **:□□□□** code. uploading from teams Java and C++

## SSH 28.4.2

referred broadly When communication. data secure for used protocol a is SHell) (Secure SSH to refers generally it roboRIO) the on running one the as (such system Linux a regarding to execute to used be can This protocol. SSH the using console line command the accessing https: PuTTY: is SSH for used be can which client free A system. remote the on commands //www.chiark.greenend.org.uk/~sgtatham/putty/latest.html

### Putty Open



settings: following the set Then prompt). security any at OK (clicking Putty Open

shows example number, team your is TEAM (where frc.localTEAM-roboRIO- Name: Host 1.
40) team

SSH Type: Connection 2.

prompt a see you If connection. the open to Open Click defaults. at left be can settings Other OK. click keys, SSH about

is roboRIO your If hostname. the as 172.22.11.2 use can you USB over connected are you If Ethernet/wireless. over connected if hostname the as IP that use can you IP static a to set

### In Log

```
login as: ad
NI Linux Rea

Log in with

Using keyboa
Password:
admin@roboRI
```

press then description) for above (see username desired the enter prompt, the see you When blank). is accounts both for (password enter press prompt password the At enter.

## Draw Current Understanding and Brownout roboRIO 28.5

system control other and itself preserve to voltage battery maintain help to order In staged a contains roboRIO the events, draw current high during radio the as such components about information provides scheme, this describes article This scheme. protection brownout functionality new the use to how describes and draw, current system for planning proactively happen do they if events brownout understand to Viewer File Log DS the as well as PDP the of robot. your on

### Protection Brownout roboRIO 28.5.1

input the preserve to attempt to scheme protection brownout staged a uses roboRIO The the in resets device prevent to order in components system control other and itself to voltage low. dangerously voltage battery the pulling draws current large of event

## drop output 6v - 1 Stage

### 6.8V - Trigger Voltage

drop. to start will pins PWM the on output 6V the 6.8V, below drops voltage the When

## Disable Output - 2 Stage

### 6.3V - Trigger Voltage

state. protection brownout the enter will controller the 6.3V, below drops voltage the When occurred: has condition this that show will indicators following The

- Amber turn will roboRIO the on LED Power
- red turn will Station Driver the on display voltage the of Background
- Brownout Voltage to change will Station Driver the on display Mode
- 1. by counter fault 12V the increment will DS the of tab CAN/Power The
- log. DS the in event brownout a record will DS The

voltage: battery the preserve to attempt to steps following the take will controller The

- value neutral their set have which outputs PWM For disabled. be will outputs PWM is output the before sent be will pulse neutral single a WPILib) in controllers motor (all disabled.
- 5V the pins, PWM the on outputs 6V the includes (This disabled Rails User 3.3V 5V, 6V, SPI the in pins 3.3V the bank, Analog the in pins 5V the bank, connector DIO the in pins bank) MXP the in pins 3.3V and 5V the and bank I2C and
- ZHigh- to go outputs as configured GPIO
- low) (driven disabled are Outputs Relay
- command disable explicit an sent are controllers motor basedCAN-
- Pneumatic REV and Module Control Pneumatics CTRE the as such Devices Pneumatic disabled are Hub

**7.5V than greater to rises voltage the until state this in remain will controller The brownout the of stage next the for trigger the below drops or**

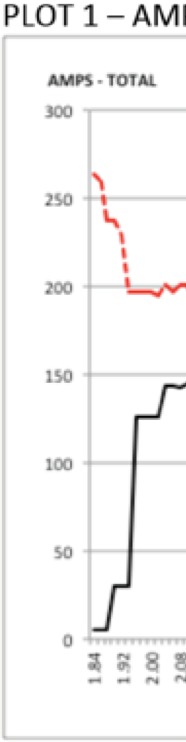
## Blackout Device - 3 Stage

### 4.5V - Trigger Voltage

depends and this than lower be may voltage exact The blackout. may device the 4.5V Below device. the on load the on

**the when 4.65V above rises voltage the until state this in remain will controller The sequence. boot normal the begin will device**

### Planning Draw Current Proactive - Brownout Avoiding 28.5.2



your of draw current the for plan proactively to is condition brownout a avoiding to key The complex a be can This budget. power of form some create to is this do to way best The robot. most to effort an in time and draw current estimated both quantify to attempts that document it or match, a of end the at state battery therefore and usage power understand completely this: do To usage. current of inventory simple a be can

here defined loosely being sustained (with draw current ”sustained“ max the Establish 1. budget. power the creating of part difficult most the probably is This momentary). not as is volts 7+ of voltage a maintaining while sustain can battery a draw current exact The measuring for article *this* (see health battery as such factors of variety a on dependent terminal the ,sheet data 12NP18- the in shown As charge. of state and health) battery draw current as especially decreases, charge of state as steep very gets chart voltage battery new brand a (54A) load continuous 3CA at that shows datasheet This increases. over of voltage terminal a maintaining while minutes 6 over for run continuously be can System Drive 234s Team from permission with (used above image the in shown As 7V. second a than more for 240A drawing battery, fresh a with even ),document Testing sustained our setting on bounds some us gives This issue. an cause to likely is two or current draw. For the purposes of this exercise, we'll set our limit at 180A.

game main manipulator, drivetrain, as such robot your of functions different the out List 2. etc. mechanism,

run you that find likely will You functions. these to current available your assigning Start 3. their slip to *torque* enough have to drivetrain their gear teams Many quickly. pretty out that drivetrain, the on motors 4 have we If motor. per draw current of 50A40- at wheels put to need may we that means This budget! power our exceeds, even or most, up eats used be be) to need (and can functions what understand and scenarios few a together current the limit to need really you that mean will this cases, many In time. same the at

trying as (such drivetrain the out maxing is robot your if/while functions other the of draw
for drivetrain a of requirements current ”driving“ the Benchmarking something). push to
factors many on depends it as complex, more little a is scenarios alternative these of some
for numbers Current efficiency. and gearing, weight, robot motors, of number as such
function the complete to required power the calculating by done be can functions other
determining by or designed) been not has mechanism the (if efficiency estimating and
current the determine to curve currenttorque- the using and motor the on load *torque* the
motors. the of draw

enforcing consider analysis, your in functions exclusive mutually determined have you If 4.
(covered PDP the of monitoring current the use also may You software. in exclusion the
exclusions or limits output provide to program robot your in below) detail more in
over is current drivetrain the when motor mechanism a run don’t as (such dynamically
Y). over is current drivetrain the when output half to up run motor the let only or X

### Brownout Settable 28.5.3

as 6.3V at fixed is It voltages. brownout custom support not does 1.0 roboRIO NI The
above. 2 Stage in mentioned

default The level. brownout settable software a for option the adds 2.0 roboRIO NI The
6.75V. is 2.0 roboRIO the of 2) (Stage level brownout

Java

```
);7.0(setBrownoutVoltageRobotController.
```

C++

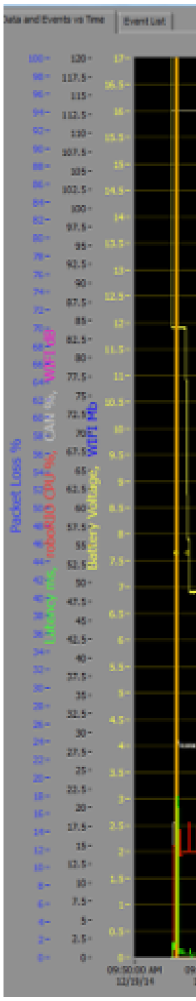
```
V);_7SetBrownoutVoltage(::RobotController::frc
```

### PDP/PDH the using Draw Current Measuring 28.5.4

extract to PDP/PDH and roboRIO the with conjunction in works Station Driver FRC® The
under still is data this for viewer A PC. DS your on it log and PDP/PDH the from data logged
development.

panel front LabVIEW a logging, manual and code robot their use can teams meantime, the In
developed. are mechanisms as robot their on draw current visualize to SmartDashboard the or
Currents PD Get the using channel PDP/PDH a on current the read can you LabVIEW, In
class PowerDistribution the use teams, Java and C++ For pallet. Power the on found VI
(easiest time over information this Plotting article. *Distribution Power* the in described as
provide can indicator Graph a using by SmartDashboard the with or Panel Front LV a with
mechanisms locate can or budget power your update and against compare to information
incorrect calculation, load incorrect to (due expected as performing be to seem not do which
binding). as such issues mechanism or assumptions, efficiency

### Brownouts Identifying 28.5.5



and DS the of tab CAN\Power the on clicking by is brownout a identify to way easiest The
the after Log Station Driver the review can you Alternately, count. fault 12V the checking
orange bright a with brownouts identify will log The Viewer. Log Station Driver the using fact
benchtop a with induced were brownouts these that (note above image the in as such line,
robot). FRC typical a on brownouts of behavior and duration the reflect not may and supply

## Mode Safe using roboRIO a Recovering 28.6

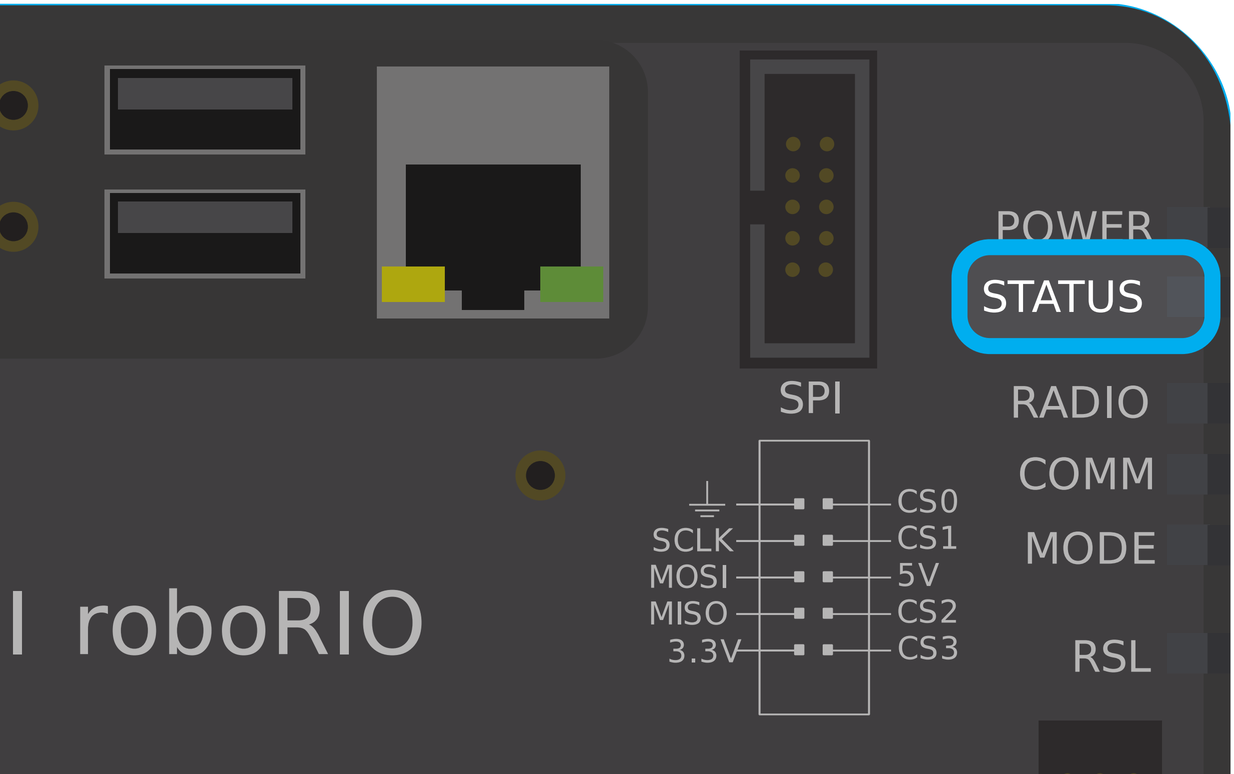
using recovered be cannot it that point the to corrupted become may roboRIO a Occasionally
the allow may Mode Safe into roboRIO the Booting process. imaging and boot normal the
imaged.re- successfully be to device

---

following card SD the Reimaging 2. roboRIO the to applicable not are steps These :□□□□
device. the reformat fully will *process imaging card microSD 2.0 roboRIO*

---

### Mode Safe into Booting 28.6.1



### roboRIO the Recovering 28.6.2

*Imaging* in described as Tool Imaging roboRIO the using by imaged be now can roboRIO The *.roboRIO your*

### Mode Safe About 28.6.3

Disk. RAM a into system operating the of copy separate a boots roboRIO the Mode, Safe In While corrupted. is OS the of copy normal the if even roboRIO the recover to you allows This device the accessing by made changes as (such OS the to made changes any Mode, Safe in disk. on stored OS the of copy normal the to persist not will Serial) or SSH via

[redacted]

roboRIO. the to code robot of deployment the powers that mechanism the is GradleRIO
This system. management build and dependency Gradle popular the on built is GradleRIO
workflow. their enhance to use can teams that configurations **advanced** highlights section

## Code Robot with Libraries External Using 29.1

> is It code! robot your with behavior unintended have may libraries external Using :□□□□□
> doing! are you what of aware are you unless recommended not

code. robot their with usage for libraries C++ or Java external add to want might team a Often
that options the or dependencies, Gradle your to libraries Java adding highlights article This
have. teams C++

### Java 29.1.1

---

to going not likely are (JNI) libraries native on rely that dependencies external Any :□□□□
work.

---

`repositories` required the add simply You dependencies. external add to simple quite is Java
`.dependencies` and

You file. `build.gradle` the in block `{} repositories` a have not do default by projects Robot
following: the add please block, `{} dependencies` the Above yourself. this add to have will

```
                 { repositories
               )(mavenCentral
                          ...
                            }
```

is import to want you library the repository whatever with replaced be can `mavenCentral()`
the adding by done is This itself. library the on dependency the add to have you Now using.

Apache adding showcases example below The block. {} `dependencies` your to line necessary
project. Gradle your to Commons

```
                                                              { dependencies
                    'org.apache.commons:commons-lang3:3.6' implementation
                                                                       ...
                                                                         }
```

work not may Intellisense downloaded. are dependencies the ensure and build a run you Now
ran! is build a until properly

### C++ 29.1.2

for compile to needing to due trivialnon- is project robot your to dependencies C++ Adding
options. of couple a have You roboRIO. the

project. robot your into library wanted the of code source the Copy .1

vendordep. a create and example an as template vendordep the Use .2

#### Code Source Copying

then can You project. robot your into headers and/or source necessary the copy Simply
below: like args platform necessary any configure

```
            { configure.)linuxx86-64""(named.platformConfigs.nativeUtils
  library filesystem C++ in links // )'lstdc++fs-'(add.args.linker.it
                                                                   }
```

#### Vendordep a Creating

.repository vendordep the in instructions the follow Please

## Actions GitHub using Code Robot for CI up Setting 29.2

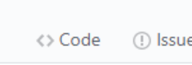
pushed is that code test to able being is environment team a in working of aspect important An
developer lead or manager project a example, For GitHub. as such repository central a to
ensure to want might or request pull a merging before tests unit of set a run to want might
order. working in is repository a of branch main the on code all that

on tests unit run and build to individuals and teams for allows that service a is Actions GitHub
commonly more are services of types These requests. pull on and branches various on code
GitHub setup to how you show will tutorial This services. Integration“ ”Continuous as known
projects. code robot on Actions

an For GitHub. on hosted being is code robot team’s your that assumes tutorial This :□□□□
.*guide introduction* this see please GitHub, and Git to introduction

### Action the Creating 29.2.1

this, create To  file. YAML a in stored are process CI the out carrying for instructions The workflow a up ”set the on click Then repository. your of top the at tab ”Actions“ the on click hyperlink. yourself“



following: the with text default the all Replace editor. text a with greeted be now will You

```
                        code. robot build to workflow basic a is This #

                                                                CI :name

   request pull or push on workflow the Triggers run. will action the when Controls #
                                          branch. main the for only but events #
                                                                           :on
                                                                       :push
                                                          ] main [ :branches
                                                               :pull_request
                                                          ] main [ :branches

␣in or sequentially run can that jobs more or one of up made is run workflow A #
                                                                  parallel ↪
                                                                        :jobs
                                     build"" called job single a contains workflow This #
                                                                       :build
                                         on run will job the that runner of type The #
                                                        ubuntu-latest :runs-on

                                              container docker WPILib the grabs This #
                                    wpilib/roborio-cross-ubuntu:2023-22.04 :container

  job the of part as executed be will that tasks of sequence a represent Steps #
                                                                        :steps
 it access can job your so GITHUB_WORKSPACE,$ under repository your Checks-out #
                                                      actions/checkout@v3 :uses -

                         ownership. dubious under not and safe repository the Declares #
                                         directories safe git to repository Add :name -
                      GITHUB_WORKSPACE$ safe.directory add-- global-- config git :run

                                                 gradlew for permission execute Grant #
                                          gradlew for permission execute Grant :name -
                                                                gradlew +x chmod :run

                                          shell runners the using command single a Runs #
```

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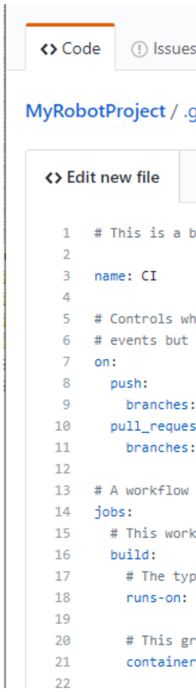
(□□□□ □□□□□ □□□□)

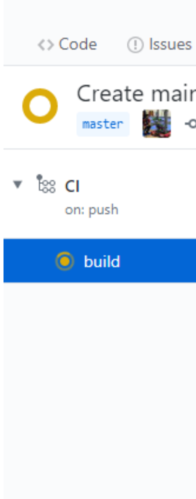
```
code robot on tests run and Compile :name -
                   build gradlew/. :run
```

the of corner righttop- the on button commit“ ”Start the clicking by changes save Then, the click Then, so. do to wish you if message commit default the amend can You screen. button. file“ new ”Commit green



```
# This is a b

name: CI

# Controls wh
# events but
on:
  push:
    branches:
  pull_reques
    branches:

# A workflow
jobs:
  # This work
  build:
    # The typ
    runs-on:

    # This gr
    container
```

pull a or main to pushed is commit a whenever build a run automatically now will GitHub on tab ”Actions“ the on click can you build, any of status the monitor To opened. is request screen. the of top the



### File YAML Actions the of Breakdown A 29.2.2

is line each of understanding strict a Although above. file YAML the of breakdown a is Here potential debug and features more add you help will understanding of level some required, not arise. may that issues

```
   request pull or push on workflow the Triggers run. will action the when Controls #
                                           branch. main the for only but events #
                                                                             :on
                                                                         :push
                                                         ] main [ :branches
                                                               :pull_request
                                                         ] main [ :branches
```

when run will action the Currently, run. will Action the when dictates code of block This main. against opened are requests pull when or main to pushed are commits

```
  ␣in or sequentially run can that jobs more or one of up made is run workflow A #
                                                                      parallel ↪
                                                                          :jobs
                               build"" called job single a contains workflow This #
                                                                        :build
                                     on run will job the that runner of type The #
                                                        ubuntu-latest :runs-on

                                        container docker WPILib the grabs This #
                             wpilib/roborio-cross-ubuntu:2023-22.04 :container
```

after (one sequentially either run that jobs more or one a of made is workflow Action Each job. ”build“ one only is there workflow, our In time). same the (at parallel in or another)

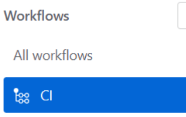
virtualized a in and machine virtual Ubuntu an on run to job the want we that specify We toolchains. roboRIO and compiler C++ JDK, the contains that container Docker

```
     job the of part as executed be will that tasks of sequence a represent Steps #
                                                                        :steps
    it access can job your so GITHUB_WORKSPACE,$ under repository your Checks-out #
                                                     actions/checkout@v3 :uses -

                           ownership. dubious under not and safe repository the Declares #
                                            directories safe git to repository Add :name -
                         GITHUB_WORKSPACE$ safe.directory add-- global-- config git :run

                                                gradlew for permission execute Grant #
                                              gradlew for permission execute Grant :name -
                                                               gradlew +x chmod :run

                                            shell runners the using command single a Runs #
                                                  code robot on tests run and Compile :name -
                                                                   build gradlew/. :run
```

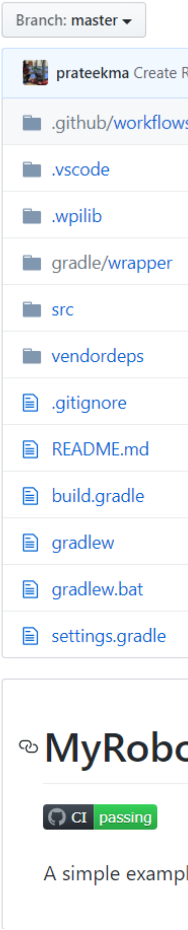
involves step first The steps. four has job This executed. be will that steps certain has job Each a for workaround a is step second The code. robot the access to repository the out checking execute to permission machine virtual the giving involves step third The .issue Actions GitHub code robot compile to `build gradlew/.` runs step final The `.gradlew/.` using tasks gradle tests. unit any run and

### File README.md a to Badge Status Build a Adding 29.2.3

quickly to file README repository’s your of top the to badge status CI a add to helpful is It top the at tab ”Actions“ the on click this, do To main. on build latest the of status the check ”Create the on click Then, screen. the of side left the on tab ”CI“ the select and screen the of code. Markdown badge status the copy and right top the on button badge“ status



and commit, file, README your of top the at copied you code Markdown the paste Finally, main your on badge status Actions GitHub the see should you Now, changes. your push page. repository



## Formatter Code a Using 29.3

the throughout consistent is written code of style the that ensure to exist formatters Code may Teams OpenCV. to Android from projects; major many in used is This codebase. entire maintains codebase the that ensure to code robot their throughout formatter a add to wish throughout. consistency and readability

teams. C++ for wpiformat and teams Java for Spotless using highlight will we article, this For

### Spotless 29.3.1

#### Configuration

`{}` `plugins` the In functional. Spotless get to required are changes `build.gradle` Necessary below. the to similar appears it so plugin Spotless the add ,`build.gradle` your of block

```
                                         { plugins
                                      java"" id
2022.1.1"" version edu.wpi.first.GradleRIO"" id
    '6.12.0' version 'com.diffplug.spotless' id
                                                 }
```

can This spotless. configure correctly to block `{} spotless` required a add you ensure Then .`build.gradle` your of end the at placed get just

```
                                        { spotless
                                         { java
                      { )'.'(fileTree target
                   '**/*.java' include
'**/build-*/**' ,'**/build/**' exclude
                                           }
                               )(toggleOffOn
                          )(googleJavaFormat
                       )(removeUnusedImports
                    )(trimTrailingWhitespace
                            )(endWithNewline
                                              }
                                 { groovyGradle
                      { )'.'(fileTree target
                 '**/*.gradle' include
'**/build-*/**' ,'**/build/**' exclude
                                           }
                                 )(greclipse
                         )4(indentWithSpaces
                    )(trimTrailingWhitespace
                            )(endWithNewline
                                              }
                                { ,'xml' format
                      { )'.'(fileTree target
                    '**/*.xml' include
'**/build-*/**' ,'**/build/**' exclude
                                           }
                           )'xml'(eclipseWtp
                    )(trimTrailingWhitespace
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                              )2(indentWithSpaces
                                                )(endWithNewline
                                                              }
                                                { ,'misc' format
                                         { )'.'(fileTree target
                    '**/.gitignore' ,'**/*.md' include
                 '**/build-*/**' ,'**/build/**' exclude
                                                            }
                                         )(trimTrailingWhitespace
                                              )2(indentWithSpaces
                                                )(endWithNewline
                                                              }
                                                                }
```

## Spotless Running

options. formatting all apply will which `spotlessApply gradlew/.` using ran be can Spotless is example An formatter. of name the adding just by task specific a specify also can You `.spotlessmiscApply gradlew/.`

this formatted; correctly is code the ensure also can Spotless code, formatting to addition In ,*check CI* a as used be can Spotless Thus, `.spotlessCheck gradlew/.` running by used be can workflow: Actions GitHub following the in shown as

```
                                                             ]push[ :on
     ␣in or sequentially run can that jobs more or one of up made is run workflow A #
                                                             parallel ↪
                                                                  :jobs
                                                             :spotless
                         on run will job the that runner of type The #
                                                  ubuntu-latest :runs-on
      job the of part as executed be will that tasks of sequence a represent Steps #
                                                                :steps
   it access can job your so GITHUB_WORKSPACE,$ under repository your Checks-out #
                                              actions/checkout@v2 :uses -
                                                                  :with
                                                         0 :fetch-depth
                                             actions/setup-java@v3 :uses -
                                                                  :with
                                                  'zulu' :distribution
                                                      17 :java-version
                                           spotlessCheck gradlew/. :run -
```

## Options of Explanation

and `java` The project. the in files custom of formatting highlights section `format` Each differently. defined are they so spotless, by supported natively are `groovyGradle`

parts. multiple into this split can we down, this Breaking

- Java Formatting
- files Gradle Formatting
- files XML Formatting

files Miscellaneous Formatting •

below The explained. be will that differences small some for except similar, all are They block. {} `java` the highlight will example

```
                                                   { java
                                  { )'.'(fileTree target
                                   '**/*.java' include
                 '**/build-*/**' ,'**/build/**' exclude
                                                     }
                                           )(toggleOffOn
                                       )(googleJavaFormat
                                    )(removeUnusedImports
                                 )(trimTrailingWhitespace
                                         )(endWithNewline
                                                          }
```

mean. options the of each what explain Let’s

```
                                  { )'.'(fileTree target
                                   '**/*.java' include
                 '**/build-*/**' ,'**/build/**' exclude
                                                     }
```

`build` the exclude to and are classes Java our where spotless tells example above The directory. The rest of the options are fairly self-.explanatory

project. a of portions specific ignore spotless have to ability the adds `toggleOffOn()` •
following the like looks usage The

```
                                          format:off //

                       { ()myWeirdFunction void public

                                                      }

                                           format:on //
```

- Guide Style Google the to according format to spotless tells `googleJavaFormat()`
- classes Java your of any from imports unused any remove will `removeUnusedImports()`
- lines your of end the at whitespace extra any remove will `trimTrailingWhitespace()`
- classes your of end the to character newline a add will `endWithNewline()`

spotless that formatter the is This option. `greclipse` a is there block, `groovyGradle` the In files. gradle format to uses

Tools Web ”Gradle for stands This block. `xml` the in option `eclipseWtp` a is there Additionally, wish may files XML any using not Teams files. `xml` format to formatter the is and Platform“ configuration. this include not to

README Spotless the on available is configurations of list full A :□□□□

### Endings Line with Issues

constantly be will diffs Git means which OS,per- endings line apply to attempt will Spotless
teams that recommended It’s Windows). vs (Unix OSes different on are users two if changing
The file. `gitattributes.` a utilize OSes multiple from repository same the to contribute who
endings. line handling for suffice should following

```
eol=lf text *.gradle
eol=lf text *.java
eol=lf text *.md
eol=lf text *.xml
```

## wpiformat 29.3.2

### דרישות

- higher or 3.6 Python
- )LLVM with (included formatclang-

**will** Clang with LLVM Installing time! this at supported currently not is Windows :□□□□
Windows. on installed if builds robot normal break

command or terminal a into `wpiformat install pip3` typing by wpiformat install can You
prompt.

### Usage

with format will This console. a in `wpiformat` typing by ran be can wpiformat
`.` `,styleguide.` `,format-clang.(` required are files configuration Three `.format-clang`
root. project the in exist must These `).license-styleguide`

- Download `:format-clang.`
- Download `:license-styleguide.`

below: shown is styleguide example An

```
{ cppHeaderFileInclude
  h$.\
  hpp$.\
  inc$.\
  inl$.\
}

{ cppSrcFileInclude
  cpp$.\
}

{ modifiableFileExclude
  gradle/
}
```

---

It’s wish. they however `license-styleguide.` and `styleguide.` adapt can Teams :□□□□
wpiformat! run to required are they as deleted, not are these that important

---

as ,`HEAD code-exit-- diff pager-no-- git` running by *check CI* a into this turn can You
below: workflow Actions GitHub example the in shown

```
                                                                 Format and Lint :name

                                                                                   :on
                                                                       :pull_request
                                                                               :push

                                                                                 :jobs
                                                                          :wpiformat
                                                                 "wpiformat" :name
                                                             ubuntu-22.04 :runs-on
                                                                            :steps
                                                     actions/checkout@v3 :uses -
                                          metadata and history all Fetch :name -
                                                                        | :run
           w/allwpilib/allwpilib__/ safe.directory add-- global-- config git
                                               unshallow-- prune-- fetch git
                                                          pr b- checkout git
                                              origin/main main f- branch git
                                                       3.8 Python up Set :name -
                                                 actions/setup-python@v4 :uses
                                                                         :with
                                                         3.8 :python-version
                                                    clang-format Install :name -
                                                                        | :run
    - add apt-key sudo | https://apt.llvm.org/llvm-snapshot.gpg.key - O- wget
    ␣llvm-toolchain-jammy-14 http://apt.llvm.org/jammy/ deb' echo" c- sh sudo
                        etc/apt/sources.list.d/proposed-repositories.list"/ >> 'main ↩
                                                      q- update apt-get sudo
                                     clang-format-14 y- install apt-get sudo
                                                       wpiformat Install :name -
                                                   wpiformat install pip3 :run
                                                                     Run :name -
                                                      14 clang- wpiformat :run
                                                            output Check :name -
                                     HEAD exit-code-- diff no-pager-- git :run
```

## Tasks Gradlew 29.4

user for team WPILib the by supported commands gradle the highlight to aims article This robot your of root the at `tasks gradlew/.` typing by viewed be can commands These use. not will commands unsupported and `tasks gradlew/.` in shown commands all Not project. here. documented be

### tasks Build 29.4.1

project your prebuilding for Useful project. this tests and Assembles - `build gradlew/.` directory. build the Deletes - `clean gradlew/.` roboRIO. the to deploying without

### tasks CompileCommands 29.4.2

a is This compile_commands.json. Generate - `generateCompileCommands gradlew/.` Environments. Development Integrated many by supported is that file configuration

### tasks EmbeddedTools 29.4.3

to project robot your deploy will This targets. all on artifacts all Deploy - `deploy gradlew/.` roboRIO). (IE, targets available the

print will This roboRIO. target of address(es) the Determine - `discoverRoborio gradlew/.` roboRIO. connected a of address IP the out

### tasks GradleRIO 29.4.4

project this by used be may that dependencies all Download - `downloadAll gradlew/.`

IE, tool. the of name the with `$TOOL$` (Replace `$TOOL$` tool the Runs - `$TOOL$ gradlew/.` etc) Shuffleboard, Glass,

the of name the with `$TOOL$` (Replace `$TOOL$` tool the Installs - `$TOOL$Install gradlew/.` etc) Shuffleboard, Glass, IE, tool.

development the excludes This tools. available all Installs - `InstallAllTools gradlew/.` required the ensure to requirement users the It's Code. Studio Visual as such environment users! advanced for recommended Only installed. is (Java) dependencies

a Exports executable. native for Task External Simulate - `simulateExternalCpp gradlew/.` tools / editors by use for file JSON

a Exports Java/Kotlin/JVM. for Task External Simulate - `simulateExternalJava gradlew/.` tools / editors by use for file JSON

projects Java the for simulation Launches - `simulateJava gradlew/.`

projects C++ for simulation Launches - `simulateNative gradlew/.`

□□□□□□ See installation. local or URL from file JSON vendordep Install - `vendordep gradlew/.` □□□□□ □□

## Deploy in Data Git Including 29.5

commit or name branch as such Git, from information include to how over go will article This as such code, robot in information such using for necessary is This code. robot the into hash, starts. robot the when name branch and hash commit out printing

when default by enabled be should This work. to this for path the in be must Git :□□□□ .Git installing

### Name Branch Deploying 29.5.1

Git The branch. current the of name the data extract to parserev- git uses example This is: this for used command

```
HEAD abbrev-ref-- rev-parse git $
```

that commit current the for name the of version short a use to Git tells flag `ref-abbrev--` The return will this branch, a on commit recent most the is HEAD When on. acting is `parse-rev` branch. that of name the

and command Git above the run will that file `build.gradle` the in task new a create Next, example an is following the example, For directory. `src/main/deploy` the in file a to it write .`branch.txt` named file a to name branch the write will that `writeBranchName` named task

```
{ )writeBranchName""(register.tasks
terminal of instead to write to stream output an Define //
)(ByteArrayOutputStream new = stdout def

command git the Execute //
{ exec
HEAD"" ,abbrev-ref"--" ,rev-parse"" ,git"" commandLine
terminal of instead stream output the to Write //
stdout = standardOutput
}

string a into output the Parse //
)(trim.)(toString.stdout = branch def

file new a Create //
(File new
directory deploy and directory project Join //
,src/main/deploy"/" + )(toString.projectDir
to write to name File //
branch.txt""
branch variable the to file the of contents the Set // branch = text.)
}
```

variable, a to output the saves command, Git above the uses that task Gradle a registers This be will it directory, `src/main/deploy` the to written was it Since file. a to it writes then and code. in accessible and robot the to deployed file jar the in included

it that so created, you task the on depend task deploy the make to is step next The name task the uses example This deployed. is code the before run automatically will

of name the with replaced be should it but example, previous the from `writeBranchName`
.`build.gradle` your in task the

```
)writeBranchName(dependsOn.frcStaticFileDeploy.artifacts.roborio.targets.deploy
```

## Hash Commit Deploying 29.5.2

commit current the parse to used be will `parse-rev git` example, previous the to Similar
is: this for used command Git The hash.

```
HEAD short-- rev-parse git $
```

commit the about information find to used is `parse-rev` command, Git previous the to Similar
with associated name branch the find to `ref-abbrev--` using of instead However, HEAD. at
hash. commit character7- the find to used is `short--` commit, that

---

can you version, character7- the of instead hash commit full the use to wish you If **:□□□□**
flag. `short--` the out leave

---

a to output the writes and command this runs that `build.gradle` in task a create to is Next
,`writeCommitHash` named is task the except example, first the as same the largely is This file.
.`branch.txt` of instead `commit.txt` to written is it and used, is command Git new the

```
{ )writeCommitHash""(register.tasks
)(ByteArrayOutputStream new = stdout def

{ exec
HEAD"" ,short"--" ,rev-parse"" ,git"" commandLine
stdout = standardOutput
}

)(trim.)(toString.stdout = commitHash def

(File new
,src/main/deploy"/" + )(toString.projectDir
commit.txt""
commitHash = text.)
}

)writeCommitHash(dependsOn.frcStaticFileDeploy.artifacts.roborio.targets.deploy
```

### Git with Files Generated Ignoring

every regenerated are and Git by tracked already is that data include files these Since
the using by Git with changes these track not to recommended is it deployed, is code time
VS WPILib the by generated project any in default by exist should file This file. gitignore
`commit.txt` and `branch.txt` the use to continues that example an is Below extension. Code
names: file

```
txt.branch/deploy/main/src
txt.commit/deploy/main/src
...
```

### 29.5.3 Using Deployed Files

In order to access files that were written to the deploy directory in code, you have to use the `getDeployDirectory()` method of the Filesystem class in Java, or the `GetDeployDirectory()` function of the frc::filesystem namespace in C++. Below is an example of opening both files from the previous examples:

□□□□: Opening and reading the files is slow and should not be performed during any periodic methods. Since the file will only change on deploy, it only needs to be read once.

```
File deployDir = Filesystem.getDeployDirectory();
File branchFile = new File(deployDir, "branch.txt");
File commitFile = new File(deployDir, "commit.txt");
```

For more information on how to interact with the file objects, see the documentation of the File class.

# 03

[redacted]

□□ □□□□□□ □□□□ □□□□□□□□□ □□□□ WPILib,-□ □□□□□□□ □□□□□ □□□□□□ □□ □□□□ □□ □□□
.□□□□□□□□ □□□ □□□□□□ feedback/feedforward

## of Validation Based Model of Walkthrough Video A 30.1 FRC in Autonomous

WPILib the from Veness Tyler 2020, in WPI“ by Presented Conference, Spring ”RSN the At FRC®. in Autonomous of Validation Based Model on presentation a gave team

.here available is presentation the to link The

## מתקדמות לבקרות מבוא 30.2

### Basics System Control 30.2.1

---

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---

#### Systems Control for Need The

you ones of list small A daily. them with interact we and us around all are systems Control the and control cruise thermostats, with conditioners air and heaters includes seen have may laptops. modern on modulation speed fan and automobiles, on (ABS) system braking lockanti- of consist may and these like systems of behavior the control or monitor systems Control control). (automatic machines only of or control), (manual directly them controlling humans

*directly* be cannot but work, useful does which mechanism a have examples these of All desired. is that state the to commanded input electrical or mechanical no have compressor and fans conditioner's air an example, For compare must mechanism additional some Rather, temperature. a specifies user the where and compressor the cycle to how choose and setpoint, some to temperature air current the temperature. that achieve to off and on fans

directly which lever mechanical no have transmission and engine automobile's an Similarly, speed current the measure must mechanism additional some Rather, speed. particular a sets achieve to cylinders the into injected fuel and gear transmission the adjust and vehicle, the of speed. vehicle desired the

bridge to mechanisms additional those design to how of study the is *Engineering Controls* actually is mechanism the how to do, to mechanism a wants user the what from gap the manipulated.

behave will example, for car, autonomous an on controllers loopclosed- prove we can How uncertainty? of presence the in specifications performance desired the meet and safely the predict and analyze to used geometry and algebra of application an is theory Control to robust them make and to, them want we how respond them make systems, of behavior uncertainty. and disturbances

As theory. control to applied process engineering the simply, put is, engineering Controls behind math beautiful some has theory control While math. applied just than more it's such, trade- with filled is that other any like discipline engineering an is engineering controls it, our by informed and checked sanity be always should gives theory control solutions The offs. to enough good be to need just we perfect; be to need don't We specifications. performance specifications. our meet

## Nomenclature

that above well knowledge of level a assume topics engineering advanced for resources Most communicates efficiently it While jargon. of use the is problem the of Part necessary. is which lost. are it with familiar aren't who people new field, the within those to ideas

A .*plant* the called is system control a by controlled being actuators of collection or system The reference). (the state desired some to state current its from plant the drive to used is controller open- called are output plant's the from measured information include don't which Controllers controllers. loop

closed- called are output plant's the from back fed information incorporate which Controllers controllers. feedback or controllers loop

Figure 1.1

The view. of point plant’s the from defined are system a of output and input The : and reference the between difference the driving is shown controller feedback negative zero. to error, the as known also output,

### Gain? is What

input an of magnitude the between relationship the shows that value proportional a is *Gain* method a contain systems Many state.steady- at signal output an of magnitude the to signal system. the to ”power“ less or more providing altered, be can gain the which by

is output the Since output. and input hypothetical a with system a shows below figure The two. of gain a has system the input, the of amplitude the twice

Figure 1.2:

### Model? a is What

this Specifically, behavior. its of description mathematical a is mechanism your of *model* A the how and outputs, and inputs mechanism’s the define must description mathematical values. input its of function a as time over change values output

some include also can It equations. algebra simple just often is description mathematical The to classes of number a provides WPILib equations. differential and matrices, algebra, linear math. complex more the simplify help

behavior. system of models up build to used equations the of many defines *Mechanics Classical* the on experiments doing by determined be can equations those inside values the of Many mechanism.

### Diagrams Block

Block graphically. it model to useful is it system, control a analyzing or designing When systematically. simplified and manipulated be can They purpose. this for used are diagrams

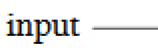

Figure 1.3

output the to circle) (the input the at node sum the from gain total the is gain loopopen- The feedback The disconnected. was loop feedback the if gain system's the be would this branch. the is output node's sum A node. sum input the to back output the from gain total the is gain inputs. its of sum

configuration. feedback a in notation formal more with diagram block a is figure below The

Figure

feedback. negative represents minus a where plus“ or ”minus means $\mp$

### Dimensionality on Note A

feedforward (except controllers and systems all section, introductory the of purposes the For single map only they means this - (SISO) out“single- in,”single- be to assumed are controllers) single a of *input* an take to considered is motor DC a example, For values. single to values position (either return in value scalar single a only of *output* an yield and (voltage) value scalar separate as *controllers velocity* and *controllers position* consider to us forces This velocity). or both control to want we when situations in confusion of source sometimes is this - entities means also systems SISO to ourselves Limiting profiles). motion a following when as (such like systems (MIMO) out“multiple- in,”multiple- complexmore- analyze to unable are we that independent two least at are (there state single a with represented be cannot that drivetrains drive). a in wheels of sets

following the present to able be to here systems SISO to ourselves restrict we Nonetheless, introductory in featured commonly is which formalism, Controller PID the of terms in tutorials implementations. available many and documentation extensive has and material course allows which systems these conceptualize to way alternate an is formalism *spacestate-* The simultaneously as well (as quantities different between interactions capture easily to us motor). a of velocity and position as such quantity, same the of aspects multiple represent and ,*input* ,*gain* the (e.g. scalars dimensionalsingle- the replacing by roughly, this, does It a of equivalent the formalism, spacestate- the In vectors. dimensionalmulti- with )*output* state, mechanism valuedvector- single a on controller proportionalvector- a is controller ”PID“ scalars). *gain* different three of (instead vector *gain* single a with

with written controller PID a just really is controller spacestate- a that remember you If transfer will articles introductory of set this in covered principles the of many notation, dense control. spacestate- of case the to seamlessly

## Strategy Control a Picking 30.2.2

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different of number a are there mechanism, robot a for algorithm control a designing When complex and advanced to approaches, simple very from range These take. to approaches some situations, different in others than better work will Some .*tradeoffs* has Each ones. others. than analysis mathematical more require

field. the on success enables which strategy easiest the picking prioritize should Teams take to step“”next- a always almost is there mind in keep experiments, do you as However, performance. field your improve to

here: cover will we that controller mechanism of types fundamental two are There

classifiable easily not are strategies control some - definitions strict not are These **:□□□□** a still is it However, controllers. feedback and feedforward both of elements incorporate and applications. FRC most in distinction useful

which algorithms of class the to refers control“) loop”open- (or **control Feedforward** Using operate. to *expected* is control under mechanism the how of knowledge incorporate to close get mechanism the make to chosen is input control the operation, of ”model“ this be. should it where

use which algorithms of class the to refers control“) loop”closed- (or **control Feedback** move to commands corrective issue and doing, is mechanism a what *measure* to sensors be. to it want you where to is, actually it where from mechanism a

pages tutorial The both. use to best usually is it fact in and exclusive, mutually not are These allow and arm), vertical and flywheel, (turret, mechanism of types three cover will follow that strategy, control of type each to responds system of type each how with experiment to you combined. and individually both

### Guess Best a Making Control: Feedforward

think you signal control the with mechanism the providing means control“ ”Feedforward
the where of knowledge any without want, you what do mechanism the make to needs it
about know already we information feeds controller feedforward A is. currently mechanism
controller feedforward The .*effort control* required the of estimate an into *forward* system the
for correct to try to system the of behavior measured the to response in this adjust *not* does
guess. the from errors

draw you if because control“, loop”open- as to referred sometimes also is control Feedforward
to controller the from line a only of consists it system controlled the of diagram block a out
(hence controller the into back output plant measured the from connection no with plant, the
all). at loop a isn’t really which loop, ”open“ an

”directly“ to joystick a use you whenever using implicitly are you control of type the is This
most and simplest the is It voltage. applied the through motor a of speed the control
when first encountered you one the probably is and control, of type straightforward
name. by to referred been have not may it though motor, FRC a programming

### Control? Feedforward Need We Do When

constant some requires system the whenever *required* is control feedforward general, In
arm vertical a of control position as (such setpoint desired the at remain to signal control
dynamics motor internal where control velocity or fall, to arm the cause will gravity where
fall naturally controllers Feedback time). over down slow to motor the cause will friction and
to needed is controller feedforward a so and setpoint, their achieve they when output zero to
it. want we where mechanism the *keep* to signal the provide

gain integral with controller feedback the in this for account instead strategies control Some
feedforward a use to better always almost is It oscillation. to prone and slow is this however, -
setpoint. the maintain to needed output the for account to controller

### Control Position and Feedforward

an generate to setpoints acceleration and velocity require classes feedforward WPILib The
magnetpermanent- a of motionof-equations- the because is This voltage. control estimated
that physics of fact a is it acceleration; and velocity to voltage applied the relate motor DC
change. cannot we

immediate no there’s motor, DC a controlling When position? control to want we if what But
for effectively feedforward use to order In signal. control and position between relation
robot the take will that velocities of sequence a with up come to need we control, position
.*profile motion* a called is This position. desired the to mechanism

doing when profile motion a using of cost technical extra the incur to wish not do teams Many
only use to opt and entirely controller feedforward the omit instead and control, position
some has but situations, *some* in work may this later, discuss will we As control. feedback
caveats. important

pure though classes, feedforward WPILib’s by describedwell- are mechanisms FRC Most
mechanisms of control velocity for results acceptable yields only typically control feedforward
and unavoidable be will model system the from errors cases, other In load. external little with
them. for correct to necessary be will controller feedback a

## Disturbances and Errors for Correcting Control: Feedback

robot’s a on exerted be will that force every know to impossible is it study, unlimited with Even
forces exact and timing the shooter, flywheel a in example, For detail. perfect in mechanism
measure to difficult extremely are mechanism the through put being ball a with associated
grease off throw gradually gearboxes that fact the consider example, another For accurately.
process complex *very* a is This time. over friction internal their increasing operate, they as
well. model to

be never will controller feedforward our by made ”guess“ the that means this practice, In
the between difference lingering some is, that - error some be always will There perfect.
in. it leaves controller feedforward the state the and in, be to mechanism our want we state
it; correct to output our adjust to need we that enough large is error this situations, many In
loop“”closed- called also are controllers Feedback controller. feedback the of job the is this
system the through *back* state current the about information of flow the because controllers,
diagram. block system’s the in loop the ”closes“

responds which controller“, ”proportional a is possible controller feedback simplest The
measured and state desired the between difference (i.e. error current the to proportionally
of-rate- the to response add controller) PID the as (such controllers advanced More state).
principle the on operate these of All error. accumulated total the to and error the of change
setpoint the towards system the ”nudge“ to order in linear, roughly is response system the that
error. the of measurements local on based

## Control? Feedback Need We Do When

control: feedback *need* we which in scenarios two are there general, In

1. time over accumulate errors so system, the of position the controlling are We
2. mechanism the with interacting forces external dynamicto-difficult- of lot a are There
game launching is that flywheel a (e.g. for account cannot loop feedforward the that
pieces).

a and controller feedforward a combine to is solution *best* the situations, these of each In
position simple a of case the in However, together. outputs their adding by controller feedback
acceptably. work can controller feedback pure a loading, external no with controller

## Control OnlyFeedback-

*explicit* require they but simple, quite and helpful extremely are controllers Feedforward
signal. control required the at guess a generate to order in behavior system the of knowledge
control feedback on rely which techniques of set a see may you textbooks, controls many In
the when especially cases, many in well works and industry, in common very are These only.
reach quickly to want you when or model, explicitly to easy not is behavior system underlying
system your investigate thoroughly to time the spending without solution enough“ ”good a
behavior.

where: situations in well works only typically control onlyFeedback-

1. loading. to relative overpowered fairly are motors The
2. controlled. being is velocity) (not position mechanism’s The
3. mechanism. the on forces external varying or substantial no are There

can control onlyfeedback- tutorial), tuning turret the in as (such met are criteria these When to model feedforward a use to necessary is it situations, other In results. acceptable yield almost are systems our FRC, In controller. feedback the by done work of amount the reduce always almost is it so support, code working with equations understoodwell- by modeled all controller. feedforward a include to idea good a

## behave? to system your expect you do How Modeling:

responds system the how of knowledge prior some have we if system a control to easiest It’s about things assumes implicitly above described strategy feedback“ ”pure the Even inputs. to work won’t consequently and linear), approximately is it that (e.g. response system the system our control To way. expected the in respond not does system the where cases in inputs. to respond will it how predict reliably to way some need we ,*optimally*

physics: from with familiar be may you concepts several combining by done be can This measurements taking mechanism, the on act that forces the of diagrams body free drawing how of equations standard applying models, CAD your from inertia of moment and mass of etc. motion, and force mechanical into energy convert cylinders pneumatic or motors DC

*modeling* called is system your of description mathematical consistent a creating of act The expect you how of *model* a called are equations of set resulting The behavior. system’s your will (we controlled be to model explicit an requires system every Not behave. to system the *in* satisfactory is controller feedback tunedmanually- pure, a that tutorial turret the in see helpful. *always* is model explicit an but ),*cases some*

later in see will we As useful. be to accurate perfectly be to have not do models that Note much effort tuning the make can mechanism a of model simple a using even exercises, tuning simpler.

## Mechanisms Your for Models Obtaining

are FRC in mechanisms Most worry! don’t daunting, seems mechanism your modeling If included is models those with interacting for code and equations studiedwell- by modeled parameters physical of set a determine to is needed is that all Usually, WPILib. in your of details specific the on depend that ”gains“) or constants“ ”tuning called (sometimes of parameters known other from theoretically estimated be can These mechanism/robot. your from measured or motor/gearbox), of choice and length, mass, as (such system your routine. identification system a through behavior actual mechanism’s

!*resource support* or mentor a ask doubt, in When

## Modeling Theoretical

common of number a for parameters physical estimates which calculator online an is ReCalc the for gains `kG` and ,`kA` ,`kV` the estimate generate can it Importantly, mechanisms. FRC classes. feedforward WPILib

to used be can that mode“ ”theoretical a supports *tool identification system WPILib* The enabling ReCalc, from gains `kA` and `kV` the from control feedback for gains PID determine routines. test any running without loop control a of tuning full theory) (in

guaranteed not are gains theoretical purely and reality not is theory that however, Remember, testing. for substitute a *never* is There well. work to

### Identification System

on experiments perform to is model physics simple a of accuracy the improve to way good A
with associated constants the *derive* to data the use and data, record mechanism, real the
or difficult are which quantities physical for useful very is This model. the of parts different
gearbox). a in friction (ex: measure to easy but predict, to impossible

including mechanisms, FRC common some supports *tool identification system WPILib's*
data, record mechanism, the exercise to robot the to code own its deploys It drivetrain.
schemes. control feedback and feedforward both for gains derive and

### Model Explicit No with Do to What Tuning: Manual

system the Maybe model. explicit an at without system a tune to have you Sometimes,
that something need and constraints time under you're maybe or complicated, uniquely is
correct a requires control basedModel- optimally. work doesn't it if even quickly, works
one. have always not do we worse, for or better for and system, the of model mathematical

.*manually* tuned be can algorithm control the of parameters physical the cases, such In
the until hand by gains controller the "sweeping" systematically by done generally is This
one only where cases in quickly work can tuning Manual expected. as behaves mechanism
complicatedmore- in however, - adjusted be to need )$kP$ and $kV$ as (such parameters two or
process. difficult and involved very a become can it scenarios

foundedwell- a distinguish to hard be can it that is tuning manual with problem common One
controller inappropriate an from properly, tuned yet not is that architecture controller
velocity a tune to possible not generally is it example, (for work cannot that architecture
In feedforward). a without well functions that controller position arm vertical or controller
gains correct such no when gains, correct for searching time of lot a waste can we case, a such
controlled being systems the of mechanics the understanding for substitute no is There exist.
do we *if even* mechanism, the for architecture controller correct a determine to enough well
methodologies. control basedmodel- any use explicitly not

tuning manual the perform to you allow will that simulations include follow that tutorials The
which govern that concepts fundamental The mechanisms. FRC typical several on process
mechanism individual the on covered are mechanism each for valid are strategies control
tutorials! the through work you as this to attention close pay pages;

## Feedforward Motor DC to Introduction 30.2.3

---

*Control Feedforward* see WPILib, with code in control PID implementing on guide a For **:□□□□**
*.WPILib in*

---

WPILib's of workings mathematical and conceptual the explains page This
classes). related other the (and SimpleMotorFeedforward

## Equation Feedforward Motor DC MagnetPermanent- The

of dynamics known the use to is controller feedforward a of point the that earlier from Recall the in mechanism the put to required *effort control* the at guess best a make to mechanism a we mechanism of kind what of idea some have to need we this, do to order In want. you state and ,*output* and *effort control* between relationship the determine will that - controlling are latter. the of value desired the us give will former the of value what at guess us let

*magnetpermanent-* the is controlling in interested we're that system common most the FRC, In .*motor DC*

to easy particularly them make that properties convenient of number a have motors These between relationship particular a obey they particular, In tasks. FRC for ideal and control, equation“. balance ”voltage a as known acceleration rotor and velocity, rotor voltage, applied

$$V = K_s \cdot sgn(\dot{d}) + K_v \cdot \dot{d} + K_a \cdot \ddot{d}$$

velocity, its is $\dot{d}$ motor, the of (position) displacement the is $d$ voltage, applied the is $V$ where with *derivative* the denotes traditionally notation ”overdot“ (the acceleration its is $\ddot{d}$ and time). to respect

follows: as equation above the in coefficients the interpret can We

just to words other in or friction, static motor's the overcome to needed voltage the is $K_s$ the has static) well, it's, (because friction static this that out turns it moving; it get barely going you're speed what matter no is, That acceleration. or velocity of regardless effect same your to applied you've voltage the of portion constant some accelerating, you're fast how or overcoming towards going be will assembly) mechanism specific the on (depending motor the of presence the Note kS. your is value this etc; bearings, gears, your in friction static the motion.of-direction- the opposes always force friction because *function signum*

constant given a at ”cruise“) (or hold to needed is voltage much how describes $K_v$ that friction additional any and *force electromotivecounter-* the overcoming while velocity relationship The ).*losses churning* some and *drag viscous* (including speed with increases legalFRC- (for linear entirely almost is acceleration) constant (at voltage and speed between work. motors DC magnetpermanent- how of because components)

,kV with As shaft. motor the in acceleration given a induce to needed voltage the describes $K_a$ perfectly almost is velocity) constant (at acceleration and voltage between relationship the components. FRC for linear

.paper this see information, more For

## Equation Feedforward the of Variants

above the into terms additional introduce classes feedforward other WPILib's of Some details - above described case simple the from differences known for account to equation below: found be can tool each for

## Feedforward Elevator

of force the under mass a to attached motor DC magnetpermanent- a of consists elevator An
the in only differs it motor, unloaded an for equation feedforward the to Compared gravity.
gravity: of action the for accounts that term $K_g$ constant a of inclusion

$$V = K_g + K_s \cdot sgn(\dot{d}) + K_v \cdot \dot{d} + K_a \cdot \ddot{d}$$

velocity, its is $\dot{d}$ drive, the of (position) displacement the is $d$ voltage, applied the is $V$ where
acceleration. its is $\ddot{d}$ and

## Feedforward Arm

under held stick a on mass a to attached motor DC magnetpermanent- a of consists arm An
the for account to term $K_g$ a includes it feedforward, elevator the Like gravity. of force the
the by multiplied is term this however, feedforward, elevator the unlike - gravity of effect
motor): the on directly act not does force gravitational the (since angle arm the of cosine

$$V = K_g \cdot cos(\theta) + K_s \cdot sgn(\dot{\theta}) + K_v \cdot \dot{\theta} + K_a \cdot \ddot{\theta}$$

its is $\dot{\theta}$ arm, the of (position) displacement angular the is $\theta$ voltage, applied the is $V$ where
acceleration. angular its is $\ddot{\theta}$ and velocity, angular

## Feedforward the Using

above the in unknown each for values in plug to need we feedforward, the use to order In
gains the of values the ,*earlier* mentioned As .*voltage the than other* equation balancevoltage-
measurement Explicit .ReCalc with modeling theoretical through obtained be can $K_a$ ,$K_v$ ,$K_g$
values needing us leaves That .$K_s$ to addition in gains aforementioned the yield will *SysId* with
position. feedforward) arm the of case the (in and acceleration, velocity, for

a making are we feedforward with that remember - setpoints our from come these Typically,
be. to system the want we where on based need we output the to as ”guess“

from value velocity the take can we - problem a pose not does this control, velocity For
the infer can we practice) in omitted be often can (it necessary if and directly, setpoint our
setpoints. velocity previous and current the between difference the from acceleration

no there’s controller, arm the for except - difficult be can this however, control, position For
calculate to but choice no have often We position. for equation feedforward the in term direct
to and positions, setpoint previous and current the between difference the from velocity our
vary setpoints our that ensure to need we better, do to order In entirely. acceleration ignore
*motion* a with accomplished usually is this - constraints of set some to according *smoothly*
*.profile*

## 30.2.4 מבוא ל-PID

:□□□□ For a guide on implementing PID control with WPILib, see *□□□□ PID □□ WPILib*.

This page explains the conceptual and mathematical workings of a PID controller. *A video explanation from WPI is also available*.

### What is a PID Controller?

The PID controller is a common *feedback controller* consisting of proportional, integral, and derivative terms, hence the name. This article will build up the definition of a PID controller term by term while trying to provide some intuition for how each term behaves.

First, we’ll get some nomenclature for PID controllers out of the way. In a PID context, we use the term *reference* or *setpoint* to mean the desired state of the mechanism, and the term *output* or *process variable* to refer to the measured state of the mechanism. Below are some common variable naming conventions for relevant quantities.

| | | | |
|---|---|---|---|
| *control effort* | $u(t)$ | *setpoint*, *reference* | $r(t)$ |
| *output*, *process variable* | $y(t)$ | *error* | $e(t)$ |

The *error* $e(t)$ is the difference between the *reference* and the *output*, $r(t) - y(t)$.

For those already familiar with PID control, this interpretation may not be consistent with the classical explanation of the P, I, and D terms corresponding to response to ”past“, ”present“, and ”future“ errors. While that model has merit, we will instead be approaching PID control from the viewpoint of modern control theory, as proportional controllers applied to different physical quantities we care about. This will provide a more complete explanation of the derivative term’s behavior for constant and moving *setpoints*.

Roughly speaking: the proportional term drives the position error to zero, the derivative term drives the velocity error to zero, and the integral term drives the total accumulated error-over-time to zero. All three terms are added together to produce the *control signal*. We’ll go into more detail on each of these below.

:□□□□ Throughout the WPILib documentation, you’ll see two ways of writing the tunable constants of the PID controller.

For example, for the proportional gain:

- $K_p$ is the standard math-equation-focused way to notate the constant.
- kP is a common way to see it written as a variable in software.

Despite the differences in capitalization, the two formats refer to the same concept.

### קבוע פרופורציונלי

the to contributing by zero to error position the drive to attempts term *Proportional* The the move to tries this Intuitively, error. position current the to proportionally signal control .*reference* the towards *output*

$$u(t) = K_p e(t)$$

.$t$ time current the at error the is $e(t)$ and gain proportional the is $K_p$ where

controller. P a by controlled *system* a for diagram block a shows figure below The

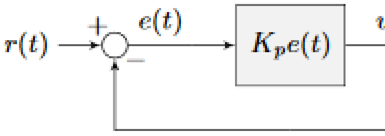


Figure 2.1: P controller

the toward *system* the pull that springs“ defined”software- a like act gains Proportional force the is $F$ where $F = -kx$ as springs model we that physics from Recall position. desired point. equilibrium the from displacement the is $x$ and constant, proportional a is $k$ applied, let we If point. equilibrium the is $0$ where $F = k(0 - x)$ as way another written be can This one to one a have equations the ,*setpoint* controller's feedback our be point equilibrium the correspondence.

$$F = k(r - x)$$
$$u(t) = K_p e(t) = K_p(r(t) - y(t))$$

the toward *output system's* the pulls controller proportional the which with ”force“ the so spring. a like just ,*error* the to proportional is *setpoint*

### Term Derivative

to contributing by zero to error the of derivative the drive to attempts term *Derivative* The make to tries this Intuitively, error. the of derivative the to proportionally signal control the .*reference* the as rate same the at move *output* the

$$u(t) = K_p e(t) + K_d \frac{de}{dt}$$

current the at error the is $e(t)$ and gain, derivative the is $K_d$ gain, proportional the is $K_p$ where .$t$ time

controller. PD a by controlled *system* a for diagram block a shows figure below The

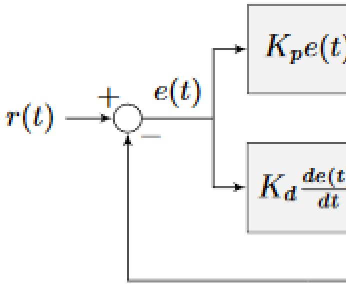


Figure 2.2: PD con

controller proportional a and )$K_p$( position for controller proportional a has controller PD A
*setpoint* position the how by provided implicitly is *setpoint* velocity The ).$K_d$( velocity for
controller. PD a for equation the rearrange will we this, prove To time. over changes

$$u_k = K_pe_k + K_d\frac{e_k - e_{k-1}}{dt}$$

as defined is $e_k$ .$k$ timestep at *error* the is $e_k$ and $k$ timestep at *effort control* the is $u_k$ where
.$k$ timestep at *state* current the is $x_k$ and *setpoint* the is $r_k$ where $e_k = r_k - x_k$

$$\begin{aligned}
u_k &= K_p(r_k - x_k) + K_d\frac{(r_k - x_k) - (r_{k-1} - x_{k-1})}{dt} \\
u_k &= K_p(r_k - x_k) + K_d\frac{r_k - x_k - r_{k-1} + x_{k-1}}{dt} \\
u_k &= K_p(r_k - x_k) + K_d\frac{r_k - r_{k-1} - x_k + x_{k-1}}{dt} \\
u_k &= K_p(r_k - x_k) + K_d\frac{(r_k - r_{k-1}) - (x_k - x_{k-1})}{dt} \\
u_k &= K_p(r_k - x_k) + K_d\left(\frac{r_k - r_{k-1}}{dt} - \frac{x_k - x_{k-1}}{dt}\right)
\end{aligned}$$

*system's* the is $\frac{x_k - x_{k-1}}{dt}$ reason, same the By .*setpoint* the of velocity the is $\frac{r_k - r_{k-1}}{dt}$ how Notice
the driving is controller PD the of term $K_d$ the means That timestep. given a at velocity
velocity. *setpoint* the to velocity estimated

the slows term $K_d$ the so zero, is *setpoint* velocity implicit the constant, is *setpoint* the If
commonly are These damper“. defined”software- a like acts This moving. it's if down *system*
velocity. with linearly increases force damping their and closers, door on seen

### קבוע אינטגרלי

---

better always almost is It use. FRC® for recommended not generally is gain Integral :□□□□
gain, integral employ do you If error. statesteady- eliminate to controller feedforward a use to
.*windup integral* against protection some provide to crucial is it

---

the to contributing by zero to error accumulated total the drive to attempts term *Integral* The
the drive to tries this Intuitively, errors. past all of sum the to proportionally signal control
values. *reference* past all of *average* the towards values *output* past all of *average*

$$u(t) = K_pe(t) + K_i\int_0^t e(\tau)\,d\tau$$

time current the at error the is $e(t)$ gain, integral the is $K_i$ gain, proportional the is $K_p$ where variable. integration the is $\tau$ and ,$t$

because integration the for $\tau$ use we .$t$ time current the to $0$ time from integrates Integral The $t$ use can’t we but integral, the throughout values multiple on take to variable a need we time. current the as that defined already we because

controller. PI a by controlled *system* a for diagram block a shows figure below The

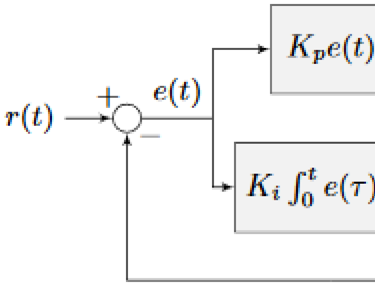
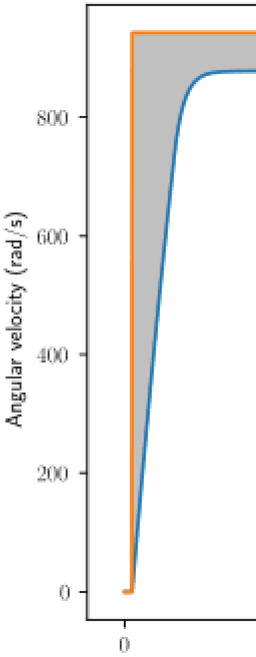


Figure 2.3: PI contr

small too be may term proportional the state,steady- in *setpoint* the close is *system* the When result can This zero. is term derivative the and ,*setpoint* the to way the all *output* the pull to 2.4 figure in shown as *error statesteady-* in



Figure

the to it add and *error* the integrate to is *error statesteady-* eliminating of way common A shows 2.4 Figure converges. *system* the until *effort control* the increases This .*effort control* added integrator an how shows 2.5 figure and flywheel, a for *error statesteady-* of example an to lead can gain integral an of high too However, it. eliminates controller flywheel the to 2.6. figure in shown as overshoot,

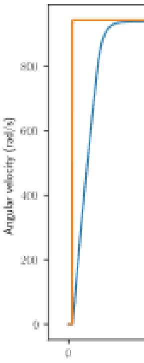


Figure 2.5: PI
ror

### Together All It Putting

.*article relevant* the see PIDController, provided WPILib the using on information For :□□□□

definition typical the gets one together, all them summing by combined are terms these When controller. PID a for

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de}{dt}$$

the is $e(t)$ gain, derivative the is $K_d$ gain, integral the is $K_i$ gain, proportional the is $K_p$ where variable. integration the is $\tau$ and ,$t$ time current the at error

controller. PID a for diagram block a shows figure below The

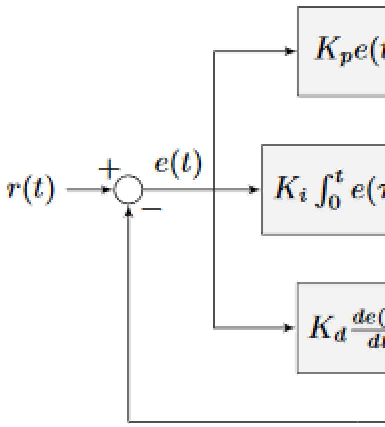


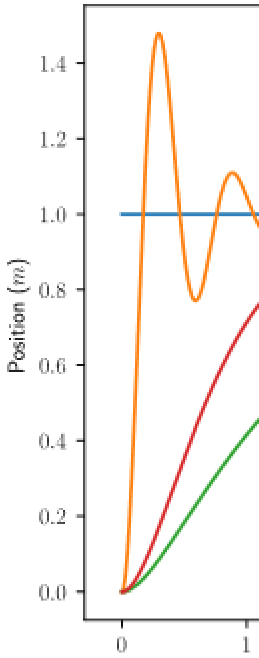
Figure 2.7: PID co

### Types Response

underdamped, responses: of types three has generally controller PID a by driven *system* A 2.8. figure in shown are These damped. critically and damped,over-

reach initially to takes *system* the time the is *time rise* 2.7, figure in *responses step* the For settle to takes *system* the time the is *time Settling* .*input step* the applying after reference the applied. is *input step* the after *reference* the at

*overdamped* An settling. before *reference* the around oscillates response *underdamped* An response



Figur

the has response *damped critically* A .*reference* the overshoot not does and rise to slow is .*reference* the overshooting without *time rise* fastest

### 30.2.5 סרטון מבוא ל-PID מאת WPI

?[illegible]
,[illegible] ,[illegible] ,[illegible]
,[illegible] WPI, [illegible] ,[illegible] .[illegible]
PID. [illegible]

### Tutorials Tuning Controls To Introduction 30.2.6

students allow to is goal Their simulations. tuning interactive three include docs WPILib The software with deal to having without behavior, system impact parameters tuning how learn to behavior. worldreal- other or bugs

through going worth is it gains, optimal with you provide can tooling WPILib though Even the with interact strategies control different the how see to process tuning manual the mechanism.

the on time their make and intuition build to examples the use should students Ultimately, productive. more robot

tutorials. the with working while tips few a details page This

### Search Exponential Parameter

”decrease“ or ”increase“ to instructions get will you simulations, the with interacting While parameters. different

After observed. is effect expected the until two by it multiply value, a ”increasing“ When mechanism the or unstable is behavior the (i.e. large too becomes value the time first the and encountered value largetoo- first the between halfway to value the reduce overshoots), zero to procedure half“”split- this iterating Continue that. before tested value previous the new the between point halfway the pick undershoots, response the (if value optimal the on in between point halfway the pick overshoots, it if - it above immediately value last the and value *exponential*term: an called is This it). below immediately value last the and value new the scale. unknown of values positive find to way efficient very a is and ,*search*

### Noise System

more a provide to plant the into error gaussian random, introduces option noise“ ”system The behavior. system of situation realistic

to on it turn Later, behavior. ideal system’s the learn to first at off turned setting the Leave effects. worldreal- of presence the in works tuning your how see

### Systematic Be

constants.Feedforward tuned *three* has controller PID a ,*PID to introduction the* in seen As constants ”correct“ the for searching means This more. even add will components procedure tuning the approach to necessary therefore is it - difficult quite be can manually systematically.

success. of chances your maximize will it - tutorials the in presented tuning of order the Follow

Then correct. to close is solution your believe you until solutions tuning the checking Resist results. own your against compare to one provided the try and answer, your check

*mechanisms Flywheel*difficult.:ref: to easy from work Furthermore, *Velocity Flywheel a flywheel:Tuningcontrols/introduction/tuning-<docs/software/advanced-* off finish Then, .*tuning turret* the into look that, After tune. to easiest the are *Controller>* .*example arm vertical* the with

## Controller Velocity Flywheel a Tuning 30.2.7

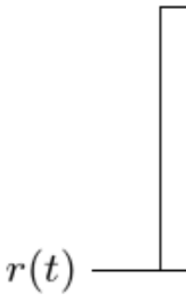
principles tuning The flywheel. a for controller velocity simple a tune will we section, this In scenario. control velocity any almost for work also will here explained

### Description Model Flywheel

of: consists ”Flywheel“ Our

- flywheel) (the piece game the launches which mass inertial rotating A
- mass. the driving gearbox) a possibly (and motor A

by used equation same the with modeled is plant this tutorial, this of purposes the For
gearbox and delay sensor for adjustment additional with ,*SimpleMotorFeedforward* WPILib’s
feedback and feedforward by controlled is plant the assumes simulation The inefficiency.
fashion: this in composed controllers,



Where:

- velocity rotational flywheel the is $y(t)$ *output* plant’s The
- flywheel the of velocity desired the is $r(t)$ *setpoint* controller’s The
- the driving motor the to applied voltage the is $u(t)$ ,*effort control* controller’s The
motion flywheel’s

.*here found be can* system the of mathematics the of description detailed more A :□□□□

### Controller Velocity Flywheel a for Strategy Control the Picking

spin. will flywheel the faster the motor, the to applied is that voltage more the general: In
to flywheel the bring and motion the oppose *EMFback-* and friction removed, is voltage Once
stop. a

this In target. a toward air, the through pieces game propel to used commonly are Flywheels
[1]simulation. the through halfway about flywheel the into injected is gamepiece a simulation,

---

torque (frictional) dependantvelocity- a as flywheel the to injected being ball a model we simulation, this For [1]
very a is This mark. second 5 the around right rotation, wheel a of quarter one for wheel the of spinning the fighting
would It load. sudden a under behavior controller’s the illustrate to sufficient is but ball, the model to way simplistic
system. the for *output* in ”pulldown“ actual the or trajectory, ball’s the predict to sufficient be not

a at spinning is it sure make to is step first good a gamepiece, a launch consistently To control accurately to want we Thus, it. into gamepiece a putting before speed particular flywheel. our of velocity the

---

which controllers, *turret* and *arm vertical* the from different fundamentally is This **:□□□□** .*position* control both

---

pure bang,bang- under system the of behavior the demonstrate will below tutorials The strategies. control feedbackfeedforward- combined and (PID), feedback pure feedforward, the expand and controllers, these tune manually to how learn to instructions the Follow parameters. tuning of set basedmodel- optimal an view to solution“ ”tuning

### Control BangBang-

controlled when responds system flywheel the how see to below simulation the with Interact controller. bangbang- a by

present)(present/not- binary a applies which controller simple a is controller Bang“”Bang- The (and description detailed more A setpoint. a to closer it get to try to mechanism a to force *here.* found be can implementation) WPILib corresponding the for documentation

adjust only can you - controller bangbang- a for parameters controller tuneable no are There weakness. a also and strength, a is simplicity This setpoint. the

output the values, all almost for that see should You down. and up setpoint the adjusting Try setpoint. the near somewhat be to converges

### Controllers BangBang- with Issues Common

These loop. control the in delays of because perfect, not is behavior system the that Note even or timers, iteration loop filters, measurement sensors, the of nature the from result can and ”overshoot“ of cycle a cause these Collectively, itself. hardware control the in delays is oscillation This setpoint. the below and above goes repeatedly output the as ”undershoot“, controller. bangbang- a with unavoidable

it that enough small is controller bangbang- a of oscillation statesteady- the Typically, cause can effort control the of cycling on/off rapid However, practice. in well quite performs and bolts loosen can forces removing and applying rapidly of cycles the - issues mechanical gearboxes. on stress of lot a put and joints,

system’s the if draw current in changes abrupt cause can effort control in changes abrupt The damage eventual cause and hardware, control motor stress may This low. too is inductance failure. or

more A slowly. relatively accelerate that mechanisms for works only technique this Finally, .*here found be can* details the of discussion depthin-

fast of sense the (in performance high and simplicity for lot a sacrifices control bangBang- different a consider to need we control, ”smoother“ achieve To setpoint). the to convergence strategy. control

### Control Feedforward Pure

controlled when responds system flywheel the how see to below simulation the with Interact controller. feedforward a by only

the until $K_v$ gain feedforward velocity the increase controller, feedforward the tune To .$K_v$ reduce overshoots, flywheel the If time. over setpoint correct the approaches flywheel

.$K_v = 0.0075$ is simulation the by used gain exact The

flywheel for well reasonably works strategy control feedforward pure a that see can We motors most control to possible it's why is this earlier, mentioned we As control. velocity still can we However, all. at loop" "control explicit any without joysticks, with "directly" while a takes so and disturbances, reject cannot strategy feedforward pure the - better do the obey perfectly not may motor the Additionally, introduced. is ball the after recover to we these, for account To vibration/noise). for accounting after (even equation feedforward controller. feedback a need

### Control Feedback Pure

controlled when responds system flywheel the how see to below simulation the with Interact controller. (PID) feedback a only by

following: the Perform

zero. to $K_v$ and ,$K_d$ ,$K_i$ ,$K_p$ Set 1.

until it decrease then ,*setpoint* the around oscillate to starts *output* the until $K_p$ Increase 2.
stop. oscillations the

.*setpoint* the to converging before "stuck" gets *output* if $K_i$ increase ,*cases some In* 3.

---

not Do velocity! flywheel for scheme control good very a not is control onlyPID- : "optimal" the when even well, behave not does below simulation the if/when surprised be used. are constants

---

will $K_d = 0.0$ and ,$K_i = 0.0$ ,$K_p = 0.1$ of values 300, of setpoint a for example, particular this In not will it good, very not is strategy control this Since results. reasonable somewhat produce some incorporating by behavior this improve to attempt can You setpoints. all for well work setpoints. of range wide a across behavior good achieve to difficult very is it but ,$K_i$

### Alone Control Feedback with Issues

even spinning, flywheel the keep to required is *effort control* of amount zeronon- a Because to order In flawed. is strategy onlyfeedback- this equal, are *setpoint* and *output* the when needed. is strategy feedbackfeedforward- combined a flywheel, a control optimally

### Control Feedback and Feedforward Combined

under responds system flywheel the how see to below simulation the with Interact control. (PID) feedback and feedforward simultaneous

controller feedforward the tune first we - simple is controller flywheel combined the Tuning PID the tune we then and section, onlyfeedforward- the in as procedure same the following PID that Notice section. onlyfeedback- the in as procedure same the following controller feedforward. accurate an of“ top ”on tune to easier *much* is controller the of portion

produce will $K_p = 0.1$ and $K_v = 0.0075$ of values 300, of setpoint a for example, particular this In behavior controller the change will $K_p$ to changes Small setpoints. all across results good very constraints. problem your on depends choice optimal the - aggressive less or more be to

and setpoints, all across well works controller feedbackfeedforward- combined the that Note flywheel. the contacting ball the of disturbance external the after quickly very recovers

## Conclusions Tuning

### Control Velocity of Applicability

It control. velocity of applications visible most the of one is flywheel launchinggamepiece- A involves autonomous in path definedpre- a following - control drivetrain to applicable also is loads. different of variety a under precision, with wheels the of velocity the controlling

### Strategies Control of Choice

*pure* a with performance good fairly achieve can we velocity, controlling are we Because velocity statesteady- motor’s DC magnetpermanent- a because is This .*controller feedforward* robot your drive can you that reason the is and applied, voltage the to proportional roughly is are you case, that in - all at loop control any use to appearing without joysticks with around model. feedforward proportional a using implicitly

the at velocity a maintain to motor the to voltage control constant a apply must we Because typically output (whose *controller (PID) feedback pure* a use successfully cannot we setpoint, feedback a velocity, control effectively to order in - setpoint) the reach you when disappears .*controller feedforward a with combined* be must controller

control PID way the in much control feedforward with combined be can control bangBang- simulation. bangbang-feedforward- combined a include not do we brevity of sake the for - can

is *effort control* no where cases in results reasonable produce can feedback only with Tuning or turrets, like mechanisms for work may This .*setpoint* the at *output* the keep to required where flywheel, a for well work not does it above, seen as However, steering. drive swerve the at motion sustaining is it when even motor the slow to act both friction and EMFback- the feedforward a with controller PID the combine to need we system, this control To setpoint. controller.

the when necessary only is it - setpoint constant a with control velocity for useful not is $K_d$ changing. is setpoint

*statesteady*- eliminate to way optimalsub- a often is *controller* the to gain integral an Adding soon, see will we As above! simulation the in is it ”laggy“ and sloppy how see can you - *error* a better approach is to combine the PID controller with a feedforward controller.

### Control Position and Velocity

position a in - inertia of effect the in control position from differs also control Velocity control the if even setpoint the past swing to mechanism the cause to tends inertia controller, infeasible, strategies control aggressive makes This setpoint. the near zero to drops voltage controller, velocity a In oscillations. inducedself- fighting energy of lots wasting up end they as applying stop you as soon as accelerating stops shaft rotor the - different is effect the however, overshoots such so EMF),back- and friction to due down slow will it fact, (in voltage control a loop of result a as only controllers velocity in occurs typically overshoot fact, (in rare are strategy control aggressive extremely simple, extremely an of use the enables This delay). .*control bangbang-* called

### Simplifications Feedforward

WPILib the from term $K_s$ the omit above simulations the simplicity, of sake the For - important be can this however, mechanisms, actual On equation. SimpleMotorFeedforward static of lot a with flywheel A gearing. mechanism the in friction of lot a there's if especially feedforward the unless relationship velocityvoltage- control linear a have not will friction out. it cancel to term $K_s$ a includes controller

move. to starts it until mechanism the to voltage the increase slowly manually, $K_s$ measure To move. to begins mechanism the before applied voltage largest the is $K_s$ of value The

the unless control velocity for feedforward the in term $K_a$ a for need no is there Additionally, here. omitted is gain the so and concern, a not is this flywheel, a for - changing is setpoint

### Footnotes

## Controller Position Turret a Tuning 30.2.8

principles tuning The turret. a for controller position simple a tune will we section, this In external no under scenarios controlposition- any almost for work also will here explained loading.

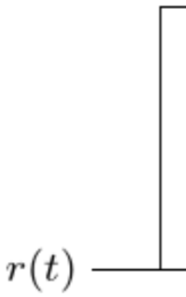
### Description Model Turret

gamepieces. scoring for it position to sideto-side- mechanism some rotates turret A

of: consists ”turret“ Our

- turret) (the mass inertial rotating A
- mass the driving gearbox and motor A

by used equation same the with modeled is plant this tutorial, this of purposes the For gearbox and delay sensor for adjustment additional with ,*SimpleMotorFeedforward* WPILib's feedback and feedforward by controlled is plant the assumes simulation The inefficiency. fashion: this in composed controllers,



Where:

- position turret’s the is $y(t)$ *output* plant’s The
- turret the of position desired the is $r(t)$ *setpoint* controller’s The
- turret the driving motor the to applied voltage the is $u(t)$ ,*effort control* controller’s The

### Controller Position Turret a for Strategy Control the Picking

turret) (and motor the faster the motor, the to applied is that voltage more the general: In until spinning the decrease slowly EMFback- and friction removed, is voltage Once spin. will position. given a to rotate turret the make to want We stops. turret the

feedforward, pure under system the of behavior the demonstrate will below tutorials The the Follow strategies. control feedbackfeedforward- combined and (PID), feedback pure solution“ ”tuning the expand and controllers, these tune manually to how learn to instructions can tooling WPILib though Even parameters. tuning of set basedmodel- optimal an view to see to process tuning manual the through going worth is it gains, optimal with you provide mechanism. the with interact strategies control different the how

are setpoints acceleration so generation, profile motion any include not does simulation This the by used not is equation feedforward the of term *kA* the Accordingly, defined.well- very not feedforward- the to inherent delay/lag of amount some be will there means This controller. response. only

## Control Feedforward Pure

when responds system turret the how examine to below simulation the with Interact
controller. feedforward a by only controlled

the of perimeter the along angle desired the on click setpoint, turret the change To **:□□□□**
indicator. setpoint the drag and click motion, smooth command To turret.

following: the perform controller, feedforward the tune To

zero. to $K_v$ Set 1.

during setpoint the tracks turret the until $K_v$ gain feedforward velocity the Increase 2.
gain. the reduce overshoots, turret the If motion. slow smooth,

as long so fine is and normal, is this - motion commanded the ”lag“ may turret the that Note
total. in amount correct the moves it

be not Do turrets! for scheme control viable a not is control onlyFeedforward- **:□□□□**
”correct“ the when even well, behave not does below simulation the if/when surprised
used. are constants

browser in inaccuracy timing to due that Note .$K_v = 0.2$ is plant the by used gain exact The
this. than smaller somewhat be may simulation the in best works that $K_v$ the simulations,

## Alone Control ForwardFeed- with Issues

WPILib the obeys perfectly mechanism simulated our above, mentioned As
disabled). is option noise“ ”system the as long (as equation *SimpleMotorFeedforward*
be should we that ,*controller velocity flywheel* the of case the in like expect, then might We
alone. loop feedforward a with setpointto-convergence- perfect achieve to able

allows it - voltage to *acceleration* and *velocity* relates equation feedforward our However,
not does it but accuracy, high with mechanism our of *motion instantaneous* the control to us
the which (in simulation our in even problem a is This .*position* the over control direct us allow
*motion* a employ we unless because motion), of equation *actual* the is equation feedforward
immediately jump to turret the ask can we setpoints velocity of sequence a generate to *profile*
turret. simulated our for even impossible, is This another. to position one from

spike“ ”voltage single a output to is controller feedforward the from behavior resulting The
high very of iteration loop single a to (corresponding changes setpoint position the when
reached already has system the that assumed is it (because voltage zero then and velocity),
”impulse“ initial an in results this that simulation the in see can we practice, In setpoint). the
between.in- position indeterminate some at stops that position, target the towards movement
undesirable. as seen generally is and ”kick,“ a called is response of kind This

be can speed achievable maximum turret’s the below motion *smooth* that notice may You
however, misleading, is This alone. feedforward with simulation the in accurately followed
noise“ ”system the With equation. feedforward its obeys perfectly mechanism real no because
compounding in results eventually motion slow smooth, even that see can we enabled, option
setpoint, the to converge accurately To used. is control feedforward only when errors position
controller. (PID) feedback a use to need we

### Control Feedback Pure

when responds system turret the how examine to below simulation the with Interact controller. (PID) feedback a by only controlled

following: the Perform

zero. to $K_v$ and ,$K_d$ ,$K_i$ ,$K_p$ Set 1.

moving by setpoint in change sudden a to responds mechanism the until $K_p$ Increase 2. setpoint, the around much too oscillates controller the If position. new the to sharply stops. it until *K_p* reduce

smoothly a track to tries controller the when ”lag“ of amount the reduce to $K_d$ Increase 3. it move to indicator directional turret’s the drag and click (reminder: setpoint moving stops. it until *K_d* reduce oscillate, to starts controller the If smoothly).

Other, setpoint. the to convergence stable and rapid yield $K_d = 0.05$ and $K_p = 0.3$ of Gains well. as nearly work will gains similar

### Alone Control Feedback with Issues

turret the drive to able is controller feedback the enabled, noise system with even that Note smoothly to possible be not may it However, time. over manner stable a in setpoint the to only can controller feedback the as alone, feedback using lag without setpoint moving a track combine to need we worlds, both of best the get To up. built have they once errors to respond controller. feedforward a with controller feedback our

### Control Feedback and Feedforward Combined

under responds system turret the how examine to below simulation the with Interact control. feedback and feedforward simultaneous

controller feedforward the tune first we - simple is controller turret combined the Tuning PID the tune we then and section, onlyfeedforward- the in as procedure same the following PID that Notice section. onlyfeedback- the in as procedure same the following controller feedforward. accurate an of“ top ”on tune to easier *much* is controller the of portion

individual the for gains optimal the just are controller combined the for gains optimal The to convergence stable and rapid yield $K_d = 0.05$ and ,$K_p = 0.3$ ,$K_v = 0.15$ of gains controllers: work will gains similar Other, motion. smooth of tracking accurate relatively and setpoint the well. as nearly

moving smoothly a track accurately should controller combined the properly, tuned Once setpoint, and also accurately converge to the setpoint over time after a ”jump“ command.

### Conclusions Tuning

#### Strategies Control of Choice

to trying are we ,*flywheel* the of case the unlike and ,*arm vertical* the of case the in Like mechanism. our of *velocity* the than rather *position* the control

with performance control good achieve could we controller *velocity* flywheel the of case the In certain a cause will voltage much how predict to hard very is it However, alone. feedforward in errors big very into velocity in errors small even turn can (time *position* in change total arm, vertical the with as - alone control feedforward on rely cannot we case, this In position). controller. feedback a need will we

the keep to required voltage no is there though, arm, vertical the of case the in Unlike effectively to possible often is it consequence, a As there. it's once setpoint the at mechanism the of output the on only relying all, at controller feedforward any without turret a control a both and well work not may this friction, of lot a has mechanism the (if controller feedback absence the in control position Simple needed). be may controller feedback and feedforward well. works control feedback pure which in cases only the of one is forces external of

where cases in results reasonable produce can feedback only with mechanism a Controlling work can this turret, a On .*setpoint* the at *output* the keep to required is *effort control* no as setpoint, moving a follow to trying when problems into run still may it however, - acceptably motion intermediate mechanism's the control to transients controller the on entirely relies it setpoints. position between

slow, track can feedforward accurate an that above example onlyfeedforward- the in saw We feedback the with controller feedforward a Combining well. quite setpoints velocity smooth long- stable the with controller feedforward a of followingvelocity- smooth the gives controller controller. feedback a of elimination error term

#### Performance IdealNon- for Reasons

are setpoints acceleration so generation, profile motion any include not does simulation This the by used not is equation feedforward the of term *kA* the Accordingly, defined.well- very not feedforward- the to inherent delay/lag of amount some be will there means This controller. response. only

#### Friction Static and Feedforward on Note A

WPILib the from term $K_s$ the omit above simulations the simplicity, of sake the For important be can this however, mechanisms, actual On equation. SimpleMotorFeedforward static of lot a with turret A gearing. mechanism the in friction of lot a there's if especially - near "stuck" get will it - alone feedback with accurately control to hard very be will friction .$K_s$ below falls output loop the when setpoint the at) not (but

move. to starts it until mechanism the to voltage the increase slowly manually, $K_s$ measure To move. to begins mechanism the before applied voltage largest the is $K_s$ of value The

without controller position a to $K_s$ measured the *apply* to difficult mildly be can It to setpoint velocity the uses class SimpleMotorFeedforward WPILib the as profiling, motion a use either this, overcome To point. should term $K_s$ the which in direction the determine which on depending controller the of output the to manually $K_s$ add else or profile, motion setpoint. the to get to move to needs mechanism the direction

## Controller Position Arm Vertical a Tuning 30.2.9

tuning same The arm. vertical a for controller position simple a tune will we section, this In the under scenarios controlposition- all almost for also work will below explained principles gravity. of load

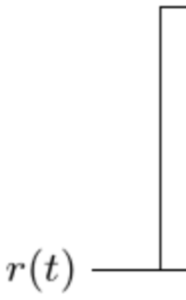
### Description Model Arm

position. scoring a to up ground the from gamepieces lift to used commonly are arms Vertical elevators. and hoods shooter include examples similar Other

of: consists arm“ ”vertical Our

- axle. an around pivoting gravity, of force the under stick, a on mass A
- attached is sticka-on-mass- the which to axle the driving gearbox and motor A

used equation same the with modeled is plant this tutorial, this of purposes the For gearbox and delay sensor for adjustment additional with ,*ArmFeedforward* WPILib’s by feedback and feedforward by controlled is plant the assumes simulation The inefficiency. fashion: this in composed controllers,



Where:

- position rotational arm’s the is $y(t)$ *output* plant’s The
- arm the of angle desired the is $r(t)$ *setpoint* controller’s The
- arm the driving motor the to applied voltage the is $u(t)$ ,*effort control* controller’s The

## Arm Vertical a for Strategy Control the Picking

or up arm the drives that mechanism the on force a causes motor the to voltage Applying is it Generally, downward. it pull to arm the on acts still gravity voltage, no is there If down. angle. specific a at arm the keep and effect, this fight to desirable

feedforward, pure under system the of behavior the demonstrate will below tutorials The the Follow strategies. control feedbackfeedforward- combined and (PID), feedback pure solution“ ”tuning the expand and controllers, these tune manually to how learn to instructions can tooling WPILib though Even parameters. tuning of set basedmodel- optimal an view to see to process tuning manual the through going worth is it gains, optimal with you provide mechanism. the with interact strategies control different the how

## Control Feedforward Pure

when responds system turret the how examine to below simulation the with Interact controller. feedforward a by only controlled

---

the of perimeter the along angle desired the on click setpoint, arm the change To **:□□□□** indicator. setpoint the drag and click motion, smooth command To turret.

---

following: the perform controller, feedforward the tune To

1. zero. to $K_v$ and $K_g$ Set
2. the If possible. as movement little as with position its hold can arm the until $K_g$ Increase will You stationary. remains it until $K_g$ decrease direction, opposite the in moves arm places). decimal four least (at precisely fairly $K_g$ on in zero to have
3. during setpoint the tracks arm the until $K_v$ gain feedforward velocity the Increase may arm the that Note gain. the reduce overshoots, arm the If motion. slow smooth, correct the moves it as long so fine is and normal, is this - motion commanded the ”lag“ total. in amount

---

not Do arms! vertical for scheme control viable a not is control onlyFeedforward- **:□□□□** ”correct“ the when even well, behave not does below simulation the if/when surprised be used. are constants

---

.$K_v = 1.95$ and $K_g = 1.75$ are simulation the by used gains exact The

## Alone Control ForwardFeed- with Issues

WPILib the obeys perfectlyalmost- mechanism simulated our above, mentioned As then might We disabled). is option noise“ ”system the as long (as equation *ArmFeedforward* achieve to able be should we that ,*controller velocity flywheel* the of case the in like expect, alone. loop feedforward a with setpointto-convergence- perfect

allows it - voltage to *acceleration* and *velocity* relates equation feedforward our However, not does it but accuracy, high with mechanism our of *motion instantaneous* the control to us the which (in simulation our in even problem a is This .*position* the over control direct us allow *motion* a employ we unless because motion), of equation *actual* the is equation feedforward

immediately jump to arm the ask can we setpoints velocity of sequence a generate to *profile*
arm. simulated our for even impossible, is This another. to position one from

spike“ ”voltage single a output to is controller feedforward the from behavior resulting The
high very of iteration loop single a to (corresponding changes setpoint position the when
reached already has system the that assumed is it (because voltage zero then and velocity),
”impulse“ initial an in results this that simulation the in see can we practice, In setpoint). the
between.in- position indeterminate some at stops that position, target the towards movement
undesirable. as seen generally is and ”kick,“ a called is response of kind This

movement slow/smooth track can mechanism the tuned, properly once that, notice will You
this with problems obvious some are there however, - accuracy of amount surprising a with
this - *setpoint the at* gravity of force the for corrects equation feedforward Our approach.
option noise“ ”system the With setpoint. the from far is arm our if behavior poor in results
compounding in results eventually motion slow smooth, even that see also can we enabled,
remain and to converge accurately To used. is control feedforward only when errors position
controller. (PID) feedback a use to need we setpoint, the at

### Control Feedback Pure

when responds system arm vertical the how examine to below simulation the with Interact
controller. (PID) feedback a by only controlled

following: the Perform

1. zero. to $K_g$ and ,$K_d$ ,$K_i$ ,$K_p$ Set
2. moving by setpoint in change sudden a to responds mechanism the until $K_p$ Increase setpoint, the around much too oscillates controller the If position. new the to sharply stops. it until *K_p* reduce
3. .*setpoint* the to converging before ”stuck“ gets *output* the when $K_i$ Increase
4. reduce further and setpoints movingsmoothly- track system the help to $K_d$ Increase oscillation.

---

not Do arms! vertical for scheme control viable a not is control onlyFeedback- :□□□□
”correct“ the when even well, behave not does below simulation the if/when surprised be
used. are constants

---

yield $K_d = 1$ and $K_p = 5$ of Values strategy. control this for solution tuning good no is There
the at actually not is equilibrium that but equilibrium, stable a to approach reasonable a
setpoint!

### Alone Control Feedback with Issues

setpoint. different a for poorly act will setpoint one for well works that gains of set A

laggy. and unstable it’s but time, over setpoint the to us push can gain integral some Adding

height, constant a at arm the keep to required is *effort control* of amount zeronon- a Because
order In flawed. is strategy onlyfeedback- this equal, are *setpoint* and *output* the when even
needed. is strategy feedbackfeedforward- combined a arm, vertical a control optimally to

## Control Feedback and Feedforward Combined

under responds system arm vertical the how examine to below simulation the with Interact control. feedback and feedforward simultaneous

controller feedforward the tune first we - simple is controller arm combined the Tuning PID the tune we then and section, onlyfeedforward- the in as procedure same the following PID that Notice section. onlyfeedback- the in as procedure same the following controller feedforward. accurate an of“ top ”on tune to easier *much* is controller the of portion

)$K_v = 1.95$ and $K_g = 1.75$( simulation first our from coefficients feedforward the Combining good a yields )$K_d = 1$ and $K_p = 5$( simulation second our from coefficients feedback the and behavior. controller

setpoint, moving smoothly a tracks accurately controller combined the properly, tuned Once and also accurately converge to the setpoint over time after a ”jump“ command.

## Conclusions Tuning

### Strategies Control of Choice

the control to trying are we ,*flywheel* the of case the unlike and ,*turret* the of case the in Like mechanism. our of *velocity* the than rather *position*

with performance control good achieve could we controller *velocity* flywheel the of case the In certain a cause will voltage much how predict to hard very is it However, alone. feedforward in errors big very into velocity in errors small even turn can (time *position* in change total arm, vertical the with as - alone control feedforward on rely cannot we case, this In position). controller. feedback a need will we

mechanism the keep to required voltage a is there though, turret, the of case the in Unlike consequence, a As gravity). of force the by affected is arm the (because setpoint the at steady combined a and system, this for acceptably work not will controller feedback pure a needed. is strategy feedbackfeedforward-

The gravity. is arm vertical the for fails strategy control onlyfeedback- the reason core The at rest at when even counteract to *effort control* constant a requires gravity of force external at when effort control any output typically not does controller feedback a but setpoint, the simulation the in clearly see can we which used, is gain integral (unless setpoint the at rest oscillations). introduces and laggy is

slow, track can feedforward accurate an that above example onlyfeedforward- the in saw We feedback the with controller feedforward a Combining well. quite setpoints velocity smooth long- stable the with controller feedforward a of followingvelocity- smooth the gives controller controller. feedback a of elimination error term

### Performance IdealNon- for Reasons

are setpoints acceleration so generation, profile motion any include not does simulation This the by used not is equation feedforward the of term $kA$ the Accordingly, defined.well- very not feedforward- the to inherent delay/lag of amount some be will there means This controller. response. only

smoothly- for even overshoot some usually is There perfect. not but good, is law control The above note the (see feedforward the in $K_a$ of lack the of combination is this - setpoints moving to Attempting simulation. the in error discretization some and here), omitted is it why for which diverge, to mechanism and setpoint the cause also can quickly too setpoint the move correcting term :math:«K_g« the to due behavior poor in result will earlier) mentioned (as Using measurement. the not setpoint, the from calculated is it as force, wrong the for to opposed (as linearization“ ”feedback called is gravity for correct to measurement the strategy control better a be can and used), is setpoint the when linearization“ ”feedforward accurate. and fast sufficiently are measurements your if

### Friction Static and Feedforward on Note A

WPILib the from term $K_s$ the omit above simulations the simplicity, of sake the For important be can this however, mechanisms, actual On equation. SimpleMotorFeedforward gearing. mechanism the in friction of lot a there’s if especially -

separately estimate to tedious somewhat be can $K_s$ elevator, or arm vertical a of case the In recommended is it important, be to $K_s$ for friction enough has elevator or arm your If .$K_g$ from gains. system your determine to *tool identification system WPILib* the use you that

## remove.. please Reviewer, testing, for just is translation This 30.2.10

feedback and feedforward tuning while arise can which issues common of number a are There controllers.

### Windup Term Integral

,*setpoint* in change large a Following occur. can windup integral large, too is $K_i$ if that Beware result, a As .*effort control* maximal the than larger error an accumulate can term integral the unwound. is error accumulated this until increase to continues and overshoots system the

this: mitigate to ways few a are There

1. possible. if zero to down ,$K_i$ of value the Decrease
2. .*setpoint* the from far too is *output* the if zero to term integrator the reset to logic Add a with this implement `PIDController` WPILib’s and controllers motor smart Some method. `setIZone()`
3. this implements `PIDController` WPILib’s value. maximum some at integrator the Cap method. `setIntegratorRange()` the with

seem that systems and control, integral any require not do FRC in mechanisms Most :□□□□ to require integral control to respond well probably have an inaccurate feedforward model.

### Sag Voltage

causes This battery. its from current draw we robot, our on mechanisms operate we When means This drop. to of off operate mechanisms robot the all that voltage“ ”bus available the the of action and loading the on depending vary will mechanisms our of performance the that ideal. not is this - robot

internal their for setting compensation“ ”voltage a offer controllers voltage most this, fix To in changes despite constant loops control the of voltage output the keep that loops control the do can method `setVoltage` a offers class `MotorController` WPILib The voltage. bus the loop robot every it call you (provided RIO the on run being are loops control the if thing same iteration).

motor the to applied voltage the increase cannot compensation voltage that mind in Keep you’ll below), (described saturating is actuator your if - bus the on available is what beyond separately. that for account to have

### Saturation Actuator

current the and *setpoint* the between error the on based output its calculates controller A controller the for available authority control unlimited have don’t world real the in *Plant* .*state* torque/acceleration achievable maximum some have mechanisms real say, to is that - apply to velocity. and

mechanism the move to try might algorithm control our aggressive, too are gains control our If and ”saturate“, will mechanism the case, this In going. actually of capable is it than faster control affect adversely might This are. they than smaller were gains control the if as behave instability). and errors in result (i.e., response

your modifying consider saturation, actuator with problems encountering are you If motor. bigger a with it powering or gearing mechanism

## Filters 30.3

found be can section this in plots demonstration various the generate to used data The :□□□□ .here

noise for useful are that WPILib with included filters of number a describes section This smoothing. input and/or reduction

### מבוא לפילטרים 30.3.1

numerous find and technology, modern in used tools common most the of some are Filters a of notion the Understanding controls. and processing signal both in robotics in applications WPILib. by provided filters of types various the of utility the understanding to crucial is filter

## מה זה פילטר?

time- dimensionalsingle- are data all assume will we article, this of sake the For :□□□□
full/rigorous a but - this than general more are involved concepts the Obviously, data. series
documentation. this of scope the of out is filtering and signals of discussion

a to inputs of stream a from mapping a is filter a put, Simply then? filter, a *is* exactly what So,
only not depend can principle) (in filter a by output value the say, to is That outputs. of stream
course, (of *values future and past of set entire the* on but input, the of value *current* the on
data; streaming on timereal- in implementable are WPILib by provided filters the practice, in
values). future on not and input, the of values *past* the on depend only can they accordingly,
unwanted remove/mitigate to filters use we generally because concept, important an is This
*signal the how* modifying in interested we're signal, a filter we When signal. a from *dynamics*
*.time over changes*

## השפעות השימוש בפילטר

### הפחתת רעש

is noise reduces that filter A reduction. noise for is filter a of uses typical most the of One
blocking while through," "pass to frequencies low allows it (because filter *passlow-* a called
passlow- effectively are WPILib in included currently filters the of Most frequencies).high-
filters.

### Limiting Rate

closely is This change. can signal a which at rate the reduce to used commonly also are Filters
change of rate the limit to tend also noise reduce that filters and reduction, noise to related
output. their of

### Detection Edge

high permits only which filter, passhigh- the is filter passlow- the to counterpart The
build to tricky somewhat be can filters passHigh- output. the to through pass to frequencies
passhigh- since - detectionedge- is filter passhigh- a for usage common a but for, intuition
useful are they changes, slower ignoring while input the in changes sudden reflect will filters
signal. the in discontinuities sharp of location the determining for

### Lag Phase

lag.“ ”phase of introduction the is filter passlow- timereal- a of effect negative unavoidable An
(we signal the of values past on depend only can filter timereal- a earlier, mentioned as Since,
up“ ”catch to time some takes value filtered the values), future the obtain to traveltime- cannot
introduced the greater the reduction,noise- the greater The changing. starts input the when
be should and filtering, timereal- of offtrade- fundamental *the* ways, many in is, This delay.
design. filter your of factor driving primary the

they as lag, phase a to opposed as ,*lead* phase a introduce filters passhigh- Interestingly,
input. the of value the to changes local exacerbate

## Filters Linear 30.3.2

- *filter linear* a is supports WPILib that filter of sort employed)commonly- most (and first The
filter. (LTI) invarianttime- linear a specifically, more or,

at stream output the of value the - average moving weighted a simply, put is, filter LTI An
difference The time. that near inputs the of average weighted localized, a is time given any
the of choice the in difference the to reducible thus is filters LTI of types different between
The used. response“) ”impulse an or function“ ”window a as known (also function weighting
.*convolution* is operation this for term mathematical

finite and (IIR), responses impulse infinite responses: impulse of ”sorts“ broad two are There
(FIR). responses impulse

infinitely- an over nonzero are they is, that - ”support“ infinite have responses impulse Infinite
value a once - ”memory“ infinite have also they that broadly, means, This region. large
typically is This .*forever outputs, subsequent all* influence will it stream, input the in appears
impulse infinite with filters however perspective, processingsignal- strict a from undesirable
recursion simple by expressed be can they as compute to easy very be to tend responses
relations.

region. bounded a on nonzero are they is, that - ”support“ finite have responses impulse Finite
equal output the setting simply is, that - average moving flat a is filter FIR ”archetypical“ The
than properties desirablemore- have to tend filters FIR inputs. n past the of average the to
compute. to costly more are but filters, IIR

).C++ ,Java( class `LinearFilter` the through WPILib in supported are filters Linear

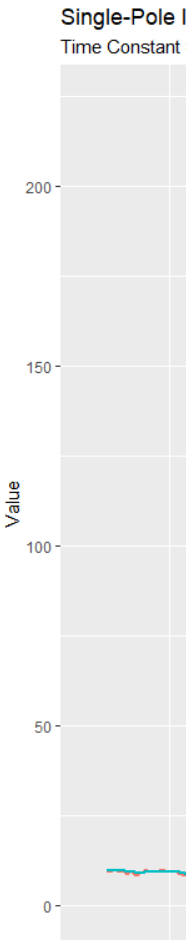
### LinearFilter a Creating

input. the for used type data the on templated is class `LinearFilter` C++ The :□□□□

Do object. filter own its requires stream input each ”memory“, have filters Because :□□□□
streams. input multiple for object filter same the use to attempt *not*

far is it filter, custom a build to class `LinearFilter` instantiate directly to possible is it While
instead: methods, factory supplied the of one use to common) (and convenient more

## singlePoleIIR



filter response impulse infinite polesingle- a creates method factory `singlePoleIIR()` The most in filter passlow- try“”first- to,“”go- the is This .*smoothing exponential* performs which cases. most in works and trivial computationally is it applications;

Java

```
                     filter IIR Single-Pole new a Creates //
                                seconds 0.1 is constant Time //
period loop main FRC standard the is this - seconds 0.02 is Period //
            );0.02 ,0.1(singlePoleIIRLinearFilter. = filter LinearFilter
```

C++

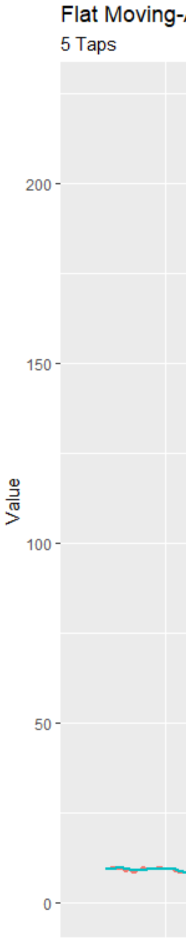
```
                     filter IIR Single-Pole new a Creates //
                                seconds 0.1 is constant Time //
period loop main FRC standard the is this - seconds 0.02 is Period //
0. s,_0.1SinglePoleIIR(::>double<LinearFilter::frc = filter >double<LinearFilter::frc
                                                                 s);_02 ↪
```

filter’s the of timescale“ ”characteristic the determines parameter constant“ ”time The timescales on occur that dynamics signal any out cancel will filter the response; impulse

the of timescale approximate the also is it Relatedly, this. than shorter significantly
”cutoff the is pi, 2 by multiplied timescale, this of reciprocal The .*lag phase* introduced
filter. the of frequency“

called. be will method `calculate()` filter’s the which at period the is parameter ”period“ The
of period loop robot main standard the be will this implementations, of majority vast the For
seconds. 0.02

### movingAverage



the is This filter. average moving flat simple a creates method factory `movingAverage` The
single- the as contexts same the of many in useful is and filter, FIR passlow- possible simplest
somewhat a in behaves generally but compute, to costly more somewhat is It filter. IIR pole
manner. nicer

Java

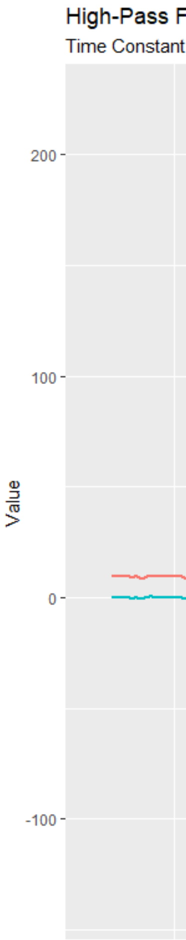
```
filter average moving flat new a Creates //
samples 5 last the over taken be will Average //
);5(movingAverageLinearFilter. = filter LinearFilter
```

C++

```
                                    filter average moving flat new a Creates //
                                 samples 5 last the over taken be will Average //
    );5MovingAverage(::>double<LinearFilter::frc = filter >double<LinearFilter::frc
```

moving flat the in included be will that samples of number the is parameter ”taps“ The constant time effective the - above constant“ ”time the to similarly behaves This average. called. is `calculate()` which at period the times taps of number the is

### highPass



passhigh- response impulse infinite orderfirst- simple a creates method factory `highPass` The .*singlePoleIIR* the to ”counterpart“ the is This filter.

Java

```
                                         filter IIR high-pass new a Creates //
                                             seconds 0.1 is constant Time //
              period loop main FRC standard the is this - seconds 0.02 is Period //
                              );0.02 ,0.1(highPassLinearFilter. = filter LinearFilter
```

C++

```
                                    filter IIR high-pass new a Creates //
                                        seconds 0.1 is constant Time //
              period loop main FRC standard the is this - seconds 0.02 is Period //
s);_0.02 s,_0.1HighPass(::>double<LinearFilter::frc = filter >double<LinearFilter::frc
```

filter's the of timescale" "characteristic the determines parameter constant" "time The timescales on occur that dynamics signal any out cancel will filter the response; impulse introduced the of timescale approximate the also is it Relatedly, this. than longer significantly of frequency" "cutoff the is pi, 2 by multiplied timescale, this of reciprocal The *.lead phase* filter. the

called. be will method `calculate()` filter's the which at period the is parameter "period" The of period loop robot main standard the be will this implementations, of majority vast the For seconds. 0.02

### LinearFilter a Using

---

its parameter, timescale specified the obey to filter created the for order In :□□□□ reason, some for If, period. specified the at regularly called be *must* function `calculate()` be should method `reset()` filter's the occur, must calls `calculate()` in lapse significant a use. further before called

---

with method `calculate()` the call simply - easy is it using created, been has filter your Once output: filtered the obtain to input recent most the

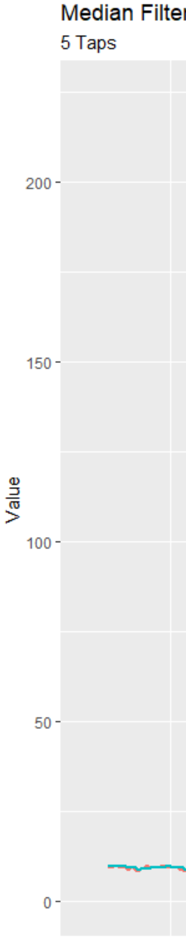
Java

```
output the of value next the Calculates //
              (input);calculatefilter.
```

C++

```
output the of value next the Calculates //
                  filter.Calculate(input);
```

### Filter Median 30.3.3



a Where .*filter median* the is *filter averagemoving-* the to alternative *robust statistically* A window, sample moving a over input the of *mean* arithmetic the takes filter average moving instead. median a takes name) the (per filter median a

This stream. input an from outliers occasional removing for usefulmost- is filter median The to prone are which sensors, distance from inputs filtering to suitedwell- particularly it makes completely remain will filter median the average, moving a Unlike interference. occasional extreme. how matter no outliers, of numbers small by unaffected

).C++ ,Java( class `MedianFilter` the through WPILib in supported is filter median The

### MedianFilter a Creating

input. the for used type data the on templated is class `MedianFilter` C++ The :□□□□

Do object. filter own its requires stream input each ”memory“, have filters Because :□□□□
streams. input multiple for object filter same the use to attempt *not*

simple: is `MedianFilter` a Creating

Java

```
samples 5 of size window a with MedianFilter a Creates //
);5MedianFilter( new = filter MedianFilter
```

C++

```
samples 5 of size window a with MedianFilter a Creates //
);5filter( >double<MedianFilter::frc
```

### MedianFilter a Using

with method `calculate()` the call simply - easy is it using created, been has filter your Once
output: filtered the obtain to input recent most the

Java

```
output the of value next the Calculates //
(input);calculatefilter.
```

C++

```
output the of value next the Calculates //
filter.Calculate(input);
```

## Limiter Rate Slew 30.3.4

the example, (for inputs control of behavior the soften to is FRC® in filters for use common A
poorly- is filter passlow- simple a Unfortunately, controls). driver your from inputs joystick
sudden to stream input an of response the soften will filter passlow- a while job; this for suited
solution better A lag. phase introduce and detail control fine out wash also will it changes,
*rate slew* a with performed is This directly. input control the of changeof-rate- the limit to is
signal. the of changeof-rate- maximum the caps that filter a - *limiter*

rate slew the fact, In profile. motion primitive of sort a as of thought be can limiter rate slew A
it - WPILib by supported *Profile Motion Trapezoidal* the of equivalent orderfirst- the is limiter
allowed is constraint acceleration the when motion trapezoidal of case limiting the precisely is
factode- a applying for choice good a is limiter rate slew the Accordingly, infinity. to tend to
approximately usually are which voltages, (or setpoints velocity of stream a to profile motion
use to better usually is it positions, control that streams input For velocity). to proportional
profile. trapezoidal proper a

).C++ ,Java( class `SlewRateLimiter` the through WPILib in supported is limiting rate Slew

### SlewRateLimiter a Creating

more For input. the of type unit the on templated is class `SlewRateLimiter` C++ The :□□□□
.*Library Units C++ The* see units, C++ on information

Do object. filter own its requires stream input each ”memory“, have filters Because :□□□□
streams. input multiple for object filter same the use to attempt *not*

simple: is SlewRateLimiter a Creating

Java

```
␣0.5 to signal the of change of rate the limits that SlewRateLimiter a Creates //
                                                              second per units ↪
                                  );0.5SlewRateLimiter( new = filter SlewRateLimiter
```

C++

```
␣0.5 to signal the of change of rate the limits that SlewRateLimiter a Creates //
                                                              second per volts ↪
                             s};_1 / V_0.5filter{ >volts::units<SlewRateLimiter::frc
```

### SlewRateLimiter a Using

with method `calculate()` the call simply - easy is it using created, been has filter your Once
output: filtered the obtain to input recent most the

Java

```
                                      output the of value next the Calculates //
                                                  (input);calculatefilter.
```

C++

```
                                      output the of value next the Calculates //
                                                  filter.Calculate(input);
```

### DifferentialDrive with SlewRateLimiter a Using

doubles, with use for `units::scalar` on filter the templates below example C++ The :□□□□
dimensionless. typically are values joystick since

be can This drive. robot’s a of acceleration the limit to is SlewRateLimiter a of use typical A do To drives. powerful very have that or heavy,top- very are that robots for handy especially function: drive robot your into passed value a to SlewRateLimiter a apply this,

Java

```
                          applied ramping no with call Ordinary //
                            turn); (forward,arcadeDrivedrivetrain.

acceleration forward/backward limiting input, forward/backward the limits Slew-rate //
                 turn); (forward),calculate(filter.arcadeDrivedrivetrain.
```

C++

```
                          applied ramping no with call Ordinary //
                           turn); drivetrain.ArcadeDrive(forward,

acceleration forward/backward limiting input, forward/backward the limits Slew-rate //
                 turn); drivetrain.ArcadeDrive(filter.Calculate(forward),
```

## Debouncer 30.3.5

”bounces,“ (termed cycles on/off quick unwanted eliminate to used filter a is debouncer A usually are cycles These thrown). is it as switch a of vibrations physical the from originally to trying is sensor the event actual the not and reflections or noise like error sensor a to due record.

a filters which ),C++ ,Java( class `Debouncer` the by WPILib in implemented is Debouncing nominal some for change a sustains input the if changes only output the that so stream boolean period. time

### Modes

modes: different three in configured be can `Debouncer` WPILib The

- only. )*true* to *false* from (transitions edges rising Debounces (default): Rising
- only. )*false* to *true* from (transitions edges falling Debounces Falling:
- transitions. all Debounces Both:

### Usage

Java

```
                                     0 DIO on DigitalInput a Initializes //
                                    );0DigitalInput( new = input DigitalInput

                                     mode. both"" in Debouncer a Creates //
        );kBoth.DebounceTypeDebouncer. ,0.1Debouncer( new = m_debouncer Debouncer

␣being before seconds 1. least at for true go must signal the false currently if So //
                                                        signal. True a as read ↪
                                    { ()))get(input.calculate(m_debouncer. if
                                 True. is DI the that now something Do //
                                                                          }
```

C++

```
                                         0 DIO on DigitalInput a Initializes //
                                                     ;}0input{ DigitalInput::frc

                                         mode. both"" in Debouncer a Creates //
         kBoth};::DebounceType::Debouncer::frc ms,_100m_debouncer{ Debouncer::frc

␣being before seconds 1. least at for true go must signal the false currently if So //
                                                          signal. True a as read ↪
                                      { (m_debouncer.calculate(input.Get())) if
                                   True. is DI the that now something Do //
                                                                               }
```

## 30.4 מחלקות גיאומטריה

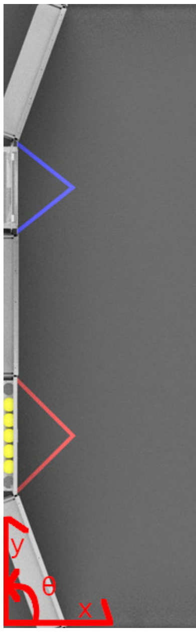
WPILib.-□ □□□□□□□□□□□□ □□□□□□□ □□ □□□□□ □□ □□□

### 30.4.1 Systems Coordinate

objects« representing for use we that systems coordinate main two are there FRC®, In positions.

#### System Coordinate Field

system coordinate absolute an is system) coordinate global (or system coordinate field The counter- the in is (theta) $\theta$ Positive origin. the as designated is field the on point a where station driver alliance’s your from away points axisx- positive the and direction, clockwise axis.x- positive the of left the to and perpendicular is axisy- positive the and wall,



## System Coordinate Robot

system coordinate relative a is system) coordinate local (or system coordinate robot The
and axis, x positive the is facing is robot the direction The origin. the is robot the where
clockwise.counter- is $\theta$ Positive robot. the of left the to perpendicular, is axis y positive the

---

order in reading the invert to have you so positive,clockwise- is class `Gyro` WPILib's **:□□□□**
system. coordinate either with rotation the get to

---

## Pose and Rotation, Translation, 30.4.2

### Translation

).C++ ,Java( class `Translation2d` WPILib's by represented is dimensions 2 in Translation a on $\begin{bmatrix} x \\ y \end{bmatrix}$ vector the or $(x, y)$ point the representing component, y and x an has class This system. coordinate dimensional2-

the using by object `Translation2d` another to distance the get can You `Translation2d` another to distance the returns which ,`other) getDistance(Translation2d` theorem. Pythagorean the using by

WPILib other using on planning you're If library. Units C++ the uses `Translation2d` :□□□□ use to sure make generator, trajectory the as such Java, in `Translation2d` use that classes meters.

### Rotation

This ).C++ ,Java( class `Rotation2d` WPILib's by represented is dimensions 2 in Rotation a on axis an to relative rotation robot's the represents which component, angle an has class counterclockwise. are rotations Positive system. coordinate dimensional2-

either accepts Java in constructor The library. Units C++ the uses `Rotation2d` :□□□□ will method `fromDegrees` the but angle, the of cosine and sine the or radians, in angle the degrees. from object `Rotation2d` a construct

passed is degrees 400 of value a if so angle, the of value the wrap not does `Rotation2d` :□□□□ calls. value subsequent in returned be will degrees 400 then constructor, the into

### Pose

class `Pose2d` the by represented is and rotation and translation both of combination a is Pose system, coordinate field the in robot your of pose the describe to used be can It ).C++ ,Java( coordinate robot the in robot your to relative targets, vision as such objects, of pose the or .$\begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$ vector the represent also can `Pose2d` system.

## Transformations 30.4.3

### Translation2d

.□□□□□□□ □□□□□ □□□□□□ □□□□□□□ □□ □□□□□□ □□□□□□ Translation2d □□□□□□□ □□ □□□□□□

- □□□□□□□□ □□□ Java-□ plus □□ □□□□ □□□□ Translation2d □□□□□□□□ □□□ □□□ □□□□□ :□□□□□ .□□□□□□□□□ □□□ □□ □□□□ □□ C++.-□ +
- □□□ Java-□ minus □□ □□□□□□ □□□□ Translation2d □□□□□□□□ □□□ □□□ □□□□□ :□□□□□ .□□□□□□□□□ □□□ □□□ □□□□□ □□ C++.-□ - □□□□□□□□
- □□ C++.-□ * □□□□□□□□ □□□ Java-□ times □□ □□□□ □□□□ □□□□□ Translation2d □□ □□□ :□□□ .□□□□□ □□□□□□□ □□ □□□□□
- C++.-□ / □□□□□□□□ □□□ Java-□ div □□ □□□□ □□□□ □□□□□ Translation2d □□ □□□□□ :□□□□□ .□□□□□ □□□□□□□ □□ □□□□ □□
- origin the about $\theta$ rotation clockwisecounter- a by `Translation2d` a of Rotation Rotation: the by vector the multiplying to equivalent is This `.rotateBy` using by performed be can $\begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix}$ matrix
- in `unaryMinus` using by degrees 180 by `Translation2d` a rotate can you Additionally, C++. in operator - unary the or Java,

### Rotation2d

.□□□□□□□ □□□□□ □□□□□□□ □□□□□□ □□ □□□□□□□ □□□□□□ □□□□ □□ Rotation2d □□□□□□□ □□ □□□□□□

- ’s`Rotation2d` `this` to `other` of component rotation the Adds (C++): + or (Java) `plus` component rotation
- `this` to `other` of component rotation the Subtracts (C++): - binary or (Java) `minus` component rotation ’s`Rotation2d`
- of scalar a by component rotation the Multiplies (C++): - unary or (Java) `unaryMinus` 1.-
- scalar. a by component rotation the Multiplies : (C++) * or (Java) `times`

### Twist2d-ı Transform2d

to transformation a represents which ),C++ ,Java( `Transform2d` classes, 2 provides WPILib `Transform2d` arc. an along movement a represents which )C++ ,Java( `Twist2d` and pose, a components. $\theta$ and y x, have all `Twist2d` and

rotation a and translation an has It transformation. **relative** a represents `Transform2d` component translation the rotates `Transform2d` a by `Pose2d` a Transforming component. component translation rotated the adds then and pose, the of rotation the by transform the of returns `Pose2d.plus(Transform2d)` words, other In pose. the to component rotation the and

$$\begin{bmatrix} x_p \\ y_p \\ \theta_p \end{bmatrix} + \begin{bmatrix} cos\theta_p & -sin\theta_p & 0 \\ sin\theta_p & cos\theta_p & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_t \\ y_t \\ \theta_t \end{bmatrix}$$

represent to used is class this Usually, arc. an along distance in change a represents `Twist2d` y the driven, distance forward the is component x the where drivetrain, a of movement the

change the is component $\theta$ the and positive), (left side the to driven distance the is component
moving after pose (new exponential pose the finding behind math underlying The heading. in
10. chapter in here found be can twist) the of curvature the along forward pose the

---

0. be always should `Twist2d` a of component y the drivetrains, nonholonomic For :□□□□

---

odometry WPILib's in used is Twist2d location. robot estimate to used be can classes Both
to used be can Transform2d while movement, on based pose robot's the update to classes
data. vision from position global robot's the estimate

## Controllers 30.5

are that classes controller feedforward and feedback WPILib various describes section This
that classes profilingmotion- as well as mechanisms, robot of motion the controlling for useful
controllers. these with use for setpoints generate automatically can

### WPILib עם PID בקרת 30.5.1

---

a For WPILib. in control PID of implementation codein- on focuses article This :□□□□
*PID-□ □□□□* see PIDController, a of working the of explanation conceptual

---

see ,*framework basedcommand-* the through control PID implementing on guide a For :□□□□
.*PIDCommands and PIDSubsystems through Control PID*

---

).C++ ,Java( class `PIDController` the through mechanisms of control PID supports WPILib
methods offering as well as user, the for calculation loop feedback the handles class This
its reached has loop control the if checking and tolerances, setting error, the returning for
tolerances. specified the within setpoint

#### PIDController שימוש במחלקה

---

should teams C++ - deprecated is namespace `frc` the in class `PIDController` The :□□□□
the in class the use should teams Java Likewise, instead. namespace, `frc2` the in one the use
package. `edu.wpi.first.math.controller`

---

### PIDController a Constructing

---

any provide *not* does it asynchronously, used be may `PIDController` While :□□□□ thus and user, the to entirely left is operation threadsafe ensuring - features safety thread teams. advanced for only recommended is usage asynchronous

---

`PIDController` a construct first must users functionality, control PID WPILib's use to order In gains: desired the with object

Java

```
kD and kI, kP, gains with PIDController a Creates //
kD); kI, PIDController(kP, new = pid PIDController
```

C++

```
kD and kI, kP, gains with PIDController a Creates //
kD}; kI, pid{kP, PIDController::frc2
```

period the specifying constructor, the to provided be can parameter fourth optional An for primarily intended is object `PIDController` The run. be will controller the which at 20ms. to defaulted is value this so and loop, robot main the from use synchronous

### Output Loop Feedback the Using

---

at regularly called being is method `calculate()` the that assumes `PIDController` The :□□□□ unintended in result will this do to Failure period. configured the with consistent interval an behavior. loop

---

automatically not does PIDController new the ,`PIDController` old the Unlike :□□□□□ use and `calculate()` call to required are users - thread own its from output an control code. own their in output resulting the

from method `calculate()` the call simply simple: is `PIDController` constructed the Using method): `autonomousPeriodic()` robot's the (e.g. loop main robot's the

Java

```
reading sensor the on based algorithm PID the of output the Calculates //
motor a to it sends and //
setpoint)); (),getDistance(encoder.calculate(pid.setmotor.
```

C++

```
reading sensor the on based algorithm PID the of output the Calculates //
motor a to it sends and //
setpoint)); motor.Set(pid.Calculate(encoder.GetDistance(),
```

### Errors Checking

---

is loop the that assuming named are `getVelocityError()` and `getPositionError()` :□□□□
error velocity the return these velocity, a controlling is that loop a for - position a controlling
respectively. error, acceleration the and

---

`getPositionError()` the by returned is variable process measured the of error current The
function: `getVelocityError()` the by returned is derivative its while function,

### Tolerances Checking and Specifying

---

infinity. to defaults tolerance velocity the specified, is tolerance position a only If :□□□□

---

its to ”velocity“ and measurement, variable process the to refers ”position“ above, As :□□□□
respectively. acceleration, and velocity actually are these loop, velocity a for thus, - derivative

---

given a within to setpoint the tracked has controller a if know to useful is it Occasionally,
a following (while or ended, be should command a if determine to example, for - tolerance
planned.re- be to needs and impeded being is motion if profile) motion

we then, method; `setTolerance()` the with tolerances the specify must first we this, do To
method. `atSetpoint()` the with it check can

Java

```
  second per 10 to tolerance derivative error the and 5, to tolerance error the Sets //
                                                                  );10 ,5(setTolerancepid.

                                   the and units, 5 than less is error the if true Returns //
                                                 units 10 than less is derivative error //
                                                                          ();atSetpointpid.
```

C++

```
  second per 10 to tolerance derivative error the and 5, to tolerance error the Sets //
                                                                  );10 ,5pid.SetTolerance(

                                   the and units, 5 than less is error the if true Returns //
                                                 units 10 than less is derivative error //
                                                                          pid.AtSetpoint();
```

### Controller the Resetting

integral the importantly, (most state internal the clear to desirable sometimes is It `PIDController` the when (e.g. valid longer no be may it as ,`PIDController` a of accumulator) `reset()` the calling by accomplished be can This enabled).re- then and disabled been has method.

### Value Integrator Max a Setting

---

It systems. loop feedback into hysteresis and instability introduce Integrators **:□□□□** other no absolutely unless gain integral using avoid teams that recommended strongly is better be can integrator an with solved be can that problems often, very - do will solution .*feedforward* accuratemore- a of use through solved

---

causing up“”wind- excessive is feedback integral using when encountered problem typical A the - ways of number a in alleviated be can This setpoint. the overshoot wildly to system the overcome teams help to limiter range integrator an enforces class `PIDController` WPILib issue. this

1.0- between be to limited is gain integral the from contribution output total the default, By 1.0. and

method. `setIntegratorRange()` the using decreased or increased be may limits range The

Java

```
from 0.5 than more subtract or add never will term gain integral The //
output loop total the //
);0.5 ,0.5-(setIntegratorRangepid.
```

C++

```
from 0.5 than more subtract or add never will term gain integral The //
output loop total the //
);0.5 ,0.5-pid.SetIntegratorRange(
```

### High Too is Error the if Gain Integral Disabling

integral where range error the limiting by is alleviated be can up“”wind- integral way Another .`IZone` setting by achieved be can This active. is gain

disabled. is `IZone` default, By

to it set it, disable To method. `setIZone()` the using decreased or increased be may `IZone` infinity.

Java

```
is error the of value absolute the if applied be not will gain Integral //
2 than more //
);2(setIZonepid.
```

C++

```
// Integral gain will not be applied if the absolute value of the error is
// more than 2
pid.SetIZone(2);
```

### Setting Continuous Input

□□□□□: If your mechanism is not capable of fully continuous rotational motion (e.g. a turret without a slip ring, whose wires twist as it rotates), *do not* enable continuous input unless you have implemented an additional safety feature to prevent the mechanism from moving past its limit!

□□□□□: The continuous input function does *not* automatically wrap your input values - be sure that your input values, when using this feature, are never outside of the specified range!

Some process variables (such as the angle of a turret) are measured on a circular scale, rather than a linear one - that is, each ”end“ of the process variable range corresponds to the same point in reality (e.g. 360 degrees and 0 degrees). In such a configuration, there are two possible values for any given error, corresponding to which way around the circle the error is measured. It is usually best to use the smaller of these errors.

To configure a `PIDController` to automatically do this, use the `enableContinuousInput()` method:

Java

```java
// Enables continuous input on a range from -180 to 180
pid.enableContinuousInput(-180, 180);
```

C++

```cpp
// Enables continuous input on a range from -180 to 180
pid.EnableContinuousInput(-180, 180);
```

### Clamping Controller Output

Unlike the old `PIDController`, the new controller does not offer any output clamping features, as the user is expected to use the loop output themselves. Output clamping can be easily achieved by composing the controller with WPI's `clamp()` function (or `std::clamp` in c++):

Java

```java
// Clamps the controller output to between -0.5 and 0.5
MathUtil.clamp(pid.calculate(encoder.getDistance(), setpoint), -0.5, 0.5);
```

C++

```cpp
// Clamps the controller output to between -0.5 and 0.5
std::clamp(pid.Calculate(encoder.GetDistance(), setpoint), -0.5, 0.5);
```

## WPILib in Control Feedforward 30.5.2

For WPILib. in control feedforward of implementation codein- on focuses article This :□□□□
*to Introduction* see WPILib, by used equations feedforward the of explanation conceptual a
*Feedforward Motor DC*

system's a (making tracking reference for PID) as (such control feedback used have may You
measure; reactionary a it's effective, is this While signal). reference desired a follow output
could we If behind. already is system the until effort control applying start won't system the
system the beforehand, input required and movement desired the about controller the tell
feeds that controller A work. less do could controller feedback the and quicker react could
controller. feedforward a called is this like plant the into forward information

mathematical a (like dynamics system's the about information injects controller feedforward A
we actions control the of parts handles Feedforward movement. intended the or does) model
compensates feedback then reference, a track system a make to applied be must know already
runtime. at behavior system's the about know cannot or not do we what for

### Classes Feedforward WPILib The

control feedforward accurate implement users help to classes of number a provides WPILib
than important more is feedforward accurate an ways, many In mechanisms. their for
obey closely mechanisms FRC® most Since mechanism. a of control effective to feedback
and easy both is feedforward accurate an with starting equations, system understoodwell-
control. mechanism robust and accurate to beneficial hugely

tools characterization mechanism available the match closely classes feedforward WPILib The
quickly to used be can toolsuite identification system The .*toolsuite SysId* the in available
to unable are you If feedforward. of type each for gains correct the determine effectively and
reasonable constraints), time and/or space to (due mechanism your characterize empirically
available also are and computation, simple fairly by obtained be can `kA` and ,`kV` ,`kG` of estimates
empirically. measured be must and model, to impossible nearly is `kS` .ReCalc from

control: feedforward for classes helper three following the provides currently WPILib

- )C++ ,Java( *SimpleMotorFeedforward*
- )C++ ,Java( *ArmFeedforward*
- )C++ ,Java( *ElevatorFeedforward*

### SimpleMotorFeedforward

for used type unit the on templated is class `SimpleMotorFeedforward` the C++, In :□□□□
have *must* gains inpassed- The linear. or angular be may which measurements, distance
should `kS` thrown. be will error timecompile- a or units, distance the with consistent units
should `kA` and ,`distance / seconds * volts` of units have should `kV` ,`volts` of units have
*The* see units, C++ on information more For .`distance / seconds^2 * volts` of units have
.*Library Units C++*

---

the by determined units in outputs calculate will components feedforward Java The :□□□□ consistent, units keep to care take *must* Users gains. feedforward provideduser- the of units system. unit safetype- a have not does WPILibJ as

---

of consist that mechanisms for feedforwards calculates class `SimpleMotorFeedforward` The such inertia, and friction than other loading external no with motors DC magnetpermanent- drives. robot and flywheels as

gains: required the with it construct simply ,`SimpleMotorFeedforward` a create To

---

many For zero. of value a to default will is, it if and omitted, be can gain `kA` The :□□□□ necessary. not is it inertia, little with those especially mechanisms,

---

Java

```
kA and kV, kS, gains with SimpleMotorFeedforward new a Create //
kA); kV, SimpleMotorFeedforward(kS, new = feedforward SimpleMotorFeedforward
```

C++

```
kA and kV, kS, gains with SimpleMotorFeedforward new a Create //
meters in measured is Distance //
kA); kV, feedforward(kS, >meters::units<SimpleMotorFeedforward::frc
```

motor desired the with method `calculate()` the call simply feedforward, the calculate To acceleration: and velocity

---

is, it if and call, `calculate()` the from omitted be may argument acceleration The :□□□□ definedclearly- a not is there whenever done be should This zero. of value a to default will setpoint. acceleration

---

Java

```
␣acceleration an and units/second 10 of velocity a for feedforward the Calculates //
units/second^2 20 of ↪
construction. at in passed gains the of units the by determined are Units //
);20 ,10(calculatefeedforward.
```

C++

```
␣acceleration an and meters/second 10 of velocity a for feedforward the Calculates //
meters/second^2 20 of ↪
volts in is Output //
mps_sq);_20 mps,_10feedforward.Calculate(
```

## ArmFeedforward

The linear. not angular, are distances assumes class `ArmFeedforward` the C++, In :□□□□ will error timecompile- a or unit, angular the with consistent units have *must* gains inpassed- `/ seconds * volts` of units have should `kV` ,`volts` of units have should `kG` and `kS` thrown. be information more For .`radians / seconds^2 * volts` of units have should `kA` and ,`radians` .*Library Units C++ The* see units, C++ on

the by determined units in outputs calculate will components feedforward Java The :□□□□ consistent, units keep to care take *must* Users gains. feedforward provideduser- the of units system. unit safetype- a have not does WPILibJ as

a by directly controlled are that arms for feedforwards calculates class `ArmFeedforward` The arm. the of mass and inertia, friction, of loading external with motor, DC magnetpermanent- FRC. in arms most of model accurate an is This

gains: required the with it construct simply ,`ArmFeedforward` an create To

many For zero. of value a to default will is, it if and omitted, be can gain `kA` The :□□□□ necessary. not is it inertia, little with those especially mechanisms,

Java

```
                 kA and kV, kG, kS, gains with ArmFeedforward new a Create //
     kA); kV, kG, ArmFeedforward(kS, new = feedforward ArmFeedforward
```

C++

```
                 kA and kV, kG, kS, gains with ArmFeedforward new a Create //
                         kA); kV, kG, (kS,feedforward ArmFeedforward::frc
```

arm desired the with method `calculate()` the call simply feedforward, the calculate To acceleration: and velocity, position,

is, it if and call, `calculate()` the from omitted be may argument acceleration The :□□□□ definedclearly- a not is there whenever done be should This zero. of value a to default will setpoint. acceleration

Java

```
 units/second, 2 of velocity a units, 1 of position a for feedforward the Calculates //
                                                                              and ↪
                                                  units/second^2 3 of acceleration an //
        construction. at in passed gains the of units the by determined are Units //
                                                      );3 ,2 ,1(calculatefeedforward.
```

C++

```
     radians/ 2 of velocity a radians, 1 of position a for feedforward the Calculates //
                                                                       and second, ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
radians/second^2 3 of acceleration an //
volts in is Output //
s));_1 * s_1(/rad_3 rad_per_s,_2 rad,_1feedforward.Calculate(
```

## ElevatorFeedforward

---

or units, distance the with consistent units have *must* gains inpassed- the C++, In :□□□□
have should `kV` ,`volts` of units have should `kG` and `kS` thrown. be will error timecompile- a
`/ seconds^2 * volts` of units have should `kA` and ,`distance / seconds * volts` of units
.*Library Units C++ The* see units, C++ on information more For .`distance`

---

the by determined units in outputs calculate will components feedforward Java The :□□□□
consistent, units keep to care take *must* Users gains. feedforward provideduser- the of units
system. unit safetype- a have not does WPILibJ as

---

of consist that elevators for feedforwards calculates class `ElevatorFeedforward` The
This elevator. the of mass the and inertia, friction, by loaded motors DC magnetpermanent-
FRC. in elevators most of model accurate an is

gains: required the with it construct simply ,`ElevatorFeedforward` a create To

---

many For zero. of value a to default will is, it if and omitted, be can gain `kA` The :□□□□
necessary. not is it inertia, little with those especially mechanisms,

---

Java

```
kA and kV, kG, kS, gains with ElevatorFeedforward new a Create //
kA); kV, kG, ElevatorFeedforward(kS, new = feedforward ElevatorFeedforward
```

C++

```
kA and kV, kS, gains with ElevatorFeedforward new a Create //
meters in measured is Distance //
kA); kV, kG, (kS,feedforward ElevatorFeedforward::frc
```

motor desired the with method `calculate()` the call simply feedforward, the calculate To
acceleration: and velocity

---

is, it if and call, `calculate()` the from omitted be may argument acceleration The :□□□□
definedclearly- a not is there whenever done be should This zero. of value a to default will
setpoint. acceleration

---

Java

```
units/second 20 of velocity a for feedforward the Calculates //
units/second^2 30 of acceleration an and //
construction. at in passed gains the of units the by determined are Units //
);30 ,20(calculatefeedforward.
```

C++

```
                    meters/second 20 of velocity a for feedforward the Calculates //
                                  meters/second^2 30 of acceleration an and //
                                                             volts in is Output //
                                    mps_sq);_30 mps,_20feedforward.Calculate(
```

### Mechanisms Control to Feedforward Using

---

the use to best is it meaningful, physically are voltages feedforward Since :□□□□
”voltage for compensate to motors to them applying when method )C++ ,Java( `setVoltage()`
battery. the from sag“

---

This controller. feedback a without own, its on entirely used be can control Feedforward be can drives) robot (especially mechanisms many for and control, loop“”open- as known is drive robot a control to employed be might `SimpleMotorFeedforward` A satisfactory. perfectly follows: as

Java

```
    { rightVelocity) double leftVelocity, double(tankDriveWithFeedforward void public
                                 (leftVelocity));calculate(feedforward.setVoltageleftMotor.
                               (rightVelocity));calculate(feedForward.setVoltagerightMotor.
                                                                                      }
```

C++

```
                 leftVelocity, meters_per_second_t::(unitsTankDriveWithFeedforward void
             { rightVelocity) meters_per_second_t::units
                            leftMotor.SetVoltage(feedforward.Calculate(leftVelocity));
                          rightMotor.SetVoltage(feedforward.Calculate(rightVelocity));
                                                                                      }
```

## Control PID and Feedforward Combining 30.5.3

---

control feedforward/PID combined of implementation codein- the covers article This :□□□□
in concepts involved the describing Documentation classes. library provided WPILib’s with
forthcoming. is detail more

---

effective most are but isolation, in used be each can controllers feedback and Feedforward *exceedingly* is methods control two these combining Thankfully, together. combined when together. outputs their adds simply one - straightforward

### PIDController a with Feedforward Using

gain feedforward any of lack the notice may class `PIDController` old the with familiar Users
is there themselves, output controller the use to expected are users As controller. new the in
add simply may users - feedforward implement to `PIDController` the for need any longer no
motors: their to it sending before controller the of output the to like they feedforward any

Java

```
                    motor the to it sending before output loop the to feedforward a Adds //
      feedforward); + setpoint) (),getDistance(encoder.calculate(pid.setVoltagemotor.
```

C++

```
                    motor the to it sending before output loop the to feedforward a Adds //
      feedforward); + setpoint) motor.SetVoltage(pid.Calculate(encoder.GetDistance(),
```

Python

```
                    motor the to it sending before output loop the to feedforward a Adds //
       feedforward) + setpoint) getDistance(),.calculate(encoder.setVoltage(pid.motor
```

reason no has thus and feedback, from entirely feature separate a is feedforward Moreover,
WPILib concerns. of separation violates this as object, controller same the in handled be to
common for voltages feedforward accurate compute to classes helper several with comes
.*WPILib in Control Feedforward* see information, more for - mechanisms FRC®

### PID with Components Feedforward Using

---

the use to best is it meaningful, physically are voltages feedforward Since :□□□□
”voltage for compensate to motors to them applying when method )C++ ,Java( `setVoltage()`
battery. the from sag“

---

like? look control feedforward/PID combined of example complete more a might What
include to this modify easily can We page. feedforward the from *example drive* the Consider
component): `SimpleMotorFeedforward` a (with control feedback

Java

```
           ␣double leftVelocitySetpoint, double(tankDriveWithFeedforwardPID void public
                                                       { rightVelocitySetpoint) ↪
                  (leftVelocitySetpoint)calculate(feedforward.setVoltageleftMotor.
             leftVelocitySetpoint)); (),getRate(leftEncoder.calculateleftPID. +
                 (rightVelocitySetpoint)calculate(feedForward.setVoltagerightMotor.
          rightVelocitySetpoint)); (),getRate(rightEncoder.calculaterightPID. +
                                                                                 }
```

C++

```
     leftVelocitySetpoint, meters_per_second_t::(unitsTankDriveWithFeedforwardPID void
  { rightVelocitySetpoint) meters_per_second_t::units
                  leftMotor.SetVoltage(feedforward.Calculate(leftVelocitySetpoint)
      leftVelocitySetpoint.value())); leftPID.Calculate(leftEncoder.getRate(), +
                 rightMotor.SetVoltage(feedforward.Calculate(rightVelocitySetpoint)
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
    rightVelocitySetpoint.value())); rightPID.Calculate(rightEncoder.getRate(), +
                                                                               }
```

Python

```
                                                   (tank_drive_with_feedforward_PID def
                                                    ,float left_velocity_setpoint:
                                                   ,float right_velocity_setpoint:
                                                                         :None >- )
                                                              setVoltage(.leftMotor
                                   calculate(left_velocity_setpoint).feedforward
                   left_velocity_setpoint) getRate(),.calculate(leftEncoder.leftPID +
                                                                                 )
                                                             setVoltage(.rightMotor
                                  calculate(right_velocity_setpoint).feedforward
                 right_velocity_setpoint) getRate(),.calculate(rightEncoder.rightPID +
                                                                                 )
```

similarly. handled be can types mechanism Other

### WPILib in Profiles Motion Trapezoidal 30.5.4

---

profiles. motion trapezoidal of generation codein- the covers article This :□□□□
forthcoming. is detail more in concepts involved the describing Documentation

---

*command*- the in class `TrapezoidProfile` the implementing on guide a For :□□□□
*and TrapezoidProfileSubsystems through Profiling Motion* see framework, *framework based*
*.TrapezoidProfileCommands*

---

a with composed when useful most is own, its on used class, `TrapezoidProfile` The :□□□□
To functionality). PID inbuilt- a with controller motor ”smart“ a as (such controller custom
*Control PID and Profiling Motion Combining* see ,`PIDController` WPILib a with it integrate
*.ProfiledPIDController with*

---

setpoint, given a achieve to ways convenient offer control feedback and feedforward While
While mechanisms. our for setpoints generating of problem the with faced still often are we
it work, may state desired its to mechanism a commanding immediately of approach naive the
command to wish often we mechanisms, our of handling the improve To suboptimal. often is
state, current its between interpolate smoothly that setpoints of *sequence* a to mechanisms
state. goal desired its and

).C++ ,Java( class `TrapezoidProfile` a provides WPILib this, do users help To

### TrapezoidProfile a Creating

---

distance for used type unit the on templated is class `TrapezoidProfile` the C++, In :□□□□ units have *must* values inpassed- The linear. or angular be may which measurements, more For thrown. be will error timecompile- a or units, distance the with consistent .*Library Units C++ The* see units, C++ on information

---

### Constraints

---

maximum the calculating for methods provide *classes helper feedforward* various The :□□□□ useful very be can These mechanism. a of acceleration and velocity achievablesimultaneously- .`TrapezoidProfile` your for constraints motion appropriate calculating for

---

on constraints some impose first must we profile, motion trapezoidal a create to order In the that acceleration and velocity maximum a specify must we Namely, motion. desired the instance an create we this, do To motion. the during achieve to expected be will mechanism ):C++ ,Java( class `TrapezoidProfile.Constraints` the of

Java

```
constraints profile motion trapezoidal of set new a Creates //
second per meters 10 of velocity Max //
squared second per meters 20 of acceleration Max //
);20 ,10(ConstraintsTrapezoidProfile. new
```

C++

```
constraints profile motion trapezoidal of set new a Creates //
second per meters 10 of velocity Max //
squared second per meters 20 of acceleration Max //
mps_sq};_20 mps,_10Constraints{::>meters::units<TrapezoidProfile::frc
```

### States End and Start

the using mechanisms our for states ending and starting desired the specify must we Next, velocity: a and position a has state Each ).C++ ,Java( class `TrapezoidProfile.State`

Java

```
meters 5 of position a with state new a Creates //
second per meters 0 of velocity a and //
);0 ,5(StateTrapezoidProfile. new
```

C++

```
meters 5 of position a with state new a Creates //
second per meters 0 of velocity a and //
mps};_0 m,_5State{::>meters::units<TrapezoidProfile::frc
```

## Together All It Putting

initializer simple a thus and classes, inner the of type the infer to able often is C++ **:□□□□**
in included are names class full The parameter. a as sent be can name) class the (without list
clarity. for below example the

are we states, start/end desired the and constraints of set a create to how know we that Now
parameters, 3 takes constructor `TrapezoidProfile` The profile. motion our create to ready
state. initial the and state, goal the constraints, the order: in

Java

```
TrapezoidProfile new a Creates //
second per meters 5 of vel max a have will Profile //
squared second per meters 10 of acceleration max a have will Profile //
meters 5 at stationary end will Profile //
position zero at stationary start will Profile //
␣,5(ConstraintsTrapezoidProfile. newTrapezoidProfile( new = profile TrapezoidProfile
),10 ↪
  ),0 ,5(StateTrapezoidProfile. new
  ));0 ,0(StateTrapezoidProfile. new
```

C++

```
TrapezoidProfile new a Creates //
second per meters 5 of vel max a have will Profile //
squared second per meters 10 of acceleration max a have will Profile //
meters 5 at stationary end will Profile //
position zero at stationary start will Profile //
profile{ >meters::units<TrapezoidProfile::frc
mps_sq},_10 mps,_5Constraints{::>meters::units<TrapezoidProfile::frc
mps},_0 m,_5State{::>meters::units<TrapezoidProfile::frc
mps}};_0 m,_0State{::>meters::units<TrapezoidProfile::frc
```

## TrapezoidProfile a Using

### Profile the Sampling

at state profile the get to simple: very is it using ,`TrapezoidProfile` a created we've Once
method: `calculate()` the call started, has profile the after time given the

Java

```
motion of seconds 5 after state profile motion the Returns //
);5(calculateprofile.
```

C++

```
motion of seconds 5 after state profile motion the Returns //
s);_5profile.Calculate(
```

### Using the State

The calculate method returns a `TrapezoidProfile.State` class (the same one that was used to specify the initial/end states when constructing the profile). To use this for actual control, simply pass the contained position and velocity values to whatever controller you wish (for example, a PIDController):

Java

```
var setpoint = profile.calculate(elapsedTime);
controller.calculate(encoder.getDistance(), setpoint.position);
```

C++

```
auto setpoint = profile.Calculate(elapsedTime);
controller.Calculate(encoder.GetDistance(), setpoint.position.value());
```

### Complete Usage Example

□□□□: In this example, the profile is re-computed every timestep. This is a somewhat different usage technique than is detailed above, but works according to the same principles - the profile is sampled at a time corresponding to the loop period to get the setpoint for the next loop iteration.

A more complete example of `TrapezoidProfile` usage is provided in the ElevatorTrapezoidProfile example project (Java, C++):

Java

```
package edu.wpi.first.wpilibj.examples.elevatortrapezoidprofile;

import edu.wpi.first.math.controller.SimpleMotorFeedforward;
import edu.wpi.first.math.trajectory.TrapezoidProfile;
import edu.wpi.first.wpilibj.Joystick;
import edu.wpi.first.wpilibj.TimedRobot;

public class Robot extends TimedRobot {
  private static double kDt = 0.02;

  private final Joystick m_joystick = new Joystick(1);
  private final ExampleSmartMotorController m_motor = new␣
↪ExampleSmartMotorController(1);
  // Note: These gains are fake, and will have to be tuned for your robot.
  private final SimpleMotorFeedforward m_feedforward = new SimpleMotorFeedforward(1,␣
↪1.5);

  private final TrapezoidProfile.Constraints m_constraints =
      new TrapezoidProfile.Constraints(1.75, 0.75);
  private TrapezoidProfile.State m_goal = new TrapezoidProfile.State();
  private TrapezoidProfile.State m_setpoint = new TrapezoidProfile.State();

  @Override
  public void robotInit() {
    // Note: These gains are fake, and will have to be tuned for your robot.
```

(continues on next page)

(□□□□ □□□□□ □□□□)

```
                                        );0.7 ,0.0 ,1.3(setPIDm_motor.
                                                                     }

                                                             @Override
                                      { ()teleopPeriodic void public
                              { ))2(getRawButtonPressed(m_joystick. if
                            );0 ,5(StateTrapezoidProfile. new = m_goal
                       { ))3(getRawButtonPressed(m_joystick. if else }
                            );0 ,0(StateTrapezoidProfile. new = m_goal
                                                                   }

          maximum and velocity maximum given the with profile motion a Create //
  the and goal, desired the setpoint, next the for constraints acceleration //
                                                        setpoint. current //
          m_setpoint); m_goal, TrapezoidProfile(m_constraints, new = profile var

  moves setpoint This timestep. next the for setpoint profiled the Retrieve //
                             constraints. the obeying while goal the toward //
                                         (kDt);calculateprofile. = m_setpoint

                                   PID controller offboard to setpoint Send //
                                                         (setSetpointm_motor.
                                ,kPosition.PIDModeExampleSmartMotorController.
                                                         ,positionm_setpoint.
                     );12.0 / )velocity(m_setpoint.calculatem_feedforward.
                                                                       }
                                                                        }
```

C++

```
                                                   numbers>< include#

                                               frc/Joystick.h>< include#
                                             frc/TimedRobot.h>< include#
                         frc/controller/SimpleMotorFeedforward.h>< include#
                            frc/trajectory/TrapezoidProfile.h>< include#
                                          units/acceleration.h>< include#
                                               units/length.h>< include#
                                                 units/time.h>< include#
                                             units/velocity.h>< include#
                                              units/voltage.h>< include#

                              ExampleSmartMotorController.h"" include#

                                   { TimedRobot::frc public : Robot class
                                                              :public
                           ms;_20 = kDt second_t::units constexpr static

                                                             { Robot()
        robot. your for tuned be to have will and fake, are gains These Note: //
                                        );0.7 ,0.0 ,1.3m_motor.SetPID(
                                                                     }

                                     { override TeleopPeriodic() void
                              { ))2(m_joystick.GetRawButtonPressed( if
                                                 mps};_0 m,_5{ = m_goal
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                   { ))3(m_joystick.GetRawButtonPressed( if else }
                                                          mps};_0 m,_0{ = m_goal
                                                                                 }

            maximum and velocity maximum given the with profile motion a Create //
      the and goal, desired the setpoint, next the for constraints acceleration //
                                                              setpoint. current //
               m_goal, profile{m_constraints, >meters::units<TrapezoidProfile::frc
                         m_setpoint};

      moves setpoint This timestep. next the for setpoint profiled the Retrieve //
                                 constraints. the obeying while goal the toward //
                                              profile.Calculate(kDt); = m_setpoint

                                       PID controller offboard to setpoint Send //
              kPosition,::PIDMode::m_motor.SetSetpoint(ExampleSmartMotorController
                                  m_setpoint.position.value(),
         V);_12 / m_feedforward.Calculate(m_setpoint.velocity)
                                                                                   }

                                                                             :private
                                                        ;}1m_joystick{ Joystick::frc
                                             ;}1m_motor{ ExampleSmartMotorController
                           m_feedforward{ >meters::units<SimpleMotorFeedforward::frc
        robot. your for tuned be to have will and fake, are gains These Note: //
                                                        m};_1 / s_1 * V_1.5 V,_1

           mps,_1.75m_constraints{ Constraints::>meters::units<TrapezoidProfile::frc
       mps_sq};_0.75
                                 m_goal; State::>meters::units<TrapezoidProfile::frc
                             m_setpoint; State::>meters::units<TrapezoidProfile::frc
                                                                                    ;}

                                                             RUNNING_FRC_TESTS ifndef#
                                                                          { ()main int
                                                    ();>Robot<StartRobot::frc return
                                                                                     }
                                                                                endif#
```

### with Control PID and Profiling Motion Combining 30.5.5 ProfiledPIDController

*basedcommand-* the in class `ProfiledPIDController` the implementing on guide a For :□□□□ *.BasedCommand- in PID and Profiling Motion Combining* see framework, *framework*

use and create to class `TrapezoidProfile` the use to how saw we article, previous the In manually demonstrates article that from code example The profile. motion trapezoidal a ”smart“ a of feature control PID external the with class `TrapezoidProfile` the composing controller. motor

with combined setpoints generating for profile motion (a functionality of combination This comes WPILib this, facilitate To common. extremely is them) following for controller PID a combining of work the of most does that )C++ ,Java( class `ProfiledPIDController` a with the of that to similar very is `ProfiledPIDController` the of API The functionalities. two these with mechanism controlledPID- a to profiling motion add to users allowing ,`PIDController` code. their to changes few very

## class ProfiledPIDController the Using

:□□□□ for used type unit the on templated is class `ProfiledPIDController` the C++, In have *must* values inpassed- The linear. or angular be may which measurements, distance more For thrown. be will error timecompile- a or units, distance the with consistent units information on C++ units, see *The C++ Units Library*.

:□□□□ that to identical effectively is `ProfiledPIDController` of functionality the of Much substantially- are that features cover only will article this Accordingly, .`PIDController` of standard on information For functionality. profiling motion the accommodate to changed `PIDController` features, see *□□□□ PID □□ WPILib*.

## ProfiledPIDController a Constructing

:□□□□ initializer simple a thus and classes, inner the of type the infer to able often is C++ list (without the class name) can be sent as a parameter. The full class name is included in the example below for clarity.

The .*PIDController a creating* to identical nearly is `ProfiledPIDController` a Creating be will which ,*constraints profile trapezoidal* of set a supply to need the is difference only instances: `TrapezoidProfile` generatedinternally- the to forwarded automatically

Java

```
                                   ProfiledPIDController a Creates //
                                  second per meters 5 is velocity Max //
                               second per meters 10 is acceleration Max //
              ProfiledPIDController( new = controller ProfiledPIDController
                                                          kD, kI, kP,
                               ));10 ,5(ConstraintsTrapezoidProfile. new
```

C++

```
                                   ProfiledPIDController a Creates //
                                  second per meters 5 is velocity Max //
                               second per meters 10 is acceleration Max //
                    controller( >meters::units<ProfiledPIDController::frc
                                                          kD, kI, kP,
         mps_sq});_10 mps,_5Constraints{::>meters::units<TrapezoidProfile::frc
```

### Setpoint vs Goal

that is `ProfiledPIDController` a and `PIDController` standard a between difference major A
user the Rather, user. the by specified directly not is loop control the of *setpoint* actual the
automatically computed is controller the for setpoint the and state, or position *goal* a specifies
user- the while So, goal. the and state current the between profile motion generated the from
identical: mostly looks call side

Java

```
reading sensor the on based algorithm PID the of output the Calculates //
motor a to it sends and //
goal)); (),getDistance(encoder.calculate(controller.setmotor.
```

C++

```
reading sensor the on based algorithm PID the of output the Calculates //
motor a to it sends and //
goal)); motor.Set(controller.Calculate(encoder.GetDistance(),
```

,`TrapezoidProfile.State` a or value position a either be can (which value `goal` specified The
is it rather, - loop the of setpoint *current* the necessarily *not* is desired) is velocity nonzero if
terminates. profile generated the once setpoint *eventual* the

### Setpoint the Getting/Using

poll to desirable often if is setpoint, the from differs goal `ProfiledPIDController` the Since
).*feedforward* with use to values get to instance, (for controller the of setpoint current the
method. `getSetpoint()` the with done be can This

example: following the in as used be then might setpoint returned The

Java

```
;0 = lastSpeed double
();getFPGATimestampTimer. = lastTime double

SimpleMotorFeedforward a using position s'motor simple a Controls //
ProfiledPIDController a and //
{ goalPosition) double(goToPosition void public
goalPosition); (),getDistance(encoder.calculatecontroller. = pidVal double
(Timer. / lastSpeed) - velocity().getSetpoint(controller. = acceleration double
lastTime); - ()getFPGATimestamp ↪
(setVoltagemotor.
pidVal
acceleration)); ,velocity().getSetpoint(controller.calculatefeedforward. +
;velocity().getSetpointcontroller. = lastSpeed
();getFPGATimestampTimer. = lastTime
}
```

C++

```
mps;_0 = lastSpeed meters_per_second_t::units
GetFPGATimestamp();::Timer::frc2 = lastTime second_t::units

SimpleMotorFeedforward a using position s'motor simple a Controls //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                               ProfiledPIDController a and //
                            { goalPosition) meter_t::(unitsGoToPosition void
     ␣meter_t{encoder.GetDistance()},::controller.Calculate(units = pidVal auto
                                                            goalPosition); ↪
       / lastSpeed) - (controller.GetSetpoint().velocity = acceleration auto
                            lastTime); - GetFPGATimestamp()::Timer::(frc2
                                                         motor.SetVoltage(
                                                             + pidVal
  acceleration)); feedforward.Calculate(controller.GetSetpoint().velocity,
                              controller.GetSetpoint().velocity; = lastSpeed
                                GetFPGATimestamp();::Timer::frc2 = lastTime
                                                                           }
```

### Example Usage Complete

the in provided is usage ProfiledPIDController of example complete more A ):C++ ,Java( project example ElevatorProfilePID

Java

```
                    ;edu.wpi.first.wpilibj.examples.elevatorprofiledpid package

                   ;edu.wpi.first.math.controller.ProfiledPIDController import
                      ;edu.wpi.first.math.trajectory.TrapezoidProfile import
                                ;edu.wpi.first.wpilibj.Encoder import
                               ;edu.wpi.first.wpilibj.Joystick import
                              ;edu.wpi.first.wpilibj.TimedRobot import
                 ;edu.wpi.first.wpilibj.motorcontrol.MotorController import
                      ;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import

                                { TimedRobot extends Robot class public
                                  ;0.02 = kDt double static private

                         );1Joystick( new = m_joystick Joystick final private
                     );2 ,1Encoder( new = m_encoder Encoder final private
               );1PWMSparkMax( new = m_motor MotorController final private

       maximum to subject is change s'setpoint whose controller PID a Create //
                              constraints. acceleration and velocity //
                  = m_constraints ConstraintsTrapezoidProfile. final private
                          );0.75 ,1.75(ConstraintsTrapezoidProfile. new
                       = m_controller ProfiledPIDController final private
          kDt); m_constraints, ,0.7 ,0.0 ,1.3ProfiledPIDController( new

                                                            @Override
                                             { ()robotInit void public
            );1.5 * PIMath. * 2.0 * 360.0 / 1.0(setDistancePerPulsem_encoder.
                                                                    }

                                                            @Override
                                         { ()teleopPeriodic void public
                                 { ))2(getRawButtonPressed(m_joystick. if
                                                  );5(setGoalm_controller.
                             { ))3(getRawButtonPressed(m_joystick. if else }
                                                  );0(setGoalm_controller.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                    }

                                        output motor update and controller Run //
                   ()));getDistance(m_encoder.calculate(m_controller.setm_motor.
                                                                      }
                                                                        }
```

C++

```
                                                         numbers>< include#

                                                     frc/Encoder.h>< include#
                                                    frc/Joystick.h>< include#
                                                  frc/TimedRobot.h>< include#
                                frc/controller/ProfiledPIDController.h>< include#
                                      frc/motorcontrol/PWMSparkMax.h>< include#
                                    frc/trajectory/TrapezoidProfile.h>< include#
                                             units/acceleration.h>< include#
                                                 units/length.h>< include#
                                                   units/time.h>< include#
                                                units/velocity.h>< include#

                                        { TimedRobot::frc public : Robot class
                                                                     :public
                                    ms;_20 = kDt second_t::units constexpr static

                                                                   { Robot()
      );1.5 * pi::numbers::std * 2.0 * 360.0 / 1.0m_encoder.SetDistancePerPulse(
                                                                      }

                                              { override TeleopPeriodic() void
                                        { ))2(m_joystick.GetRawButtonPressed( if
                                                     m);_5m_controller.SetGoal(
                                   { ))3(m_joystick.GetRawButtonPressed( if else }
                                                     m);_0m_controller.SetGoal(
                                                                    }

                                        output motor update and controller Run //
                                                                   m_motor.Set(
          meter_t{m_encoder.GetDistance()}));::m_controller.Calculate(units
                                                                      }

                                                                    :private
                                                   ;}1m_joystick{ Joystick::frc
                                                ;}2 ,1m_encoder{ Encoder::frc
                                                   ;}1m_motor{ PWMSparkMax::frc

            maximum to subject is change s'setpoint whose controller PID a Create //
                                      constraints. acceleration and velocity //
         mps,_1.75m_constraints{ Constraints::>meters::units<TrapezoidProfile::frc
     mps_sq};_0.75
             ,0.7 ,0.0 ,1.3m_controller{ >meters::units<ProfiledPIDController::frc
       kDt}; m_constraints,
                                                                        ;}

                                                    RUNNING_FRC_TESTS ifndef#
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                  { ()main int
          ();>Robot<StartRobot::frc return
                                             }
                                        endif#
```

## BangBangController with Control BangBang- 30.5.6

(when on states: two only employs that strategy control a is algorithm *control bangbang-* The
a to equivalent roughly is This (otherwise). off and setpoint) the below is measurement the
gain. infinite with loop proportional

unstable become to known are loops PID as strategy, control poor a like seem initially may This
*on controller bangbang- a use to idea bad very* a is it indeed, and - large become gains the as
*.mechanism inertiahigh- a of control velocity than other anything*

a (like loads varying under mechanisms inertiahigh- of velocity the controlling when However,
better/more thus and time recovery faster yield can controller bangbang- a flywheel), shooter
bang- a loop, P ordinary an Unlike controller. proportional a than performance consistent
is variable process the when on turns controller the is, that - *asymmetric* is controller bang
forward the in effort control the allows This otherwise. nothing does and setpoint, the below
control the as oscillations destructive risking without possible as large as made be to direction
overshoot. resulting a correct to tries loop

,Java( class BangBangController the by WPILib in provided is control bangbang- Asymmetric
).C++

### BangBangController a Constructing

constructor any need not does it gains, any have not does controller bangbang- a Since
it but ,`atSetpoint` by used tolerance controller the specify optionally can (one arguments
required). not is

Java

```
                          BangBangController a Creates //
BangBangController(); new = controller BangBangController
```

C++

```
                 BangBangController a Creates //
controller; BangBangController::frc
```

Python

```
                  BangBangController a Creates #
BangBangController().wpimath = controller
```

### BangBangController a Using

> response on relies that algorithm aggressive extremely an is control bangBang- :□□□□□
> been have controllers motor your that *certain absolutely* Be stable. remain to asymmetry
> else or controller, bangbang- a with them control to attempting before mode“ ”coast to set
> oscillation. destructive potentially cause and controller the fight will action braking the

easy: is controller bangbang- a Using

Java

```
controller BangBang the of output the with motor a Controls //
setpoint)); (),getRate(encoder.calculate(controller.setmotor.
```

C++

```
controller BangBang the of output the with motor a Controls //
setpoint)); motor.Set(controller.Calculate(encoder.GetRate(),
```

Python

```
controller BangBang the of output the with motor a Controls #
setpoint)) getRate(),.calculate(encoder.set(controller.motor
```

### Feedforward with Control Bang Bang Combining

controller *feedforward* a with conjunction in obtained are results best controller, PID a Like that so speed, desired the at output system the sustain to voltage necessary the provides that bangbang- the Since disturbances. rejecting for responsible only is controller bangbang- the a use to preferable be may it however, direction, forward the in correct *only* can controller speed.over- not does shooter the that ensure to estimate feedforward conservative slightly

Java

```
feedforward a and controller BangBang the of output the with motor a Controls //
shooter the overspeeding avoid to slightly feedforward the Shrinks //
␣* 0.9 + 12.0 * setpoint) (),getRate(encoder.calculate(controller.setVoltagemotor.
(setpoint));calculatefeedforward. ↪
```

C++

```
feedforward a and controller BangBang the of output the with motor a Controls //
shooter the overspeeding avoid to slightly feedforward the Shrinks //
␣* 0.9 + 12.0 * setpoint) motor.SetVoltage(controller.Calculate(encoder.GetRate(),
feedforward.Calculate(setpoint)); ↪
```

Python

```
feedforward a and controller BangBang the of output the with motor a Controls #
␣* 0.9 + 12.0 * setpoint) getRate(),.calculate(encoder.setVoltage(controller.motor
calculate(setpoint)).feedforward ↪
```

# 30.6 יצירה ומעקב מסלולים עם WPILib

This section describes WPILib support for generating parameterized spline trajectories and following those trajectories with typical FRC® robot drives.

## 30.6.1 Trajectory Generation

WPILib contains classes that help generating trajectories. A trajectory is a smooth curve, with velocities and accelerations at each point along the curve, connecting two endpoints on the field. Generation and following of trajectories is incredibly useful for performing autonomous tasks. Instead of a simple autonomous routine – which involves moving forward, stopping, turning 90 degrees to the right, then moving forward – using trajectories allows for motion along a smooth curve. This has the advantage of speeding up autonomous routines, creating more time for other tasks; and when implemented well, makes autonomous navigation more accurate and precise.

This article goes over how to generate a trajectory. The next few articles in this series will go over how to actually follow the generated trajectory. There are a few things that your robot must have before you dive into the world of trajectories:

- A way to measure the position and velocity of each side of the robot. An encoder is the best way to do this; however, other options may include optical flow sensors, etc.
- A way to measure the angle or angular rate of the robot chassis. A gyroscope is the best way to do this. Although the angular rate can be calculated using encoder velocities, this method is NOT recommended because of wheel scrubbing.

If you are looking for a simpler way to perform autonomous navigation, see *the section on driving to a distance*.

### Splines

A spline refers to a set of curves that interpolate between points. Think of it as connecting dots, except with curves. WPILib supports two types of splines: hermite clamped cubic and hermite quintic.

- Hermite clamped cubic: This is the recommended option for most users. Generation of trajectories using these splines involves specifying the (x, y) coordinates of all points, and the headings at the start and end waypoints. The headings at the interior waypoints are automatically determined to ensure continuous curvature (rate of change of the heading) throughout.
- Hermite quintic: This is a more advanced option which requires the user to specify (x, y) coordinates and headings for *all* waypoints. This should be used if you are unhappy with the trajectories that are being generated by the clamped cubic splines or if you want finer control of headings at the interior points.

Splines are used as a tool to generate trajectories; however, the spline itself does not have any information about velocities and accelerations. Therefore, it is not recommended that you use the spline classes directly. In order to generate a smooth path with velocities and accelerations, a *trajectory* must be generated.

### config trajectory the Creating

contains config The trajectory. a generate to order in created be must configuration A addition in acceleration max the velocity, max the constraints, special about information whether about information contains also config The velocity. end and velocity start the to The waypoints). the along backward travels (robot reversed be should trajectory the this for constructor The config. a construct to used be should class `TrajectoryConfig` fields other The acceleration. max and velocity max the arguments, two takes class values reasonable to defaulted are )`constraints` ,`reversed` ,`endVelocity` ,`startVelocity`( these of any of values the modify to wish you If created. is object the when )`{}` ,`false` ,`0` ,`0`( methods: following the call can you fields,

- / (Java) `startVelocityMetersPerSecond)` `setStartVelocity(double` (C++) `startVelocity)` `SetStartVelocity(units::meters_per_second_t`
- / (Java) `endVelocityMetersPerSecond)` `setEndVelocity(double` (C++) `endVelocity)` `SetEndVelocity(units::meters_per_second_t`
- (C++) `reversed)` `SetReversed(bool` / (Java) `reversed)` `setReversed(boolean`
- / (Java) `constraint)` `addConstraint(TrajectoryConstraint` (C++) `constraint)` `AddConstraint(TrajectoryConstraint`

---

If backward. traveling is robot the whether represents simply property `reversed` The **:□□□□** through order same the in travel still will robot the d, and c, b, a, waypoints, four specify you account must you that means also This .`true` to set is flag `reversed` the when waypoints the is robot your if example, For waypoints. the providing when robot the of direction the for starting the element, field some to backwards travels and wall station alliance your facing degrees. 180 of rotation a have should waypoint

---

### trajectory the Generating

four are There .`generateTrajectory(...)` is trajectory a generate to used method The use that others two the and splines cubic clamped use that Two method. this for overloads The trajectory. a construct to ways two are there spline, of type each For splines. quintic objects. `Pose2d` accept that overloads the are methods easiest

starting the for one objects, `Pose2d` two accepts method this splines, cubic clamped For `Translation2d` of vector a in takes method The waypoint. ending the for one and waypoint are waypoints interior these at headings The waypoints. interior the represent which objects method the splines, quintic For curvature. continuous ensure to automatically determined heading and point a representing `Pose2d` each with objects, `Pose2d` of list a in takes simply field. the on

when used is method This splines. for vectors“ ”control accepts overload complex more The the of magnitude the control to able are you where Pathweaver, with trajectories generating Each arrays. `double` two of consists class `ControlVector` The point. each at vector tangent that at derivatives the represent elements its and y), or (x dimension one represents array (0th coordinate x the represents array x the of 0 element at value the example, For point. on. so and dimension x the in derivative 1st the represents 1 element at value the derivative),

derivatives), 1st and (0th 2 be must array the of length the splines, cubic clamped using When 2nd and 1st, (0th, 3 be should array the of length the splines, quintic using when whereas is method simpler and first the doing, are you what exactly know you Unless derivative).

Pathweaver using not when (i.e. trajectories. generating manually for recommended HIGHLY files). JSON

game, 2018 the for splines cubic clamped using trajectory a generating of example an is Here Up: Power FIRST

Java

```
                                            { ExampleTrajectory class
                                      { ()generateTrajectory void public

                                 waypoints. auto scale cross 2018 //
   ),23.23(feetToMetersUnits. ),1.54(feetToMetersPose2d(Units. new = sideStart var
                                          ));180-(fromDegreesRotation2d.
    ),6.8(feetToMetersUnits. ),23.7(feetToMetersPose2d(Units. new = crossScale var
                                          ));160-(fromDegreesRotation2d.

                     ();>Translation2d<ArrayList new = interiorWaypoints var
         Units. ),14.54(feetToMetersTranslation2d(Units. new(addinteriorWaypoints.
                                                 )));23.23(feetToMeters ↪
         Units. ),21.04(feetToMetersTranslation2d(Units. new(addinteriorWaypoints.
                                                 )));18.23(feetToMeters ↪

     Units. ),12(feetToMetersTrajectoryConfig(Units. new = config TrajectoryConfig
                                                     ));12(feetToMeters ↪
                                             );true(setReversedconfig.

                    (generateTrajectoryTrajectoryGenerator. = trajectory var
                                                  sideStart,
                                          interiorWaypoints,
                                                 crossScale,
                                                    config);
                                                            }
                                                             }
```

C++

```
                                             { ()GenerateTrajectory void
                                      waypoints auto scale cross 2018 //
      deg)};_180Rotation2d(::frc ft,_23.23 ft,_1.54sideStart{ Pose2d::frc const
      deg)};_160-Rotation2d(::frc ft,_6.8 ft,_23.7crossScale{ Pose2d::frc const

                           interiorWaypoints{ >Translation2d::frc<vector::std
                                  ft},_23.23 ft,_14.54Translation2d{::frc
                                 ft}};_18.23 ft,_21.04Translation2d{::frc

                              fps_sq};_12 fps,_12config{ TrajectoryConfig::frc
                                                    );trueconfig.SetReversed(

                GenerateTrajectory(::TrajectoryGenerator::frc = trajectory auto
                         config); crossScale, interiorWaypoints, sideStart,
                                                                         }
```

conversions. unit easy for utility, Units the utilizes code Java The :□□□□

it's but long, isn't This ms. 25 to ms 10 about takes trajectory typical a Generating :□□□□

).`robotInit(` startup on trajectories all generate to recommended highly still

## Trajectories Concatenating

the using trajectory single a into combined be can Java in Trajectories trajectories two the )+( add simply can users C++ function. `concatenate(trajectory)` together.

□□□□□: It is up to the user to ensure that the end of the initial and start of the appended trajectory match. It is also the user's responsibility to ensure that the start and end velocities of their trajectories match.

Java

```
                                                                   = trajectoryOne var
                                               (generateTrajectoryTrajectoryGenerator.
                                       )),0(fromDegreesRotation2d. ,0 ,0Pose2d( new
                        )),1- ,2Translation2d( new ),1 ,1Translation2d( new(ofList.
                                       )),0(fromDegreesRotation2d. ,0 ,3Pose2d( new
           )));3.0(feetToMetersUnits. ),3.0(feetToMetersTrajectoryConfig(Units. new

                                                                   = trajectoryTwo var
                                               (generateTrajectoryTrajectoryGenerator.
                                       )),0(fromDegreesRotation2d. ,0 ,3Pose2d( new
                         )),3 ,6Translation2d( new ),4 ,4Translation2d( new(ofList.
                                       )),0(fromDegreesRotation2d. ,0 ,6Pose2d( new
           )));3.0(feetToMetersUnits. ),3.0(feetToMetersTrajectoryConfig(Units. new

                            (trajectoryTwo);concatenatetrajectoryOne. = concatTraj var
```

C++

```
                    GenerateTrajectory(::TrajectoryGenerator::frc = trajectoryOne auto
                                                      rad),_0 m,_0 m,_0Pose2d(::frc
                     m)},_1- m,_2Translation2d(::frc m),_1 m,_1Translation2d(::frc{
             fps_sq));_3 fps,_3TrajectoryConfig(::frc rad),_0 m,_0 m,_3Pose2d(::frc

                    GenerateTrajectory(::TrajectoryGenerator::frc = trajectoryTwo auto
                                                      rad),_0 m,_0 m,_3Pose2d(::frc
                      m)},_3 m,_5Translation2d(::frc m),_4 m,_4Translation2d(::frc{
             fps_sq));_3 fps,_3TrajectoryConfig(::frc rad),_0 m,_0 m,_6Pose2d(::frc

                                  m_trajectoryTwo; + m_trajectoryOne = concatTraj auto
```

## Constraints Trajectory 30.6.2

when added were constraints custom no that noticed have might you ,*article previous* the In
on restrictions more impose to users allow constraints Custom trajectories. the generating
curvature. and location on based trajectory the along points at acceleration and velocity the

certain a under trajectory the of velocity the keep can constraint custom a example, For
purposes. stability for turns near robot the down slow or region certain a in threshold

### Constraints ProvidedWPILib-

generating when utilize can users that constraints predefined of set a includes WPILib
follows: as is constraints providedWPILib- of list The trajectories.

- robot the of acceleration centripetal the Limits :`CentripetalAccelerationConstraint`
  turns. tight around robot the down slow help can This trajectory. the along traverses it as
- around robot the of velocity the Limits :`DifferentialDriveKinematicsConstraint`
  maximum specified a over goes robot drivedifferential- a of wheel no that such turns
  velocity.
- drive differential a of acceleration the Limits :`DifferentialDriveVoltageConstraint`
  maximum. specified a over goes voltage commanded no that such robot
- the on region elliptical an in only constraint a Imposes :`EllipticalRegionConstraint`
  field.
- composed be can This constraint. velocity max a Imposes :`MaxVelocityConstraint`
  the limit to `RectangularRegionConstraint` or `EllipticalRegionConstraint` the with
  region. specific a in only robot the of velocity
- such turns around robot the of velocity the Limits :`MecanumDriveKinematicsConstraint`
  velocity. maximum specified a over goes robot drivemecanum- a of wheel no that
- on region rectangular a in only constraint a Imposes :`RectangularRegionConstraint`
  field. the
- such turns around robot the of velocity the Limits :`SwerveDriveKinematicsConstraint`
  velocity. maximum specified a over goes robot driveswerve- a of wheel no that

voltage theoretical that ensures only `DifferentialDriveVoltageConstraint` The :□□□□
robot the If .*model feedforward* a using maximum specified the over go not do commands
higher be may voltage commanded the tracking, while reference the from deviate to were
maximum. specified the than

### Constraint Custom a Creating

interface. `TrajectoryConstraint` the implementing by constraint own their create can Users

Java

```
                                                          @Override
      ␣double poseMeters, (Pose2dgetMaxVelocityMetersPerSecond double public
                                                curvatureRadPerMeter, ↩
{ velocityMetersPerSecond) double
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                   here code //
                                                              }

                                                      @Override
         poseMeters, (Pose2dgetMinMaxAccelerationMetersPerSecondSq MinMax public
     curvatureRadPerMeter, double
{ velocityMetersPerSecond) double
                                                   here code //
                                                              }
```

C++

```
                               (MaxVelocity meters_per_second_t::units
                       curvature, curvature_t::units pose, &Pose2d const
                        { override velocity) meters_per_second_t::units
                                                   here code //
                                                              }

      curvature, curvature_t::units pose, &Pose2d const(MinMaxAcceleration MinMax
                 { override speed) meters_per_second_t::units
                                                   here code //
                                                              }
```

given the for velocity allowed maximum the return should method MaxVelocity The The constraints. any without trajectory the of velocity original and curvature, pose, acceleration allowed maximum and minimum the return should method MinMaxAcceleration velocity. constrained and curvature, pose, given the for

on examples more for constraints providedWPILib- the for )C++ ,Java( code source the See constraints. trajectory custom own your write to how

### Trajectories Manipulating 30.6.3

certain using it from information retrieve can you generated, been has trajectory a Once trajectories. these follow to code writing when useful be will methods These methods.

#### trajectory the of duration total the Getting

take should it time of amount the point, each at timestamps have trajectories all Because / (C++) `TotalTime()` The determined.pre- is trajectory entire the traverse to robot a for traverse to takes it time the determine to used be can method (Java) `getTotalTimeSeconds()` trajectory. the

Java

```
              seconds in trajectory the of time total the Get //
             ();getTotalTimeSecondstrajectory. = duration double
```

C++

```
                       trajectory the of time total the Get //
            trajectory.TotalTime(); = duration second_t::units
```

### trajectory the Sampling

acceleration and velocity, pose, the get to timesteps various at sampled be can trajectory The `timeSeconds)` `sample(double` / (C++) `time)` `Sample(units::second_t` The point. that at to refers parameter The timestep. any at trajectory the sample to used be can method (Java) method This trajectory). the of point starting (the seconds 0 since passed time of amount the point. sample that about information with `Trajectory::Sample` a returns

Java

```
robot the where represents This seconds. 1.2 at trajectory the Sample //
traversal. of seconds 1.2 after be should //
);1.2(sampletrajectory. = point SampleTrajectory.
```

C++

```
robot the where represents This seconds. 1.2 at trajectory the Sample //
traversal. of seconds 1.2 after be should //
s);_1.2trajectory.Sample( = point State::Trajectory
```

point: sample the about information of pieces several has struct `Trajectory::Sample` The

- point. sample the to up trajectory the of beginning the from elapsed time The :`t`
- point. sample the at velocity The :`velocity`
- point. sample the at acceleration The :`acceleration`
- point. sample the at heading) y, (x, pose The :`pose`
- the along distance to respect with heading of change of (rate curvature The :`curvature` point. sample the at trajectory)

velocity the multiplying by calculated be can point sample the at velocity angular The Note: curvature. the by

### (advanced) trajectory the of states all Getting

`States()` the calling by trajectory the of states all of list a get can user advanced more A *the When* trajectory. the on point a represents state Each method. (Java) `getStates()` / (C++) method, `TrajectoryGenerator::GenerateTrajectory(...)` the using *created is trajectory* a at trajectory the samples user the When created. are states / points trajectory of list a states / points existing two between interpolated is point sample new a timestep, particular list. the in

## Trajectories Transforming 30.6.4

within moved and another to system coordinate one from transformed be can Trajectories methods These methods. `transformBy` the and `relativeTo` the using system coordinate a trajectory existing already an redefining or space, within trajectories moving for useful are reference. of frame another in

trajectory. original the of shape the changes methods these of Neither :□□□□

### Method `relativeTo` The

of frame another in trajectory existing already an redefine to used is method `relativeTo` The with defined is that object) `Pose2d` a (via pose, a argument: one takes method This reference. coordinate new the of origin the represents that system, coordinate current the to respect system.

coordinate in redefined be can A system coordinate in defined trajectory a example, For `relativeTo` the using A, system coordinate in degrees) 30 3, (3, at is origin whose B, system method.

Java

```
));30(fromDegreesRotation2d. ,3 ,3Pose2d( new = bOrigin Pose2d
(bOrigin);relativeToaTrajectory. = bTrajectory Trajectory
```

C++

```
deg)};_30Rotation2d(::frc m,_3 m,_3bOrigin{ Pose2d::frc
aTrajectory.RelativeTo(bOrigin); = bTrajectory Trajectory::frc
```

been has above) code the in `aTrajectory`( trajectory original the above, diagram the In at located axes, red The axes. black the by represented A, system coordinate in defined B. system coordinate represent system, coordinate original the to respect with 30° and 3) (3, to relative be to trajectory the in poses all redefine will `aTrajectory` on `relativeTo` Calling axes). (red B system coordinate

### Method `transformBy` The

a within trajectory a rotate) and translate (i.e. move to used be can method `transformBy` The object) `Transform2d` a (via transform a argument: one takes method This system. coordinate same the of position initial desired a to trajectory the of position initial current the maps that trajectory.

make to degrees) 30 2, (2, at begins that trajectory a transform to want may one example, For method. `transformBy` the using degrees) 50 4, (4, at begin it

Java

```
(trajectory.minus)).50(fromDegreesRotation2d. ,4 ,4Pose2d( new = transform Transform2d
                                                                   ());getInitialPose ↪
                     (transform);transformBytrajectory. = newTrajectory Trajectory
```

C++

```
      trajectory. - deg))_50Rotation2d( m,_4 m,_4Pose2d( = transform Transform2d::frc
                                                                      InitialPose(); ↪
                 trajectory.TransformBy(transform); = newTrajectory Trajectory::frc
```

blue. in visible is 30° at and 2) (2, at starts which trajectory, original the above, diagram the In
to changed is location starting trajectory’s resultant the above, transform the applying After
orange. in visible is trajectory resultant The 50°. at 4) (4,

### Ramsete בקר 30.6.5

be can tracker This WPILib. to in built is that tracker trajectory a is Controller Ramsete The disturbances. minor for correction with trajectories track accurately to used

#### Object Controller Ramsete the Constructing

values Larger `.zeta` and `b` namely gains, two with initialized be should controller Ramsete The of values larger whereas term proportional a like aggressive more convergence make `b` of the how dictate only gains controller These response. the in damping more provide `zeta` of tracking velocity actual the affect NOT does It velocities. adjusted output will controller agnostic.robot- generally are gains controller these that means This robot. the

---

produce to repeatedly tested been have `zeta` and `b` for `0.7` and `2.0` of Gains :□□□□ for constructor argumentzero- a such, As meters. in were units all when results desirable values. these to defaulted gains with exists `RamseteController`

---

Java

```
                   Here RamseteController. of constructor default the Using //
                                  0.7. and 2.0 to initialized are gains the //
                   RamseteController(); new = controller1 RamseteController

               where RamseteController of constructor secondary the Using //
                                 gains. other any choose can user the //
           );0.8 ,2.1RamseteController( new = controller2 RamseteController
```

C++

```
                   Here RamseteController. of constructor default the Using //
                                  0.7. and 2.0 to initialized are gains the //
                                  controller1; RamseteController::frc

               where RamseteController of constructor secondary the Using //
                                 gains. other any choose can user the //
                         ;}0.8 ,2.1controller2{ RamseteController::frc
```

#### Velocities Adjusted Getting

these tracks robot the when the that so velocities“ ”adjusted returns controller Ramsete The periodically updated be should controller The point. goal the reaches accurately it velocities, desired and velocity, linear desired pose, desired a of comprises goal The goal. new the with updated be also should robot the of position current the Furthermore, velocity. angular and linear adjusted the return to arguments four these uses controller The periodically. velocities angular and linear these to robot their command should Users velocity. angular tracking. trajectory optimal achieve to

---

particular a at be should robot the that position the represents pose“ ”goal The :□□□□ the of endpoint final the represent NOT does It trajectory. the tracking when timestep trajectory.

---

There method. (Java) `calculate` / (C++) `Calculate` the using updated be can controller The position robot current the accept overloads these of Both method. this for overloads two are goal the in takes overloads these of one parameters, other the For parameter. first the as other the whereas velocity) angular and velocity, linear (pose, parameters separate three as pose. goal the about information contains which object, `Trajectory.State` a accepts overload trajectories. tracking when method latter the use should users ease, its For

Java

```
     ␣3.4 at trajectory the sample // );3.4(sampletrajectory. = goal StateTrajectory.
                                                        beginning the from seconds ↪
        goal); (currentRobotPose,calculatecontroller. = adjustedSpeeds ChassisSpeeds
```

C++

```
␣at trajectory the sample // s);_3.4trajectory.Sample( = goal State::Trajectory const
                                                     beginning the from seconds 3.4 ↪
        goal); controller.Calculate(currentRobotPose, = adjustedSpeeds ChassisSpeeds
```

position robot updated an with iteration, loop every at performed be should calculations These goal. and

## Velocities Adjusted the Using

in velocity (linear vx a contains which ,`ChassisSpeeds` type of are velocities adjusted The (angular omega an and direction), sideways the in velocity (linear vy a direction), forward the controller a is controller Ramsete the Because frame). robot the of center the around velocity object speeds adjusted the sideways), move cannot which (robots robots holonomicnon- for zero. of vy a has

classes kinematics the using speeds usable to converted be can speeds adjusted returned The right and left to converted be can velocities adjusted the example, For type. drivetrain your for object. `DifferentialDriveKinematics` a using drive differential a for velocities

Java

```
        goal); (currentRobotPose,calculatecontroller. = adjustedSpeeds ChassisSpeeds
  (adjustedSpeeds);toWheelSpeedskinematics. = wheelSpeeds DifferentialDriveWheelSpeeds
                             ;leftMetersPerSecondwheelSpeeds. = left double
                           ;rightMetersPerSecondwheelSpeeds. = right double
```

C++

```
        goal); controller.Calculate(currentRobotPose, = adjustedSpeeds ChassisSpeeds
  kinematics.ToWheelSpeeds(adjustedSpeeds); = wheelSpeeds DifferentialDriveWheelSpeeds
                 kinematics.ToWheelSpeeds(adjustedSpeeds); = right] [left, auto
```

PID two voltages, not and speeds still are velocities right and left new these Because WPILib the Either velocities. these track to used be may side each for one Controllers, controllers motor smart on feature PID Velocity the or used, be can )Java ,C++( PIDController used. be can MAX SPARK the and TalonSRX the as such

### Framework BasedCommand- the in Ramsete

a For WPILib. to in built is class RamseteCommand a users, for ease of sake the For see RamseteCommand, using autonomous followingpath- a implementing on tutorial full *.Tutorial Trajectory*

## Controller Drive Holonomic 30.6.6

drivetrains holonomic with robots for tracker trajectory a is controller drive holonomic The with trajectories track accurately to used be can This etc.). mecanum, swerve, (e.g. disturbances. minor for correction

### Controller Drive Holonomic a Constructing

profiled 1 and controllers PID 2 with instantiated be should controller drive holonomic The controller. PID

---

*.WPILib □□ PID □□□□* see control, PID on information more For :□□□□

---

and x relativefield- the in error for correct should that controllers are controllers PID 2 The `0,` `PIDController(1,` are arguments 2 first the if example, For respectively. directions y an add will controller drive holonomic the respectively, `0)` `0,` `PIDController(1.2,` and `0)` and direction x the in error of meter every for direction x the in second per meter additional the in error of meter every for direction y the in second per meters 1.2 additional an add will direction. y

Because robot. the of rotation the for `ProfiledPIDController` a is parameter final The in movement from decoupled are drivetrain holonomic a of dynamics rotation the a following while references heading custom set can users directions, y and x the the in set parameters the to according profiled are references heading These trajectory. `.ProfiledPIDController`

Java

```
                          HolonomicDriveController( new = controller var
                  ),0 ,0 ,1PIDController( new ),0 ,0 ,1PIDController( new
                                     ,0 ,0 ,1ProfiledPIDController( new
                         )));3.14 ,6.28(ConstraintsTrapezoidProfile. new
             velocity max a were constraints profile rotation our Here, //
         degrees 180 of acceleration max a and second per rotation 1 of //
                                                     squared. second per //
```

C++

```
                                 controller{ HolonomicDriveController::frc
             ,}0 ,0 ,1PIDController{::frc2 ,}0 ,0 ,1PIDController{::frc2
                                  {>radian::units<ProfiledPIDController::frc
         Constraints{::>radian::units<TrapezoidProfile::frc ,0 ,0 ,1
                             s}}};_1 / rad_per_s_3.14 rad_per_s,_6.28
             velocity max a were constraints profile rotation our Here, //
         degrees 180 of acceleration max a and second per rotation 1 of //
                                                     squared. second per //
```

### Velocities Adjusted Getting

tracks robot the when that such velocities“ ”adjusted returns controller drive holonomic The
updated be should controller The point. goal the reaches accurately it velocities, these
and velocity, linear pose, desired a of comprised is goal The goal. new the with periodically
heading.

---

particular a at be should robot the that position the represents pose“ ”goal The :□□□□
endpoint. trajectory’s the represent NOT does It trajectory. the tracking when timestamp

---

There method. (Java) `calculate` / (C++) `Calculate` the using updated be can controller The
as position robot current the accept overloads these of Both method. this for overloads two are
parameters, middle the For parameter. last the as heading desired the and parameter first the
other the while reference velocity linear the and pose desired the accepts overload one
The pose. goal the about information contains which object, `Trajectory.State` a accepts
trajectories. tracking for preferred is method latter

Java

```
                    beginning. the from seconds 3.4 at trajectory the Sample //
                             );3.4(sampletrajectory. = goal StateTrajectory.

              facing be to robot the want we Here, speeds. adjusted the Get //
                   system). coordinate field-relative the (in degrees 70 //
                     (calculatecontroller. = adjustedSpeeds ChassisSpeeds
                   ));70.0(fromDegreesRotation2d. goal, currentRobotPose,
```

C++

```
                    beginning. the from seconds 3.4 at trajectoty the Sample //
                                  s);_3.4trajectory.Sample( = goal auto const

              facing be to robot the want we Here, speeds. adjusted the Get //
                   system). coordinate field-relative the (in degrees 70 //
                        controller.Calculate( = adjustedSpeeds auto const
                                        deg);_70 goal, currentRobotPose,
```

### Velocities Adjusted the Using

in velocity (linear vx a contains which ,`ChassisSpeeds` type of are velocities adjusted The
(angular omega an and direction), sideways the in velocity (linear vy a direction), forward the
frame). robot the of center the around velocity

kinematics the using speeds usable into converted be can speeds adjusted returned The
drive swerve a assume will we below, code example the In type. drivetrain your for classes
except robot drive mecanum a for same the exactly is code kinematics the however, robot;
.`MecanumDriveKinematics` using

Java

```
   (adjustedSpeeds);toSwerveModuleStateskinematics. = moduleStates ][SwerveModuleState

                                    ;]0[moduleStates = frontLeft SwerveModuleState
                                   ;]1[moduleStates = frontRight SwerveModuleState
```

page) next on (continues

([illegible])

```
;]2[moduleStates = backLeft SwerveModuleState
;]3[moduleStates = backRight SwerveModuleState
```

C++

```
kinematics.ToSwerveModuleStates(adjustedSpeeds); = br] bl, fr, [fl, auto
```

PID use to need will you angles, and speeds still are states module swerve these Because angles. and speeds these set to controllers

## פתרון בעיות 30.6.7

### פתרון כשלונות מוחלטים

[illegible]. [illegible]. [illegible].

- [illegible].
  - [illegible]?
  - [illegible] `MalformedSplineException` [illegible]-Driver? Station [illegible], [illegible] `MalformedSplineException` [illegible].
  - [illegible]?
- direction. other the facing trajectory the drive to around swings robot My
  - wrong? trajectory your of headings end and start the Are
  - heading? wrong the to reset getting gyro robot’s your Is
  - *incorrectly? set flag reverse the have you Do*
  - them. negate should you so, If positive? clockwise angles gyro your Are
- [illegible].
  - [illegible] (Gyro) [illegible]?
  - units? correct the with object odometry your to heading gyro your passing you Are
  - units? correct the in it Is correct? width track your Is
- `MalformedSplineException` [illegible]-Driver Station [illegible].
  - *incorrectly? set flag reverse the have you Do*
  - opposite approximately with together close very waypoints two have you Do headings?
  - coordinates? same) the nearly (or same the with waypoints two have you Do
- [illegible].
  - [illegible]?
  - [illegible]?
- [illegible], [illegible].
  - [illegible].

## Performance Poor Troubleshooting

tracking trajectory poor troubleshooting with concerned mostly is section This :□□□□
robots errors, compilation like failures catastrophic not error, of meter a like performance
s.`MalformedSplineException` or direction, wrong the in going and around turning

be can ideas the of most but robots, drive differential for designed is section This :□□□□
mecanum. or drive swerve to adapted

trajectory the Although troubleshoot. to difficult be can performance tracking trajectory Poor
are there box, the of out performant and useto-easy- be to intended are follower and generator
generator trajectory The should. it where up end quite doesn't robot your where situations
and followers have many knobs to tune and many moving parts, so it can be difficult to know
problems trajectory of source the locate to difficult is it because especially start, to where
behavior. general robot's the from

is that followers and generator trajectory the of layer the locate to hard so be can it Because
tracking poor general for recommended is approach layerby-layer- systematic, a misbehaving,
steps below The degrees). twenty than more or feet few by off is robot the (e.g. performance
that so order this follow to important is it in; them do should you that order the in listed are
other. each from steps different of effects the isolate can you

to way easiest The .*NetworkTables* onto values diagnostic put examples below The :□□□□
.*capabilities graphing Shuffleboard's use* to is values these graph

### Odometry Verify

modifies it because misbehave, may controller Ramsete your then bad, is odometry your If
is. robot the thinks odometry your where on based velocities target robot's your

is robot your that verify help can *field2d to trajectory and pose robot your Sending* :□□□□
trajectory. robot the to relative correctly driving

update: odometry each after position robot's your record to code your up Set .1

Java

```
          (getTable().getDefaultNetworkTableInstance. = m_xEntry NetworkTableEntry
                                         );"X"(getEntry)."troubleshooting" ↪
          (getTable().getDefaultNetworkTableInstance. = m_yEntry NetworkTableEntry
                                         );"Y"(getEntry)."troubleshooting" ↪

                                                                     @Override
                                                   { ()periodic void public
                            block periodic the in odometry the Update //
      m_leftEncoder. (getHeading()),fromDegrees(Rotation2d.updatem_odometry.
                                                          (),getDistance ↪
                                     ());getDistancem_rightEncoder.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                  ();getTranslation().getPoseMetersm_odometry. = translation var
                                        ());getX(translation.setNumberm_xEntry.
                                        ());getY(translation.setNumberm_yEntry.
                                                                              }
```

C++

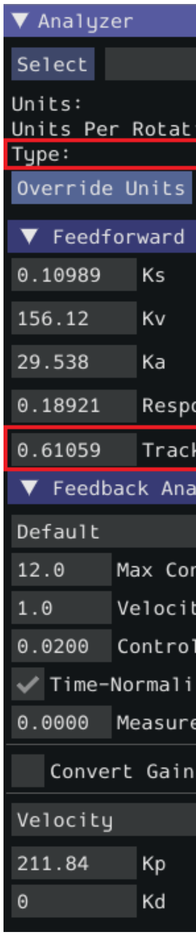
```
     GetDefault().GetTable(::NetworkTableInstance::nt = m_xEntry NetworkTableEntry
                                    );"X"GetEntry(>-)"troubleshooting" ↪
     GetDefault().GetTable(::NetworkTableInstance::nt = m_yEntry NetworkTableEntry
                                    );"Y"GetEntry(>-)"troubleshooting" ↪

                                         { ()DriveSubsystem::Periodic void
                     here. goes method periodic subsystem of Implementation //
                 degree_t(GetHeading())),::Rotation2d(units::m_odometry.Update(frc
                  meter_t(m_leftEncoder.GetDistance()),::units
                meter_t(m_rightEncoder.GetDistance()));::units

                        m_odometry.GetPose().Translation(); = translation auto
                             m_xEntry.SetDouble(translation.X().value());
                             m_yEntry.SetDouble(translation.Y().value());
                                                                              }
```

meter one about out robot your push and robot your to parallel measure tape a out Lay 2.
pushing over, start and axis Y the along measure tape a out Lay measure. tape the along
arc. rough a in axis Y the along meter one and axis X the along meter one robot your

than more by off is X If Y. and X actual to robot the by reported Y and X Compare 3.
wheel your measured you that check should you then test first the in centimeters 5
by off is test second the If down. worn not are wheels your that and correctly, diameter
center the from (distance width track your then Y or X either in centimeters 5 than more
you that sure you're if incorrect; be may wheel) right the of center the to wheel left the of
may wheels robot's your then measure tape a with correctly width track the measured
you then case the is this width–if track by for accounted not is that way a in slipping be
SysID in test (Angular)" "Drivetrain the using *identification width track the run* should
measure. tape your from one the of instead width track that use and



0.10989 Ks
156.12 Kv
29.538 Ka
0.18921 Respo
0.61059 Track
12.0 Max Con
1.0 Velocit
0.0200 Control
✓ Time-Normali
0.0000 Measure
211.84 Kp
0 Kd

### Feedforward Verify

as track not will robot the of side each for controllers P the then bad are feedforwards your If acceleration robot's your limit not will `DifferentialDriveVoltageConstraint` your and well, test and isolate can we that so controllers P wheel the off turn to want mostly We accurately. feedforwards. the

every for 0 to gain P the Set wheel. each for controller P the disable set must we First, 1.
0: to `kPDriveVel` set would you example, `RamseteCommand` the In controller.

Java

```
),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
),0 ,0 ,kPDriveVelPIDController(DriveConstants. new
```

C++

```
,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc2
```

isolate to easier it make to controller Ramsete the disable to want we Next, 2.
the on `setEnabled(false)` call simply so, do To behavior. problematic our
:`RamseteCommand` your into passed `RamseteController`

Java

```
                        RamseteController(); new = m_disabledRamsete RamseteController
                                                  );false(setEnabledm_disabledRamsete.

                                  variable disabledRamsete new your pass to sure Be //
                                   RamseteCommand( new = ramseteCommand RamseteCommand
                                                                exampleTrajectory,
                                                            m_robotDrive::getPose,
                                                                m_disabledRamsete,
                                                                               ...
                                                                                    );
```

C++

```
                                             m_disabledRamsete; RamseteController::frc
                                                  );falsem_disabledRamsete.SetEnabled(

                                  variable disabledRamsete new your pass to sure Be //
                                                  (ramseteCommand RamseteCommand::frc2
                                                                  exampleTrajectory,
                                             ,} m_drive.GetPose(); return { ]()this[
                                                                  m_disabledRamsete,
                                                                                 ...
                                                                                    );
```

put should (you velocity wheel actual and velocity wheel desired log to need we Finally, 3.
your if or Shuffleboard, using you’re if graph same the on velocities desired and actual
capability): that has software graphing

Java

```
            );"troubleshooting"(getTable().getDefaultNetworkTableInstance. = table var
                                 );"left_reference"(getEntrytable. = leftReference var
                             );"left_measurement"(getEntrytable. = leftMeasurement var
                               );"right_reference"(getEntrytable. = rightReference var
                           );"right_measurement"(getEntrytable. = rightMeasurement var

                             );0 ,0 PIDController(kPDriveVel, new = leftController var
                            );0 ,0 PIDController(kPDriveVel, new = rightController var
                                   RamseteCommand( new = ramseteCommand RamseteCommand
                                                                exampleTrajectory,
                                                            m_robotDrive::getPose,
                                  here disabledRamsete in Pass // disabledRamsete,
                       ␣kvVoltSecondsPerMeter, SimpleMotorFeedforward(ksVolts, new
                                                      kaVoltSecondsSquaredPerMeter), ↪
                                                                 kDriveKinematics,
                                                     m_robotDrive::getWheelSpeeds,
                                                                   leftController,
                                                                  rightController,
                                    callback the to volts passes RamseteCommand //
                                                      { >- rightVolts) (leftVolts,
                           rightVolts); (leftVolts,tankDriveVoltsm_robotDrive.

  );leftMetersPerSecond().getWheelSpeeds(m_robotDrive.setNumberleftMeasurement.
                        ());getSetpoint(leftController.setNumberleftReference.

                     ().getWheelSpeeds(m_robotDrive.setNumberrightMeasurement.
                                                              );rightMetersPerSecond ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                        ());getSetpoint(rightController.setNumberrightReference.
                                                                             ,}
                                                                   m_robotDrive
                                                                               );
```

C++

```
                                                                    = table auto
                ;"troubleshooting"GetDefault().GetTable(::NetworkTableInstance::nt
                                  );"left_reference"GetEntry(>-table = leftRef auto
                               );"left_measurement"GetEntry(>-table = leftMeas auto
                                );"right_reference"GetEntry(>-table = rightRef auto
                             );"right_measurement"GetEntry(>-table = rightMeas auto

                 );0 ,0 kPDriveVel,::(DriveConstantsleftController PIDController::frc2
                );0 ,0 kPDriveVel,::(DriveConstantsrightController PIDController::frc2
                                                 (ramseteCommand RamseteCommand::frc2
                          ,} m_drive.GetPose(); return { ]()this[ exampleTrajectory,
                                 kRamseteB,::RamseteController(AutoConstants::frc
                             kRamseteZeta),::AutoConstants
                                        (>meters::units<SimpleMotorFeedforward::frc
                   ka),::DriveConstants kv,::DriveConstants ks,::DriveConstants
                                                      kDriveKinematics,::DriveConstants
                       leftController, ,} m_drive.GetWheelSpeeds(); return { ]this[
                                                                   rightController,
                                                         { right) auto left, auto](=[
                                                      leftRef; = leftReference auto
                                                   leftMeas; = leftMeasurement auto
                                                    rightRef; = rightReference auto
                                                 rightMeas; = rightMeasurement auto

                                                  right); m_drive.TankDriveVolts(left,

              leftMeasurement.SetDouble(m_drive.GetWheelSpeeds().left.value());
                         leftReference.SetDouble(leftController.GetSetpoint());

            rightMeasurement.SetDouble(m_drive.GetWheelSpeeds().right.value());
                       rightReference.SetDouble(rightController.GetSetpoint());
                                                                             ,}
                                                                     m_drive});&{
```

if see to check and line), straight and (curved trajectories of variety a on robot the Run 4.
NetworkTables. from graphs at looking by velocity desired the tracks velocity actual the

diameter wheel the if check should you then *lot a* by off are actual and desired the If 5.
that verified you've If correct. were identification system for used you `encoderEPR` and
same the on recharacterizing try should you then correct, are conversions and units your
data. better get can you if see to on testing you're that floor

### Gain P Verify

can problem your then away went problem the and step previous the completed you If
wheel your that verify to going we're step this In steps. next the of one in found be probably
we that so Ramsete off turn to want we then Java using you're If tuned.well- are controllers P
own. their on controllers PF our view just can

1. velocity desired vs. actual logs that step previous the from code the all usere- must You
**must gain P the** that except Java), using you're if Ramsete, disables that code the (and
**value. nonzero previous its to back set be**
2. desired vs. actual your that check and trajectories, of variety a on again robot the Run
good. look graphs
3. desired) the from different very is velocity actual the (i.e. good look not do graphs the If
trajectories. test your rerunning and gain P your tuning try should you then

### Constraints Check

---

logging the have still you that and step this for nonzero is gain P your that sure Make **:□□□□**
to code the remove should you then Java using you're If steps. previous the in added code
Ramsete. disable

---

issue an have might you then steps previous the of all through persisted issue accuracy your If
constraints available different the that symptoms of list a are Below constraints. your with
tuned. poorly when exhibit will

remaining one your tune constraints, other the Remove time! a at constraint one Test
checklist below The use. to want you constraint each for process that repeat and constraint,
time. a at constraint one use only you that assumes

- `DifferentialDriveVoltageConstraint`:
  - this for voltage max the that possible it's then slowly very accelerates robot your If
    low. too is constraint
  - data identification system your then path the of end the reach doesn't robot your If
    problematic. may
- `DifferentialDriveKinematicsConstraint`:
  - drivetrain max the that possible it's then heading wrong the at up ends robot your If
    max the tune to is tell to way only The high. too it's that or low, too is speed side
    happens. what see to and speed
- `CentripetalAccelerationConstraint`:
  - your If culprit. the be could this then heading wrong the at up ends robot your If
    centripetal max the increase should you then enough turn to seem doesn't robot
    should you then quickly to turns tight around go to seems it if but acceleration,
    acceleration. centripetal maximum the decrease

### Waypoints Trajectory Check

(and waypoints moving Try  driveable. very not is itself trajectory your that possible is It
turns. sharp reduce to applicable) if waypoints, the at headings

## WPILib with Control Based Model and SpaceState- 30.7

control. spacestate- for support WPILib describes and to introduction an provides section This

### SpaceState- מבוא לבקרת 30.7.1

---

permission. with Veness Tyler by FRC in Engineering Controls from is article This :□□□□

---

#### מבקרת PID לבקרה מבוססת מודל

the to relating parameters controller with fiddling on focus we controllers, PID tuning When
states. system underlying the than rather terms) D and I (P, *error* future and past, current,
world. the of view incomplete an is it situations, of lot a in works approach this While

we (mechanism) *system* the of model accurate an developing on focuses control basedModel-
based controllers feedback for picked *gains* inform help models These control. to trying are
derived *gain* proportional arbitrary an than rather system, the of responses physical the on
but react, will system a how time of ahead predict to only not us allows This testing. through
bugs. simple debugging time save and robot physical a without controllers our test also

---

algebra linear on More  algebra. linear of use extensive makes control spaceState- :□□□□
be can resources, and algebra linear to introduction an including theory, control modern in
.FRC in Engineering Controls of 4 Chapter in found

---

classes, sister its or `SimpleMotorFeedforward` for classes feedforward WPILib's used you've If
control! basedmodel- with familiar already you're you, for *gains* PID pick to SysId used or
react will drivetrain) or arm, (or motor a how describe to used be can *gains* `ka` and `kv` The
WPILib's using notation spacestate- standard into constants these put can We  voltage. to
article. later a in do will we something ,`LinearSystem`

#### Vocabulary

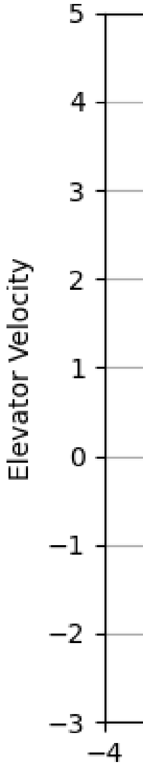
.*Glossary* the see article, this throughout used be will that vocabulary background the For

### Algebra Linear to Introduction

recommend we Algebra, Linear of concepts core the to introduction intuitive and short a For even what (Vectors, series algebra linear of Essence 3Blue1Brown's of 4 through 1 chapters matrices, and transformations Linear vectors, basis and span, combinations, Linear they?, are composition). as multiplication Matrix and

### Space?State- is What

pair a as space this within locations represent We y. and x axes: two has space 2D that Recall along move to far how of measure a is coordinate each and vector, a in packaged numbers of each for axis an with *system coordinate Cartesian* a is spaceState- axis. corresponding the a with space: 2D for do we way same the it within locations represent we and variable, state system. the of state a to corresponds vector the in element Each vector. a in numbers of list with model elevator an of spacestate- the in vectors state example two shows example This :$[\text{position}, \text{velocity}]$ states the



these on now From arrows. are spacestate- in states representing vectors the image, this In rest the that remember but tip, vector's the at point a by simply represented be will vectors there. still is vector the of

mapping the Since vectors. as represented are *outputs* and *inputs* ,*state* the to addition In natural it's equations, of system a is state in change the to inputs and states current the from notation. spacestate- in written be can equation matrix This form. matrix in it write to

### Notation? SpaceState- is What

over evolve will system a how describe which equations matrix of set a is notation spaceState- combinations linear to ,$\mathbf{y}$ *output* the and ,$\dot{\mathbf{x}}$ state in change the relate equations These time. .$\mathbf{u}$ vector *input* and $\mathbf{x}$ vector state current the of

the In systems. timediscrete- and timecontinuous- with deal can control spaceState- linear a as expressed is $\mathbf{x}$ state system's the of change of rate the case, timecontinuous- .$\mathbf{u}$ input and $\mathbf{x}$ state current the of combination

$\mathbf{x}_{k+1}$ timestep next our at system the of state the expresses systems timediscrete- contrast, In the is $k+1$ and timestep current the is $k$ where ,$\mathbf{u}_k$ input and $\mathbf{x}_k$ state current the on based timestep. next

linear a as expressed is $\mathbf{y}$ vector *output* the forms, timediscrete- and continuous- the both In the of subset a is output the cases, many In .*input* and *state* current the of combination input. current the from contribution no has and state, system's

the because representation timecontinuous- the derive first we systems, modeling When linear a as state system's a of change of rate the as written naturally are motion of equations on timediscrete- to representation this convert We inputs. and state current its of combination continuously. of instead there timesteps discrete in system the update we because robot the

discrete- and timecontinuous- of form standard the are equations of sets two following The notation: spacestate- time

$$
\begin{aligned}
\text{Continuous:}\dot{\mathbf{x}} &= \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u} \\
\mathbf{y} &= \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u}
\end{aligned}
$$

$$
\begin{aligned}
\text{Discrete:}\mathbf{x}_{k+1} &= \mathbf{A}\mathbf{x}_k + \mathbf{B}\mathbf{u}_k \\
\mathbf{y}_k &= \mathbf{C}\mathbf{x}_k + \mathbf{D}\mathbf{u}_k
\end{aligned}
$$

| | | | |
|---|---|---|---|
| $\mathbf{A}$ | matrix system | $\mathbf{x}$ | vector state |
| $\mathbf{B}$ | matrix input | $\mathbf{u}$ | vector input |
| $\mathbf{C}$ | matrix output | $\mathbf{y}$ | vector output |
| $\mathbf{D}$ | matrix feedthrough | | |

through system timediscrete- a into converted be can system spacestate- timecontinuous- A discretization. called process a

---

This updates. between constant held is state system's the form, timediscrete- the In :□□□□ updated. is estimate state our as quickly as disturbances to react only can we that means WPILib's point. a to up performance, improve help can quickly more estimate our Updating desired. are loop robot main the than faster updates if used be can class `Notifier`

---

the have D and C, B, A, matrices timediscrete- and timecontinuous- system's a While :□□□□ of rate the describes matrices timecontinuous- The equivalent. not are they names, same the at state system's the describe matrices timediscrete- the while ,$\mathbf{x}$ state, the of change next timestep as a function of the current state and input.

---

them converts and matrices, system timecontinuous- takes LinearSystem WPILib's :□□□□ necessary. where form timediscrete- the to internally

---

### Ka and Kv from Flywheel Example: Notation spaceState-

the with motor DC brushed a to connected flywheel a of motion the model can we that *Recall* a and velocity angular flywheel's the is v output, voltage is V where ,$V = K_v \cdot v + K_a \cdot a$ equation .$a = \frac{-K_v}{K_a} \cdot v + \frac{1}{K_a} \cdot V$ or ,$a = \frac{V - K_v \cdot v}{K_a}$ as rewritten be can equation This acceleration. angular its is its to flywheel the of acceleration angular the relates equation This familiar? anything Notice applied. voltage the and velocity angular

state one with system a create can We notation. spacestate- to equation this convert can We derivative first the that Recalling (velocity). *output* one and (voltage), *input* one (velocity), ,**x** with velocity replacing follows, as equation our write can we acceleration, is velocity of :**u** with **V** voltage and ,**x** with acceleration

$$\mathbf{x} = \left[\frac{-K_v}{K_a}\right]\mathbf{x} + \left[\frac{1}{K_a}\right]\mathbf{u}$$

following: the is equation output the so same, the are state and output The

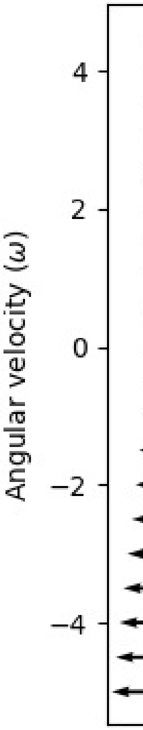
$$\mathbf{y} = \left[1\right]\mathbf{x} + \left[0\right]\mathbf{u}$$

constants. $K_a$ and $K_v$ the have we which for system a of model spacestate- the That's it! That's velocity drivetrain and flywheels model to identification system in used is math same This systems.

### Portrait Phase Responses: SpaceState- Visualizing

space.state- in system a of response the for intuition visual a give help can *portrait phase* A the in point and space,state- in **x** point some at roots their have graph the on vectors The a shows example This time. over evolve will system the that direction the ,**x** of direction velocity. angular and angle of states the with pendulum a of model

to point a choose space,state- through take could system a that trajectory potential a trace To there, From .$[-2, 0]$ at start might we example, this In around. arrows the follow and at start the reach we until decrease to starts and vertical through swing we as increases velocity the indefinitely. repeats origin the about spinning of cycle This swing. the of extreme opposite



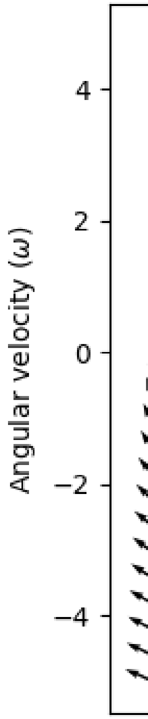
$\pi$ of rotation a as around wraps axis X the portrait, phase the of edges the near that Note point. same the at end will clockwise radians $\pi$ of rotation a and clockwise counter radians

Differential 3Blue1Brown's see portraits, phase and equations differential on more For around at space phase pendulum the animating of job great a do they – video Equations 15:30.

### Feedforward Visualizing

if react will it how is, that – system the of responses loop“ ”open the shows portrait phase This horizontal pendulum the balance say, to, want we If naturally. evolve state the let to were we the counteract to *input* control a apply somehow to need would we space), state in $(\frac{\pi}{2}, 0)$ (at trying is feedforward what is This downward. swing to pendulum the of tendency loop open position *reference* the at equilibrium an have will portrait phase our that so it make – do to space.state- in setpoint) (or

gravity space, state in $(\frac{\pi}{2}, 0)$ at that see can we before, from portrait phase our at Looking angular downward some producing and T, *torque* some with down pendulum the pulling is we If pendulum. the of *inertia of moment* angular is I where ,$\frac{\tau}{I}$ magnitude with acceleration can *input* an apply to need would we ,$(\frac{\pi}{2}, 0)$ of *reference* our at equilibrium an create to want the solve to is here goal The downward. swing to tendency natural system's the counteract *input* constant a apply we where portrait phase a shown is Below .$\mathbf{u}$ for $\mathbf{0} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$ equation :$(\frac{\pi}{2}, 0)$ at gravity of force the opposes that



### Control Feedback

states current all of knowledge and model mathematical a just with motor, DC a of case the In voltage future the given states future all predict can we velocity), angular (i.e., system the of like equations, our by modeled isn't that way any in disturbed is system the if But inputs. model the from deviate will motor the of velocity angular the friction, unexpected or load a feedback a using commands corrective motor the give can we this, combat To time. over controller.

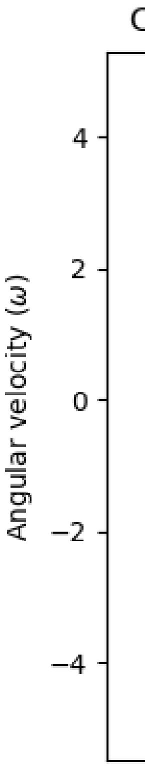
following the uses often control spaceState- control. feedback of form a is controller PID A the is $\mathbf{x}$ and state, *reference* the is $\mathbf{r}$ matrix, *gain* controller some is $\mathbf{K}$ where ,*law control* .*error* the is ,$\mathbf{r} - \mathbf{x}$ vectors, two these between difference The space.state- in state current

$$\mathbf{u} = \mathbf{K}(\mathbf{r} - \mathbf{x})$$

Proportional system. our of state each for controller proportional a is *law control* This reference our toward state system's our pull that springs definedsoftware- create controllers velocity and position has controlled being system the that case the In space.state- in state position drive to tries also which controller, PD a as behave will above *law control* the states, zero. to error velocity and

from system pendulum the use We'll action. in law control this of example an show Let's $\mathbf{K}$ where case The space.state- in origin the circled pendulum swinging the where above, no – zero of gains D and P picking like be would zeros) all with matrix (a matrix zero the is above. one the to identical look would portrait phase the and applied, be would *input* control

is pendulum the to *input* our where 2], [2, of **K** a pick arbitrarily we feedback, some add To angular the ,*error* position of radian every for that mean would K This acceleration. angular per radians 2 by accelerate we similarly, squared; second per radians 2 be would acceleration somewhere from arrow an following Try .*error* of second per radian every for squared second *reference* the at settle will state the conditions, initial the matter no – inwards spacestate- in feedforward. pure with endlessly circle than rather



manually can we While system? our for K matrix *gain* optimal an choose we can how But controller, PID a like roboton- it tune or response system the simulate and *gains* choose (LQR). Regulator QuadraticLinear- the answer: better a has theory control modern

## Regulator QuadraticLinear- The

an given system a of states future the predict can we that means control basedmodel- Because matrix *gain* optimal mathematically a pick can we inputs, control future and condition initial do We like. look would **K** ”bad“ or ”good“ a what define to have first we this, do To .**K** number a us gives which time, over input control and error of square the summing by this arrived have will we sum, this minimize we If be. will law control our ”bad“ how representing law. control optimal the at

### Definition LQR:

cost following the minimizes that *law control* a finding by work Regulators QuadraticLinear-
linear the to subject time, over *effort control* and *error* of sum the weights which function,
.$\mathbf{x_{k+1}} = \mathbf{A}\mathbf{x_k} + \mathbf{B}\mathbf{u_k}$ dynamics *system*

$$J = \sum_{k=0}^{\infty} \left(\mathbf{x}_k^T \mathbf{Q} \mathbf{x}_k + \mathbf{u}_k^T \mathbf{R} \mathbf{u}_k\right)$$

.*error* the is $r_k - x_k$ where ,$\mathbf{u} = \mathbf{K}(\mathbf{r_k} - \mathbf{x_k})$ as written be can $\mathbf{J}$ minimizes that *law control* The

---

for calculated **K** the but discretization, need don't matrices **R** and **Q** design's LQR :□□□□
different. be will *systems* time discrete and timecontinuous-

---

### tuning LQR:

our how change to want also we gains, their adjusting by tuned be can controllers PID Like
minimize to want might spaceship a example, For input. and error our balances law control
to need might arm robotic speedhigh- a while reference, given a reach to expends it fuel the
disturbances. to quickly react

function cost our In matrices. **R** and **Q** with LQR our in effort control and error weight can We
and error our weight **R** and **Q** perform), will law control our "bad" how describes (which
**Q** a use might we above, from example spaceship the In other. each to relative input control
our while error, penalize highly to want don't we that show to numbers small relatively with
undesirable. is fuel expending that show to large be might **R**

control and excursions state maximum desired of vector a takes class LQR the WPILib, With
use often We rule. Bryson's with matrices R and Q full to internally them converts and efforts
matrices. the to refer to **R** and **Q** and vectors, these to refer to **r** and **q** lowercase

the and errors, large weight heavily less LQR the make would elements **q** the Increasing
penalizing to effect similar a has This conservatively. more behave will *law control* resulting
elements. 's**r** decreasing by heavily more *effort control*

heavily, more errors large penalize LQR the make would elements **q** the decreasing Similarly,
to effect similar a has This aggressively. more behave will *law control* resulting the and
elements. **r** increasing by heavily less *effort control* penalizing

and position with system elevator an for R and Q following the use might we example, For
states. velocity

Java

```
                             robot. your match to changed be must -- system Example //
0.  ,5(identifyPositionSystemLinearSystemId. = elevatorSystem >N1 N1, N2,<LinearSystem
                                                                                  );5 ↪
                                ␣new = controller >N1 N1, N2,<LinearQuadraticRegulator
                                            LinearQuadraticRegulator(elevatorSystem, ↪
                                                                      elements s'q //
                                                          ),0.4  ,0.02(fillVecBuilder.
                                                                      elements s'r //
                                                               ),12.0(fillVecBuilder.
                                                                            dt our //
                                                                              );0.020
```

C++

```
                            robot. your match to changed be must -- system Example //
,5IdentifyVelocitySystem(::LinearSystemId::frc = elevatorSystem >1 ,1 ,2<LinearSystem
                                                                              );0.5 ↪
                                          controller{ >1 ,2<LinearQuadraticRegulator
                                                                    elevatorSystem,
                                                                    elements s'q //
                                                                       ,}0.4 ,0.02{
                                                                    elements s'r //
                                                                            ,}12.0{
                                                                          dt our //
                                                                          s};_0.020
```

### application example LQR:

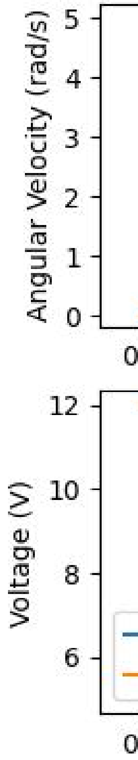
flywheel a have we Say example. worldreal- a to Regulator QuadraticLinear- a apply Let's
and $K_v = 1 \frac{\text{volts}}{\text{second per radian}}$ have to identification system through determined system velocity
linear following the have we above, example flywheel the Using .$K_a = 1.5 \frac{\text{volts}}{\text{squared second per radian}}$
:*system*

$$\mathbf{x} = \left[\frac{-K_v}{K_a}\right] v + \left[\frac{1}{K_a}\right] V$$

an and ,$q = [0.1$ rad/sec$]$ of error) (maximum excursion state desired a choose arbitrarily We
K This .$\mathbf{K} = \ 81$ of *gain* a find we 20ms, of timestep a with discretization After .$[12$ volts$]$ of $\mathbf{r}$
velocity. flywheel's on loop PID a of component proportional the as acts *gain*

elements $\mathbf{r}$ the decreasing or elements q the increasing that know We .$\mathbf{r}$ and $\mathbf{q}$ adjust Let's
,*effort control* penalize heavily more controller our make would $\mathbf{R}$ and $\mathbf{Q}$ create to use we
if fact, In economy. fuel improve to conservatively more car a driving to trying to analogous
~11. to ~81 from drops $\mathbf{K}$ matrix *gain* our 1.0, to 0.1 from q tolerance *error* our increase we
.$\mathbf{K}$ decreases 1.2 to 12.0 from $r$ voltage maximum our decreasing Similarly,

with time over voltage applied and velocity angular flywheel's the shows graph following The
reference the reach system the make will *gain* higher a how see can We s.*gain* different two
This longer. for 12V at saturated motor our keeping while seconds), 0.8 = t (at quickly more
~8x. of factor a by controller PID a of gain P the increasing as same the exactly is



### Compensation Latency Measurement and LQR

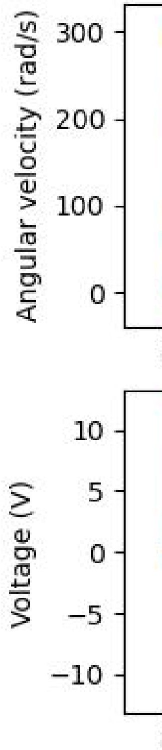
the example For measurements. their with associated delay a have sensors our Oftentimes, velocity with associated delay of 30ms to up have can CAN over controller motor MAX SPARK measurements.

based commands voltage generating be will controller feedback our that means lag This and instability introducing of effect the has often This past. the from estimates state on below. graph the in shown as system, our into oscillations

into delayed is *state* system's the where control to controller our model can we However, for performance controller off trading ,**K** matrix *gain* LQR's the reduce will This future. the used also is delay, for account to matrix *gain* the adjusts which formula, below The stability. identification. system in

$$\mathbf{K}_{\mathbf{compensated}} = \mathbf{K} \cdot (\mathbf{A} - \mathbf{BK})^{\text{delay}/dt}$$

we case, this In timestep. one by gains the advances essentially $\mathbf{A} - \mathbf{BK}$ by $\mathbf{K}$ Multiplying delay. measurement's by gains the advance to $(\mathbf{A} - \mathbf{BK})^{\text{delay}/dt}$ by multiply



control. feedback disabling effectively zero, to **K** reducing of effect the have can This **:□□□□**

and 19.5ms, of delay a with filter FIR tap40- a uses controller motor MAX SPARK The **:□□□□** 20ms. every sent default by are frames status

delays: input sensor for gain K controller’s LQR the adjust to how shows below code The

Java

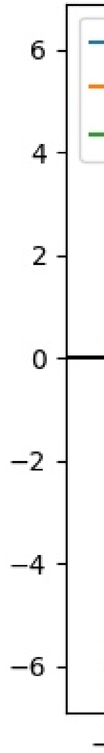
```
We delay. input sensor of ms 25 for controller s'LQR our Adjust //
sensor the and timestep, discretization system, linear the provide //
arguments. as delay input //
);0.025 ,0.02 (elevatorSystem,latencyCompensatecontroller.
```

C++

```
We delay. input sensor of ms 25 for controller s'LQR our Adjust //
sensor the and timestep, discretization system, linear the provide //
arguments. as delay input //
ms);_25 ms,_20 controller.LatencyCompensate(elevatorSystem,
```

## Linearization

using systems spacestate- and functions nonlinear approximate to used tool a is Linearization
nonlinear while lines straight are functions linear space, dimensionaltwo- In ones. linear
linear corresponding its and function nonlinear a of example common A curve. functions
This zero. near $y = x$ by approximated be can function This .$y = \sin x$ is approximation
the from further stray we as accuracy looses but ,$x = 0$ near while accurate is approximation
within 0.02 within to accurate is $\sin x \approx x$ approximation the example, For point. linearization
see we picture, following the In that. past accuracy loses quickly but ,$y = 0$ of radians 0.5
.$x$ at $\sin x$ of value true the and approximation the between difference the and $y = x$ ,$y = \sin x$



a picking by this do We .*dynamics* nonlinear with systems spacestate- linearize also can We
above the in Like functions. nonlinear our to input the as this using and spacestate- in $\mathbf{x}$ point
but linearized, was system the which about point the near states for well works this example,
state. that from further diverge quickly can

## 30.7.2 State-Space Controller Walkthrough

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□□□□: Before following this tutorial, readers are recommended to have read an □□□□ □□□□□ State-Space.

---

The goal of this tutorial is to provide “end-to-end” instructions on implementing a state-space controller for a flywheel. By following this tutorial, readers will learn how to:

1. Create an accurate state-space model of a flywheel using *system identification* or CAD software.
2. Implement a Kalman Filter to filter encoder velocity measurements without lag.
3. Implement a *LQR* feedback controller which, when combined with model-based feedforward, will generate voltage *inputs* to drive the flywheel to a *reference*.

This tutorial is intended to be approachable for teams without a great deal of programming expertise. While the WPILib library offers significant flexibility in the manner in which its state-space control features are implemented, closely following the implementation outlined in this tutorial should provide teams with a basic structure which can be reused for a variety of state-space systems.

The full example is available in the state-space flywheel (Java/C++) and state-space flywheel system identification (Java/C++) example projects.

### Why Use State-Space Control?

Because state-space control focuses on creating an accurate model of our system, we can accurately predict how our *model* will respond to control *inputs*. This allows us to simulate our mechanisms without access to a physical robot, as well as easily choose *gains* that we know will work well. Having a model also allows us to create lagless filters, such as Kalman Filters, to optimally filter sensor readings.

### Modeling Our Flywheel

*Recall* that continuous state-space systems are modeled using the following system of equations:

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$$
$$\mathbf{y} = \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{u}$$

Where *x-dot* is the rate of change of the *system*’s *state*, $\mathbf{x}$ is the system’s current state, $\mathbf{u}$ is the *input* to the system, and $\mathbf{y}$ is the system’s *output*.

Let’s use this system of equations to model our flywheel in two different ways. We’ll first model it using *system identification* using the SysId toolsuite, and then model it based on the motor and flywheel’s *moment of inertia*.

The first step of building up our state-space system is picking our system’s states. We can pick anything we want as a state – we could pick completely unrelated states if we wanted – but it helps to pick states that are important. We can include *hidden states* in our state (such as elevator velocity if we were only able to measure its position) and let our Kalman Filter estimate their values. Remember that the states we choose will be driven towards their

*Regulator QuadraticLinear-* the (typically controller feedback the by *references* respective optimal). it's since

also to chose could we While velocity. its state: one about only care we flywheel, our For system. our for necessary isn't state this of inclusion the acceleration, its model

put can we things as of thought be can Inputs system. our to *inputs* the identify we Next, single- other many (and flywheel the of case the In state. its change to system our ”into“ By motor. the to applied voltage input: one just have we FRC®), in mechanisms jointed for compensate can we cycle), duty motor like something (over input our as voltage choosing increases. load battery as sag voltage battery

the of change of rate instantaneous the or ,*dotx-* writes system spacestate- timecontinuous- A is state our Because .*inputs* and *state* current the to proportional as state, 's*system* system's acceleration. angular flywheel's the be will **x** velocity, angular

WPILib's system. spacestate- timecontinuous- a as flywheel our model will we Next, for *notation spacestate-* Review internally. timediscrete- to this convert will `LinearSystem` systems. timediscrete- and timecontinuous- on more

## Identification System with Modeling

flywheel the from recall we ,*identification system* using notation spacestate- in this rewrite To .**a** of terms in equation following the rewrote we where ,*example notation spacestate-*

$$V = kV \cdot \mathbf{v} + kA \cdot \mathbf{a}$$
$$\mathbf{a} = \dot{\mathbf{v}} = \left[\frac{-kV}{kA}\right] v + \left[\frac{1}{kA}\right] V$$

Rewriting voltage. is $V$ and acceleration, flywheel are $\dot{\mathbf{v}}$ and **a** velocity, flywheel is **v** Where find: we vector, input the for **u** and vector state the for **x** of convention standard the with this

$$\mathbf{x} = \left[\frac{-kV}{kA}\right] \mathbf{x} + \left[\frac{1}{kA}\right] \mathbf{u}$$

the to *inputs* and *state* current system's the relates notation spacestate- of part second The measure) can sensors our that things (or **y** vector output our flywheel, a of case the In .*output* Therefore, .**x** vector *state* our of element an be to happens also which velocity, flywheel's our is out this Writing .$\mathbf{D} = [0]$ is matrix feedthrough system our and ,$\mathbf{C} = [1]$ is matrix output our following. the yields notation spacestate- timecontinuous- in

$$\mathbf{x} = \left[\frac{-kV}{kA}\right] \mathbf{x} + \left[\frac{1}{kA}\right] \mathbf{u}$$
$$\mathbf{y} = [1]\, \mathbf{x} + [0]\, \mathbf{u}$$

identified systems spacestate- creating easily for methods contains class `LinearSystem` The a and 0.023 of kV a with model flywheel a shows example This .*identification system* using 0.001: of kA

Java

```
                                     second) per (radian per Volts //
                   ;0.023 = kFlywheelKv double final static private

                             squared) second per (radian per Volts //
                   ;0.001 = kFlywheelKa double final static private

  ␣the has system This flywheel. our of model state-space a holds plant The //
                                                    properties: following ↪
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                                     //
                                      second. per radians in [velocity], States: //
                             volts. in [voltage], in"): put" can we (what Inputs //
                    second. per radians in [velocity], measure): can we (what Outputs //
                                                                     //
      toolsuite. Characterization FRC the using found are constants Ka and Kv The //
                                    = m_flywheelPlant >N1 N1, N1,<LinearSystem final private
                    kFlywheelKa); (kFlywheelKv,identifyVelocitySystemLinearSystemId.
```

C++

```
                                    frc/system/plant/LinearSystemId.h>< include#
```

```
                                                  second) per (radian per Volts //
                    rad_per_s;_1 / V_0.023 = kFlywheelKv auto constexpr static

                                          squared) second per (radian per Volts //
                  rad_per_s_sq;_1 / V_0.001 = kFlywheelKa auto constexpr static

       the has system This flywheel. our of model state-space a holds plant The //
                                                           properties: following //
                                                                     //
                                      second. per radians in [velocity], States: //
                             volts. in [voltage], in"): put" can we (what Inputs //
                    second. per radians in [velocity], measure): can we (what Outputs //
                                                                     //
      toolsuite. Characterization FRC the using found are constants Ka and Kv The //
                                           = m_flywheelPlant >1 ,1 ,1<LinearSystem::frc
     (kFlywheelKv,>radian::units<IdentifyVelocitySystem::LinearSystemId::frc
    kFlywheelKa);
```

### Gearing and Inertia of Moment Flywheel Using Modeling

the about information using robot, physical a to access without modeled be also can flywheel A presented is model this of derivation full A .*inertia of moment* flywheel's and gearing motors, .FRC in Engineering Controls of 8.2.1 Section in

the from flywheel a of model a create easily to methods contains class `LinearSystem` The calculated be can inertia of moment The .*inertia of moment* and gearing motors, flywheel's flywheel the in detailed are here used examples The physics. using or software CAD using ).C++/Java( project example

if is, that – input over output as written is gearing classes, spacestate- WPILib's For :□□□□
one. than greater be should number this motors, the than slower spins flywheel the

and mixups unit prevent to *Library Units C++ the* uses class LinearSystem C++ The :□□□□
dimensionality. assert

Java

```
m^2 * kg // ;0.00032 = kFlywheelMomentOfInertia double final static private

␣flywheel the If input. over output as encoder, and motors between Reduction //
                                                            than slower spins ↪
                          one. than greater be should number this motors, the //
                                   ;1.0 = kFlywheelGearing double final static private

␣the has system This flywheel. our of model state-space a holds plant The //
                                                        properties: following ↪
                                                                             //
                                   second. per radians in [velocity], States: //
                          volts. in [voltage], in"): put" can we (what Inputs //
              second. per radians in [velocity], measure): can we (what Outputs //
                         = m_flywheelPlant >N1 N1, N1,<LinearSystem final private
                                         (createFlywheelSystemLinearSystemId.
          kFlywheelGearing); kFlywheelMomentOfInertia, ),2(getNEODCMotor.
```

C++

```
frc/system/plant/LinearSystemId.h>< include#
```

```
= kFlywheelMomentOfInertia kilogram_square_meter_t::units constexpr static
                                                            kg_sq_m;_0.00032

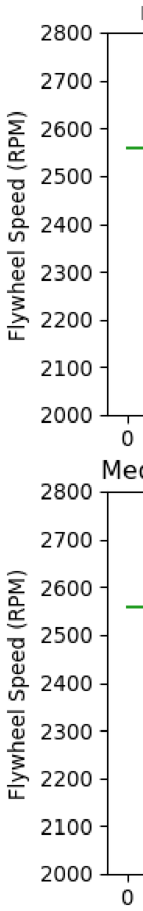
flywheel the If input. over output as encoder, and motors between Reduction //
      one. than greater be should number this motors, the than slower spins //
                                  ;1.0 = kFlywheelGearing double constexpr static

the has system This flywheel. our of model state-space a holds plant The //
                                                      properties: following //
                                                                             //
                                   second. per radians in [velocity], States: //
                          volts. in [voltage], in"): put" can we (what Inputs //
              second. per radians in [velocity], measure): can we (what Outputs //
                                      = m_flywheelPlant >1 ,1 ,1<LinearSystem::frc
                                           FlywheelSystem(::LinearSystemId::frc
        kFlywheelGearing); kFlywheelMomentOfInertia, ),2NEO(::DCMotor::frc
```

### State Flywheel Observing Filters: Kalman

to model spacestate- our using measurements velocity our filter to used are filters Kalman filter Kalman a use can we linear, is model flywheel our As .$\hat{x}$ estimate state a generate we (which LinearSystem a takes filter Kalman WPILib's velocity. flywheel's the estimate to can We measurements. sensor and model of deviations standard with along above), found standard state Larger weights. these adjusting by is estimate state our "smooth" how adjust measurements new favor and estimate state our "distrust" to filter the cause will deviations opposite. the do will deviations standard measurement larger while highly, more

measurement a and rad/s 3 of deviation standard state a with start we flywheel a of case the In weights these – choose to user the to up are values These rad/s. 0.01 of deviation standard to reacted quickly estimate state whose but noise some to tolerant was that filter a produced well behaves that filter a create to tuned be should and – flywheel *a* for disturbances external outputs and references, inputs, measurements, states, Graphing flywheel. specific your for filters. Kalman tune to way visual great a is time over



*filter IIR polesingle-* a as well as filters, Kalman tuned differently two shows graph above The four and seconds, ~5 over shooter a with collected was data This .*Filter Median* a and are there While velocity). in dips four the in seen (as shooter the through run were balls in should they deviations, standard measurement and state good choosing on rules hard no external to quickly reacting while noise reject to enough model the trust to tuned be general disturbances.

Kalman the by estimated *hatx-* the using error computes controller feedback the Because estimate state filter's the quickly as only disturbances to react will controller the filter, and 3.0 of deviation standard state a (with plot left upper the chart, above the In changes. disturbances to quickly reacted that filter a produced 0.2) of deviation standard measurement the by affected barely was that filter a shows plot right upper the while noise, rejecting while dips. velocity

Java

```
          noise. reject to inputs voltage and data encoder our fuses observer The //
                                  = m_observer >N1 N1, N1,<KalmanFilter final private
                                                            (><KalmanFilter new
                                                                  (),N1Nat.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                        (),N1Nat.
                                                 m_flywheelPlant,
          is model our think we accurate How // ),3.0(fillVecBuilder.
           encoder our think we accurate How // ),0.01(fillVecBuilder.
                                                        is data //
                                                          );0.020
```

C++

```
                          frc/estimator/KalmanFilter.h>< include#
```

```
  noise. reject to inputs voltage and data encoder our fuses observer The //
                                        m_observer{ >1 ,1 ,1<KalmanFilter::frc
                                                          m_flywheelPlant,
                              is model our think we accurate How //   ,}3.0{
                       is data encoder our think we accurate How //  ,}0.01{
                                                                  ms};_20
```

that important is it ,*step Predict* the in model spacestate- our use filters Kalman Because input flywheel's a record to is this verify to way One possible. as accurate as is model our Kalman the on `predict` only calling by data this replay and time, over velocity and voltage adjusted be can constants) other and inertia of moment (or gains kA and kV the Then, filter. data. recorded the matches closely model the until

### Feedforward Inversion Plant and Regulators QuadraticLinear-

to *system* flywheel our drive to controller feedback a finds *Regulator QuadraticLinear- The* will LQR our by picked law control the state, one just has flywheel our Because .*reference* its picked law control the words, other in matrix; 1x1 a is $\mathbf{K}$ where $\mathbf{u} = \mathbf{K}(\mathbf{r} - \mathbf{x})$ form the in be gain This gain. P a only with controller PID a or controller, proportional a simply is LQR by on More it. pass we efforts control and excursion state the on based LQR our by chosen is .*example application LQR* the in found be can controllers LQR tuning

inputs voltage feedforward generate to used be can `SimpleMotorFeedforward` like Much *feedforward* generate class Feedforward Inversion Plant the constants, kA and kV, kS, given the by generated commands voltage The system. spacestate- a given inputs voltage inputs. feedback and feedforward the of sum the are class `LinearSystemLoop`

Java

```
                              commands. voltage create to feedback uses LQR A //
                 = m_controller >N1 N1, N1,<LinearQuadraticRegulator final private
                                                (><LinearQuadraticRegulator new
                                                           m_flywheelPlant,
   ␣per radians in tolerance, error Velocity qelms. // ),8.0(fillVecBuilder.
                                                            Decrease second. ↪
   ␣controller the make or excursion, state penalize heavily more to this //
                                                                 more behave ↪
                                                            aggressively. //
       ␣tolerance. (voltage) effort Control relms. // ),12.0(fillVecBuilder.
                                                         more to this Decrease ↪
 ␣aggressive. less controller the make or effort, control penalize heavily //
                                                                  good a is 12 ↪
    ␣a of voltage maximum (approximate) the is that because point starting //
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                      battery. ↪
  be can but TimedRobot, for 0.020 loops. between time Nominal // );0.020
                                           notifiers. using if lower //
```

C++

```
                      frc/controller/LinearQuadraticRegulator.h>< include#
```

```
                            commands. voltage create to feedback uses LQR A //
                            m_controller{ >1 ,1<LinearQuadraticRegulator::frc
                                                           m_flywheelPlant,
      this Decrease second. per radians in tolerance, error Velocity qelms. //
     behave controller the make or excursion, state penalize heavily more to //
                                                       aggressively. more //
                                                                     ,}8.0{
           more to this Decrease tolerance. (voltage) effort Control relms. //
               less controller the make or effort, control penalize heavily //
                the is that because point starting good a is 12 aggressive. //
                            battery. a of voltage maximum (approximate) //
                                                                    ,}12.0{
     if lower be can but TimedRobot, for 20ms loops. between time Nominal //
                                                         notifiers. using //
                                                                    ms};_20

    plant and feedforward observer, controller, a combines loop state-space The //
                                                        control. easy for //
              m_controller, m_loop{m_flywheelPlant, >1 ,1 ,1<LinearSystemLoop::frc
                ms};_20 V,_12 m_observer,
```

### LinearSystemLoop Together: All it Bringing

earlier. created we that observer and controller, system, our combines LinearSystemLoop `.PlantInversionFeedforward` a instantiate also will shown constructor The

Java

```
 ␣for plant and feedforward observer, controller, a combines loop state-space The //
                                                             control. easy ↪
                              = m_loop >N1 N1, N1,<LinearSystemLoop final private
 );0.020 ,12.0 m_observer, m_controller, (m_flywheelPlant,><LinearSystemLoop new
```

C++

```
                              frc/system/LinearSystemLoop.h>< include#
```

```
    plant and feedforward observer, controller, a combines loop state-space The //
                                                        control. easy for //
              m_controller, m_loop{m_flywheelPlant, >1 ,1 ,1<LinearSystemLoop::frc
                ms};_20 V,_12 m_observer,
```

that, do To it. run actually is do to left thing only the ,`LinearSystemLoop` our have we Once and measurements velocity encoder new our with filter Kalman our update periodically we'll with `correct` then ,*reference* the set first we that, do To it. to commands voltage new apply the apply and timestep, next the into filter Kalman the `predict` speed, flywheel current the .`getU` using generated inputs

Java

```
@Override
{ ()teleopPeriodic void public
␣setpoint the setting to similar is This flywheel. our of speed target the Sets //
a of ↩
controller. PID //
{ ())getTriggerPressed(m_joystick. if
reference next our set s'let so trigger, the pressed just We //
(kSpinupRadPerSec));fill(VecBuilder.setNextRm_loop.
{ ())getTriggerReleased(m_joystick. if else }
down spin s'let so trigger, the released just We //
));0.0(fill(VecBuilder.setNextRm_loop.
}

data. encoder with estimate vector state s'filter Kalman our Correct //
()));getRate(m_encoder.fill(VecBuilder.correctm_loop.

␣to voltages the use and commands voltage new generate to LQR our Update //
next the predict ↩
filter. Kalman out with state //
);0.020(predictm_loop.

motors. the to voltage calculated new the Send //
so voltage, battery * cycle duty = voltage //
voltage battery / voltage = cycle duty //
);0(getUm_loop. = nextVoltage double
(nextVoltage);setVoltagem_motor.
}
}
```

C++

```
numbers>< include#

frc/DriverStation.h>< include#
frc/Encoder.h>< include#
frc/TimedRobot.h>< include#
frc/XboxController.h>< include#
frc/controller/LinearQuadraticRegulator.h>< include#
frc/drive/DifferentialDrive.h>< include#
frc/estimator/KalmanFilter.h>< include#
frc/motorcontrol/PWMSparkMax.h>< include#
frc/system/LinearSystemLoop.h>< include#
frc/system/plant/DCMotor.h>< include#
frc/system/plant/LinearSystemId.h>< include#
```

```
{ override ()TeleopPeriodic void
the setting to similar is This flywheel. our of speed target the Sets //
controller. PID a of setpoint //
{ (m_joystick.GetRightBumper()) if
reference next our set s'let so bumper, the pressed We //
kSpinup.value()});{>1<Vectord::m_loop.SetNextR(frc
{ else }
down spin s'let so bumper, the released We //
);}0.0{>1<Vectord::m_loop.SetNextR(frc
}
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
    data. encoder with estimate vector state s'filter Kalman our Correct //
                      m_encoder.GetRate()});{>1<Vectord::m_loop.Correct(frc

 to voltages the use and commands voltage new generate to LQR our Update //
                          filter. Kalman out with state next the predict //
                                                     ms);_20m_loop.Predict(

                          motors. the to voltage calculated new the Send //
                              so voltage, battery * cycle duty = voltage //
                                  voltage battery / voltage = cycle duty //
                            )});0volt_t{m_loop.U(::m_motor.SetVoltage(units
                                                                            }
```

### LQR with Wrap Angle

below code the calling by wrapped angle that have can angle continuous a with Mechanisms .r) lqr.Calculate(x, of instead

Java

```
                                       (x);minus().getRlqr. = error var
        )));0 ,0(get(error.angleModulusMathUtil. ,0 ,0(seterror.
                                       (error);times().getKlqr. = u var
```

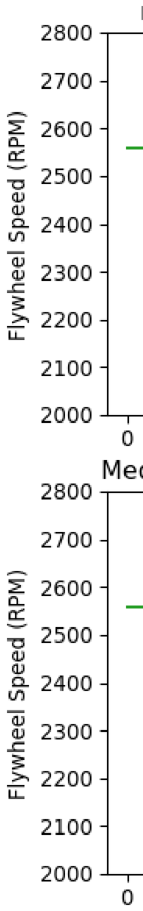
C++

```
                                 x; - lqr.R() = error >2 ,double<Vector::Eigen
                   )}).value();0radian_t{error(::AngleModulus(units::frc = )0error(
                                 error; * lqr.K() = u >2 ,double<Vector::Eigen
```

## Filters Kalman and Observers State 30.7.3

measurements external and behavior system’s a about information combine observers State the is systems linear for used observer common A system. the of *state* true the estimate to measurements fuse they as *filters* other over advantageous are filters Kalman Filter. Kalman a estimate optimally to system the of model spacestate- a with sensors more or one from state. system’s

different of variety a through run time, over measurements velocity flywheel shows image This spinup flywheel during lag measurement no shows filter Kalman tunedwell- a that Note filters. it. through pass balls as disturbances to quickly reacting and data noisy rejecting still while .*section filters* the in found be can filters on More



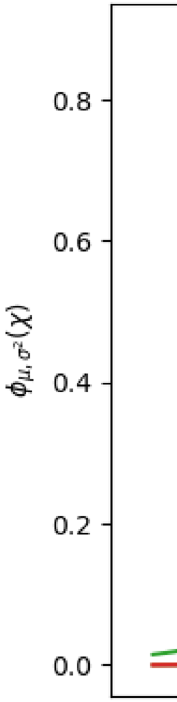
## Functions Gaussian

a of case the In .[1]process a in noise the model to *distribution Gaussian* a utilize filters Kalman measure a is variance the while mean, the is system the of *state* estimated the filter, Kalman .*state* true the about is filter the uncertain) (or certain how of

is Covariance filter. Kalman a of function the to central is covariance and variance of idea The state, single a with system a In correlated. are variables random two how of measurement a the of var($\mathbf{x_1}$) variance the containing matrix a or ,cov($\mathbf{x_1}, \mathbf{x_1}$) simply is matrix covariance the Gaussian the of deviation standard the of square the is variance this of magnitude The .$x_1$ state

---

[1] voltages extra adds radiation electromagnetic Stray sources. of sorts all from comes noise robot, real a In causes lash gear units, measurement inertial off throw variations temperature and vibrations readings, sensor to by that, realize to important It's things. of sorts all change... directions when inaccuracies have to encoders be might them of Some pattern. any follow to guaranteed aren't "noise" of sources these of each themselves, loopsingle- or "pops" be might Others radio. the on heard probably you've vibrations random noise" "white the *Central* the However, robot. the on events with correlated strongly but zero, nominally be might Others errors. we as distributed, are noise of sources individual the how of regardless that mathematically shows *Theorem Limit* know not do we Since Gaussian. a like distributed is eventually effect combined their up them of more and more add function. Gaussian that indeed is make can we model a of choice best the noise, of sources individual exact the


$\phi_{\mu,\sigma^2}(\chi)$
0.8
0.6
0.4
0.2
0.0

might covariance for values large Relatively estimate. state current the describing function confident more is filter the that indicate might covariances small while data, noisy indicate are covariance or variance for values ”small“ and ”large“ that Remember estimate. it’s about $\text{cov}(\mathbf{x_1}, \mathbf{x_1})$ meters, in measured was $\mathbf{x_1}$ if example, for – used being unit base the to relative squared. meters in be would

form: following the in written are matrices Covariance

$$\square = \begin{bmatrix} \text{cov}(x_1, x_1) & \text{cov}(x_1, x_2) & \dots & \text{cov}(x_1, x_n) \\ \text{cov}(x_2, x_1) & \text{cov}(x_2, x_2) & \dots & \text{cov}(x_1, x_n) \\ \vdots & \vdots & \ddots & \vdots \\ \text{cov}(x_n, x_1) & \text{cov}(x_n, x_2) & \dots & \text{cov}(x_n, x_n) \end{bmatrix}$$

### Filters Kalman

---

The doing. actually is filter Kalman a what for intuition an develop to important is It :□□□□ and visual great a provides Labbe Roger by Python in Filters Bayesian and Kalman book algebra linear use WPILib in filters Kalman The filters. Bayesian to introduction interactive suggest We case. dimensionalsingle- the to similar are ideas the but math, the gentrify to doing. are filters these what for intuition an gain to 4 Chapter through reading

---

and prediction parts: two have filters) Bayesian all (and filters Kalman summarize, To system’s our to according time in forward estimate state our projects Prediction correction. filters While state. measured the towards state estimated the steers correct and dynamics, WPILib’s example, For – necessary strictly not it’s timestep, same the in both perform often is data measurement new when only correct and frequently, predict call estimators pose system). vision frameratelow- a from example, (for available

filter: Kalman timediscrete- a of equations the shows following The

step Predict

$$\hat{\mathbf{x}}_{k+1}^- = \mathbf{A}\hat{\mathbf{x}}_k^+ + \mathbf{B}\mathbf{u}_k$$

$$\mathbf{P}_{k+1}^- = \mathbf{A}\mathbf{P}_k^-\mathbf{A}^T + \square\mathbf{Q}\square^T$$

step Update

$$\mathbf{K}_{k+1} = \mathbf{P}_{k+1}^-\mathbf{C}^T(\mathbf{C}\mathbf{P}_{k+1}^-\mathbf{C}^T + \mathbf{R})^{-1}$$

$$\hat{\mathbf{x}}_{k+1}^+ = \hat{\mathbf{x}}_{k+1}^- + \mathbf{K}_{k+1}(\mathbf{y}_{k+1} - \mathbf{C}\hat{\mathbf{x}}_{k+1}^- - \mathbf{D}\mathbf{u}_{k+1})$$

$$\mathbf{P}_{k+1}^+ = (\mathbf{I} - \mathbf{K}_{k+1}\mathbf{C})\mathbf{P}_{k+1}^-$$

| | | | |
|---|---|---|---|
| $\mathbf{A}$ | matrix system | $\hat{\mathbf{x}}$ | vector estimate state |
| $\mathbf{B}$ | matrix input | $\mathbf{u}$ | vector input |
| $\mathbf{C}$ | matrix output | $\mathbf{y}$ | vector output |
| $\mathbf{D}$ | matrix feedthrough | $\square$ | vector intensity noise process |
| $\mathbf{P}$ | matrix covariance error | $\mathbf{Q}$ | matrix covariance noise process |
| $\mathbf{K}$ | matrix gain Kalman | $\mathbf{R}$ | matrix covariance noise measurement |

Gaussian the of covariance and mean the describe ,$\mathbf{P}$ with together ,$\mathbf{x}$ estimate state The state. true system’s the of estimate filter’s our describes that function

### Matrices Covariance Noise Measurement and Process

of variance the describe **R** and **Q** matrices covariance noise measurement and process The variance function, Gaussian a for that Remember measurements. and states our of each diagonal are R and Q WPILib, a In deviation. standard function’s the of square the is filter Kalman a example, For variances. respective their contain diagonals whose matrices and $\begin{bmatrix}0.1\\1.0\end{bmatrix}$ deviations standard state with $\begin{bmatrix}\text{position}\end{bmatrix}$ measurements and $\begin{bmatrix}\text{position}\\\text{velocity}\end{bmatrix}$ states with matrices: **R** and **Q** following the have would $\begin{bmatrix}0.01\end{bmatrix}$ deviation standard measurement

$$Q = \begin{bmatrix}0.01 & 0\\0 & 1.0\end{bmatrix}, R = \begin{bmatrix}0.0001\end{bmatrix}$$

### Matrix Covariance Error

Informally, .$\hat{\mathbf{x}}$ estimate state the of covariance the describes **P** matrix covariance error The the about uncertainty our large, is **P** If .*state* estimated the about certainty our describes **P** about uncertainty less imply would elements smaller with **P** a Conversely, large. is state true state. true our

state true system’s the about certainty our as increases **P** forward, model the project we As decreases.

### step Predict

dynamics system linear the to according updated is estimate state our prediction, In covariance noise process the by increases **P** covariance error our Furthermore, .$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$ is **P** This quickly. more grow **P** covariance error our make will **Q** of values Larger .**Q** matrix measurements. and model the weight to step correction the in used

### step Correct

information. measurement new include to updated is estimate state our step, correct the In Large .**K** gain Kalman the by $\hat{\mathbf{x}}$ estimate state the against weighted is information new This more **K** of values smaller while measurements, incoming weight highly more **K** of values increase will **P** of values larger ,**P** to related is **K** Because prediction. state our weight highly long a for predicted is filter a example, for If, measurements. weight heavily more and **K** information. new the weight heavily would **P** large the duration,

estimate. state the in confidence our increase to decreases **P** covariance error the Finally,

### Filters Kalman Tuning

noise process of vector a system, linear a take constructors classes« Filter Kalman WPILib’s to converted are These deviations. standard noise measurement and deviations standard or deviations, standard the of square the with diagonals the filling by matrices **R** and **Q** (and deviation standard state’s a decreasing By measurement. or state each of variances, more. measurements incoming distrust will filter the ),**Q** in entry corresponding its therefore more. measurements incoming trust will deviation standard state’s a increasing Similarly, make will entry an decreasing – deviations standard measurement the for holds same The while state, corresponding the for measurement incoming the trust highly more filter the measurement. the in trust decrease will it increasing

Java

```
          noise. reject to inputs voltage and data encoder our fuses observer The //
                                 = m_observer >N1 N1, N1,<KalmanFilter final private
                                                             (><KalmanFilter new
                                                                   (),N1Nat.
                                                                   (),N1Nat.
                                                            m_flywheelPlant,
                 is model our think we accurate How // ),3.0(fillVecBuilder.
                 encoder our think we accurate How // ),0.01(fillVecBuilder.
                                                                  is data //
                                                                     );0.020
```

C++

```
                                                                    numbers>< include#

                                                        frc/DriverStation.h>< include#
                                                              frc/Encoder.h>< include#
                                                           frc/TimedRobot.h>< include#
                                                       frc/XboxController.h>< include#
                                  frc/controller/LinearQuadraticRegulator.h>< include#
                                              frc/drive/DifferentialDrive.h>< include#
                                               frc/estimator/KalmanFilter.h>< include#
                                             frc/motorcontrol/PWMSparkMax.h>< include#
                                              frc/system/LinearSystemLoop.h>< include#
                                                 frc/system/plant/DCMotor.h>< include#
                                          frc/system/plant/LinearSystemId.h>< include#
                                                   units/angular_velocity.h>< include#
```

```
          noise. reject to inputs voltage and data encoder our fuses observer The //
                                              m_observer{ >1 ,1 ,1<KalmanFilter::frc
                                                                m_flywheelPlant,
                                  is model our think we accurate How //   ,}3.0{
                           is data encoder our think we accurate How //  ,}0.01{
                                                                         ms};_20
```

**Footnotes**

## Estimators Pose 30.7.4

These  drivetrains. mecanum and swerve differential, for estimators pose includes WPILib classes *odometry* existing the for replacements indrop- be to designed are estimators gyro and encoder with estimates pose robot compensatedlatency- fusing support also that These data. vision noisy and drift encoder for account can estimators These measurements. is `update` only if classes odometry corresponding their to identically behave can estimators estimators. these on called

the with system spacestate- a using position robot estimate estimators Pose WPILib .`Pose2d` a as position robot represent can which ,$[x \quad y \quad \theta]^T$ states and `SwerveDrivePoseEstimator` ,`DifferentialDrivePoseEstimator` includes `update` call users these, In position. robot estimate to `MecanumDrivePoseEstimator` update to classes) odometry the as (same measurements gyro and encoder with periodically relativefield- its of measurements receives robot the When position. estimated robot's the pose the SLAM,V- or vision computer as such sensors from )`Pose2d` a as (encoded position position. robot estimate accurately to measurement the compensateslatency- estimator

:`DifferentialDrivePoseEstimator` a initialize to how Here's

Java

```
           = m_poseEstimator DifferentialDrivePoseEstimator final private
                                   DifferentialDrivePoseEstimator( new
                                                     m_kinematics,
                                          (),getRotation2dm_gyro.
                                     (),getDistancem_leftEncoder.
                                    (),getDistancem_rightEncoder.
                                                     Pose2d(), new
          )),5(degreesToRadiansUnits. ,0.05 ,0.05(fillVecBuilder.
            )));30(degreesToRadiansUnits. ,0.5 ,0.5(fillVecBuilder.
```

C++

```
                     m_poseEstimator{ DifferentialDrivePoseEstimator::frc
                                                         m_kinematics,
                                                m_gyro.GetRotation2d(),
                           meter_t{m_leftEncoder.GetDistance()},::units
                          meter_t{m_rightEncoder.GetDistance()},::units
                                                         Pose2d{},::frc
                                                   ,}0.01 ,0.01 ,0.01{
                                                     ;}}0.1 ,0.1 ,0.1{
```

.`Update()` calling by loop every measurements odometry Add

Java

```
                                                (updatem_poseEstimator.
  m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
                                                     ());getDistance ↪
```

C++

```
                          m_poseEstimator.Update(m_gyro.GetRotation2d(),
            meter_t{m_leftEncoder.GetDistance()},::units
           meter_t{m_rightEncoder.GetDistance()});::units
```

.AddVisionMeasurement() calling by occasionally measurements pose vision Add

Java

```
          ␣vision from exclusively position field-relative s'robot the Compute //
                                                                measurements. ↪
                                             = visionMeasurement3d Pose3d
  m_cameraToObjectEntry); m_robotToCamera, objectToRobotPose(m_objectInField,

measurements. vision apply to needed Pose2d to Pose3d from pose robot Convert //
                  ();toPose2dvisionMeasurement3d. = visionMeasurement2d Pose2d

   ␣a input t'don we only, purposes simulation For measurements. vision Apply //
                                                           on -- delay latency ↪
     ␣or latency known on either based calculated be must this robot, real a //
                                                                  timestamps. ↪
            Timer. (visionMeasurement2d,addVisionMeasurementm_poseEstimator.
                                                        ());getFPGATimestamp ↪
```

C++

```
             vision from exclusively position field-relative s'robot the Compute //
                                                                  measurements. //
                                 ObjectToRobotPose( = visionMeasurement3d Pose3d::frc
                        m_cameraToObjectEntryRef); m_robotToCamera, m_objectInField,

              vision apply to needed Pose2d to Pose3d from pose s'robot Convert //
                                                                  measurements. //
                        visionMeasurement3d.ToPose2d(); = visionMeasurement2d Pose2d::frc

         a input t'don we only, purposes simulation For measurements. vision Apply //
         on either based calculated be must this robot, real a on -- delay latency //
                                                      timestamps. or latency known //
                                m_poseEstimator.AddVisionMeasurement(visionMeasurement2d,
              GetFPGATimestamp());::Timer::frc
```

## Estimators Pose Tuning

measurements and model for deviations standard customizableuser- offer estimators pose All spread how of measure a is deviation Standard them). provide don't you if used are (defaults will it means deviation standard smaller a state a Giving signal. random a for is noise the out fusion. data during more trusted be

a for do might one (as measurements for deviation standard the increasing example, For incoming the than more estimate state its trusting estimator the to lead would signal) noisy data vision noisy reject can filter the that mean might this field, the On measurements. be can values these While deviations. model for correct to slow being of cost the at well, global and robot each of setup unique the on depend much very they beforehand, estimated method. measurement

large, very deviation standard heading vision the make poses, AprilTag incorporating When standard y and x vision the scale and small, deviation standard heading gyro the make tag. the from distance by deviation

### Controllers and Models SpaceState- Debugging 30.7.5

#### Signs Checking

flipped. being signs is controllers spacestate- with bugs of causes common most the of One
positive a in result to voltage positive expect WPILib in included models example, For
mechanism the make not does voltage positive a applying If versa. vice and acceleration,
readings) sensor other (or encoder makes ”forwards“ moving if or forwards, accelerate
encoder positive a in results input voltage positive that so inverted be should they decrease,
motors) right and left the for forwards (full $[12, 12]^T$ of *input* an apply I if example, For reading.
axis +X the (along ”forwards“ robot my propel should wheels my drivetrain, differential my to
velocity. positive a read to encoders my for and locally),

---

may You motors. any invert not does default, by ,`DifferentialDrive` WPILib The :□□□□
that so invert to object controller motor the on method `setInverted(true)` the call to need
motion. forward creates input positive

---

#### Graphs of Importance The

when important is time over s*output* and s*input* s,*state system's* the of data Reliable
data this send to is approach common One observers. and controllers spacestate- debugging
the graph both to us allow which ,*Shuffleboard* as such tools use and NetworkTables over
Google as such tools with later plotting for file CSV a to it save as well as timereal- in data
Python. or Excel Sheets,

---

be can this testing, For rate. update 10hz a to limited is NetworkTables default, By :□□□□
be should code This 100hz. to up at data submit to snippet code following the with bypassed
data. new publish forcibly to periodically run

---

lag cause can which NetworkTables, over 100hz) to up (at data extra send will This :□□□□
It utilization. network increase also will This dashboards. robot and code user both with
competitions. during this disable to idea good a often is

Java

```
                                                        @Override
                                          { ()robotPeriodic void public
                        ();flush().getDefaultNetworkTableInstance.
                                                                    }
```

C++

```
                                              { ()RobotPeriodic void
              GetDefault().Flush();::NetworkTableInstance
                                                                    }
```

### Lag Input for Compensating

onboard to due delayed be may readings) velocity (i.e. data input sensor some times, Often no assumes gain K LQR's default, By perform. to tend controllers motor smart that filtering cause can milliseconds of tens of order the on delay significant introducing so delay, input for performance off trading reduced, be can gain K LQR's the this, combat To instability. rigorous mathematically a in latency this for compensate to how for example code A stability. .*here* available is manner

## Glossary Controls 30.8

**control bangbang-**
on" "turns simply It technique. control loopclosed- requiredtuning-no- simple, very A control the off" "turns and small, too is *variable process* the when *effort control* the See all. not but cases, some in well works It big. too is variable process the when effort info. more for Wikipedia on control bang""Bang-

**system coordinate Cartesian**
its indicating numbers, of set a by described is point each where space in points of set A *orthogonal* the of expression an are coordinates These space. that within *coordinates* 2- system). "rectangular" a (IE, axes orthogonal fixed, of set a from point each of distance learned was what likely (and FRC in common most are spaces dimension3- and dimension Cartesian See possible. theoretically is dimensions of number any but 1), algebra in info. more for Wikipedia on system coordinate

**losses churning**
rotate, bearings and gears when that fact the from arising forces likefriction- Complex mechanisms. rotating of efficiency the reduces This lubricant. liquid displace must they

**signal control**
voltage. a as quantified usually ,*controller* a by *plant* a to sent signal driving The

**effort control**
*signal Control*

**law control**
given ,*state* desired a to *system* a drive to *inputs* generates that formula mathematical A $\mathbf{u} = \mathbf{K}(\mathbf{r} - \mathbf{x})$ law control the is example common A .*state* current the

**controller**
*state system* desired a about bring to *plant* a with feedback negative or position in Used zero. to *output* the and signal *reference* a between difference the driving by

**convolution**
function, one of average moving weighted a calculates that operation mathematical A input sensor "filter" to way common A function. second a by assigned weights the with .convolution See function. filtering chosencarefully- a using it, to *convolution* a apply to is info. more for Wikipedia on

**force electromotivecounter-**
a has that fact the of result a is voltage The motor. spinning a in generated *voltage* A for Wikipedia on electromotive_forceCounter- See magnet. a near rotating wire of coil info. more

**current**
"Amps" of unit a with described is Current conductor. a through electrons of flow The

to equal is amp One circuit. a in point single a at measured is and ”A“), simply (or
second. one in point measurement the past moving electrons 6241509074000000000

**dynamics**
In forces. of action the under bodies of motion the with concerned physics of branch A
dynamics. their to according evolve systems control, modern

**derivative**
given a at function a of change“of-”rate- the evaluates which operation mathematical A
info. more for Wikipedia on derivative See point.

**error**
.*state* or *output* an minus *Reference*

**search exponential**
a applying by range search wide a within value specific a finding of process iterative An
more for Wikipedia on search exponential See value. search the to factor multiplicative
info.

**smoothing exponential**
window exponential an using filter, passlow- simple a implement to way common very A
down simplifies operation convolution The signal. input an with *convolution* a in function
See output. previous and input current the on operations math of set simple very a to
info. more for Wikipedia on smoothing exponential

**gain**
output an of magnitude the to signal input an of magnitude the relates that value scalar A
would one than greater gain A .`input * gain = output` in `gain` example, For signal.
A signal. input an dampen would one than less gain a while signal, input an amplify
signal. input the negate would gain negative

**distribution Gaussian**
of graph The averages. of distributions describes that function mathematical special A
(the mean its by described is function This shape. curve“ ”bell a is function Gaussian a
out“ ”spread how of measure (a variance and curve) bell the of ”peak“ the of location
info. more for Wikipedia on distribution Gaussian See is). curve bell the

**gradient**
is output the result, a As inputs. multiple with function a to applied but ,*derivative* The
occurs. it which along direction vector the and change, of rate the of magnitude the both

**state hidden**
other to related be can *dynamics* whose but measured, directly be cannot that *state* A
states.

**input**
.*state plant’s* the change to used be can that name) the (hence *plant* the to input An

- it. driving motor the of voltage the input: 1 have will flywheel A Ex.
- motors. right and left the of voltages the inputs: 2 have might drivetrain A Ex.

*input* per entry one with vector column a ,**u** variable the by represented often are Inputs
.*system* the to

**regression squaresleast-**
error the of *square* the minimizes to curve a picks which technique fittingcurve- A
squaresleast- ordinary See data. measured actual the and curve, fitted the between
info. more for Wikipedia on regression

**LQR**
system a operate to seeks which scheme control feedback A - Regulator QuadraticLinear-
of square the minimizing of sense the in manner, cost“ ”lowest or optimal“ ”most a in
effort. control and error system of combination a represents that function“ ”cost some
and controlled, being system the of model mathematical accurate an requires This
for Wikipedia on LQR See state. system given any of ”cost“ the describing function
info. more

**measurement**
using system, physical or ,*plant* a from measured are that *outputs* are Measurements
sensors.

**model**
behavior. *system’s* physical a of aspect some reflects that equations mathematical of set A

**observer**
given a of *state* internal the of estimate an provides that system a theory, control In
WPILib .*system* real the of *output* and *input* the of measurements from *system* real
ExtendedKalmanFilter and systems, linear observing for class Filter Kalman a includes
systems. nonlinear for classes UnscentedKalmanFilter and

**orthogonal**
example, For influence. mutual lacking or independent, being of property the Having
zero causes line one along units of number any moving if orthogonal are lines two
lines orthogonal ,*system coordinate cartesian* a In line. other the along displacement
other. each between angles degree90- have to said often are

**output**
These states. then measurements more be can There sensors. from Measurements
Filters. Kalman of step ”correct“ the in used are outputs

- velocity. it’s measures that encoder a from *output* 1 have might flywheel A Ex.
- on position x/y/heading it’s find to SLAMV- and solvePNP use might drivetrain A Ex.
SLAMV- and x/y/heading (solvePNP measurements 6 are there that fine It’s field. the
x/y/heading). (robot states 3 and x/y/heading)

with vector column a ,**y** variable the using represented often are *system* a of Outputs
states had *system* our if example, For measure). can we thing (or *output* per entry one
*output* our our, velocity, measure only could sensor our but acceleration and velocity for
velocity. 's*system* the include only would vector

**portrait phase**
some given time, in change they as *derivative* its and value function’s a of graph A
(stable/unstable behavior system analyzing for useful are They conditions. starting initial
starting or parameters of set certain a given etc.) cycles, limit points, operating
info. more for Wikipedia on portrait phase See conditions.

**PID**
*signal control* a calculates which controller feedback A - DerivativeIntegral-Proportional-
accumulated an and error, the of change of rate the ,*error* the of sum weighted a from
info. more for Wikipedia on .controller PID See errors. previous of sum

**plant**
controlled. being actuators of collection or *system* The

**variable process**
control. PID of context the in *plant* a of output the describe to used term The

**squaredr-**
representing data, of set a predicts model a well how of measurement statistical A accurately is that variable independent the in variation observed the of fraction the to equivalent fit, terrible (a 0.0 from runs typically value The model. the by predicted See fit). perfect (a 1.0 to variable) independent your of value average the guessing just info. more for Wikipedia on Coefficient_of_determination

**reference**
error controller's a for point reference the as used is value This state. desired The calculation.

**time rise**
.*input step* a applying after *reference* the reach initially to takes *system* a time The

**RMSE**
set a to fit is curve a well how of measurement Statistical - Error Squared Mean Root all of squares the of (mean) average the of root square the as calculated is It data. of input original the of units has It fit. curve the and sample actual the between errors the info. more for Wikipedia on Error Squared Mean Root See data.

**setpoint**
controller. PID a of *reference* the describe to used term The

**time settling**
applied. is *input step* a after *reference* the at settle to takes *system* a time The

**function signum**
all for 1- to equal is It input. its of ”sign“ the expresses that function continuousnon- A See numbers. input positive all for 1 and 0, of input an for 0 numbers, input negative info. more for Wikipedia on ,function signum

**state**
*system's* the determine to used be can that velocity) (e.g., *system* a of characteristic A column a as written is system a of state the notation, spacestate- In behavior. future space.state- in position it's describing vector

- the on position it's describe to $\begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$ states the have might system drivetrain A Ex. field.
- current its describe to $\begin{bmatrix} \text{position} \\ \text{velocity} \end{bmatrix}$ states the have might system elevator An Ex. velocity. and height

entry one with vector column a ,$\mathbf{x}$ variable the by represented often is state *system's* A .*state* per

**robust statistically**
outlier- or noisy a to resilient it makes which algorithm processing data a of property The because important is robots on algorithms robust statistically Designing set. data prone is behavior robot unexpected but unpredictable, be often can data sensor worldreal- info. more for Wikipedia on Statistics Robust See desirable. never

**error statesteady-**
equilibrium. reaches *system* after *Error*

**input step**
that input step A .$t \geq 0$ for $0$ than greater constant a and $t < 0$ for $0$ is that *input system* A input. step unit a called is $t \geq 0$ for $1$ is

**response step**

.*input step* a to *system* a of response The

**system**

which ,*observer* and *controller* a with interaction it’s and *plant* a encompassing term A
*outputs* to *inputs* maps *system* a speaking, Mathematically entity. single a as treated is
.*states* of combination linear a through

**identification system**

measured using model mathematical a in *dynamics systems* a capturing of process The
terms. kA and kV kS, find to identification system uses toolsuite SysId The data.

**response system**

.*input* given a for time over *system* a of behavior The

**voltage**

circuit. a through electrons ”pushing“ is field electric an much how of measurement The
”Volts“. of units in measured is It ”EMF“. or Force“, ”Electromotive called sometimes is It
two between travels electron one If circuit. a in points *two* between defined is always It
point the to accelerated been have will it them, between EMF of volt one have that points
energy. of joules $\frac{1}{6241509074000000000}$ having of

**drag viscous**

fluid. turbulentnon- through slowly *relatively* moving object an from generated force The
describes It object. the of *velocity* the to proportional roughly is force the region, this In
as well as encounter, would robot FRC an resistance“ ”air of type common most the
more for Wikipedia on (physics) Drag See grease. displacing from gearbox a in losses
info.

**dotx-**

,*state* velocity a just had *system* the If .$\mathbf{x}$ vector *state* the of derivative the dot:x- or ,$\dot{\mathbf{x}}$
acceleration. 's*system* the represent would $\dot{\mathbf{x}}$ then

**hatx-**

.*observer* an by estimated as system, a of *state* estimated the hat:x- or ,$\hat{\mathbf{x}}$

# [redacted]

advanced other with used be that features convenience general some covers section This features. programming

## Frequencies Custom at Functions Scheduling 31.1

faster rate a at methods custom run to one allows method `addPeriodic()` ’s`TimedRobot` make to had teams Previously, ms). (20 rate update periodic `TimedRobot` default the than 20 of period loop `TimedRobot` the than often more controllers feedback run to `Notifier` a feedback run can users Now, advised). not is this than often more `TimedRobot` (running ms `TimedRobot` the with synchronously but loop, robot main the than often more controllers issues. safety thread potential eliminating functions, periodic

to function (the lambda a in takes method (C++) `AddPeriodic()` / (Java) `addPeriodic()` The time. starting common the from offset optional an and period requested the with along run), relative timeslot different a in function a scheduling for useful is argument third optional The methods. periodic `TimedRobot` other the to

---

can *library units* the C++, In Java. in seconds are offset and period the for units The :□□□□ unit. time any in offset and period a specify to used be

---

Java

```
                                          { TimedRobot extends Robot class public
                                  );0Joystick( new = m_joystick Joystick private
                                  );2 ,1Encoder( new = m_encoder Encoder private
                                          );1Spark( new = m_motor Spark private
       );0.01 ,0.5 ,0.0 ,1.0PIDController( new = m_controller PIDController private

                                                                  { ()Robot public
                                                           { >- addPeriodic(()
          ()));getRate(m_encoder.calculate(m_controller.setm_motor.
                                                           );0.005 ,0.01 ,}
                                                                             }

                                                                     @Override
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                                                          { ()teleopPeriodic public
                                       { ))1(getRawButtonPressed(m_joystick. if
                                   { )0.0 == ()getSetpoint(m_controller. if
                                        );30.0(setSetpointm_controller.
                                                                   { else }
                                         );0.0(setSetpointm_controller.
                                                                          }
                                                                              }
                                                                                  }
                                                                                    }
```

(Header) C++

```
                                                 { TimedRobot::frc public : Robot class
                                                                              :private
                                                         ;}0m_joystick{ Joystick::frc
                                                        ;}2 ,1m_encoder{ Encoder::frc
                                                               ;}1m_motor{ Spark::frc
                              ms};_10 ,0.5 ,0.0 ,1.0m_controller{ PIDController::frc2

                                                                             Robot();

                                                      ;override ()TeleopPeriodic void
                                                                                     ;}
```

(Source) C++

```
                                                                  { ()Robot::Robot void
                                                                    { ]&AddPeriodic([
                          m_motor.Set(m_controller.Calculate(m_encoder.GetRate()));
                                                                     ms);_5 ms,_10 ,}
                                                                                      }

                                                         { ()Robot::TeleopPeriodic void
                                             { ))1(m_joystick.GetRawButtonPressed( if
                                           { )0.0 == (m_controller.GetSetpoint() if
                                                  );30.0m_controller.SetSetpoint(
                                                                           { else }
                                                   );0.0m_controller.SetSetpoint(
                                                                                  }
                                                                                    }
                                                                                      }
```

update controller the and ms, 20 every runs example this in method `teleopPeriodic()` The their that so runs `teleopPeriodic()` when from ms 5 of offset an with ms 10 every run is the etc.; ms, 40 ms, 20 ms, 0 at runs `teleopPeriodic()` (e.g., conflict don't timeslots etc.). ms, 25 ms, 15 ms, 5 at runs controller

## EventLoop With Programming BasedEvent- 31.2

common one are buttons conditions; certain by driven are code robot in operations Many
an using by style *programming imperative* an with polled be can Conditions example.
*drivenevent-* an offers WPILib alternative, an As method. periodic a in statement if
classes. `BooleanEvent` and `EventLoop` the of shape the in API of style *programming*

).C++/Java( project example EventLoop the from taken is here code example The :□□□□

### EventLoop 31.2.1

polled be can which actions, and conditions of pairs for ”container“ a is class `EventLoop` The
it if and queried be will condition every polled, When method. `Poll()/poll()` the using
executed. be will condition the with associated action the `true` returns

Java

```
                                 EventLoop(); new = m_loop EventLoop final private
                                                                         @Override
                                                   { ()robotPeriodic void public
                                                          bindings the all poll //
                                                                   ();pollm_loop.
                                                                                 }
```

C++

```
                                          m_loop{}; EventLoop::frc
  } m_loop.Poll(); { override ()RobotPeriodic void
```

*Periodic() a in consistently called be should method `poll()` ’sEventLoop The :□□□□□
behavior. loop unintended in result will this do to Failure method.

### BooleanEvent 31.2.2

/ )Java( `BooleanSupplier` a condition: boolean a represents class `BooleanEvent` The
(C++). `><bool()std::function`

:`IfHigh()/ifHigh()` use condition, the to action callback a bind To

Java

```
                                  = atTargetVelocity BooleanEvent
       m_controller::atSetpoint) BooleanEvent(m_loop, new
                                 stability more for debounce //
                                              );0.2(debounce.

wheel shooter the into ball the kick velocity, target the at re'we if //
                 ));0.7(setm_kicker. >- (()ifHighatTargetVelocity.
```

C++

```
                                               = atTargetVelocity BooleanEvent::frc
                                                                BooleanEvent(::frc
                                                                     m_loop,&
        )} controller.AtSetpoint(); return { m_controller] = controller&[
                                             stability more for debounce //
                                                       s);_0.2Debounce(.

      wheel shooter the into ball the kick velocity, target the at re'we if //
            );} );0.7kicker.Set( { m_kicker] = kicker&atTargetVelocity.IfHigh([
```

ideally once, declared be to need only bindings :*declarative* is binding button that Remember else. everything handles library The initialization. robot during time some

### Conditions Composing 31.2.3

done is this C++ In conditions. composite create to composed be can objects `BooleanEvent` using done are Java in compositions all and cases other applicable, when operators using methods.

#### && / and()

`true` returns that condition third a into conditions `BooleanEvent` two composes &&/`and()` The .`true` return conditions the of **both** when only

Java

```
                                                   held is button thumb the if //
                                                                  intakeButton
                                      kicker the at ball a not is there and //
                                                  ())negate(isBallAtKicker.and.
                                                        intake the activate //
                                              ));0.5(setm_intake. >- (()ifHigh.
```

C++

```
                                                   held is button thumb the if //
                                                                 (intakeButton
                                        kicker the at ball a not is there and //
                                                          isBallAtKicker)! &&
                                                        intake the activate //
                          );} );0.5intake.Set( { m_intake] = intake&IfHigh([.
```

#### || / or()

`true` returns that condition third a into conditions `BooleanEvent` two composes `||/or()` The .`true` return conditions the of **either** when only

Java

```
                                                held not is button thumb the if //
                                                                  intakeButton
                                                                     ()negate.
```

page) next on (continues

(□□□□ □□□□□ □□□□)

```
                         kicker the in ball a is there or //
                                    (isBallAtKicker)or.
                                        intake the stop //
                         (m_intake::stopMotor);ifHigh.
```

C++

```
                             held not is button thumb the if //
                                                intakeButton!(
                           kicker the in ball a is there or //
                                          isBallAtKicker) ||
                                         intake the stop //
          );} );0.0intake.Set( { m_intake] = intake&IfHigh([.
```

### ! / negate()

returns that condition another into condition BooleanEvent one composes !/negate() The did. conditional original the what of opposite the

Java

```
                    kicker the at ball a not is there and //
                          ())negate(isBallAtKicker.and.
```

C++

```
                    kicker the at ball a not is there and //
                                          isBallAtKicker)! &&
```

### Debounce() / debounce()

digital from originating those (especially conditions activation, repeated rapid avoid To method: *debounce* the using *class Debouncer WPILib* the with debounced be can inputs)

Java

```
                                  = atTargetVelocity BooleanEvent
                  m_controller::atSetpoint) BooleanEvent(m_loop, new
                                     stability more for debounce //
                                                  );0.2(debounce.
```

C++

```
                            = atTargetVelocity BooleanEvent::frc
                                                 BooleanEvent(::frc
                                                       m_loop,&
   )} controller.AtSetpoint(); return { m_controller] = controller&[
                                     stability more for debounce //
                                                 s);_0.2Debounce(.
```

### falling() rising(),

to instead but condition, a of state *current* the to not action an bind to desired is it times Often pressed newly is button a when to action an binding example, For .*changes* state that when do: decorators `falling()` and `rising()` the what is This held. is it when to opposed as `true` returned condition original the when only `true` is that condition a return will `rising()` that condition a returns `falling()` polling; *previous* the in `false` and polling *current* the in .`false` to `true` from transition a on only `true` returns

> in instance same the use not do have, conditions these ”memory“ the to Due :□□□□□ places. multiple

Java

```
     shot was ball the means it velocity, target the at being stop we when //
                                                          atTargetVelocity
                                                              ()falling.
                                                      kicker the stop so //
                                         (m_kicker::stopMotor);ifHigh.
```

C++

```
     shot was ball the means it velocity, target the at being stop we when //
                                                          atTargetVelocity
                                                              Falling().
                                                      kicker the stop so //
                          );} );0.0kicker.Set( { m_kicker] = kicker&IfHigh([.
```

### Objects `BooleanEvent` Downcasting

used subclass `Trigger` the commonly most types, other to objects `BooleanEvent` convert To exists: decorator `CastTo()`/`castTo()` generic the ,*conditions to commands binding* for

Java

```
                      );new(Trigger::castTobooleanEvent. = trigger Trigger
```

C++

```
                 ();>Trigger::frc2<booleanEvent.CastTo = trigger Trigger::frc2
```

---

an accepting constructor a to reference method a expects parameter the Java, In :□□□□ this references, method of lack the to Due .`BooleanSupplier` a and instance `EventLoop` `Type(frc::EventLoop*,` form the of constructor a as long as C++ in defaulted is parameter exists. `>)<bool()std::function`

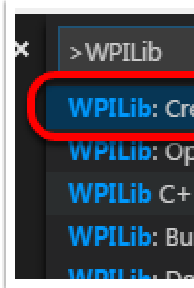
---

# 23

[redacted]

> *not* are they functional, examples WPILib keep to made is attempt every While :□□□□□ be to need will constants specificrobot- least, very the At is.“”as- used be to intended values their have constants empirical Many robot. user a on work to code the for changed own their write to encouraged strongly are Users purposes. demonstration for ”faked“ code. example copy than rather template) existing an from or scratch (from code

patterns. use and features library of number large a demonstrate projects example WPILib competition- complete, to functionality single a of demonstrations simple from range Projects entering by Code VS in available are examples these of All programs. robot capable example. choosing and *project new a Create WPILib:* selecting then ,`Ctrl+Shift+P`



## 32.1 דוגמאות בסיסיות

beginning for useful are They functionality. robot basic/minimal demonstrate examples These in limited highly are but programming, robot with familiarity initial gaining are who teams functionality.

- implementation drive differential simple a Demonstrates ):C++ ,Java( **Arcade Drive** class. `DifferentialDrive` the through controls style”arcade“- using
- seen functionality same the Demonstrates ):C++ ,Java( **Arcade Drive Xbox Controller** joystick. ordinary an of instead `XboxController` an using except example, previous the in

- drives that routine autonomous simple a Demonstrates ):C++ ,Java( **Started Getting** speed. half at seconds two for forwards
- implementation drive mecanum simple a Demonstrates ):C++ ,Java( **Drive Mecanum** class. `MecanumDrive` the using
- with motor a of output the control to how Demonstrates ):C++ ,Java( **Controller Motor** position. motor read to encoder an with joystick a
- to camera USB a from video stream to how Demonstrates ):C++ ,Java( **Vision Simple** dashboard. the
- output relay a control to class `Relay` the of use the Demonstrates ):C++ ,Java( **Relay** buttons. joystick of set a with
- `DoubleSolenoid` and `Solenoid` the of use the Demonstrates ):C++ ,Java( **Solenoids** buttons. joystick of set a with outputs solenoid control to classes
- using implementation drive differential simple a Demonstrates ):C++ ,Java( **TankDrive** class. `DifferentialDrive` the through controls style”tank“-
- in seen functionality same the Demonstrates ):C++ ,Java( **Controller Xbox Drive Tank** joystick. ordinary an of instead `XboxController` an using except example, previous the

## Examples Control 32.2

Sensors controls. robot common of implementations WPILib demonstrate examples These examples. these of concept emphasized the not are but present, be may

- differential advanced an Demonstrates ):C++ ,Java( **DifferentialDriveBot** the through odometry gyroand-encoder- including implementation, drive through control velocity PID with composition and class, `DifferentialDriveOdometry` classes. `PIDController` and `DifferentialDriveKinematics` the
- the of use the Demonstrates ):C++ ,Java( **controller PID profiled with Elevator** mechanism. elevator an of position the control to class `ProfiledPIDController`
- the of use the Demonstrates ):C++ ,Java( **PID profiled trapezoid with Elevator** the control to controller“ motor ”smart a with conjunction in class `TrapezoidProfile` mechanism. elevator an of position
- robot mecanum a of control orientedfield- Demonstrates ):C++ ,Java( **Mecanum Gyro** gyro. a with conjunction in class `MecanumDrive` the through
- implementation, drive mecanum advanced an Demonstrates ):C++ ,Java( **MecanumBot** and class, `MecanumDriveOdometry` the through odometry gyroand-encoder- including and `MecanumDriveKinematics` the through control velocity PID with composition classes. `PIDController`
- and class `PIDController` the of use the Demonstrates ):C++ ,Java( **PotentiometerPID** mechanism. elevator an of position the control to potentiometer a
- `RamseteController` the of use the Demonstrates ):C++ ,Java( **RamseteController** period. autonomous the during trajectory a follow to class
- implementation, drive swerve advanced an Demonstrates ):C++ ,Java( **SwerveBot** and class, `SwerveDriveOdometry` the through odometry gyroand-encoder- including `SwerveDriveKinematics` the through control velocity and position PID with composition classes. `PIDController` and

- in class `PIDController` the of use the Demonstrates ):C++ ,Java( **UltrasonicPID** object. an from distance set a to drive to sensor ultrasonic an with conjunction

## Examples Sensor 32.3

Mechanisms WPILib. using processing data and reading sensor demonstrate examples These examples. these of concept emphasized the not is but present, be may control

- Axis an and OpenCV of use the Demonstrates ):C++ ,Java( **Sample Camera Axis** dashboard. the to it stream and feed video captured a on rectangle a overlay to Netcam
- sensor obtaining Demonstrates ):C++ ,Java( **Monitoring CAN Distribution Power** `PowerDistribution` the using CAN over module Distribution Power a from information class.
- class `DutyCycleEncoder` the of use the Demonstrates ):C++ ,Java( **Encoder Cycle Duty** encoder. absolute typePWM- a from values read to
- to class `DutyCycleInput` the of use the Demonstrates ):C++ ,Java( **DutyCycleInput** input. PWM a of cycle duty fractional and frequency the read
- a from values read to class `Encoder` the of use the Demonstrates ):C++ ,Java( **Encoder** encoder. quadrature
- robot measure to class `AnalogGyro` the of use the Demonstrates ):C++ ,Java( **Gyro** driving. stabilize and heading
- camera USB a and OpenCV of use the Demonstrates ):C++ ,Java( **Vision Intermediate** dashboard. the to it stream and feed video captured a on rectangle a overlay to
- using AprilTags of detection roboRIOon- Demonstrates ):C++ ,Java( **AprilTagsVision** camera. USB attached an
- data read to class `Ultrasonic` the of use the Demonstrates ):C++ ,Java( **Ultrasonic** signal reduce to class `MedianFilter` the with conjunction in sensor ultrasonic an from noise.

## Examples BasedCommand- 32.4

.*framework BasedCommand-* the of use the demonstrate examples These

- a control to `ProfiledPIDSubsystem` a of use the Demonstrates ):C++ ,Java( **ArmBot** arm. robot
- `TrapezoidProfileSubsystem` a of use the Demonstrates ):C++ ,Java( **ArmBotOffboard** arm. robot a control to controller“ motor ”smart a with conjunction in
- a of use the Demonstrates ):C++ ,Java( **DriveDistanceOffboard** drive to controller“ motor ”smart a with conjunction in `TrapezoidProfileCommand` profile. motion trapezoidal a with distance set a by forward
- shootingfrisbee- simple a for code robot of set complete A ):C++ ,Java( **FrisbeeBot** control PID simple Demonstrates .*Ascent Ultimate* game FRC® 2013 the of typical robot class. `PIDSubystem` the through
- robot, demonstration WPI the for code robot of set complete A ):C++ ,Java( **Bot Gears** GearsBot.

- and `PIDCommand` of use the Demonstrates ):C++ ,Java( **Commands Drive Gyro** specified a face to robot a turn to gyro a with conjunction in `ProfiledPIDCommand` driving. while heading stabilize to and heading
- deliveryhatch- simple a for code robot of set complete A ):C++ ,Java( **Hatchbot Inlined** in written are Commands .*Space Deep Destination:* game FRC 2019 the of typical bot avoided. is `Command` of subclassing explicit which in style, "inline" an
- hatch- simple a for code robot of set complete A ):C++ ,Java( **Hatchbot Traditional** are Commands .*Space Deep Destination:* game FRC 2019 the of typical bot delivery robot each for written are `Command` of subclasses which in style, "traditional" a in written action.
- generation trajectory Demonstrates ):C++ ,Java( **MecanumControllerCommand** and `TrajectoryGenerator` the using drive mecanum a with following and classes. `MecanumControllerCommand`
- following and generation trajectory Demonstrates ):C++ ,Java( **RamseteCommand** classes. `RamseteCommand` and `TrajectoryGenerator` the using drive differential a with .*here* found be can tutorial stepby-step- matching A
- `SelectCommand` the of use the Demonstrates ):C++ ,Java( **Example Command Select** condition. evaluatedruntime- a on depending commands of selection a of one run to class
- generation trajectory Demonstrates ):C++ ,Java( **SwerveControllerCommand** and `TrajectoryGenerator` the using drive swerve a with following and classes. `SwerveControllerCommand`

## Examples SpaceState- 32.5

.*Control SpaceState-* the of use the demonstrate examples These

- flywheel. a of control spacestate- Demonstrates ):C++ ,Java( **StateSpaceFlywheel**
- using control spacestate- Demonstrates ):C++ ,Java( **StateSpaceFlywheelSysId** flywheel. a controlling for Identification System SysId's
- elevator. an of control spacestate- Demonstrates ):C++ ,Java( **StateSpaceElevator**
- Arm. an of control spacestate- Demonstrates ):C++ ,Java( **StateSpaceArm**
- a of control spacestate- Demonstrates ):C++ ,Java( **StateSpaceDriveSimulation** and controller following path RAMSETE a with combination in drivetrain differential class. Field2d

## Examples Physics Simulation 32.6

simulation. physics the of use the demonstrate examples These

- a with simulation physics of use the Demonstrates ):C++ ,Java( **ElevatorSimulation** elevator. simple
- simple a with simulation physics of use the Demonstrates ):C++ ,Java( **ArmSimulation** arm. jointedsingle-

a of control spacestate- Demonstrates ):C++ ,Java( **StateSpaceDriveSimulation** •
and controller following path RAMSETE a with combination in drivetrain differential
class. Field2d

basic a of example barebones A ):C++ ,Java( **SimpleDifferentialDriveSimulation** •
simulation. in used be can that drivetrain

## Examples Miscellaneous 32.7

of any into fit not does that functionality WPILib miscellaneous demonstrate examples These
categories. above the

to class `AddressableLED` the of use the Demonstrates ):C++ ,Java( **LED Addressable** •
feedback. driver and/or decoration robot for LEDs RGB control

from read to Access) Memory (Direct DMA of use the Demonstrates ):C++ ,Java( **DMA** •
CPU. RoboRIO's the using without sensors

the without Layer) Abstraction (Hardware HAL of use the Demonstrates ):C++( **HAL** •
only). (C++ users advanced for is example This WPILib. of rest the of use

tactile for functionality ”rumble“ the of use the Demonstrates ):C++ ,Java( **Rumble HID** •
XboxControllers). as (such HIDs supported on feedback

the on layouts tab/widget configuring Demonstrates ):C++ ,Java( **Shuffleboard** •
fluent class's `Shuffleboard` the through code robot from dashboard ”Shuffleboard“
API. builder

.*robot Romi* the run to how of example based command A ):C++ ,Java( **RomiReference** •

.*Mechanism2d* using of example simple A ):C++ ,Java( **Mechanism2d** •

# 33

[redacted]

find can You devices. party third with use for programs example find you helps list This page. □□□□□ □□□□□ the on parties third these of many for support

- (CTRE) Electronics Road The Cross
- (navX) Labs Kauai
- left) the on found be can studies, case called examples, (additional Limelight
- PhotonVision
- Robotics REV

[redacted]

## Practices Best Wiring 34.1

where connects what of details the through walks *Wiring Robot FRC to Intro* article The :
Practices" "Best additional some provides article this and System Control FRC the up wire to
*Preemptive* at look a Take easier. maintenance make and reliability increase may that
tricks. and tips more for *Troubleshooting*

### Vibration/Shock 34.1.1

shock and vibrations to comes it when environment rough incredibly an is Robot FRC® An
mechanical for tested extensively are electronics specific FRC the of many While loads.
specifically not are radio, the as such components, few a conditions, these in robustness
these vibration and shock the reduce to steps Taking platform. mobile a on use for designed
reduce may that suggestions Some failures. reduce help may to exposed are components
failures: mechanical

- excessive create which components any isolate to sure Make - Isolation Vibration
reduce help will This isolators". "vibration using compressors, as such vibration,
failure fatigue premature cause and fasteners loosen can which robot the on vibration
components. electronic some on
- design. your for possible as robot the of much as cover to Bumpers Use - Bumpers
robot, your of corners the around coverage bumper specific require rules the While
damped be will collisions all that likelihood the increases bumpers of use the maximizing
collision a in experienced forcesg- the reduce significantly Bumpers bumpers. your by
by experienced shock the reducing surface, robot hard a on directly hitting to compared
failure. related shock a of chance the decreasing and electronics the
- electronic your of all or some mount shock to choose may You - Mounting Shock
especially is This collisions. robot in see they forces the reduce further to components
be not may which processors,co- as such electronics other and radio robot the for helpful
mounting or foams, springs, isolators, Vibration platforms. mobile on use for designed
components. these by seen forces shock the reduce may all materials flexible to

### Redundancy 34.1.2

feasible. is redundancy where System Control FRC the in places few are there Unfortunately primary The reliability. increase can redundancy for opportunities of advantage Taking PoE provided the to addition in radio the to connector barrel the wiring is this of example the dislodged, or damaged becomes cables the of one if that ensures This connection. provide to areas potential other for out eye an Keep radio. the to power maintain will other robot. your programming and wiring when redundancy

### Savers Port 34.1.3

and plugged frequently be may that station Driver or Robot the on connections any For tether) Ethernet and tether, USB roboRIO Ethernet, DS joysticks, DS as (such unplugged port. the damaging for potential the reduce substantially can ”pigtail“ or Saver“ ”Port a using on port the that cycles of number the reducing both duty, double serve can device of type This location. convenient more a to connection the relocating as well as sees, device electronic the damage. port avoid to item) next the (see saver port the secure to sure Make

### Relief Strain and Management Wire 34.1.4

wire good is maintenance and reliability robot to components critical most the of One components: few a of comprised is management wire Good relief. strain and management

- manage. to more just is length wire excess Any length. correct the are cables sure Make extra the secure cabling, COTS on length additional to due wire extra have must you If wire. the of rest the securing before ties cable separate using bundle small a into
- avoid to slack enough with points, connection to close secured are cables that Ensure the minimizing to critical is and relief, strain called is This connectors. on strain putting (these point connection a at off breaks wire a or unplugged comes cable a that likelihood concentrators). stress generally are
- secure are runs wire all that sure Make components. moving any near cables Secure bend to were components moving the if even components, moving from protected and travel.over- or
- care Take clean. and neat wiring keep to necessary as points additional at cables Secure make actually may it locations, many too in secured are wires if wires; secure over not to difficult. more maintenance and troubleshooting

### תיעוד 34.1.5

is what describing documentation create to is easier maintenance make to way great A of type this creating of ways of number a are There robot. the on where connected list quick a to charts excel to diagrams wiring complete from range which documentation with lists these integrate also teams Many channels. which to attached are functions what of bullet). next the (see labeling

out, burns component a or malfunctioning, is mechanism a or cut, accidentally is wire a When connected is what you tell to documentation some have you if repair to easier much be will it neat!) is wiring your if (even through way the all wiring the trace to having without where

### Labeling 34.1.6

are There above. described documentation wiring the supplement to way great a is Labeling cons. and pros own their with all electronics, and wiring labeling to strategies different many (some maker label a using or hand, by made be can wires for flags and electronics for Labels labeling or tape electrical of colors different use can you or labels), shrinkheat- do also can understand you sure make choose, you system Whatever things. different indicate to flags familiar is team your on everyone sure make and documentation your complements it how it. with

### connections and wiring all Check 34.1.7

on pulling connection, each check to sure make complete, is robot the on wiring all After ”whiskers“ wire stray no that ensure Additionally, secure. is everything that ensure to each, exposed. are connections uninsulated no that and point connection any of out sticking are the makere- discovered, are ”whiskers“ any or testing, while loose come connections any If complete. when it check person second a have to sure make and connection

any For fasteners. boltand-nut- or typescrew- is connections poor of source common A roboRIO), PDP, breaker, main connections, battery (e.g. robot the on type this of connections the that ensure connections, style boltand-nut- For tight. are fasteners the sure make breaker main or wire battery your rotate can you if hand; by rotate be cannot wire/terminal enough. tight not is connection the twisting, and terminal the grasping by connection

are fuses these Ensure PDP. the of end the at fuses the is failures of source common Another completely. them seat to expect you than force more apply to need may you seated; completely hand. by remove to impossible or difficult be likely will they properly seated are fuses the If

ties cable or clips using secured be should connector 50SB- the as such connections inSnap- impacts. during loose pop not do they ensure to

### Often and Early CheckRe- 34.1.8

match first the playing after possible as thoroughly as system electrical entire the checkRe- loosen may sees robot the impacts few first The testing). vigorous very doing (or two or issues. expose or fasteners

rough very a As basis. regular a on connections electrical checkingre- for checklist a Create checked be should connections PDP and battery as such fasteners rotational point, starting connectors Weidmuller and WAGO the as such connections type Spring matches. 31- every responsible is who knows team the that Ensure event. per once checked be to need only likely done. been has it that document will they how and checklist the completing for

### Maintenance Battery 34.1.9

poorly, functional to robot a cause easily can battery bad A batteries! your of care good Take during usage of track keep help to batteries your of all Label match. a during all, at not or label. this on battery the of age the as such information include also teams Many event. the

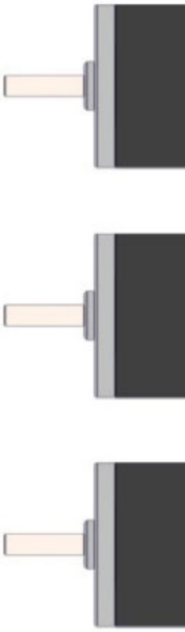
- the has wires the by batteries Carrying wires! the by batteries carry or lift Never plates, the and terminals the between connection internal the damage to potential performance. degrading and resistance internal increasing dramatically
- the to addition In conducted. be can test complete a until bad battery dropped any Mark damage to potential the has also battery a dropping connections, terminal mentioned hiding instead test, voltage simple a on register not may damage This cells. individual load. under placed is battery the until
- charge to time most the have batteries that ensure helps This evenly. batteries Rotate cycles) charge/discharge of number (equal evenly wear they that and rest and
- commercially of number a are There health. monitor to possible if batteries test Load designed one least at including batteries, test load to use teams products available measuring by health battery of indicator an provide can test load A FRC. for specifically match to comes it when meaningful more much is measurement This resistance. internal multimeter. a by provided number voltage loadno- simple a than performance

### Logs DS Check 34.1.10

looks usage current and voltage battery the what see to logs DS the review match, each After you robot, your for is items these of range normal the what established have you Once like. before binding) mechanical motors, failing batteries, (bad issues potential spot to able be may failures. critical become they

## Basics Wiring CAN 34.2

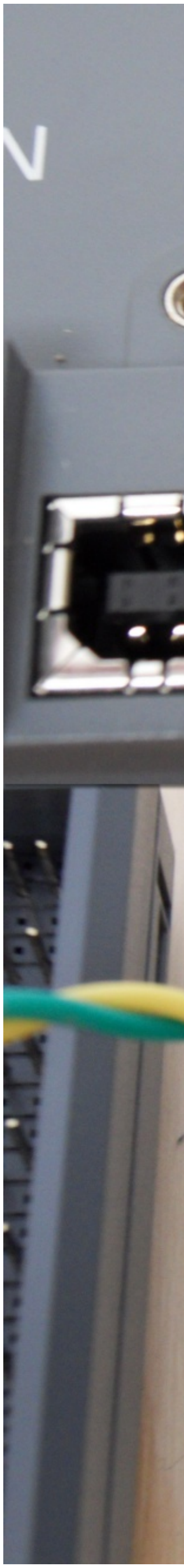
multiple between communication facilitate to designed is that network wire two a is CAN chain“”daisy- a follow robot your on CAN that recommended is It robot. your on devices into go and roboRIO your at start usually should wiring CAN the that means This topology. PDP. the at ending finally until successively device each of out and



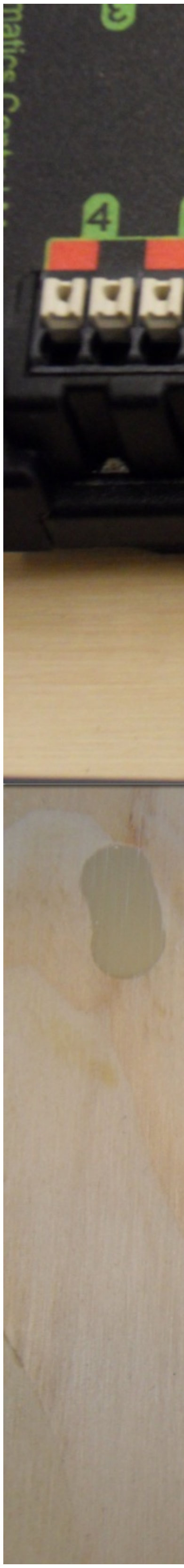
### Wiring Standard 34.2.1

and HighCAN- the as acting yellow with wire green and yellow with wired generally is CAN to scheme color green and yellow this show devices Many signals. LowCAN- the as green in. plugged be should wires the how indicate

PCM. the to roboRIO the from wiring CAN



PDP. the to PCM the from wiring CAN


4

### Termination 34.2.2

CAN the because PDP the at ends and roboRIO the at starts wiring the that recommended is It two these into built are these and resistors Ω 120 by terminated be to required is network position. ”ON“ the in jumper resistor terminating bus CAN the with ships PDP The devices. nodes CAN additional any place and position this in jumper the leave to recommended is It to wish you If bus). the of end the as PDP the (leaving PDP the and roboRIO the between the move terminals) CAN PDP of pairs both (utilizing bus the of middle the in PDP the place of end the at resistor terminating Ω 120 own your place and position ”OFF“ the to jumper chain. bus CAN your

## Module Control Pneumatic CTRE - Pneumatics Wiring 34.3

For (PCM). Module Control Pneumatic CTRE the with pneumatics wiring describes page This .*page this* see (PH) Hub Pneumatic REV the with pneumatics wiring on instructions

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Robot year’s this consult requirements, mechanical & safety pneumatics For **:□□□** is Manual Pneumatics FIRST the guidelines, design mechanical For rules. Construction here located

---

### Overview Wiring 34.3.1

the for output an providing applications, pneumatics most support will PCM single A (12V channels solenoid 8 to up for outputs and switch, pressure the for input compressor, powered and bus CAN the over roboRIO the to connected is module The selectable). 24V or PDH. or PDP the from 12V via

voltages, solenoid multiple or channels more requiring designs robot complicated For system. control the to added be can PHs or PCMs additional

### Wiring Control and Power PCM 34.3.2

of end the on connectors VRM/PCM PDP the from wired be can robot your on PCM first The
a controlling if recommended amp (20 PDH the on port amp 20 or amp 15 a from or PDP the
in anywhere placed be can and CAN via roboRIO the to connected is PCM The compressor).
on details more For terminator). custom a with end the on (or chain CAN the of middle the
*(Optional) Power Pneumatics* see PCM, single a wiring

and PDP the of side the on connector WAGO standard a to wired be can PCMs Additional
placed be also should PCMs Additional breaker. circuit smaller or 20A a with protected
chain. CAN the of middle the in anywhere

### Compressor The 34.3.3

If PCM. the on connectors Out Compressor the to directly wired be can compressor The
extension. the for larger or wire AWG 18 use to sure make required, is length additional

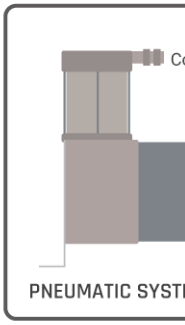
### Switch Pressure The 34.3.4

on terminals input switch pressure the to directly connected be should switch pressure The
either itself, switch pressure the on or terminals input the on polarity no is There PCM. the
spade or Ring switch. the on terminal either to connected be can PCM the on terminal
screws the that (note screws switch the to connection the for recommended are terminals
#6 a for hole a with terminal ring a through threaded be can but #6, than larger slightly are
image). the in shown terminals the as such screw

### Solenoids 34.3.5

PCM. the on terminals of pair numbered a to directly wired be should channel solenoid Each
will solenoid acting double A pair. terminal numbered one use will solenoid acting single A
datasheet the check wiring, coded color with come not does solenoid your If pairs. two use
polarity. proper the with wire to sure make to

### Wiring Control and Power PCM 34.4.2



the of end the on connectors VRM/PCM PDP the from wired be can robot your on PH first The compressor). a controlling if recommended amp (20 PDH the on port 20A or 15A a from or PDP of middle the in anywhere placed be can and CAN via roboRIO the to connected is PH The single a wiring on details more For terminator). custom a with end the on (or chain CAN the *(Optional) Power Pneumatics* see PCM,

and PDP the of side the on connector WAGO standard a to wired be can PHs Additional PHs Additional PDH. the on port 15A a to or breaker circuit smaller or 20A a with protected chain. CAN the of middle the in anywhere placed be also should

### Compressor The 34.4.3

additional If PH. the on connectors Compressor the to directly wired be can compressor The extension. the for larger or wire AWG 18 use to sure make required, is length

### Switch Pressure The 34.4.4

analog an or switch, pressure digital a pressure, detecting for options two has PH The switch. pressure

#### Digital

input sensor pressure digital the to directly connected be should switch pressure digital A switch pressure the on or terminals input the on polarity no is There PCM. the on terminals Ring switch. the on terminal either to connected be can PH the on terminal either itself, the that (note screws switch the to connection the for recommended are terminals spade or hole a with terminal ring a through threaded be can but #6, than larger slightly are screws image). the in shown terminals the as such screw #6 a for

#### Analog

pressure analog the to directly connected be can 110711-REV-( switch pressure analog An pressure the reading allows sensor pressure analog an Using terminals. input 0 port sensor on turning for thresholds trigger custom setting and code through system pneumatic the in compressor. the off and

attention. special requires and fit tight very a is port Sensor Pressure Analog The ..warning:: tips more for Sensor Pressure Analog an Wiring REV See

### Solenoids 34.4.5

PH. the on terminals of pair numbered a to directly wired be should channel solenoid Each will solenoid acting double A pair. terminal numbered one use will solenoid acting single A datasheet the check wiring, coded color with come not does solenoid your If pairs. two use polarity. proper the with wire to sure make to

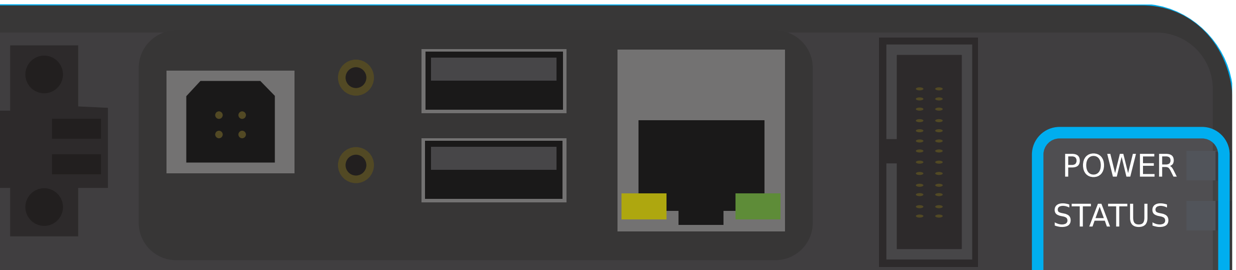
### Switch Voltage Solenoid 34.4.6

to connected solenoids all but solenoids, 24V or 12V either powering of capable is PH The for voltage appropriate the to switch voltage the Set voltage. same the be must PH single a use. to prior solenoids

## Light Status על קצר הסבר 34.5

be can that lights indicator have System Control FRC® the of components the of Many hardware the of each shows guide This robot. your with problems diagnose quickly to used from information and Photos indicators. the of meaning the describes and components Electronics. Road the Cross and FIRST Innovation

## (RSL) Light Signal Robot 34.5.1



| | | |
|---|---|---|
| **Power** | □□□□□ | |
| | □□□□□ | disabled outputs tripped, pr |
| | □□□□□ | circuit short for rails user |
| **Status** | | off turn should then |
| | □□□□□□□□ 2 | roboRIO reima |
| | □□□□□□□□ 3 | resolved not if reimage roboRIO, |
| | □□□□□□□□ 4 | roboRIO, reboot rebooting, without twice<br>resol |
| | on solid stays or flash Constant | □□□□□□□ □□□□□ □□□□□□ |
| **Radio** | | |
| **Comm** | □□□□□ | |
| | □□□□□ □□□□□ | □□□□□ □□□□□ □□□□□□□ □□□ |
| | □□□□□□ □□□□□ | |
| | □□□□□ □□□□□ | |
| **Mode** | □□□□□ | etc.) out,brown- Disabled, in (robo |
| | □□□□□ | |
| | □□□□□ | |
| | □□□□□ | |
| **RSL** | | |

## Radio OpenMesh 34.5.3

| | | |
|---|---|---|
| Power | □□□□□ | □□□□□ □□ □□□□□ |
| | □□□□□□ □□□□□ | □□□□□ |
| Link Eth | □□□□□ | □□□□□□ |
| | □□□□□□ □□□□□ | □□□□□□□ □□□□□□ |
| WiFi | □□□□□ | firmware FRCnon- or Unlinked mode, Bridge |
| | □□□□□ | Unlinked AP, |
| | □□□□□/□□□□□ | Linked AP, |
| | □□□□□ | Linked mode, Bridge |

## Panel Distribution Power 34.5.4

## Hub Distribution Power 34.5.5

later and 21.1.7 version firmware to apply only patterns led These :□□□□

## LED Status PDH 34.5.6

| Color LED | Status |
|---|---|
| Solid Blue | established communication no but on Device |
| □□□□ □□□□ | established roboRIO with Communication Main |
| Blinking Magenta | Timeout Alive Keep |
| Cyan Solid | Client) Hardware REV to (Connected Heartbeat Secondary |
| Blinking Orange/Blue | Battery Low |
| Blinking Orange/Yellow | Fault CAN |
| Blinking Orange/Cyan | Fault Hardware |
| Blinking Orange/Red | Safe Fail |
| Blinking Orange/Magenta | Current Over Device |

### LEDs Channel

| LED Color | Status |
|---|---|
| □□□□ | expected as operating is and voltage has Channel |
| □□□□ □□□□ | or tripped for Check fault. active an is there and voltage NO has Channel fuse / breaker circuit missing |
| □□□□ □□□□□ | fuse. / breaker circuit tripped for Check channel. the on fault Sticky |

## Module Regulator Voltage 34.5.7

is supply the If supplies. power two the of state the indicate VRM the on LEDs status The
the dim, is or lit not is LED the If green. bright lit be should LED the properly functioning
current. much too drawing or shorted be may output

### (PCM) Module Control Pneumatics 34.5.8

communicate cannot device the if only occur not will fault Comm CAN No the that Note **:□□□□** the not but other, each with communicate can PDP and PCM the if device, other any with roboRIO.

### Table States Special LED PCM

| Problems | LED |
|---|---|
| Hardware Damaged | □□□□□/□□□□□ |
| Bootloader In | □□□□□/□□□□□ |
| Polarity Power/Incorrect No | LED No |

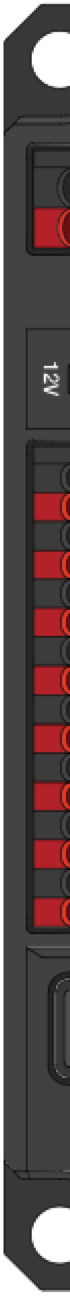
### LED Comp PCM

active is output compressor the when green is LED This LED. Compressor the is This active. not is output compressor the when off and on) currently is (compressor

### LEDs Channel Solenoid PCM

disabled. is it if lit not and enabled is channel Solenoid the if red lit are LEDs These

## Hub Pneumatic 34.5.9



later and 21.1.7 version firmware to apply only patterns led These :

### LED Status PH

| Color LED | Status |
|---|---|
| Solid Blue | established communication no but on Device |
| □□□□□ □□□□□ | established Communication Main |
| Blinking Magenta | Timeout Alive Keep |
| Cyan Solid | Client) HW REV to (connected Heartbeat Secondary |
| Blinking Orange/Blue | Fault Hardware |
| Blinking Orange/Yellow | Fault CAN |
| Blinking Orange/Red | Safe Fail |
| Blinking Orange/Magenta | Current Over Device |
| Blinking Orange/Green | Blinking Orange/Green |

### LED Compressor

| Color LED | Status |
|---|---|
| □□□□□ □□□□□ | On Compressor |
| Solid Black | Off Compressor |

### LEDs Solenoid

| Color LED | Status |
|---|---|
| □□□□□ □□□□□ | On Solenoid |
| Solid Black | Off Solenoid |

## Controllers Motor FX Talon & SPX Victor & SRX Talon 34.5.10

### Operation Normal During LEDs Status

| LEDs | Colors | State SRX Talon |
|---|---|---|
| Both | Blinking Green | is rate Blink applied. is throttle Forward Cycle. Duty to proportional |
| Both | Blinking Red | is rate Blink applied. is throttle Reverse Cycle. Duty to proportional |
| None | None | SRX Talon to applied being is power No |
| Alternate LEDs | Off/Orange | disabled robot detected, bus CAN |
| Alternate LEDs | Off/Slow Red | detected not is bus/PWM CAN |
| Alternate LEDs | Off/Fast Red | Detected Fault |
| Alternate LEDs | □□□□/□□□□ | Hardware Damaged |
| towards Strobe LEDs )(M- | □□□□/□□□□ | Limit Soft Forward or Switch Limit Forward |
| towards Strobe LEDs (M+) | □□□□/□□□□ | Limit Soft Reverse or Switch Limit Reverse |
| to (closest Only LED1 M+/V+) | □□□□/□□□□ | loaderBoot- In |
| towards Strobe LEDs (M+) | Off/Orange | Only) FX (Talon Shutoff / Fault Thermal |

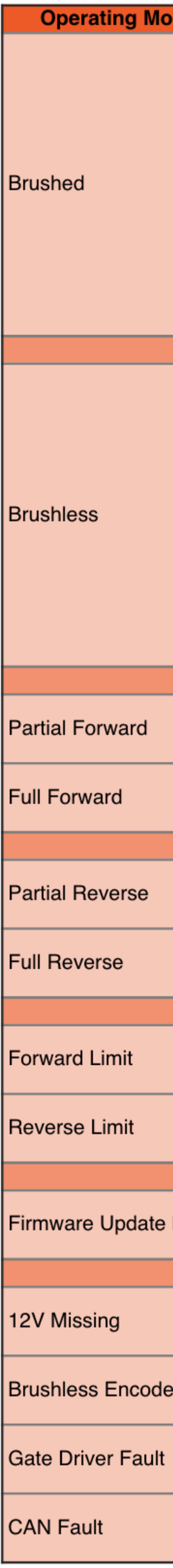
### Calibration During LEDs Status

| State SRX Talon | Code Blink LEDs Status |
|---|---|
| Mode Calibration | Red/Green Flashing |
| Calibration Successful | Green Blinking |
| Calibration Failed | Red Blinking |

### Codes Blink CAL B/C

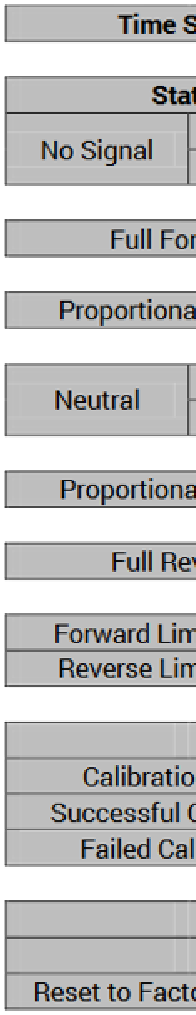
| State SRX Talon | Color Button CAL B/C |
|---|---|
| Mode Brake | [illegible] [illegible] |
| Mode Coast | [illegible] |

## Controller Motor MAXSPARK- 34.5.11



| Operating Mo |
|---|
| Brushed |
| |
| Brushless |
| |
| Partial Forward |
| Full Forward |
| |
| Partial Reverse |
| Full Reverse |
| |
| Forward Limit |
| Reverse Limit |
| |
| Firmware Update |
| |
| 12V Missing |
| Brushless Encode |
| Gate Driver Fault |
| CAN Fault |

## SPARK Robotics REV 34.5.12



Time S

Stat

No Signal

Full For

Proportiona

Neutral

Proportiona

Full Rev

Forward Lim

Reverse Lim

Calibratio

Successful C

Failed Cal

Reset to Facto

## Controller Motor SPVictor- 34.5.13

in is controller the if off mode, brake in is controller the if Red - Button/LED Brake/Coast/Cal mode coast

### Status

| | | |
|---|---|---|
| □□□□ | Solid | output forward Full |
| | □□□□□ | voltage output forward to Proportional |
| □□□□ | Solid | output reverse Full |
| | □□□□□ | voltage output forward to Proportional |
| □□□□ | Solid | 4% (+/- range deadband in signal or lost, signal PWM disabled, robot FRC output) |
| □□□□/□□□□ | □□□□□ | calibration, successful indicates flashes green Several calibration. for Ready calibration. unsuccessful indicates times several red and |

## Controller Motor Talon 34.5.14

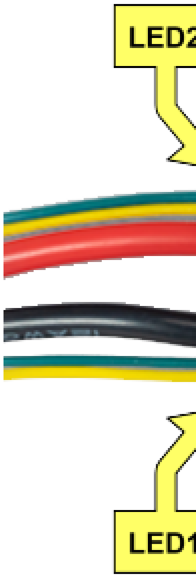
| | | |
|---|---|---|
| [illegible] | Solid | output forward Full |
| | [illegible] | voltage output forward to Proportional |
| [illegible] | Solid | output reverse Full |
| | [illegible] | voltage output reverse to Proportional |
| [illegible] | Solid | connected are devices CAN No |
| | [illegible] | deadband in signal or disabled, robot FRC lost, signal PWM state, Disabled output) 4% (+/- range |
| | | [illegible] Talon to power input No |
| [illegible]/[illegible] | Flashing | successful indicates flashes green Several calibration. for Ready calibration. unsuccessful indicates times several red and calibration, |

## Controller Motor Victor888 34.5.15

### Controller Motor Jaguar 34.5.16

| State LED | Status Module |
|---|---|
| | Conditions Op |
| Yellow Solid | 0) to set (speed Neutral |
| Green Flashing Fast | Forward |
| □□□ □□□□□□ □□□□ | Reverse |
| Green Solid | forward speedFull- |
| □□□□ □□□□ | reverse speedFull- |
| | C |
| Yellow Flashing Slow | link Network or servo of Loss |
| Yellow Flashing Fast | ID CAN Invalid |
| □□□ □□□□□□ □□□□ | condition fault Switch Limit or Temperature, Voltage, |
| and Red Flashing Slow Yellow | condition fault Current |
| | Conditions CAN |
| Green and Red Flashing | active mode Calibration |
| Yellow and Red Flashing | failure mode Calibration |
| Yellow and Green Flashing | success mode Calibration |
| Green Flashing Slow | mode assignment ID CAN |
| Yellow Flashing Fast | ID) determine to flashes (count ID CAN Current |
| Yellow Flashing | ID valid awaiting 0) to Set is, (that invalid ID CAN assignment |

## 60DMC- Digilent 34.5.17



LED. CAL Brake/Coast one and LEDs Blue) and Green, (Red, RGB four contains DMC60C The normal during status indicate to used are and corners the in located are LEDs RGB four The of center the in located is LED CAL Brake/Coast The occurs. fault a when as well as operation, current the indicate to used is and housing, the of center the at located is which triangle, the When mode. coast in operating is device the off, is LED center the When setting. Brake/Coast mode Brake/Coast The mode. brake in operating is device the illuminated, is LED center the button. the releasing then and triangle, the of center the on down pressing by toggled be can

for lasts This brighter. getting continually Blue, illuminate LEDs RGB the on,power- At an to respond not will controller motor the time, this During seconds. five approximately completed, has onpower- initial the After enabled. be drivers output the will nor signal, input function a is LEDs RGB the on displayed gets what and operation normal begins device the faults no that Assuming state. fault current the as well as applied, being signal input the of follows: as function LEDs RGB the occurred, have

| Signal PWM Applied | State LED |
|---|---|
| Input No or Signal Input Invalid Width Pulse | LEDs LED4) and (LED3 bottom and LED2) and (LED1 top between Alternate Off. and Red illuminated being |
| Neutral Pulse Input Width | Orange. illuminated LEDs 4 All |
| Positive Pulse Input Width | → LED3 → LED2 → (LED1 pattern circular clockwise a in Green blink LEDs of cycle duty the to proportional is rate update LED The LED1). → LED4 all cycle, duty 100% At cycle. duty increased with increases and output the Green. illuminated are LEDs 4 |
| Negative Pulse Input Width | → LED4 → (LED1 pattern circular clockwisecounter- a in Red blink LEDs duty the to proportional is rate update LED The LED1). → LED2 → LED3 duty 100% At cycle. duty increased with increases and output the of cycle Red. illuminated are LEDs 4 all cycle, |

| State Control Bus CAN | State LED |
|---|---|
| bus CAN or Signal Input No detected error | bottom and LED2) and (LED1 top between Alternate Off. and Red illuminated being LEDs LED4) and (LED3 |
| received Frame Control CAN No the or 100ms last the within specified frame control last Disabled) (Output modeNoDrive | bottom and LED2) and (LED1 top between Alternate and Orange illuminated being LEDs LED4) and (LED3 Off. |
| Frame Control CAN Valid 100ms. last the within received mode control specified The Cycle Duty Neutral a in resulted Output Motor to applied being | Orange. solid illuminated LEDs 4 All |
| Frame Control CAN Valid 100ms. last the within received mode control specified The Cycle Duty Positive a in resulted Output Motor being | (LED1 pattern circular clockwise a in Green blink LEDs update LED The LED1). → LED4 → LED3 → LED2 → and output the of cycle duty the to proportional is rate cycle, duty 100% At cycle. duty increased with increases Green. illuminated are LEDs 4 all |
| Frame Control CAN Valid 100ms. last the within received mode control specified The Duty Negative a in resulted Output Motor being Cycle | pattern circular clockwisecounter- a in Red blink LEDs LED The LED1). → LED2 → LED3 → LED4 → (LED1 the of cycle duty the to proportional is rate update At cycle. duty increased with increases and output Red. illuminated are LEDs 4 all cycle, duty 100% |

### Indicators Color Fault

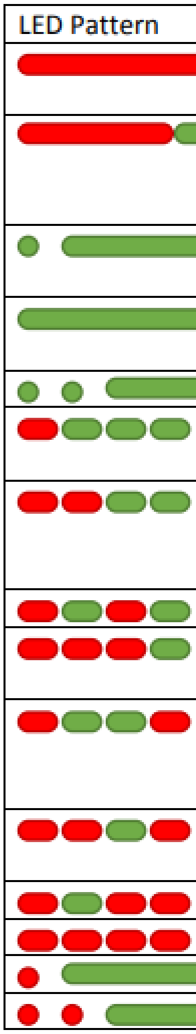
is fault a and 0% to reduced is cycle duty output the detected, is condition fault a When LEDs onboard the time this During seconds. 3 for disabled remains then output The signaled. toggling by indicated is condition fault The condition. fault the indicate to used are 4)(LED1- Red illuminated being LEDs LED4) and (LED3 bottom and LED2) and (LED1 top the between table The active. presently are faults which on depends LEDs bottom the of color The off. and faults. active presently the to maps LEDs bottom the of color the how describes below

| צבע | Temperature Over | Voltage Under |
|---|---|---|
| □□□□ | On | □□□□ |
| □□□□ | □□□□ | On |
| Aqua / Cyan | On | On |

### Mode Break/Coast

is LED center the When mode. coast in operating is device the off is LED center the When
by toggled be can mode Brake/Coast The mode. brake in operating is device the illuminated
button. the releasing then and triangle the of center the on down pressing

## Controller Motor Venom 34.5.18


LED Pattern

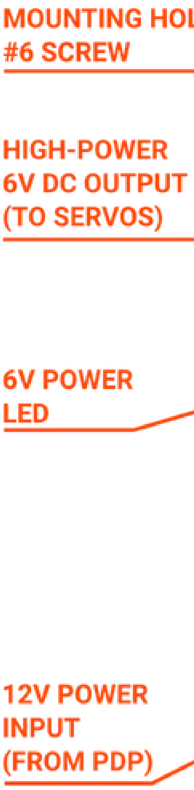
### (PWM) SD540B Mindsensors 34.5.19

| | | |
|---|---|---|
| LED Power | ▯▯▯▯ | supplied not is Power |
| | ▯▯▯▯ | supplied is Power |
| LED Motor | ▯▯▯▯ | direction Forward |
| | ▯▯▯▯ | direction Reverse |
| LED Signal PWM | ▯▯▯▯ | detected is signal PWM valid No |
| | ▯▯▯▯ | detected is signal PWM Valid |

### Bus) (CAN SD540C Mindsensors 34.5.20

| | | |
|---|---|---|
| LED Power | □□□□□ | supplied not is Power |
| | □□□□□ | supplied is Power |
| LED Motor | □□□□□ | direction Forward |
| | □□□□□ | direction Reverse |
| Signal CAN LED | □□□□□□ □□□□□□□□ | connected are devices CAN No |
| | □□□□□ | open is station driver the and roboRIO the to Connected |

## Module Power Servo Robotics REV 34.5.21



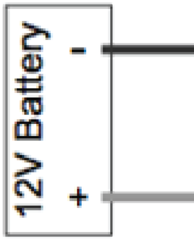
### LEDs Status

the of state sensed the indicate will that LED status corresponding a has channel Each pattern. LED corresponding state's each describes below table The signal. PWM connected

| State | Pattern |
|---|---|
| Signal No | □□□□□□ □□□□□ |
| Signal Left/Reverse | □□□□□ □□□□□ |
| Signal Center/Neutral | □□□□□ □□□□□ |
| Signal Right/Forward | Green Solid |

- shutdown currentOver- = applied power with flickering or dim off, LED Power 6V

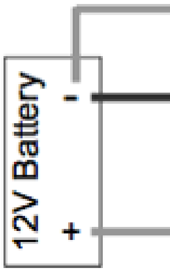
## switch solenoid or light, motor, a as configured relay Spike 34.5.22



| Inputs | | Outputs | | Indicator | Function Motor |
|---|---|---|---|---|---|
| **Forward (White)** | **Reverse (Red)** | **M+** | **M-** | | |
| □□□□ | □□□□ | GND | GND | □□□□ | (default) Condition Off/Brake |
| On | □□□□ | +12v | GND | □□□□ | direction one in rotates Motor |
| □□□□ | On | GND | +12v | □□□□ | opposite in rotates Motor direction |
| On | On | +12v | +12v | □□□□ | Condition Off/Brake |

of shorting the to due motor the of stopping dynamic the to refers Condition« »Brake :□□□□ state. off an to going when optional not is condition This inputs. motor the

## solenoids two or one for as configured relay Spike 34.5.23



| Inputs | | Outputs | | Indicator | Function Motor |
|---|---|---|---|---|---|
| **Forward (White)** | **Reverse (Red)** | **M+** | **M-** | | |
| □□□□ | □□□□ | GND | GND | □□□□ | (default) Off Solenoids Both |
| On | □□□□ | +12v | GND | □□□□ | is M+ to connected Solenoid ON |
| □□□□ | On | GND | +12v | □□□□ | is M- to connected Solenoid ON |
| On | On | +12v | +12v | □□□□ | ON Solenoids Both |

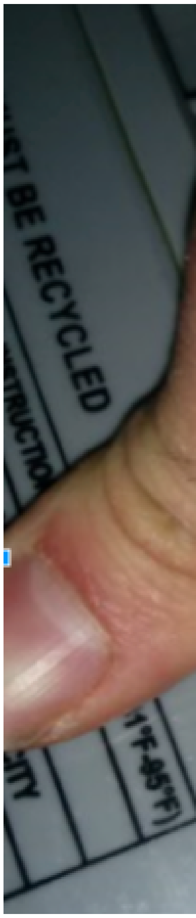
## Encoder CANCoder 34.5.24

| LED Color | LED Brightness | Bus CAN detection | Strength Field Magnet | Description |
|---|---|---|---|---|
| □□□□ | □□□□ | | | not is CANCoder powered |
| Yellow/Green | Bright | | | loader.boot- in is Device for manual user See information. more |
| Slow Red Blink | Bright | has bus CAN lost been | | |
| Rapid Red Blink | Dim | bus CAN never detected boot since | range of out is Magnet >135mT) or (<25mT | |
| Rapid Yellow Blink | | | with range in Magnet accuracy reduced slightly 135mT)75- or 45mT(25- | |
| Rapid Green Blink | | | (between range in Magnet 75mT) - 45mT | |
| Rapid Red Blink | Bright | bus CAN present | range of out is Magnet >135mT) or (<25mT | |
| Rapid Yellow Blink | | | with range in Magnet accuracy reduced slightly 135mT)75- or 45mT(25- | |
| Rapid Green Blink | | | (between range in Magnet 75mT) - 45mT | |

## Troubleshooting Preemptive Robot 34.6

around driving while stress of lot a take robots Competition, Robotics ®*FIRST* In **:□□□□** securely bolted are parts tight, are connections that sure make to important is It field. the not does field the around bouncing robot a that so mounted is everything that and place in break.

### בדיקת חיבורי מצבר 34.6.1

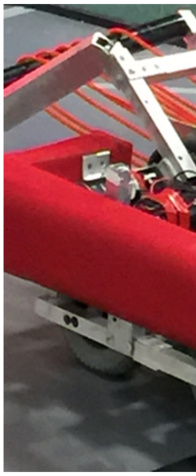


removed been has examples these in connection battery the covering be should that tape The
covered. be should connections the robots, your On on. going is what illustrate to

or loosen, screws the because loose are these Often connector. harness battery Wiggle
though ones bad really the catch only will You closed. completely not is crimp the sometimes
Using stiff. feels it where point a to connection the stiffens tape electrical the often because
this. with help will Beak Battery or voltmeter a

of direction the move to try to degrees 90 at cable battery the onto force considerable Apply
with begin to enough tight not was connection the successful if battery, the leaving cable the
information. battery detailed more has *article* This redone. be should it and

### Robot the to Battery the Securing 34.6.2



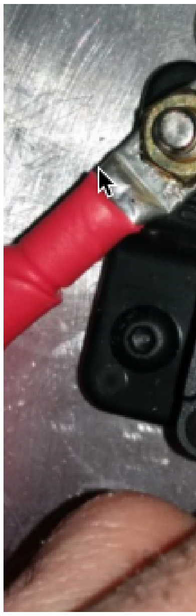
battery secured properly not a where robot one least at see we event every almost In
This robot. the from power disconnects and apart comes Anderson) large (the connector
to easy an Its else. everywhere and Einstein the on matches championship in happened has
wrap tie a wrapping by connectors two the securing by you to happen doesn’t this that ensure
high a not is event an during mind of piece the for wraps tie 12 or 10 connection. the around
event actual an from robot this of problem the have not will you that guarantee to pay to price
loop and hook with chassis the to battery your secure Also, defense. a over ride bumpy a after
climbing. or obstacles defense, rough with games in especially method, another or tape

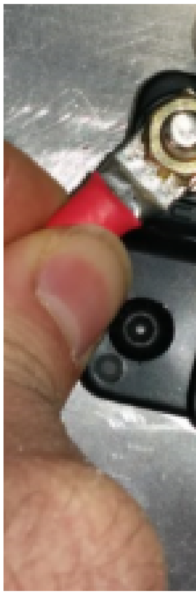
### Leads Power Main & Connector Battery the Securing 34.6.3

leads power main the allow can SB) Anderson large (the connector battery siderobot- loose A
”tug“ that loose, are leads power main the If replaced. is battery the when tugged be to
Power or Breaker Circuit Amp 120 the to attached lugs crimp the to back way the all get can
fatigue. from break to end lug the cause time over and lug, the bend (PDP), Panel Distribution
down bolting and chassis the to leads power main the attaching wraps tie couple a Putting
the connect to easier it make as well as this, prevent can connector battery siderobot- the
battery.

### Breaker) Circuit Amp 120) Breaker Main 34.6.4

element. rigid a to attached is breaker the and firmly tightened are nuts Ensure **:□□□□**





nut the then rotates lug the If lug. crimped the rotate to try to force twisting strong a Apply lug. the rotate to trying again once by retest nut, the tightening After enough. tight not is

require may these time: over out wear can which feature, locking star a has nut original The attached not is connector battery siderobot- your if especially matches, few every checking chassis. the to

is nut the if correct is this ensure thread: 281/4- uncommon relatively a normally is nut The replaced.

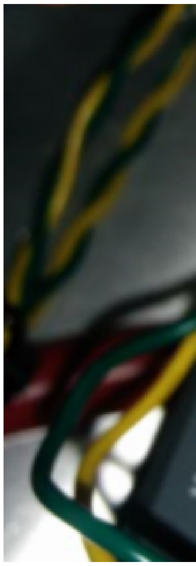
off break may you awhile in once every case, the into molded just is stud metal the Because assembly. the replace just stress, Don’t stud. the

fatigue to susceptible is Breaker Main the seasons, competition multiple to subjected When thermal the time Each impact. under opening start can and use, and vibration from damage teams veteran Many trip. to easier progressively become can it triggered, is function fuse spares. carry and breaker, main fresh a with season each start

### (PDP) Panel Distribution Power 34.6.5

visually to easy not is it but screws, PDP the under placed were washers split that sure Make squeeze you if Also case. the removing by check can You can’t. you sometimes and confirm, connections. lose really the catch can you sometimes together, wires black and red the

### Testing Tug 34.6.6



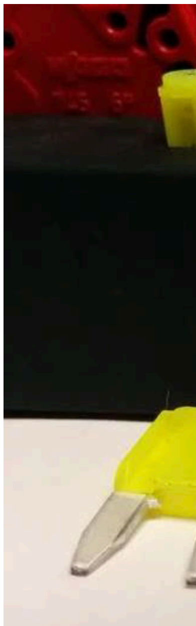
radio and connector, power roboRIO output, compressor power, for contacts Weidmuller The none that sure Make shown. as connections the on tugging by verify to important are power out. pull connections the of

each to close are that connections Weidmuller with shorts impending or possible for Look long). extra stripped are that (wires lengths leadwire- longtoo- have and other,

well. as those testtug- so crimps, improper to due fail also can connectors Spade

### Fuses Blade 34.6.7

right. the on (red) fuse 10A the and left the on (yellow) fuse 20A the place to sure Be



fuses The holders. fuse the into seated fully are fuses ensure to care Take **:**
different have fuses brand (different below figure the as far as least at descend should
(without hands bare with fuse the remove to impossible nearly be should It lengths). lead
intermittent exhibit may robot/radio the done, properly not is this If pliers). of use the
issues. connectivity

that sure Make completely. in not are they then hand by fuses blade the remove can you If
operation. robot during out pop don't they that so PDP the in seated completely are they

### swarf roboRIO 34.6.8

machining a by produced material other or metal, stone, of filings or chips fine is Swarf
are parts system control the while robot a to made be must modifications Often operation.
absolutely doesn't that but coated, conformally is roboRIO the for board circuit The place. in
case, this In case. the inside components or traces out short won't chips metal that guarantee
any or roboRIO the in up end chips the of none that sure making in care exercise must you
chips where place a are headers pin 3 exposed the particular, In components. other the of
usually is flashlight a with sides four the of each through sweep quick A case. the enter can
infiltration. of areas bad really the find to sufficient

### Jack Barrel Radio 34.6.9

reason. no for out falls and small too is that one not used, is jack barrel correct the sure Make random some use will team a awhile in once every and FTA an ask but common, isn't This contact. first on match a in out falls it and correctly, sized not is that jack barrel

### Cable Ethernet 34.6.10

another get in, connector the locks that clip the missing is cable ethernet radio to RIO the If Make competition. every in times several happen will that problem common a is This cable. through it pulling when especially off, breaks often clip The secure. are cables your that sure breaks. then something on snags it path, tight a

### Cables Loose 34.6.11

radio The cable. ethernet and power radio the particularly down, tightened be must Cables barrel) correct the is it if (even out fall will and force friction of lot a have don't cables power freely. swing to allowed is slackcable- the of weight the if

be not may clip plastic the freely, swing to allowed it's if heavy, pretty also is cable Ethernet circuit. in connectors pin ethernet the hold to enough

### Pit the in Problems Reproducing 34.6.12

suggested is it tethered, and powered is robot the whilst cables of shaking normal the Beyond against especially field, the on Driving dropped. and up picked be robot the of side one that better is It out. falls nothing sure makes helps this and violent, very be often will defenders, match. a of middle the in than rather pits the in fail to robot the for

otherwise tethered, USB not and tethered ethernet be to important it's test this doing When paths. critical the of all testing not are you

### Versions and Firmware Check 34.6.13

they and out inspectors robot helps it well, as it do should you but this, do inspectors Robot code. fixed bug recent, most the with running are you that guarantees it And it. appreciate software system control of piece date of out an of because match a lose to want wouldn't You robot. your on

### Checks Station Driver 34.6.14

should: You Station. Drivers the with problems see often We

- battery the good how matter doesn't it field, the to cable power laptop the bring ALWAYS field. the at in plug to allowed are you is,
- etc. savers, screen hibernate, and sleep off turn settings, sleep and power the Check
- manager) (dev devices USB for management power off Turn
- manager) (dev ports ethernet for management power off Turn

- Defender Windows □□ □□□
- □□□ □□□□ □□ □□□
- field. the on out when DS/Dashboard for except apps all Close
- menu start the in tray application the in running unnecessary nothing is there that Verify side) right (bottom

### Tools Handy 34.6.15

scrutinize to enough not least at robots, inside light enough be to seems never There the inspect to flashlight LED handheld a using consider so points, connection critical the hardware/automotive any or depot home from available They're robot. your on connections store.

I'll Often wires. stranded with connections Weidmuller redoing for tool nice is tool WAGO A down press to tool WAGO the using rest the do them have then and team, the show to one do makes tool WAGO the of angle The wire. stranded the insert they while plungerwhite- the helpful. particularly this

## Basics Battery Robot 34.7

non- Acid) Lead (Sealed SLA 18Ah 12V single a is robot FRC® an for supply power The fully when 500A over arcing and 180A over supplying briefly of capable battery, spillable contacts, with cables lead battery, *COTS* the includes assembly Battery Robot The charged. Batteries. Robot multiple have to encouraged are Teams connector. SB Anderson and

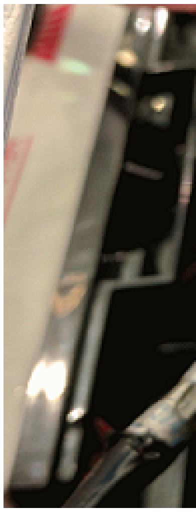
### Battery COTS 34.7.1

battery acid lead sealed spillablenon- COTS a specify Manual Game the in Rules Robot The vendors. of variety a from numbers part legal of examples gives and criteria, specific meeting

## Handling & Safety Battery 34.7.2

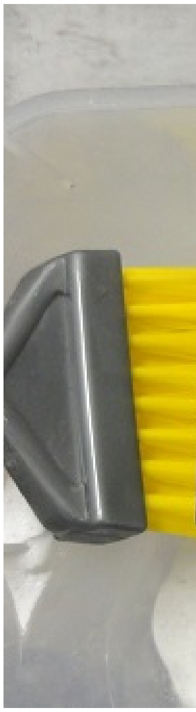
polarities the If energized. **always** are terminals the and ”On“ **always** is battery healthy A
two between gap the bridges and falls can aerosol or wrench a example, for - together short
drives risk This arc. dangerous a in released be will energy stored the all - terminals bare
and uncovering only storage, in terminals covering as such practices, best of range wide a
connectors, in inserted fully contacts SB keeping time, a at polarity or terminal one on working
etc.

them. by pulling avoid always and ,**cables the by assembly battery a carry *NOT* Do**
internal the and tabs, lugs, the damage to begin will cables the by batteries on Pulling
of out tears tab entire the until up add can damage fatigue time, Over tab. the of connection
battery the increase can damage fatigue internal broken, clearly isn’t it if Even housing! the
to able be not will battery The battery. the out wearing prematurely resistance, internal
*connectors* the if or resistance internal increased with current of amount same the provide
*.loose are*



create issues, performance cause and plates internal the bend can batteries the Dropping
Glass Absorbent use batteries FRC most While open. case battery the crack even or bulges,
may it punctured is cell a when performance, and safety for technology Gel or [AGM] Mat
teams recommends FIRST reasons the of one is This acid. battery of amount small a leak still
available. kit spill battery a have

*overcharge* can features mode“ ”maintenance without chargers battery older certain Finally,
acid. battery the of some off boiling in resulting battery, the



sell that retailers All possible. as soon as of disposed safely be should batteries Damaged may They you. for it of dispose to able be should batteries, car like batteries, SLA large law. state your on depending refund“, charge ”core small a provide or fee, small a charge

batteries. functionalnon- or damaged ”repair“ to attempt **NOT DO** :□□□□

### Tools & Construction Battery 34.7.3

#### Leads Battery

and SWG) 7 (16mm2, AWG 6 section) (cross size minimum copper, be must leads Battery Standard connector. SB Anderson an with polarity, for coded color 12“, length maximum are and Parts of Kit the in come often leads battery SB50 Pink/Red with leads copper 6AWG vendors. FRC by sold

#### Cables Lead

aluminum), clad (copper CCA use not Do allowed. is copper coated or annealed, Tinned, the on printed normally is metal conductor The metal. base coppernon- other or aluminum, ratings. cable other the with insulation the of outside

small A contacts. SB50 standard fits and robots all almost for sufficient is 6AWG size Wire benefits. performance marginal for sizes wire larger adopt teams of number

bend smaller a has wire“) ”welding or ”Flex“ as sold (sometimes wire count strand Higher count strand no is There limit. fatigue higher a and route, to easier it makes which radius, wire“) ”welding strand (259 259/30 and wire) hookup ”flex“ strand (84 84/25 but requirement, wire). hookup strand (19 19/0.0372 than with work to easier *much* be both will must wire +12Vdc the 2021, of as Manual: Game the per codedcolor- be must insulation The black be must wire) (return wire ground the and w/stripe black or yellow, brown, white, red, be or blackened any but requirement, rating temperature insulation explicit no is There blue. or lower and plenty is 105C hand, off replaced: be to needs wire the means insulation damaged is lower requirement, rating voltage insulation no is There robots. all almost for work will insulation. thinner for better

## Connector SB

Anderson another or SB50, Pink/Red standard the be may Connector SB Anderson The for SB50 Pink/Red the use to recommended *STRONGLY* are Teams connector. SB be will you and intermate, not will housings of sizes and colors other the interoperability: chargers. or batteries borrow to unable

Anderson into leads the assemble and contacts crimp to instructions manufacturer's Follow the on (push contacts the insert to help can screwdriver flathead small A connectors. SB contact the if latch internal the disengage to help can it or insulation), wire the on not contact, down. upside or slot wrong the in is

## Lugs Battery

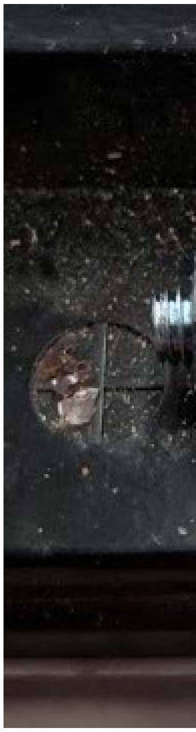
hole ~5mm or (~0.2“ tabs battery M5) (or bolt #10 for lugs“) (”crimp lugs Compression accepted the by sold houses, supply electrical through and online available are diameter) end Higher diameter“). ”hole size“, (”bolt diameter post and mm2) (or AWG in sizes wire their in counts strand (>80) Flex and (~19) Standard between distinguish also will vendors straight common more to addition in lugs, angle right offer also vendors Some catalogs. lug lugs. the crimp to instructions manufacturer's Follow styles.

the use lugs, terminal screw using If recommended. not but legal, are lugs terminal Screw frequently tightness terminal the Check terminal. the tighten to screwdriver size tip correct time. over loosen may they because

## Connection Post To Lug Lead Battery

tab. battery the to lug lead battery the connect bolt & nut M5 or #10 A

> of washer a put not do copper: to copper contact, directly must tab and lug The **:□□□□□**
> them. separating kind any



with replaced or used, be may they package: the in bolts tab with come batteries Some star #10 a as such washer, lock functional a add to idea good a is It bolts. steel alloy stronger use Only nut. (”nylock“) locking nylon a to addition in system, washer nordlock a or washer lock ring split provides manufacturer the if Even connection. each in washer lock of style one them. use to required not are you package, the in washers

in while lug the of movement Any reliability. for tight very be must connections These disconnections field and reboots robot in resulting power, robot interrupt may operation more. or seconds 30 lasting

will tape electrical safety; electrical for covered completely be also must connection This ratios shrink High recommended. is connection entire the over fits that heatshrink but work, lined Adhesive heatshrink. the apply to easier it make will 4:1) recommend 3:1, (minimum up“ ”touched be must shrink Heat covered! is copper the *all* sure Be allowed. is shrink heat with electrical tape if some copper shows.

## Chargers Battery

rated batteries, SLA 12V for designed chargers battery ”smart“ COTS good many are There are 6A over rated Chargers features. mode« »maintenance with battery, per less or 6A for pits. FRC in allowed not

a Attaching connectors. SB Anderson use to required are competition at used Chargers nuts wire sized appropriately using leads charger the to lead battery connector SB COTS shrink heat with copper exposed any cover to sure (be simple and fast is terminals screw or the if sizes, wire smaller for available also are Contacts Connector SB tape). electrical or capability. crimping has team

> multimeter a with polarities charger the check double SB, the attaching After :□□□□□ battery. first the in plugging before

attached.pre- connectors SB50 red with chargers sell vendors FRC Some

## Tools Evaluation Battery

### Charger Battery

can you LED, GREEN a as such indicator, Mode Maintenance has charger battery your If between cycle will chargers Some READY. are you whether you tell to indicator that use sometimes behavior, ”maintenance“ a is This periodically. ”READY“ and ”CHARGING“ charge. more accept to able being and off cooling battery the with associated

### Log and Display Station Driver

voltage battery the laptop, station driver the to connected and in plugged is robot the When software. Station Driver NI the on displayed is

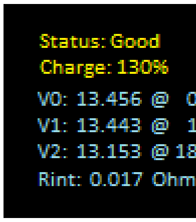
*Viewer. Log the in voltage battery the review* can you session, driving a finish you After

### **Multimeter** or **Voltmeter** heldHand-

you give will battery disconnected a of connector SB the on probes from reading voltage A ”Unloaded“ the in is voltage“) ”float or circuit, open (Voltage Voc the what of snapshot a the health: battery understanding for method recommended a not is Voc the general In state. at voltages and resistance internal of combination the as useful as not is voltage circuit open Analyzer). Battery (or Tester Load a by provided loads specific

### Tester Load

a of readiness detailed the determine to way quick a as used be can tester load battery A internal load, under voltage voltage, loadopen- like: information provide may It battery. battery a that confirm quickly to used be can metrics These charge. of state and resistance, battery. the with problems term long some identify to help even and match a for ready is



Status: Good
Charge: 130%
V0: 13.456 @ 0
V1: 13.443 @ 1
V2: 13.153 @ 18
Rint: 0.017 Ohm

for specification manufacturer The Ohms. 0.015 than less be should resistance internal Ideal to idea good a is it Ohms 0.020 than higher gets battery a If Ohms. 0.011 is batteries most matches. competition for battery that using not consider

be not may it loads, current test higher the at voltages lower significantly shows battery a If retired. be to need may it or charging, done

## Voltages Battery Understanding 34.7.4

12.0V. but anything is battery“ ”12V A

Open (Voc). circuit open volts 13.5 to 12.7 from anywhere be can battery a charged, Fully connected. *nothing* with measured is voltage circuit

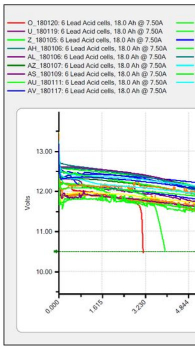
battery the flowing, is current of amount any and connected, is robot) a (like load a Once then and 13.2, reads it and Voltmeter, a with battery a check you if So drop. will voltage Station Driver the on 12.9 maybe lower, read will it on, power and robot your to it connect Characterization see robot, specific and battery every with vary will numbers Those display. drop will voltage the and current, more pull will it running, starts robot your Once below. further.

match. a before charged and swapped be should robot idle an on 12.5V reading Batteries thresholds safety brownout reaching starts robot the before batteries the swap Always voltage low entering frequently as display), Station Driver the on voltages low at (dwelling states Voc of variety a at happen can behavior this damage; battery permanent risks ranges of State battery The design. robot and manufacturer, battery health, battery on depending longevity. battery for 50% over kept be should Charge

batteries. happy are batteries cool temperature: on depends also current and voltage Battery

### Characterization Battery

battery of comparison and inspection detailed a give to used be can analyzer battery A performance.



time significant takes test This time. over performance battery of graphs provide will It recommended is It competition. during testing to suited less is it so hours) two (roughly will This performance. its track and monitor to year every battery each on test this run to of. disposed or testing, practice, matches, used: be should it how determine

amp 11.5 a least at have should batteries competition load, test amps 7.5 standard the At demanding less other or practice for used be only should that than less Anything rating. hour cases. use

### Longevity Battery

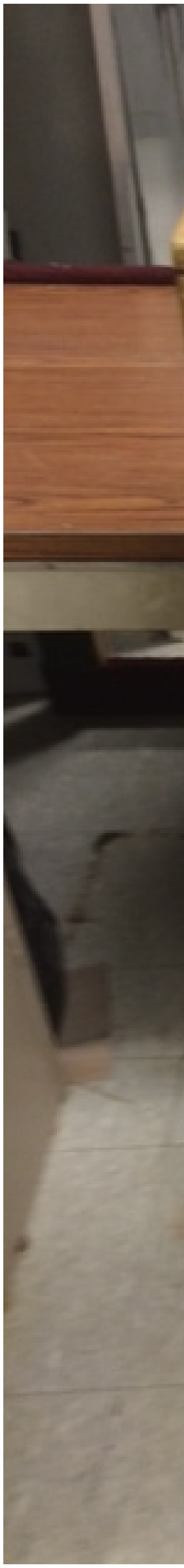
required currents high The cycles. charge/recharge normal 1200 about for rated is battery A be to intended are cycles These cycles. 400 about to lifespan that reduce match FRC an for battery the cycling Deep volts. 12.5 or 12 to down 13.5 around from discharge, low relatively it. damage will down) way the all it (running

charging by either use, in not when charged fully kept are they if longest the last Batteries of month every 0.1V roughly drop Batteries charger. maintenance a of use by or regularly use.non-

storing means generally This cold. and heat extreme both from away kept be to need Batteries lot parking a fine, usually is closet classroom a area: controlled climate a in batteries the risky. more is container shipping

## Practices Best Battery 34.7.5

- you where situation a in are you If matches. competition for battery charged a use Only to wants Nobody help! for team veteran a ask please batteries, charged of out run have battery. uncharged or bad a to due )*brownout*( field the on dead robot a see
- quality stringent and tools rated properly use to recommended strongly are Teams commercial a or teams veteran local (ask processes crimping for practices control Leads. Battery madevendor- use or help), for electrician
- warm be not should case the recharging: before match the after cool to batteries for Wait plenty. usually is minutes fifteen touch, the to
- their keep help to year each batteries new several purchasing consider should Teams be not may there and batteries many require can matches Elimination fresh. batteries recharge. to time enough

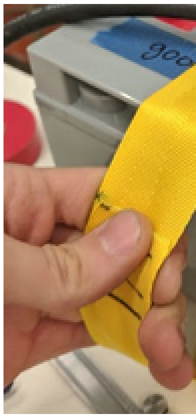


Many time. a at battery one than more charge to you allows charger battery bank multi A and transport easy for allowing chargers and batteries their for cart robot a build teams storage.

- year, number, team least: at with battery each identify permanently to idea good a is It identifier. unique a and
- to etc.) machine labeling (stickers, removable something use to want also may Teams when and data performance its on based for used be should battery that what identify run. was test analyzer last the

- way common a is connector) battery the in placed plastic of piece (a flags battery Using printed. 3D easily be also can flags Battery charged. been has battery a that indicate to
- the on pulling avoid help to printed 3D or purchased be can contacts SB50 for Handles the carry to handles these use not Do batteries. disconnecting or connecting while leads battery. the of weight

- fit that nylon flat other or seatbelts old from straps carrying battery sew teams Some leads. by carrying prevent help to battery the around



leads. battery relieve strain to lugs crimp degree 90 with used be can clips edge tie Cable •

# 53

[redacted]

[illegible]: [illegible].

## 35.1 מנועים ליישומים ברובוטיקה

[illegible]. [illegible], [illegible], [illegible] WPI, [illegible], [illegible].

## 35.2 חיישנים

the allow Sensors vehicles. controlled radio really are robots sensing and sensors Without the as well as systems mechanical robots the of operation internal the understand to robots Professor WPI videos, these In robot. the around environment the with interact to ability provides and used, are they how sensors, of classes of number a describes Putnam Craig applications. your for best are sensors what on guidance

## 35.3 פניאומטיקה

are There robots. on used be can that device actuation underused often an is Pneumatics Stafford Ken Professor video this In motors. using over pneumatics to advantages many the calculating and robots, with applications pneumatics, of characteristics the describes application. an for system sized right

## 35.4 המרות כוח

motor that transmitting is application an for motors correct the choosing with hand in Hand ways effective two are sprockets and chains or gears Using needed. it’s place the to power Robotics WPI video, this In driven. being application the to power motor the matching of choosing including transmission, power about talks Delph Michael student PhD Engineering robot your from performance maximum the get to ratios sprocket and chain or gear correct design.

[redacted]

## Hardware - Overview Sensor 36.1

software a For code. in sensors of use the not hardware, sensor covers section This :□□□□
.□□□□□ - □□□□□□□ □□□□□ see guide, sensor

their about information gather to able be to robots for vital often is it effective, be to order In are environment its of state the on robot the to feedback provide that Devices surroundings. measuring for teams, FRC® to available sensors of variety large a are There ”sensors.“ called positioning. motor/mechanism to orientation robot to positioning fieldon- from everything games FRC most while success; fieldon- for skill crucial absolutely an is sensors of use Making on heavily rely robots best the robot, ”blind“ a by accomplished be can that tasks have do possible. as reliably and quickly as tasks game accomplish to sensors

mechanisms robot many - safety robot for important extremely be can sensors Additionally, against safeguard a provide Sensors incorrectly. used if themselves breaking of capable are stop.hard- a against is mechanism a if motor a disable example, for to, robots allowing this,

### 36.1.1 סוגי חיישנים

by and function, by ways: different two in categorized generally be can FRC in used Sensors latter the design; robot for relevant is categorization former The protocol. communication programming. and wiring for

#### Function by Sensors

Sensor state. robot’s the of aspects different of variety a on feedback provide can Sensors include: FRC to common functions

- switches Proximity
  - switches“) (”limit switches proximity Mechanical
  - switches proximity Magnetic
  - switches proximity Inductive

  - switches proximity Photoelectric
- sensors Distance
  - *sensors Ultrasonic*
  - *rangefinders Triangulating*
  - *LIDAR*
- sensors rotation Shaft
  - *Encoders*
  - *Potentiometers*
- *Accelerometers*
- *Gyroscopes*

### Protocol Communication by Sensors

several are There roboRIO. the to ”talk“ to able be must it useful, be to sensor a for order In roboRIO: the to readings their communicate can sensors which by methods main

- *input Analog*
- *input Digital*
- *bus Serial*

is inputs digital and analog via communicate that sensors for support general, In complicated. more be can bus serial over communication while straightforward,

## קלט אנלוגי - חומרה 36.2

see inputs, analog to guide software a For hardware. input analog covers section This :□□□□ .*Software - Inputs Analog*

lies This interval. continuous a in anywhere lie can value whose signal a is signal analog An The values. discrete several of one only take can which ,*signal digital* a to contrast stark in 0V from values with signals analog of measurement the allow ports input analog roboRIO’s 5V. to

a as such device digital a with signal analog ”true“ a measure to way no is there practice, In bit12- a as measured actually are inputs analog the Accordingly, roboRIO). the (like computer .[1] resolution high a quite is this however, - signal digital

vary measurements whose sensors for used always!) not (but typically are inputs Analog can they as ,*potentiometers* and *rangefinders ultrasonic* as such range, a over continuously measurements. their to proportional voltage a outputting by communicate

---

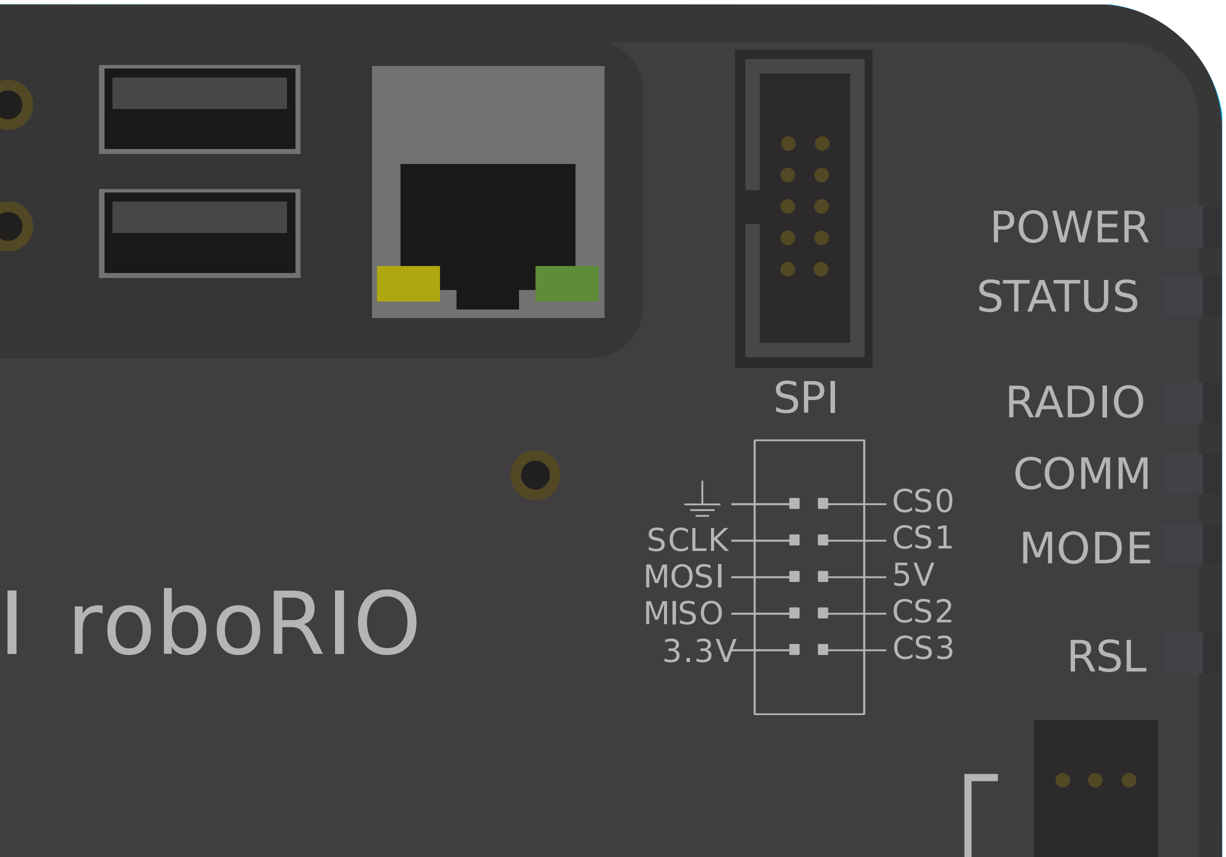
[1] of resolution effective an that’s range, 5V a For values. different 4096 or ,$2^{12}$ yields resolution bit12- A approximately 1.2 mV, or .0012V. The actual accuracy specification is plus-minus- 50mV, so the discretization is not the limiting factor in the measurement accuracy.

### ports input analog roboRIO to Connecting 36.2.1

use To port. expansion ”MXP“ the via available are inputs analog four additional An **:□□□□**
needed. is MXP the to connects that sort some of board breakout a these,

*before* using are you sensor the of specifications technical the consult Always **:□□□□□**
Failure pin. each to connected being is wire correct the that ensure to sensor, the wiring
RIO. the or sensor the to damage in result can so do to

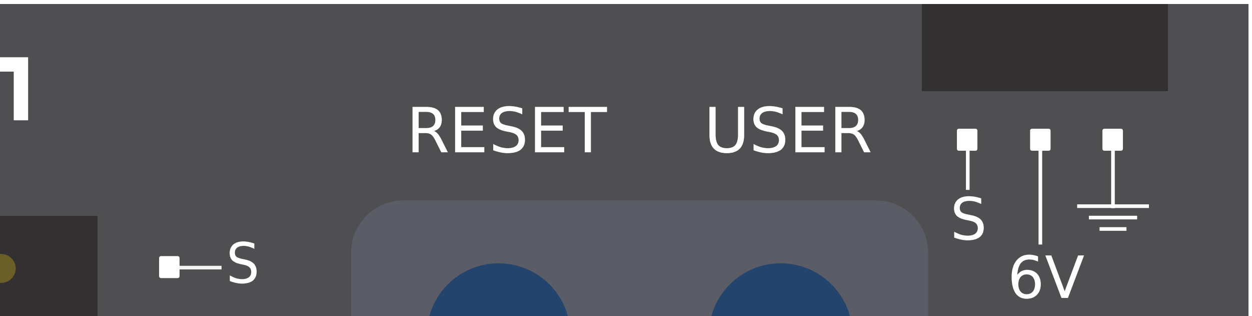
roboRIO! the on port any on pin ground the to pin power the connect directly **Never** **:□□□□□**
behavior. unexpected in result may and roboRIO the on features protection trigger will This

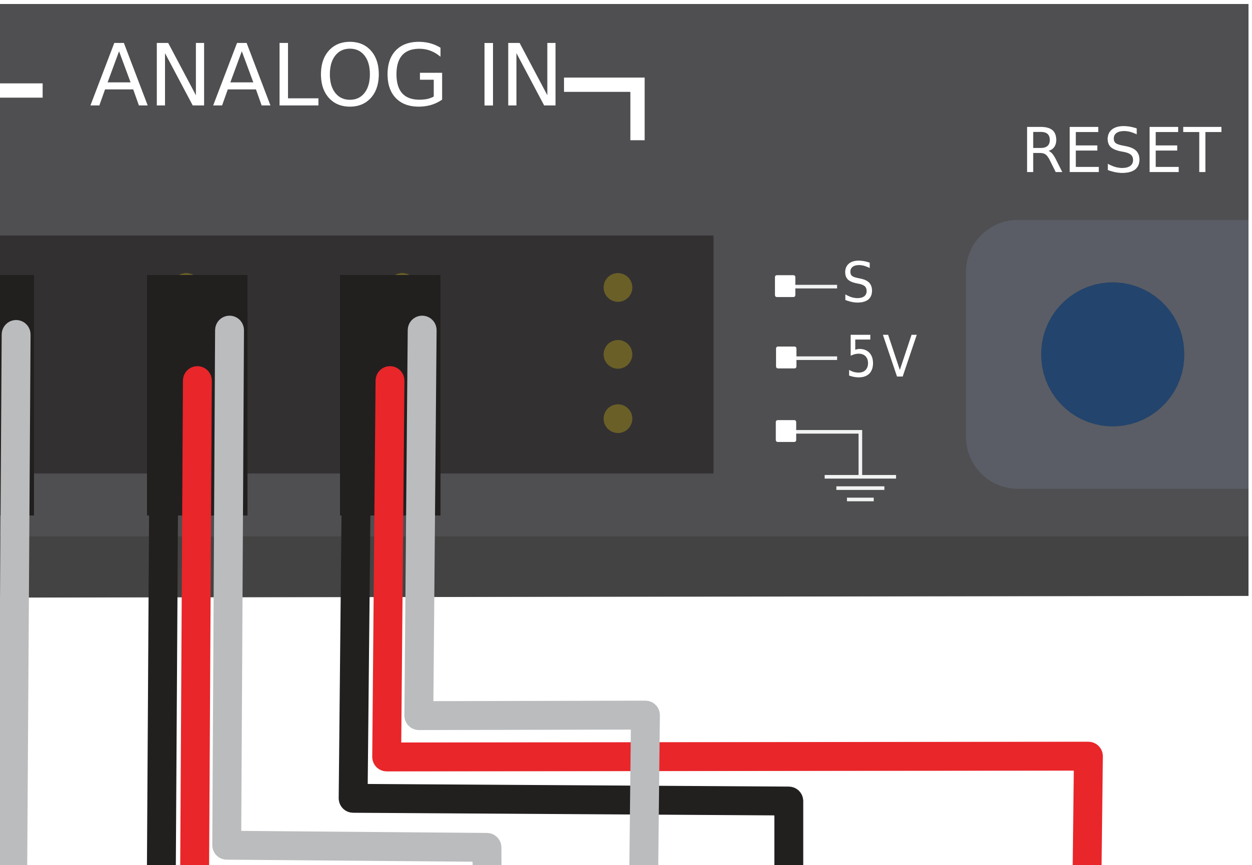

POWER
STATUS
RADIO
COMM
MODE
RSL
SPI
SCLK
MOSI
MISO
3.3V
CS0
CS1
5V
CS2
CS3
I roboRIO

## port input analog single a to sensor a Connecting

> ground and power interchangeable have may )*potentiometers* as (such sensors Some **:□□□□**
> connections.

and power, signal, - wires three have will ports input analog to connect that sensors Most be should They ports. input analog the of pins three the to precisely corresponding - ground accordingly. connected

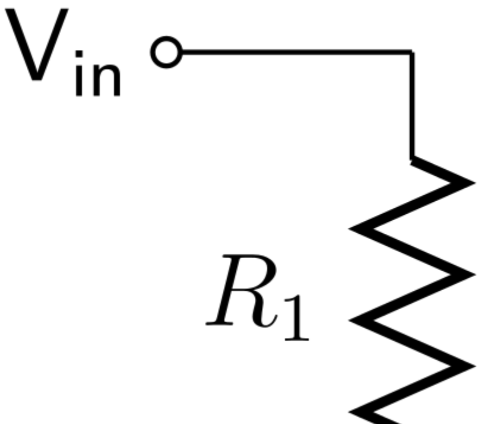



ANALOG IN
RESET
S
5V

the of position rotational the calculate to used be then can which potentiometer, the across shaft.

### potentiometer analog an Wiring 36.3.1

*input analog* roboRIO’s the to connect potentiometers analog names, the by suggested As to important is it however, potentiometers, wire to exactly how understand To ports. circuitry. internal their understand



### Footnotes 36.3.2

## Hardware - Inputs Digital 36.4

see inputs, digital to guide software a For hardware. input digital covers section This :□□□□
.*Software - Inputs Digital*

majority vast the In states. discrete several of one in be can that signal a is signal digital A
- signal digital a for states two only are there and wire, a in voltage the is signal the cases, of
respectively). false, and true or 0, and 1 denoted (also low or high,

”high“ so 5V, on function ports ”DIO“) (or ports outputinput- digital inbuilt- roboRIO’s The
.[2][1] 0V of signal a to ”low“ and 5V, of signal a to corresponds

### ports DIO roboRIO the to Connecting 36.4.1

a these, use To port. expansion ”MXP“ the through available are ports DIO Additional :□□□□
needed. is MXP the to connects that sort some of board breakout

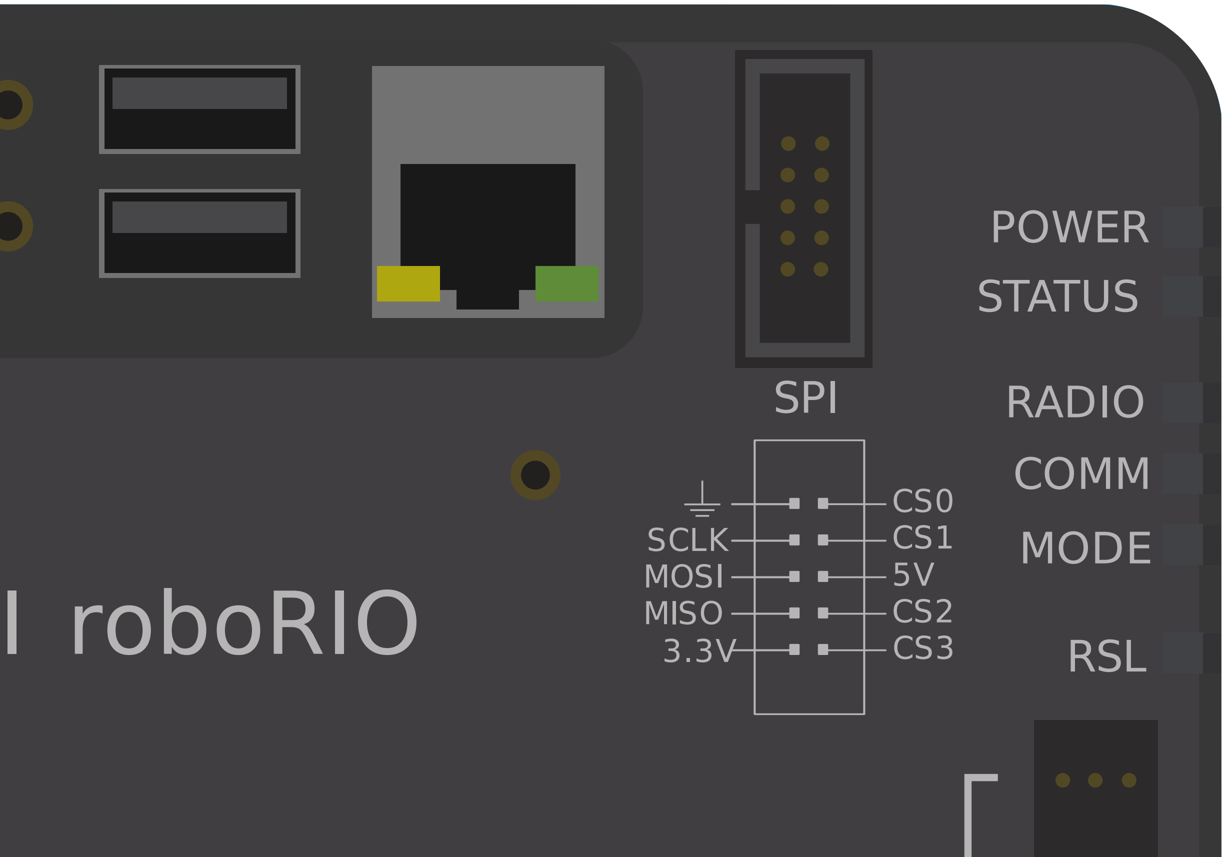
*before* using are you sensor the of specifications technical the consult Always :□□□□□
Failure pin. each to connected being is wire correct the that ensure to sensor, the wiring
device. the to damage in result can so do to

roboRIO! the on port any on pin ground the to pin power the connect directly **Never** :□□□□□
behavior. unexpected in result may and roboRIO the on features protection trigger will This

---

[1] 0.8V below back falls it when ”low“ reads and 2.0V, above rises it when ”high“ reads signal the precisely, More
consistent. be to guaranteed not is thresholds two these between behavior -

[2] common less far is this of use the however, port; expansion ”MXP“ the via logic 3.3V offers also roboRIO The
5V. the than


SPI
POWER
STATUS
RADIO
COMM
MODE
RSL
SCLK
MOSI
MISO
3.3V
CS0
CS1
5V
CS2
CS3
I roboRIO

### port DIO a to switch simple a Connecting

).*switch limit* a as (such switch a is port DIO a to connected be can that device simplest The
circuit the when ”high“ read will port the port, DIO a to correctly connected is switch a When
closed. is circuit the when ”low“ and open, is

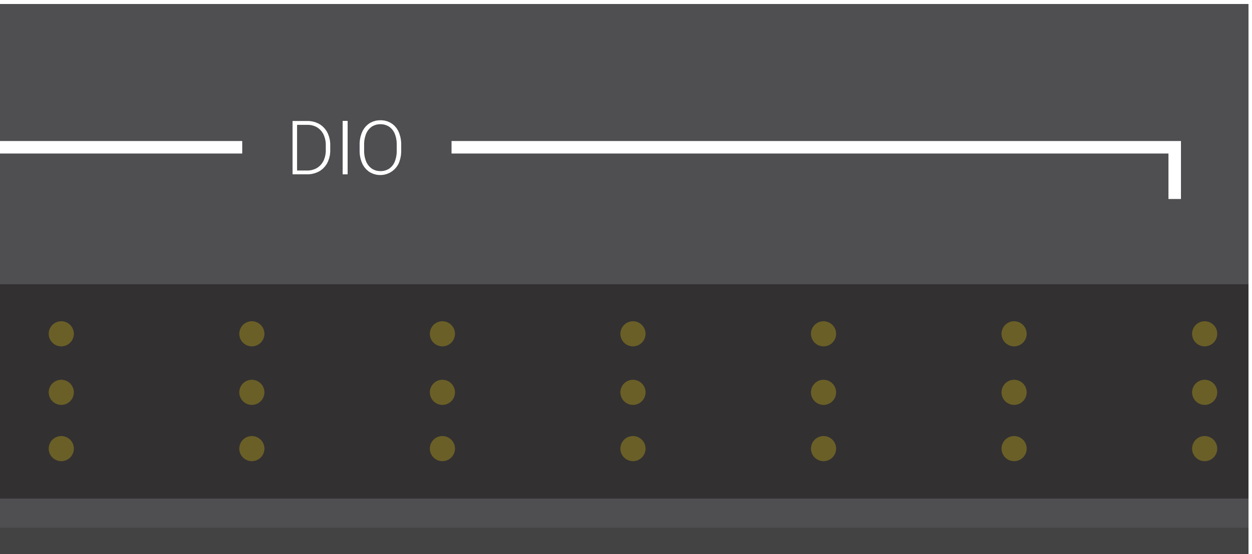
should Switches wires. two has only thus and powered, be to need not does switch simple A
is circuit switch the When port. DIO the of pins *ground* the and *signal* the between wired be
When ”high.“ reads it that ensure will resistor uppull- the and float, will pin signal the open,
”low.“ read thus and rail, ground the to directly connect will it closed, is circuit switch the

## port DIO a to sensor powered a Connecting

to order in power require switches) proximity contactno- most as (such sensors digital Many
These ground. and power, signal, - wires three have generally will sensor powered A work.
port. DIO the of pins corresponding the to connected be should

### ports DIO multiple uses that sensor a Connecting

in ports DIO multiple to connect to need may )*encoders quadrature* as (such sensors Some single a and power single a require ever only will sensors these general, In function. to order needed. be will port(s) additional the of pin signal the only - pin ground



### Footnotes 36.4.2

## Hardware - Switches Proximity 36.5

switches proximity using to guide a For hardware. switch proximity covers section This :□□□□ .*Software - Inputs Digital* see software, in

a it (be object an when detecting is robot a on tasks sensing common most the of One on point known a of distance certain a within is element) field or piece, game mechanism, switch.“ ”proximity a by accomplished is sensing of type This robot. the

### operation switch Proximity 36.5.1

which (in state ”open“ an between circuit a operate they - switches are switches Proximity Thus, ).*is* there which (in one ”closed“ a and circuit) the across connectivity *not is* there always almost are they accordingly, and signal, digital a generate switches proximity ports. *input digital* roboRIO’s the to connected

the closes switch the activating which in open,“”normally- either be can switches Proximity switches Some circuit. the opens switch the activating which in closed,“ ”normally or circuit, effective the practice, In switch. same the to connected circuit NC a and NO a *both* offer the that case the in system the of behavior the is switch NC a and NO a between difference NC circuit. open an in result always almost will failure wiring a as fails, switch the to wiring switch the if as behave to system the causes failure wiring a that in ”safer,“ often are switches this itself, damaging from mechanism a prevent to used often are switches as - pressed were fault. wiring a of case the in mechanism the to damage of chance the mitigates

(1 high be input the make will that resistors uppull- have roboRIO the on inputs digital The input the since 0 to goes value the closes switch the when but open, is switch the when value) ground. to connected now is

### Switches Proximity of Types 36.5.2

FRC®: in used commonly are that switches proximity of types several are There

- *switches“) (”limit Switches Proximity Mechanical*
- *Switches Proximity Magnetic*
- *Switches Proximity Inductive*
- *Switches Proximity Photoelectric*
- *Switches Proximity flightof-Time-*

## switches“) (”limit Switches Proximity Mechanical

# Switches Proximity Magnetic

present. is magnet no when deactivates and pole, either of presence the in activate

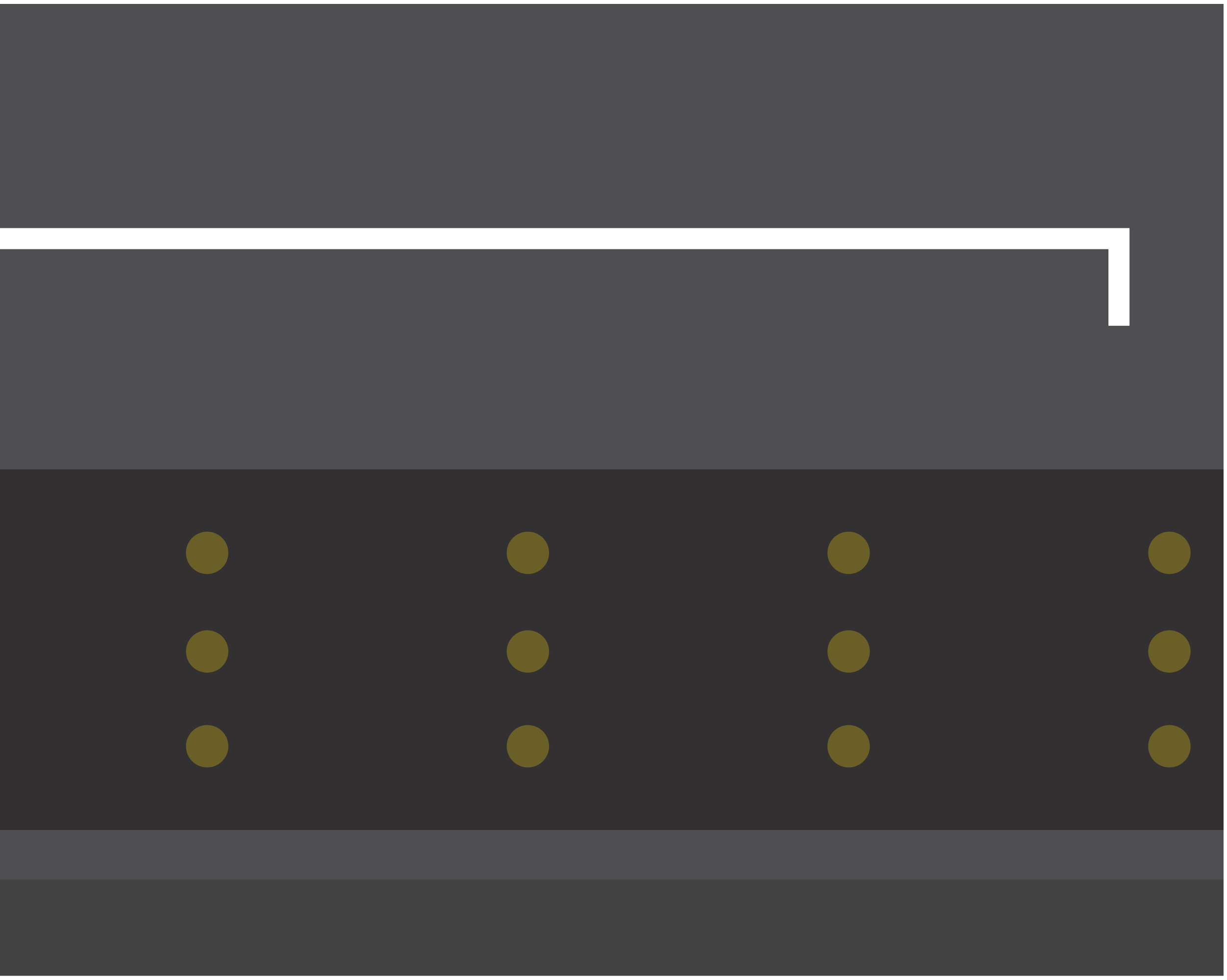
mechanical their than reliable more often are switches proximity magnetic While thus, - sensed be to object the on magnet a mount to user the require they counterparts, location. mechanism sensing for used mostly are they

## Switches Proximity Inductive

a within comes sort any of conductor a when activated are switches proximity Inductive switches. contact“”no- are they switches, proximity magnetic Like sensor. the of range certain

proximity magnetic as purposes same the of many for used are switches proximity Inductive than rather conductor, any of presence the in (activating nature generalmore- Their switches. application. the of nature the on depending hindrance, a or help a either be can magnet) a just

## Switches Proximity Photoelectric




Flight Distance Sensor
VL53L0X

time the measure and laser, small a as such source, light concentrated a use They FRC.
it light, of speed the Using it. detects receiver the when and light of emission the between
on Range area. target small very a for measurement distance accurate very a produce can
VL53L0X the for 1000mm around to 30mm between greatly, range can sensor of type this
information More available. versions range longer also are There above. pictured sensor
be can circuitry the about more and article this in found be can sensors flight of time about
.article this in found

## הרמוח - אנקודרים 36.6

*Encoders* see encoders, to guide software a For hardware. encoder covers section This :□□□□
.*Software -*

and FRC®, in motion rotational measuring for method common most the far by are Encoders
signals, digital produce they As reliable. and use,to-easy- cheap, are they - reason good for
).*potentiometers* as (such devices analog than interference and noise to proneless- are they

### Encoders of Types 36.6.1

FRC: in used typically are that physically connect encoders ways main three are There

- *encoders Shafted*
- *encoders shaftOn-*
- *encoders Magnetic*

to addition In question. in mechanism the to mounted are they how in vary encoders These
integrated encoders quadrature with come mechanisms FRC many encoders, of types these
design. their into

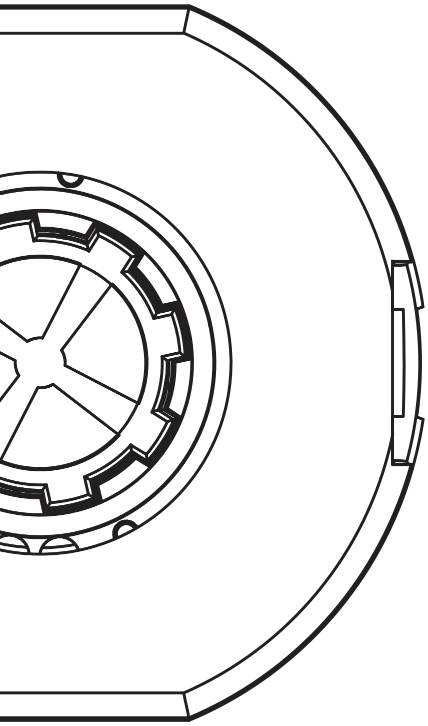
in used typically are that communicated is data encoder the ways main three also are There
FRC:

- *encoders Quadrature*
- *encoders Cycle Duty*
- *encoders Analog*

method communication one then more support may encoders Some :□□□□

# Grayhill 63R Optical Encoder

# Incremental Encoder



**103**

### Encoders Magnetic

the track they rather, all; at shaft the to coupling mechanical no require encoders Magnetic encoders magnetic of nature contactno- the While shaft. the to fixed magnet a of orientation is magnet the that ensure to order in construction precise require often they handy, be can encoder. the to respect with correctly positioned

encoders: magnetic of Examples

- Encoder Mag CTRE
- Encoder Magnetic Absolute Thrifty
- Lamprey2 221 Team

### Encoders Quadrature

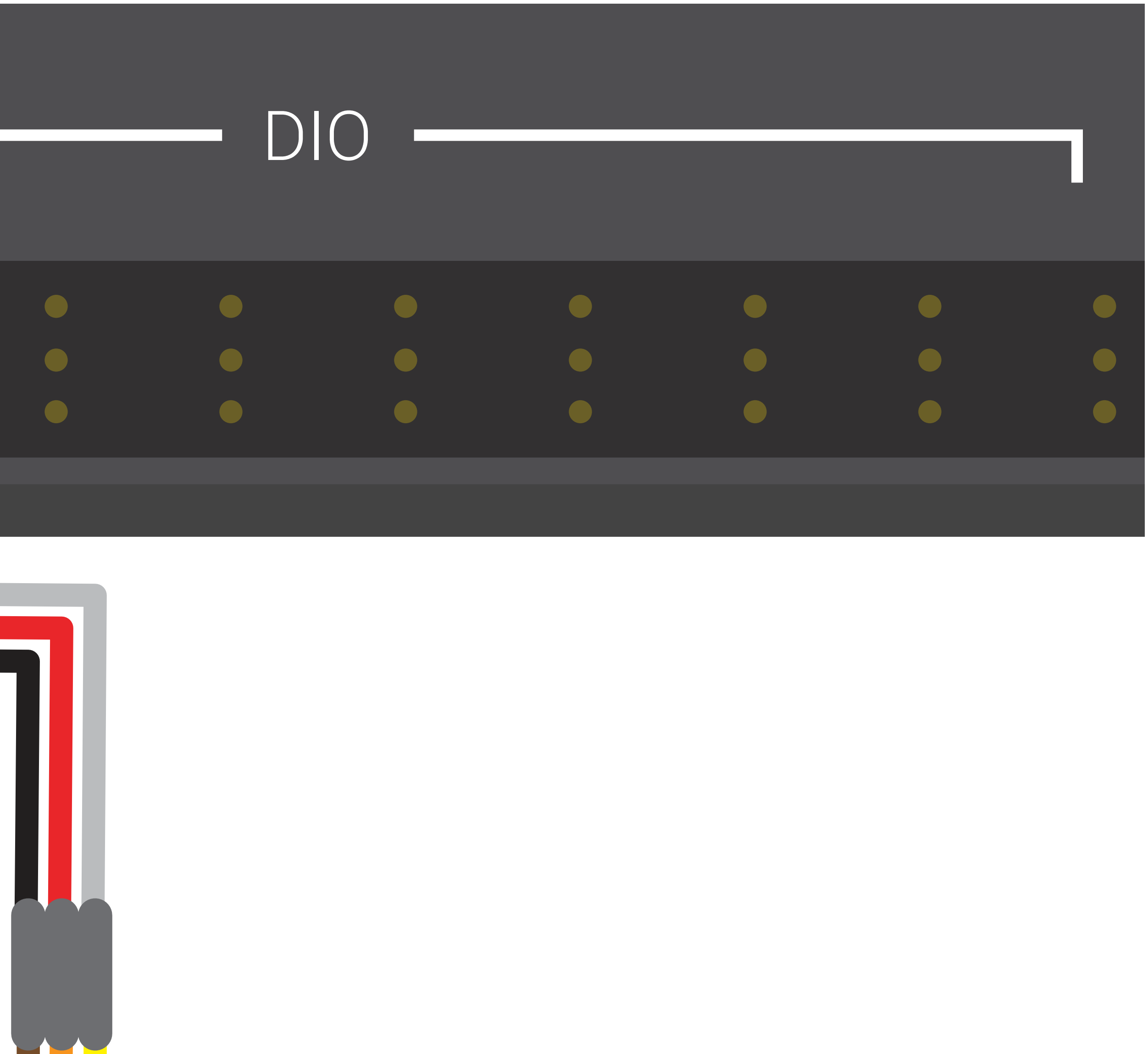
A measured/encoded. is motion the which by method the to refers ”quadrature“ term The from phaseof-out- degrees90- are that pulses wavesquare- two produces encoder quadrature below: picture the in seen as other, each

use The ”quad“). (hence period per ”edges“ total four are there channels, both across Thus, determined unambiguously be to motion of direction the allows pulses phaseof-out- two of other. the ”leads“ pulse which from

*input digital* the to connect encoders quadrature signal, digital a is pulse wave square each As roboRIO. the on ports

encoders: quadrature of Examples

- Choice FIRST through available VAMT103-
- Encoder Mag CTRE
- 63r Grayhill
- Encoder Bore Through REV
- E4T Digital US


DIO

hightto-low- or lowto-high- from transitions of number total the to refers *revolution per Edges* edges. *four* contains period full A shaft. encoder the of revolution per channels both across

per channels both of *periods complete* of number total the to refers *revolution per Cycles* cycle. *one* is period full A shaft. encoder the of revolution

same the of that times four value a has revolution per edges in stated resolution a Thus, revolution. per cycles in stated resolution

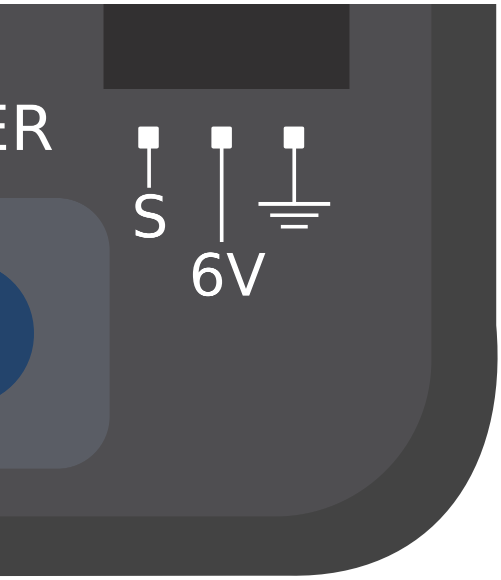
finer somewhat be should revolutionper-edges- in encoder your of resolution the general, In mechanism the know to want you if Thus, positioning. in error acceptable smallest your than higher somewhat resolution a with encoder an have should you degree, one minusor-plus- revolution. per edges 360 than

### Encoders Cycle Duty

pulse a output They roboRIO. the on input digital single a to connect encoders cycle Duty encoder. the of position absolute the to proportional is pulse a of length the where

encoders: cycle duty of Examples

- Encoder Mag AndyMark
- Encoder Mag CTRE
- Encoder Bore Through REV
- Lamprey2 221 Team
- MA3 Digital US


ER
S
6V

### Gyros of Types 36.7.1

and gyros axisthree- gyros, axissingle- FRC: in usedcommonly- Gyros of types two are There gyro. axis3- a include often which IMUs,

#### Gyros axisSingle-

## Gyros axisThree-

y, x, labeled (typically axes spacial three all around rate rotation measure gyros axisThree- roll. and yaw, pitch, called is axis these around motion The z). and

Choice FIRST in been has that Robotics FIRST for Board IMU ADIS16470 Devices Analog The gyro. axisthree- used commonly a is years recent in

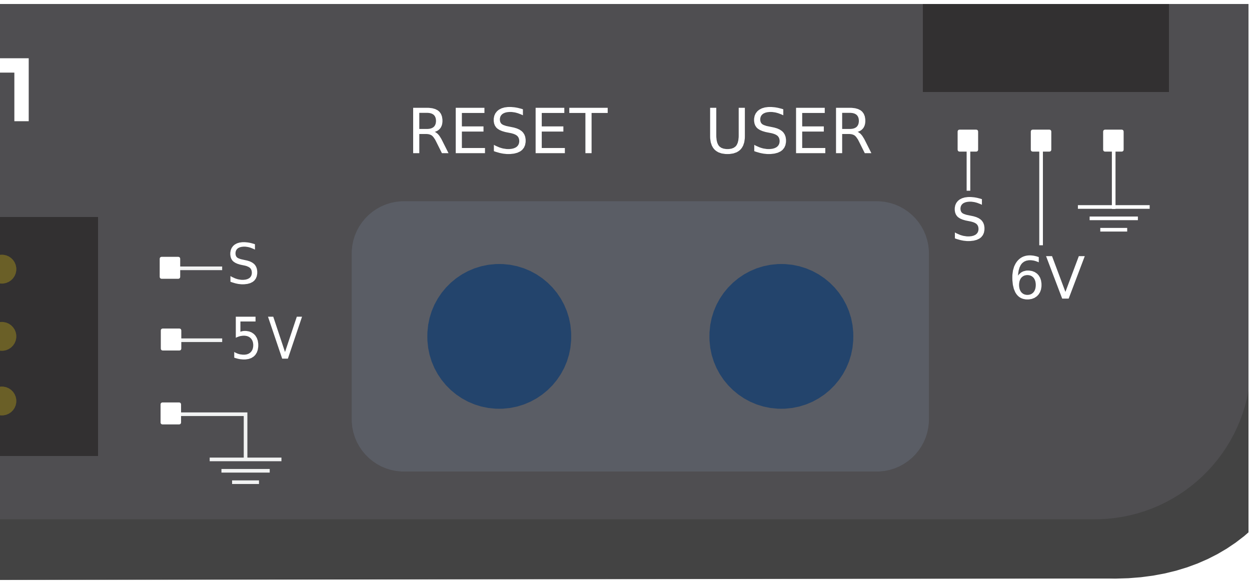
## Hardware - Ultrasonics 36.8

ultrasonics, to guide software a For hardware. sensor ultrasonic covers section This **:□□□□**
.*Software - Ultrasonics* see

are They FRC®. in used rangefinders common most the of some are rangefinders Ultrasonic
of pulse a emitting by work rangefinders Ultrasonic reliable. fairly and use,to-easy- cheap,
sensor the reach to echo the takes it long how measuring then and sound, frequencyhigh-
is it air, in sound of speed the and time measured the From target. the off bouncing after
target. the to distance the calculate to possible

### ultrasonics of Types 36.8.1

above, outlined principle response“”ping- the on operate rangefinders ultrasonic all While
roboRIO. the with communicate they way the in vary may they


RESET
USER
S
6V
S
5V

## ultrasonics responsePing-

## ultrasonics Serial

the of one over RIO the with communicate may sensors ultrasonic complicatedmore- Some 232.RS- as such ,*buses serial*

### חסרונות 36.8.2

As caveats. few a are there however use, to easy quite generally are sensors Ultrasonic generally they echo, its and pulse the between time the measuring by work ultrasonics important extremely is it Thus, range. their in target *closest* the to only distance measure generally will sensors ultrasonic for documentation The job. the for sensor right the pick to the which in ”window“ the of shape the shows that pattern“ ”beam the of picture a include sensor. your selecting when this to attention close pay - target a detect will ultrasonic

order In sensors. ultrasonic other from interference to susceptible also are sensors Ultrasonic fashion robin“”round- a in ultrasonics responseping- run can roboRIO the this, minimize to sensors from interference that ensure to way sure no is there competition, in however, - occur. not does robots other on mounted

redirect that or waves, sound absorb that objects detect to able be not may ultrasonics Finally, objects. flat hard, detecting for best work they Thus, ways. strange in them

## Hardware - Accelerometers 36.9

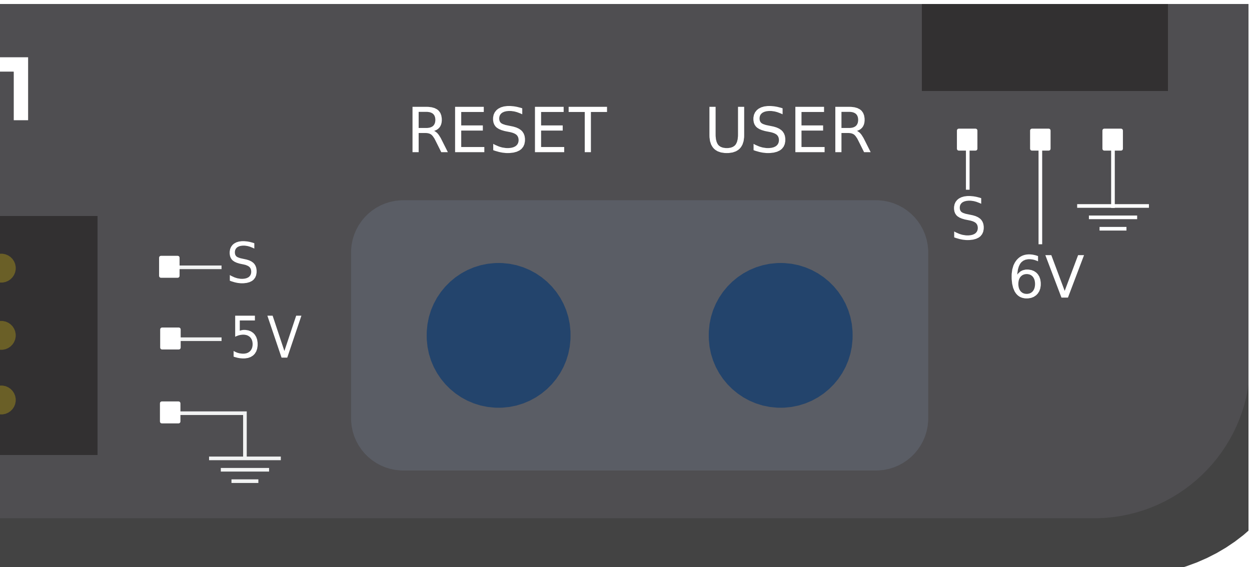
acceleration. measure to used sensors common are Accelerometers

track to used and integrateddouble- be can acceleration of measurements precise principle, In integrated be can gyroscope a from rate turn of measurement the how to (similarly position the within available are that accelerometers practice, in however, - heading) determine to are accelerometers However, use. this for accurate nearly not are range price FRC® legal FRC. in tasks of number a for useful still

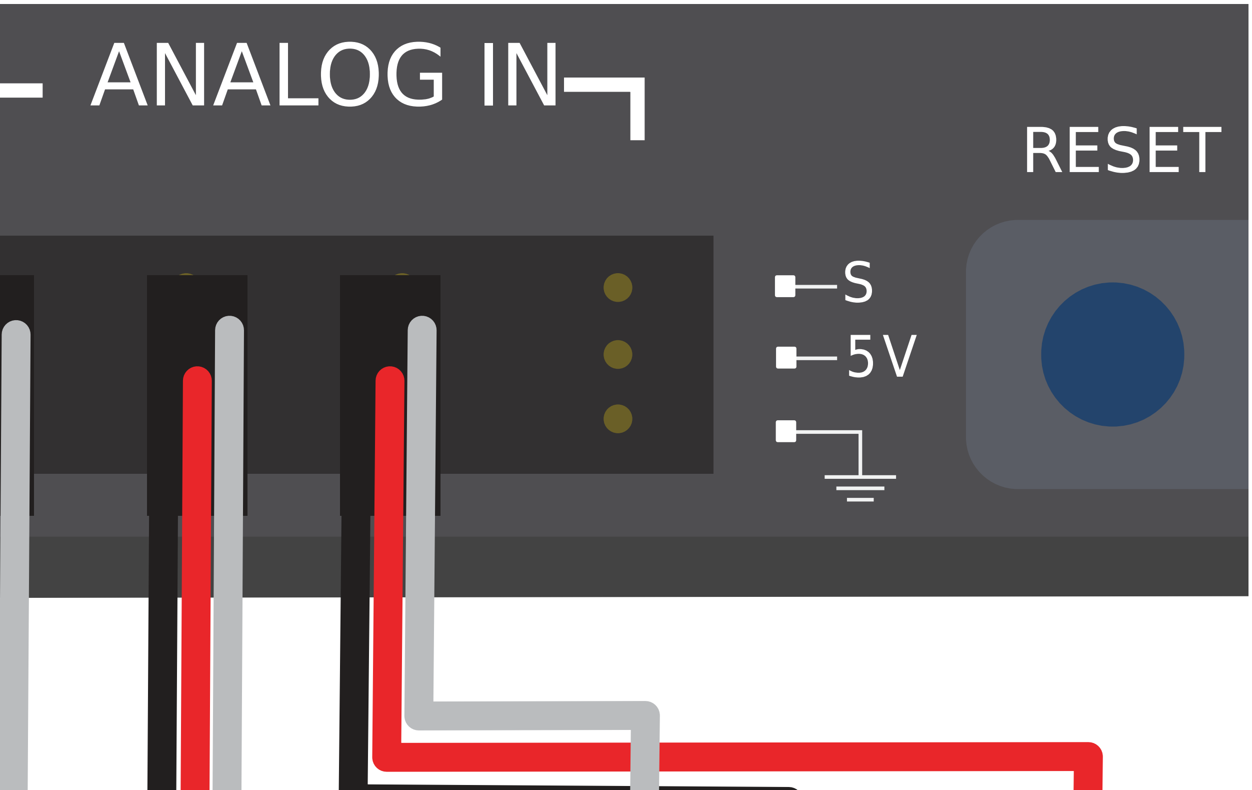
use, can teams all that *accelerometer axisthree- inbuilt-* a with comes roboRIO The peripheral a use and purchase may measurements precisemore- seeking teams however well. as accelerometer,

### accelerometers of Types 36.9.1

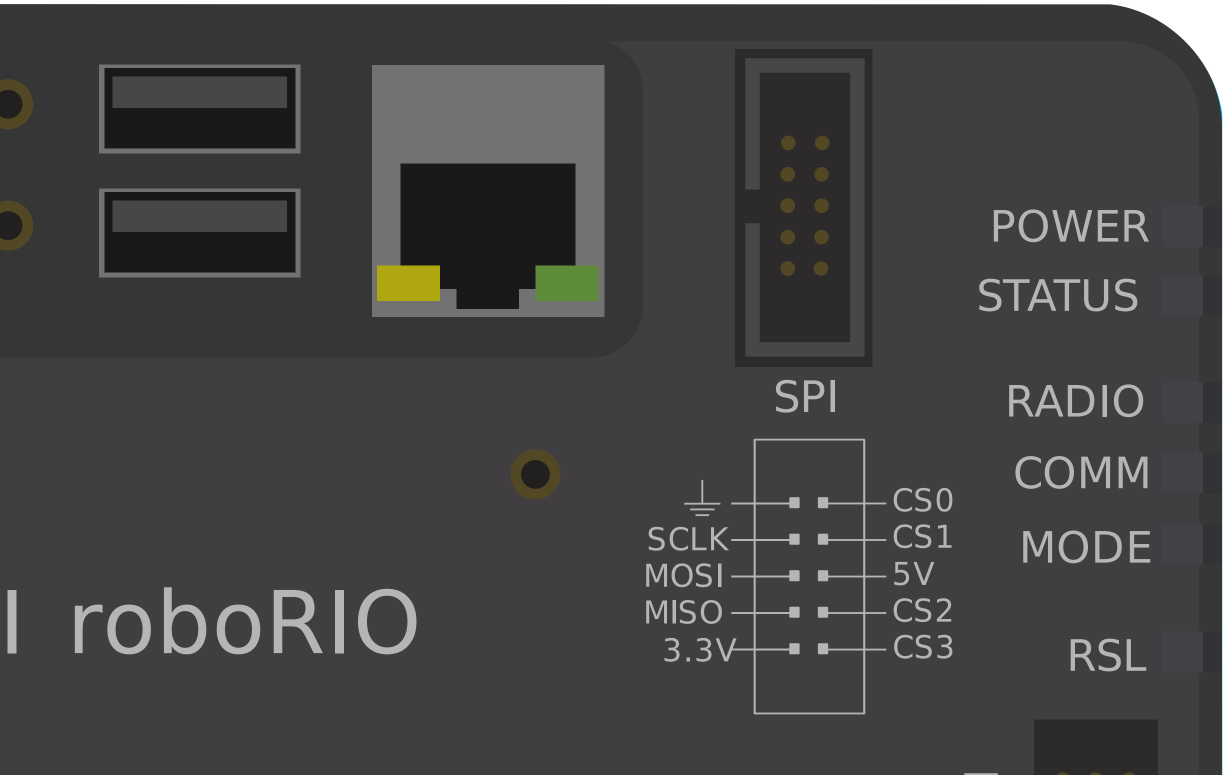
accelerometers, axissingle- FRC: in usedcommonly- accelerometers of types three are There IMUs. and accelerometers, axismulti-

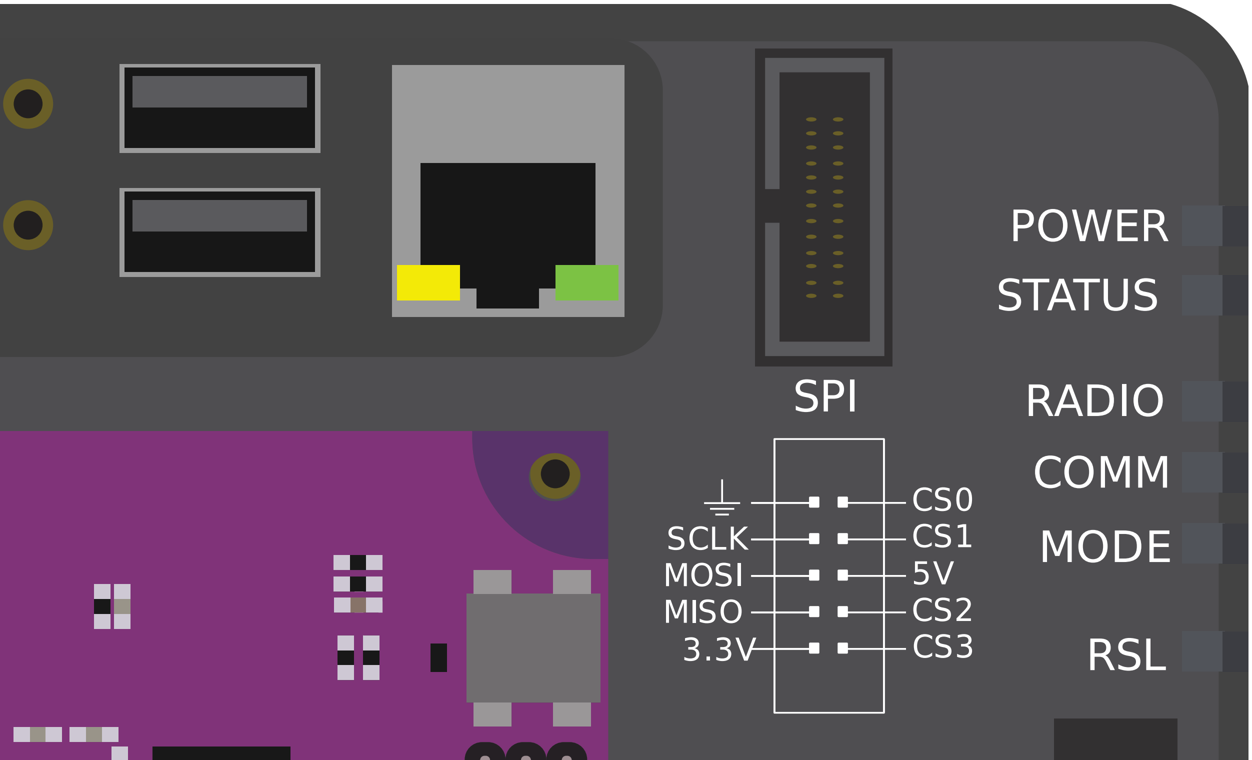

RESET
USER
S
5V
S
6V

## accelerometers axisMulti-



## accelerometer inbuilt- roboRIO




SPI
SCLK
MOSI
MISO
3.3V
CS0
CS1
5V
CS2
CS3
POWER
STATUS
RADIO
COMM
MODE
RSL

# Hardware - LIDAR 36.10

increasing seeing rangefinder of variety a are sensors ranging) and detection (light LIDAR FRC®. in use

is laser A sound. of instead light use but ,*ultrasonics* to similarly quite work sensors LIDAR back. bounces pulse the until time the measures sensor the and pulsed,

## LIDAR of Types 36.10.1

LIDAR, dimensional1- FRC: current in used commonly sensors LIDAR of types two are There LIDAR. dimensional2- and

### LIDAR Dimensional-1

the measures it - sensor ultrasonic an like much works sensor LIDAR (1D) dimensional1- A sensors LIDAR 1D it. of front in line a along less or more object nearest the to distance are and profiles“ ”beam narrower have they as ultrasonics, than reliablemore- be often can Distance Optical LiteLIDAR- Garmin the is above Pictured interference. to susceptible less .Sensor

distance, measured the to proportional voltage analog an output generally sensors LIDAR 1D .*buses serial roboRIO's* the of one to or ports *input analog* roboRIO's the to connect thus and

## LIDAR Dimensional-2

Generally, plane. a in directions all in distance measures sensor LIDAR (2D) dimensional2- A that turntable a on sensor LIDAR 1D a placing simply by less)or-(more- accomplished is this rate. constant a at spins

roboRIO, the to back data of amount large a send to need sensors LIDAR 2D nature, by Since, .*buses serial* roboRIO’s the of one to connect always almost they

### 36.10.2 חסרונות

drawbacks: common few a from suffer do sensors LIDAR

Thus, sensor. the to back pulse emitted the of reflection the on relies LIDAR ultrasonics, Like laser. the of wavelength the in material the of reflectivity the on depends critically LIDAR infrared the in transparent be to tends which polycarbonate, of made is wall field FRC The to struggle to tends LIDAR Thus, use). FRC for legal generally is what is (which wavelength barrier. field the detect processing and noisy, quite be to tend use) FRC for legal range price the (at sensors LIDAR 2D software. complex of lot a involve can cloud“) ”point a as (known data measured their software so FRC, for specifically made sensors LIDAR 2D few very are there Additionally, scarce. be to tends support

at rate the by limited is rate update their work, to turntable a on rely sensors LIDAR 2D As that means often this FRC, for legal range price the in sensors For spins. turntable the which robot the when limitation a be can which quickly, particularly values their update not do they moving. are targets) the (or

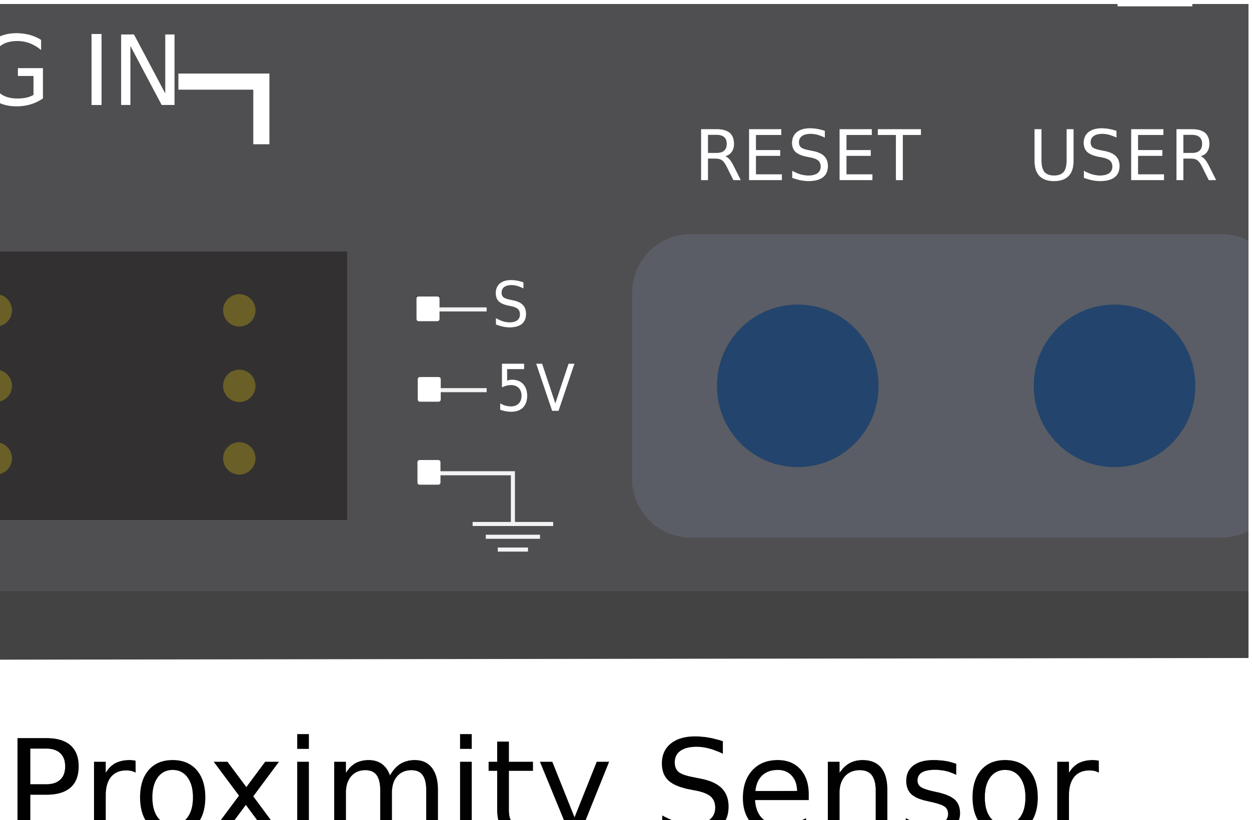
of resolution *spatial* the resolution, *angular* in limited are sensors LIDAR 2D as Additionally, away. further are targets when worse is cloud point the

## 36.11 מדי טווח שפועלים בשיטת הטריאנגולציה

the in function commonly they as rangefinders,“ ”IR called (often rangefinders Triangulating The FRC®. in used rangefinder of type common another are band) wavelength infrared sensor brandSharp- common a is above shown sensor

of emission the between time the measure not do rangefinders triangulating ,*LIDAR* Unlike a emitting by work rangefinders IR most Rather, reflection. a of receiving the and pulse a closer The beam. reflected the of position the measuring and angle, slight a at beam constant the point of contact of the reflected beam to the emitter, the closer the object to the sensor.

## rangefinders IR Using 36.11.1

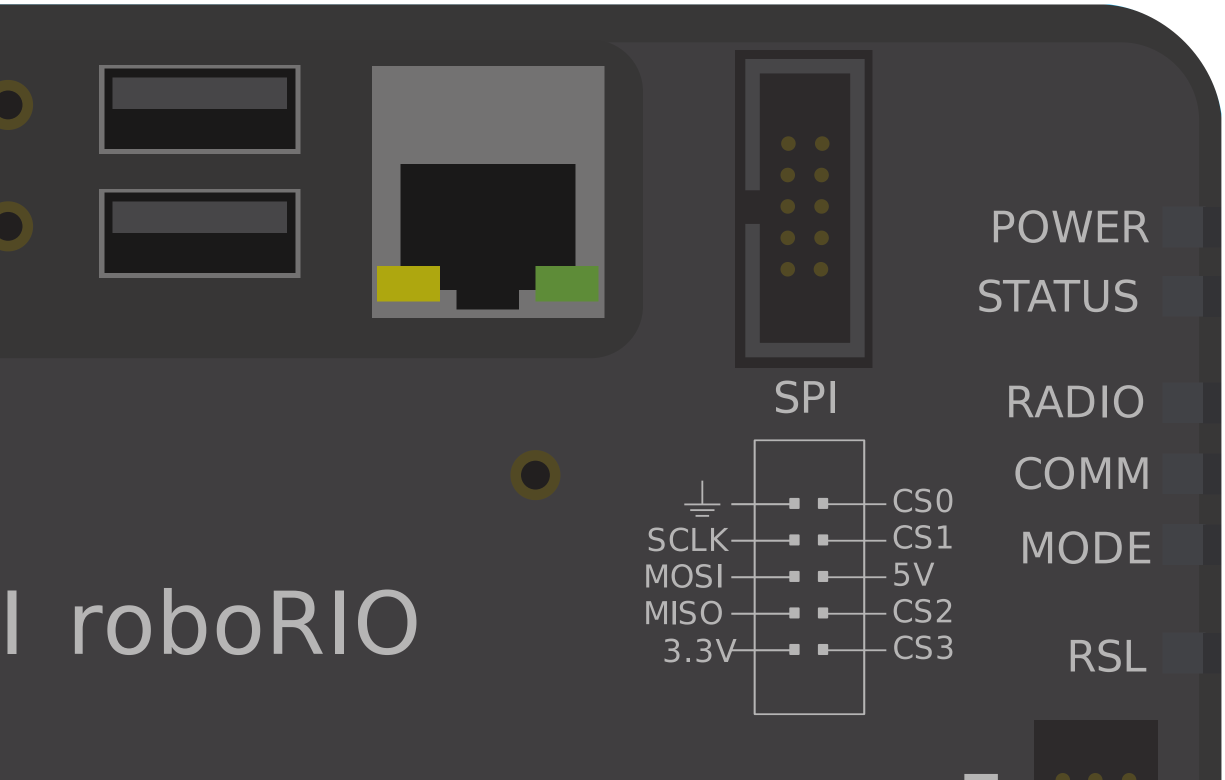


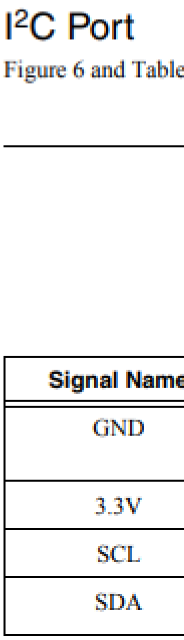
### buses serial supported of Types 36.12.1

communications: serial of types basic many supports roboRIO The

- I2C
- SPI
- 232RS-
- Host USB
- Bus CAN

CAN the over devices peripheral with communications supports roboRIO the Additionally, peripheral few relatively idiosyncratic, quite is protocol CAN FRC® the as However, bus. controllers). motor for used heavily is it (though it support sensors


SPI
POWER
STATUS
RADIO
COMM
MODE
RSL
CS0
SCLK
CS1
MOSI
5V
MISO
CS2
3.3V
CS3
I roboRIO



I²C Port

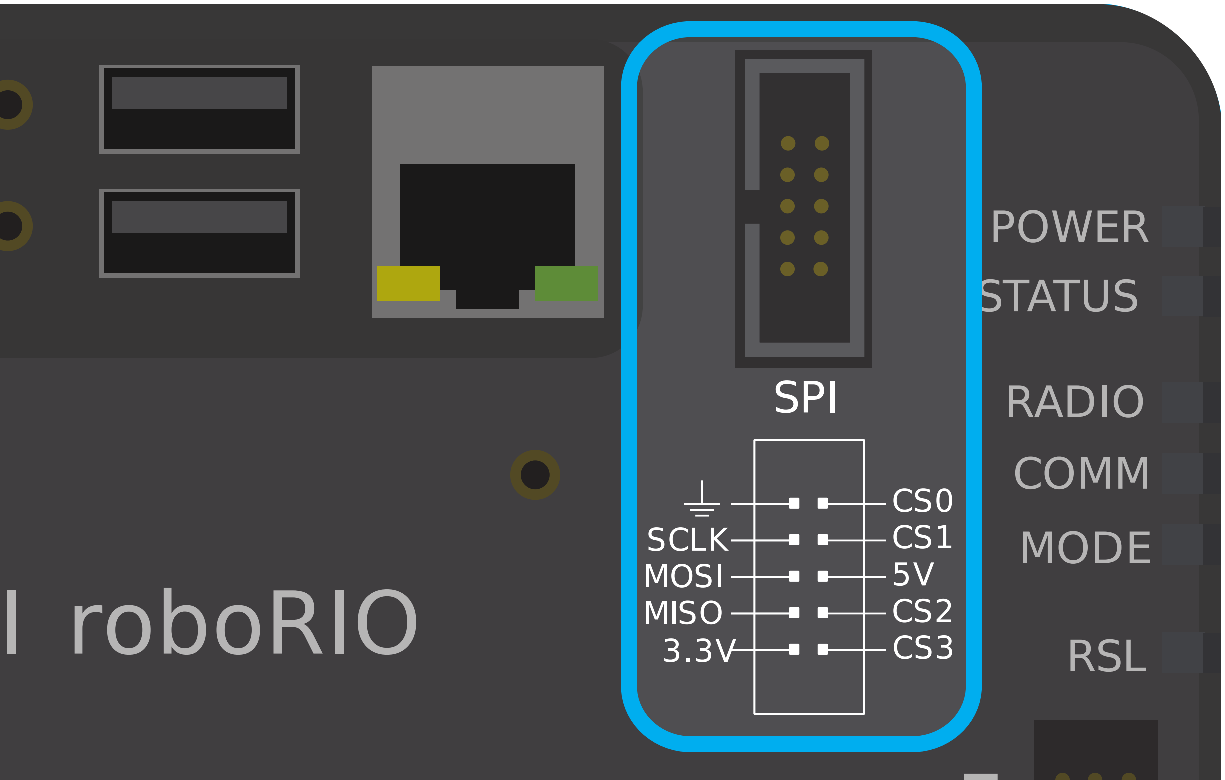
Figure 6 and Table

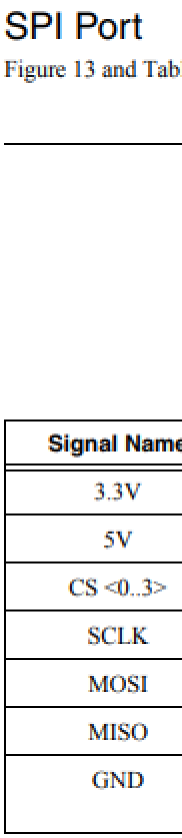
| Signal Name |
|---|
| GND |
| 3.3V |
| SCL |
| SDA |

corresponding its to wired be should pin each I2C, over devices peripheral to communicate To long so port, single a to devices slave of ”chain“ a wire to users allows I2C device. the on pin set. IDs separate have devices those as

is MXP the on bus I2C The .*port expansion MXP* the through used be also can bus I2C The the on device a as ID same the have can bus main the on device a example, For independent. bus. MXP

> the using before issue known following the on yourself familiarize to sure Be **:□□□□□**
> *Lockups System Causing I2C Onboard* port: I2C onboard


SPI
CS0
SCLK
CS1
MOSI
5V
MISO
CS2
3.3V
CS3
POWER
STATUS
RADIO
COMM
MODE
RSL
roboRIO



SPI Port

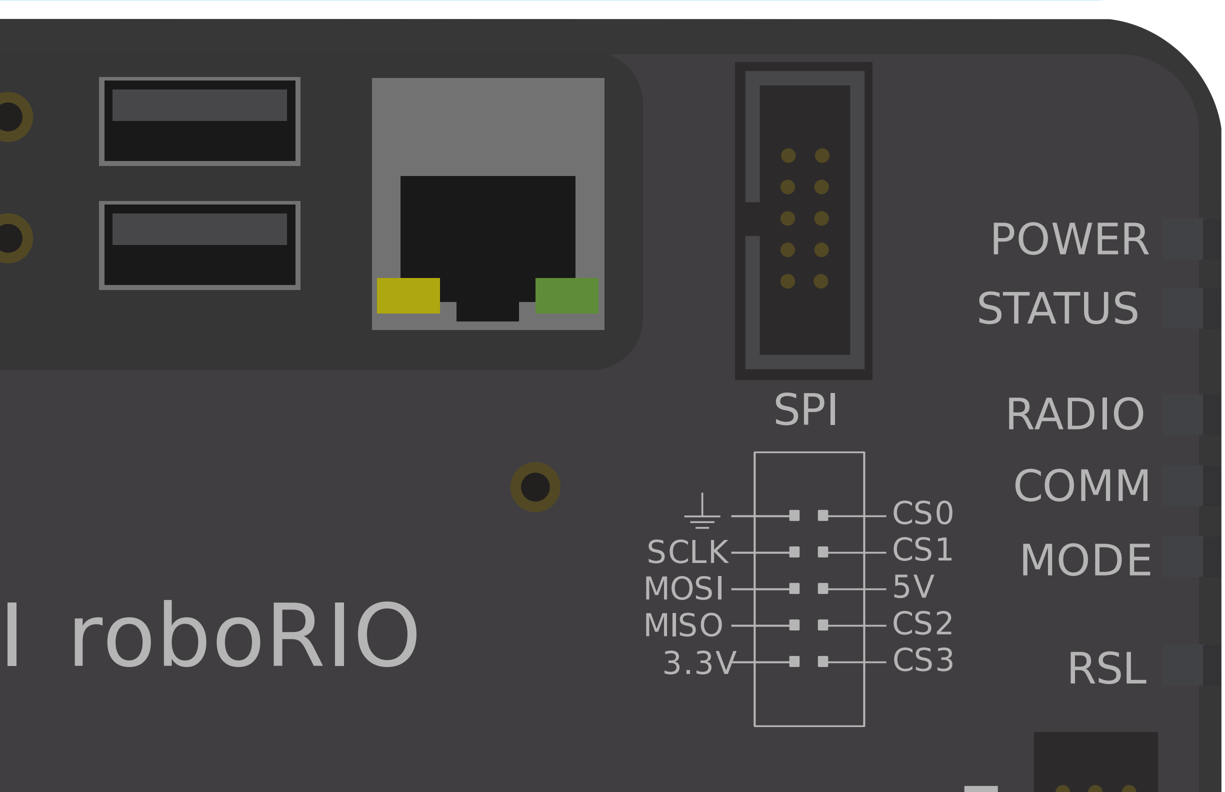
Figure 13 and Tab

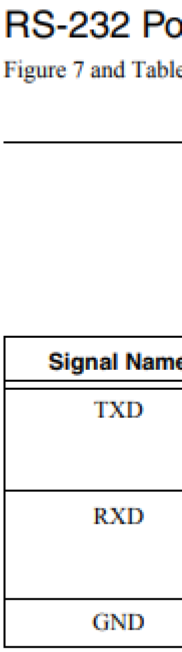
| Signal Name |
|---|
| 3.3V |
| 5V |
| CS <0..3> |
| SCLK |
| MOSI |
| MISO |
| GND |

corresponding its to wired be should pin each SPI, over devices peripheral to communicate To (corresponding devices four to up to communications supports port SPI The device. the on pin above). diagram the on pins 30- (CS) Select Chip the to

provides port MXP The .*port expansion MXP* the through used be also can bus SPI The CS. additional an and lines input/output and clock, independent

## 232RS- 36.12.4


SPI
POWER
STATUS
RADIO
COMM
MODE
RSL
SCLK
MOSI
MISO
3.3V
CS0
CS1
5V
CS2
CS3
I roboRIO



RS-232 Po

Figure 7 and Table

| Signal Name |
|---|
| TXD |
| RXD |
| GND |

its to wired be should pin each 232,RS- over devices peripheral to communicate To device. the on pin corresponding

.*port expansion MXP* the through used be also can bus 232RS- The

port serial MXP The 15v). (+/- levels signaling 232RS- uses port serial 232RS- roboRIO The 3.3v). (+/- levels signaling CMOS uses

---

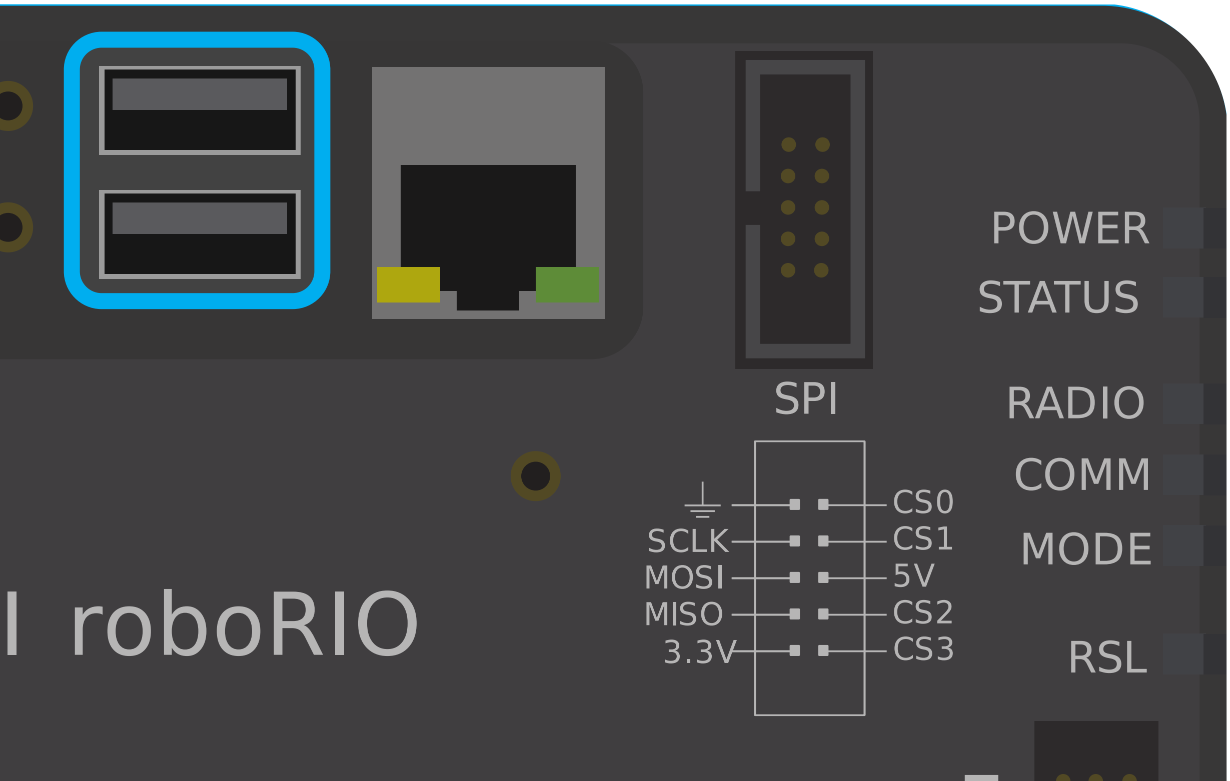
In console. serial roboRIO's the by utilized is port 232RS- onboard the default, By **:** *Imaging* the using disabled be must console serial the device, external an for it use to order .*Dashboard Web roboRIO* or *Tool*

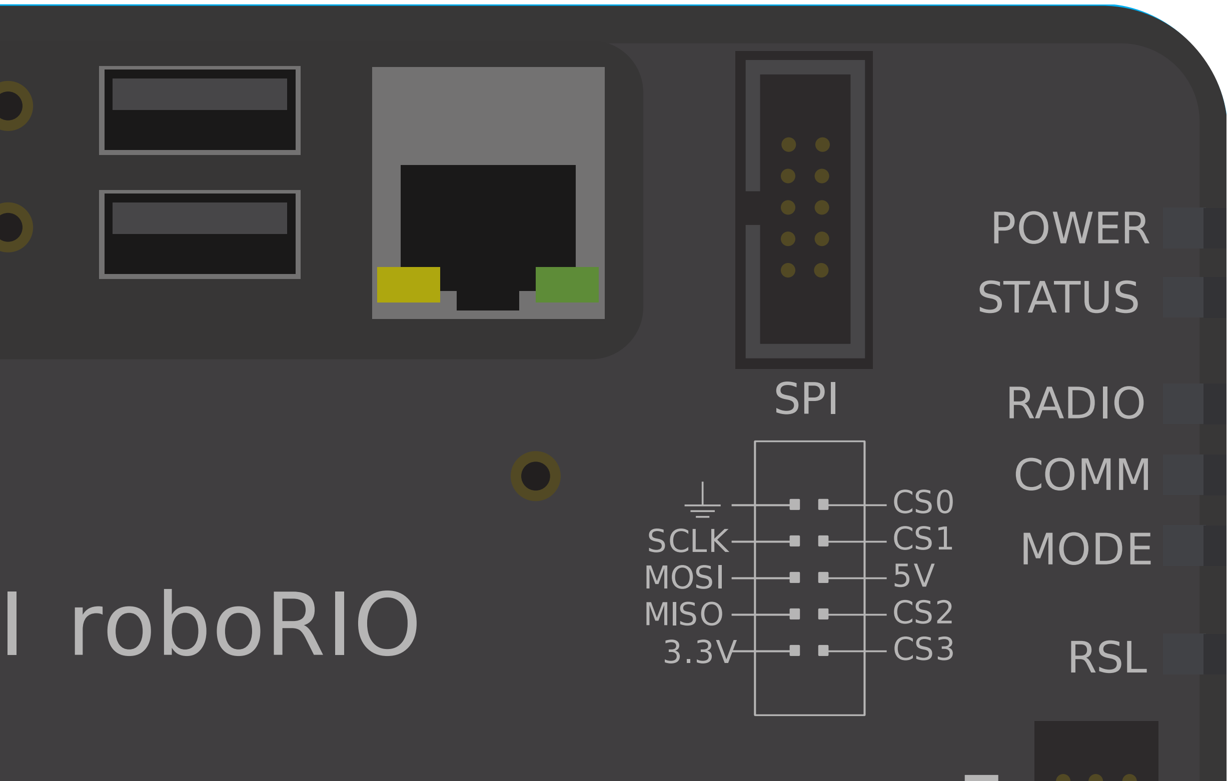
---

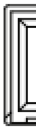
### Client USB 36.12.5

connected be can This port. client USB or B,USB- a is roboRIO the on ports USB the of One cable. USB standard a with computer, Station Driver a as such devices, to

### Host USB 36.12.6

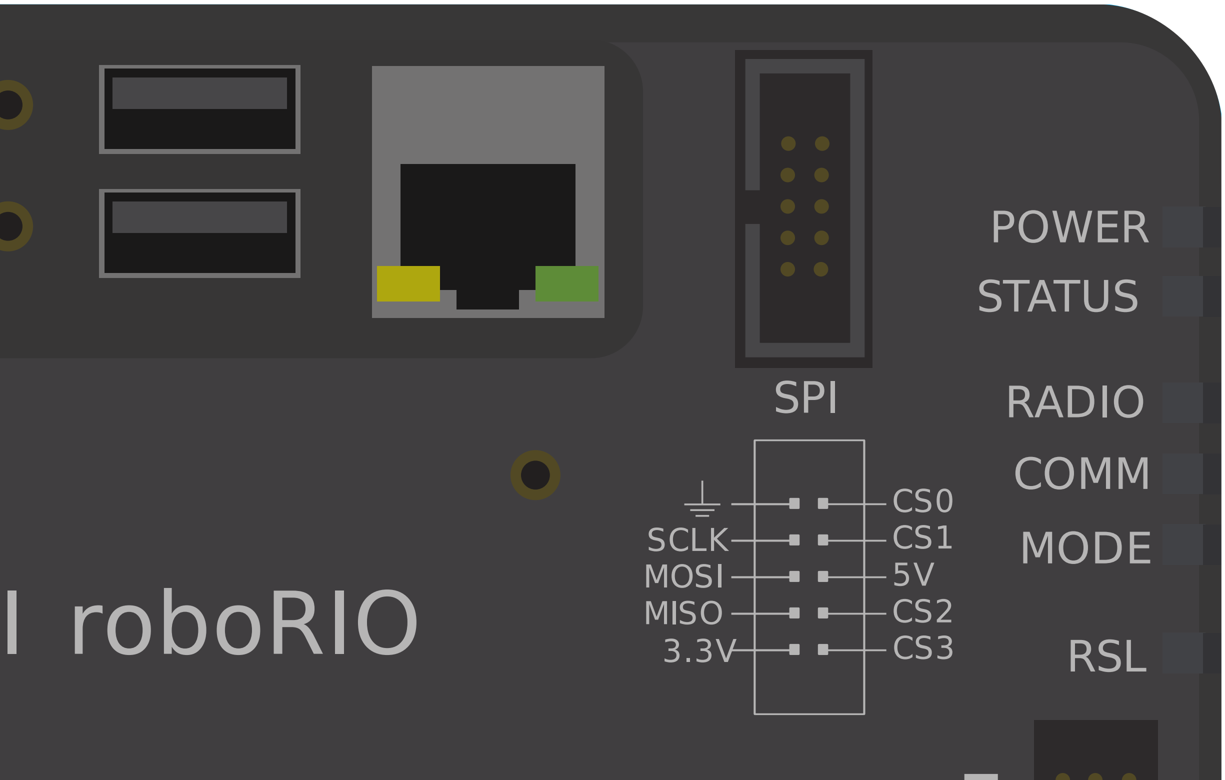


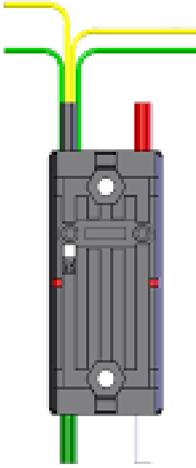

SPI
CS0
SCLK
CS1
MOSI
5V
MISO
CS2
3.3V
CS3
POWER
STATUS
RADIO
COMM
MODE
RSL
I roboRIO



Expansion MXP roboRIO’s the through use for available also are buses serial the of Several well as inputs, *analog* and *digital* additional many of use make to users allows port This Port. buses. serial various the as

wiring no requiring convenience, for port MXP the to directly attach devices peripheral Many user. the of part the on


SPI
POWER
STATUS
RADIO
COMM
MODE
RSL
SCLK
MOSI
MISO
3.3V
CS0
CS1
5V
CS2
CS3
roboRIO



include: examples Some bus. CAN the use primarily sensors Several

- playingwithfusion.com from Sensor Range/Distance Flightof-Time- Based CAN
- Encoder MAG SRX the and IMU Pigeon Gadgeteer the as such sensors, basedTalonSRX-
- CANifier
- the and *(PDP) Panel Distribution Power CTRE* the into built sensors monitoring Power *(PDH) Hub Distribution Power REV*

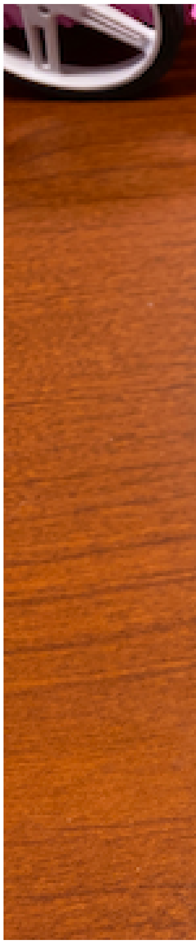
article the in found be can bus CAN the to connected devices using about information More .*devices can using* about

## 73

# [redacted]

Romi-[illegible] FRC. [illegible] FRC [illegible] Romi.-[illegible] [illegible] Romi-[illegible] [illegible] IMU [illegible]. [illegible] Romi-[illegible] [illegible].

**[illegible]:** A course that teaches programming using the Romi Robot is available via Thinkscape.
Information on this course is available here



## 37.1 חומרה והרכבה של Romi

[illegible] Romi-[illegible],[illegible].

1. Romi Kit from Pololu – Order qualifies for free shipping
2. Raspberry Pi – 3B+ [illegible] 4
3. 8GB (or larger) Micro SD card
4. Micro SD card reader - if you don't already have one
5. 6 AA batteries – Rechargeable is best (don't forget the charger)

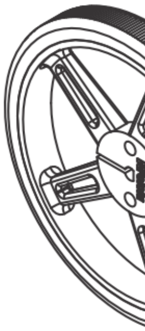
### הרכבה 37.1.1

[illegible] Romi [illegible]-FIRST [illegible]. [illegible]:

1. [illegible] ([illegible]).

2. [illegible]. [illegible], [illegible], [illegible]. [illegible].

3. [illegible] D-[illegible]



the into caster ball rear the for rollers three the place and down upside chassis the Flip 4.
the push Then rollers. three the of top on ball plastic 1″ the Place chassis. the in cutouts
into snap legs three the so chassis the into and ball the over clip retention caster ball
holes. respective their

robot. the of back the and front the on caster a is there so caster ball front the for Repeat 5.

6. Optional: The front ball caster is supported by a flexible arm that acts as a suspension system. If you want to make it stiffer, you can wrap a rubber band around the two hooks located on either side of the ball caster on the top side of the chassis.

down) side (thread standoffs Two board. Pi Raspberry the support to standoffs the Install 7.
as label 32U4“ ”Romi the to closest board Romi the of side the on holes the in mount
compartment. battery the inside are standoffs these for nuts The picture. the in shown
attach To board. the of side opposite the on holes the into go standoffs two other The
standoffs. the in screw you while nut the hold to pliers noseneedle- a need will you them,
go. should standoffs the where show below image the in holes circled The

8. The chassis works with four or six AA batteries (we recommend using rechargeable AA NiMH cells). The correct orientation for the batteries is indicated by the battery-shaped holes in the Romi chassis as well as the + and - indicators in the chassis itself.

connector pin 2x20 the aligning carefully down, upside board Pi Raspberry the Attach 9.
to care taking pressure even with Push Romi. the on socket pin 2x20 the with Pi the on
Raspberry the fasten to screws supplied the use inserted, Once pins. the of any bend not
step. previous a in installed were that standoffs the to board Pi

battery the inside hole hexagonal a in nut a placing require will screws the of Two **:□□□□**
compartment. The locations are shown by the blue circles in the image above.

complete! now is chassis Romi your of assembly The

## Romi-ה צריבת 37.2

boards: microprocessor 2 has Romi The

running program robot the with communication levelhigh- handles that **Pi Raspberry** A 1. and desktop the on

operation. sensor and motor levellow- handles that **Board Control 32U4 Romi** A 2.

properly. operates robot the that so installed firmware have to need boards Both

### Pi Raspberry 37.2.1

**הורדה**

be must and FRCVision) (formerly WPILibPi on based is firmware Pi Raspberry The of bottom the at `Assets` on Click card. SD micro Pi Raspberry the to written and downloaded files: image available the see to description the

WPILibPi Romi

Romi The WPILibPi. of release standard the not and version Romi the download to sure Be example. an for image below the See .`Romi-` with suffixed is version

**צריבה**

.*Installation WPILibPi* here: described is image the installing for procedure The

### הגדרת רשת אלחוטית

Romi: the with use to ready Pi Raspberry your get to steps following the Perform

1. position. on the to board 32U4 Romi the on switch power the sliding by on Romi the Turn
boot to minutes 32- approximately take will it image new a with started is it time first The a than less in boot will it times Subsequent reboots. and system file the resizes it while minute.

2. SSID the using network WiFi Romi the to connect computer, your Using number) serial Pi Raspberry the on based is `><number` (where `><number-WPILibPi` .`WPILib2021!` passphrase WPA2 the with

runningWPILibPi- multiple with environment an in Pi Raspberry the on powering If :□□□□ the through audibly announced also is Pi Raspberry particular a for SSID the Pis, Raspberry which file, `ssid.txt-boot/default/` the to written also is SSID default The port. headphone `boot` the opening and computer a into reader) a (via card SD the inserting by read be can partition.

3. `http://10.` either at dashboard Pi Raspberry the to connect and browser web a Open .`http://wpilibpi.local/` or `0.0.2/`

button `Writable` the click to necessary is it so default, by onlyread- up boots image The :□□□□ memory prevent to button `Only-Read` the click changes, making done Once changes. make to corruption.

4. page. web dashboard the of top the at *Writable* Select
5. `WPA2` the in password new a setting by Romi your for password default the Change field. `Passphrase`
6. changes. save to page the of bottom the at button *Save* the Press
7. a on Romi your operating on plan you if name unique a to SSID network the Change Romis. other with network wireless
8. set. you password new the with network WiFi Romi's the to Reconnect

completed. been have changes the all when `only-Read` to Dashboard the set to sure Be

### Board Control 32U4 37.2.2

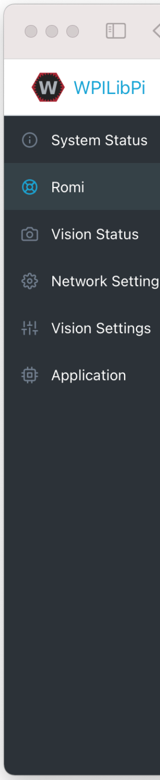
Board. Control 32U4 the to image firmware the write to used be now can Pi Raspberry The

Romi the off Turn 1.

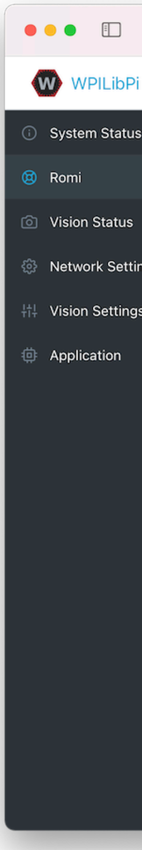
micro the to ports USB Pi’s Raspberry the of one from cable Bmicro- to A USB a Connect 2.
Board. Control 32U4 the on port USB

as dashboard web the to connect and network Wifi its to connect and Romi the on Turn 3.
steps. previous the in

button. *Firmware Update* the press page, configuration `Romi` the On 4.



has firmware the Once process. deploy firmware the of log a showing appear will console A will `you. Thank done. avrdude` message the Board, Control 32U4 the to deployed been appear.

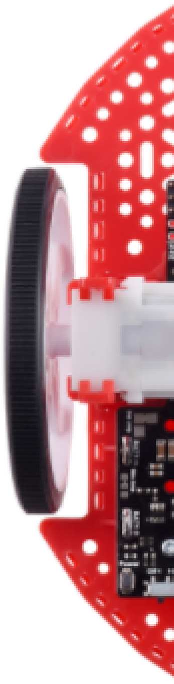


## Romi your know to Getting 37.3

### Conventions Directional 37.3.1

caster suspended and pins GPIO ports, USB Pi Raspberry the where is Romi the of front The are. wheel

”front“. of definition above the use forward driving to references documentation, Romi all In



## GPIO and Sensors, Hardware, 37.3.2

hardware/peripherals: inbuilt- following the has Romi The

- encoders with motors geared 2x
- (IMU) Unit Measurement Inertial 1x
- red) yellow, (green, LEDs 3x
- C) and B, A, (marked pushbuttons 3x
- (EXT) channels GPIO configurable 5x
- Buzzer

WPILib. by supported not currently is Buzzer The :□□□□

### Encoders and Wheels, Motors,

150 of speed output loadno- a and reduction, gear 120:1 a have Romi the on used motors The is torque Stall amps. 1.25 is current stall the and amps 0.13 is current free The 4.5V. at RPM torques. lower at slipping start might clutch safety inbuilt- the but m)N- (0.1765 inoz- 25

(5.55“). 141mm of trackwidth a have They (2.75“). 70mm of diameter a have wheels The

Per Counts 12 have and shaft output motor the to directly connected are encoders The revolution. wheel per counts 1440 nets this ratio, gear provided the With (CPR). Revolution

below. table the in listed are channels PWM motor The

| רכיבי התוכנה של Romi | Channel |
|---|---|
| Motor Left | 0 PWM |
| Motor Right | 1 PWM |

applied. is output positive when direction backward a in spin will motor right The :□□□□ code. robot in inverted be to needs controller motor corresponding the Thus,

below. table the in listed are channels encoder The

| רכיבי התוכנה של Romi | Channel |
|---|---|
| A Channel Quadrature Encoder Left | 4 DIO |
| B Channel Quadrature Encoder Left | 5 DIO |
| A Channel Quadrature Encoder Right | 6 DIO |
| B Channel Quadrature Encoder Right | 7 DIO |

forward. moves Romi the when up count encoders the default, By :□□□□

### Unit Measurement Inertial

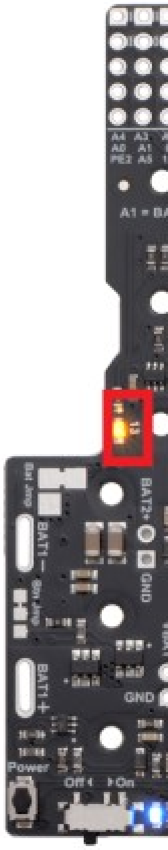
which (IMU) Unit Measurement Inertial LSM6DS33 STMicroelectronics an includes Romi The
accelerometer. axis3- a and gyro axis3- a contains

selectable has gyro The 16G. and 8G, 4G, 2G, of sensitivity selectable has accelerometer The
DPS. 2000 and DPS, 1000 DPS, 500 DPS, 250 (DPS), Second Per Degrees 125 of sensitivity

offsetszero- its measure and gyro the calibrate to means a provides also UI Web Romi The
code. robot with use before

### Buttons Push and LEDs Onboard

as exposed are that onboard LEDs 3 and buttons push 3 has board control 32U4 Romi The
code. robot to channels (DIO) IO Digital

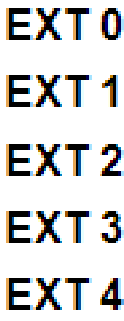


| רכיבי התוכנה של Romi | Channel DIO |
|---|---|
| only) (input A Button | 0 DIO |
| (output) LED Green (input), B Button | 1 DIO |
| (output) LED Red (input), C Button | 2 DIO |
| only) (output LED Yellow | 3 DIO |

ops.no- in result will 7 and 6 5, 4, 0, DIO to Writes

### Pins GPIO Configurable

a allow that EXT4) through EXT0 (named pins GPIO configurable 5 has board control The Romi. the to actuators and sensors external connect to user



exception the (with PWM and In, Analog IO, Digital modes: following the support pins 5 All configured be can ports the of mode The PWM). and IO Digital supports only which 0, EXT of .*UI Web Romi The* with

Ground, for connections with interface, style servo pin,3- a via exposed are channels GPIO The and board, the of edge the to closest being connection Ground the (with Signal and Power board). the of inside the to closest being signal the

into hooked be can but unconnected left initially are pins GPIO the for connections power The (as bus power the to pin 5V the connect to jumper a using by supply 5V boardon- Romi's the needed, is provide can Romi the than power more if Additionally, above). image the in seen and bus power to directly it connect and supply power 5V own their provide can user the pins. ground

### Configuration Default GPIO

*The* EXT4). through (EXT0 pins GPIO the of configuration default the shows below table The The pins. GPIO configurable 5 the of functions the customize to user the allows *UI Web Romi* IO the once screen on mappings channel/device WPILib appropriate the provide also will UI complete. is configuration

| Channel | Pin Ext |
|---|---|
| 8 DIO | EXT0 |
| 0 In Analog | EXT1 |
| 1 In Analog | EXT2 |
| 2 PWM | EXT3 |
| 3 PWM | EXT4 |

## Support Hardware Romi 37.4

with compatible is roboRIO, a than architecture hardware different a having robot, Romi The components. system control FRC used commonly of subset a

### Hardware Compatible 37.4.1

following: the with compatible is Romi the general, In

- LEDs) single switches, bumper (e.g. devices Input/Output Digital Simple
- controllers) motor based PWM servos, (e.g. devices output PWM styleRC- Standard
- voltage) a as distance report that sensors distance (e.g sensors Input Analog

### Hardware Incompatible 37.4.2

following: the with compatible not is Robot Romi the limitations, hardware to Due

- encoders integratedRomi- the than other Encoders
- channels) DIO 2 require (which sensors ultrasonic style ”Ping“
- sensors based Timing
- devices based CAN
- buzzer inbuilt- Romi

### Classes Compatible 37.4.3

assume here, listed not is class a If Robot. Romi the by supported are here listed classes All work. *not will* and supported not is it that

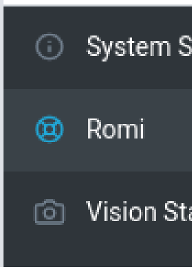
- )`Spark` (i.e. Controllers Motor PWM
- `Encoder`
- `AnalogInput`
- `DigitalInput`
- `DigitalOutput`
- `Servo`
- `BuiltInAccelerometer`

.Vendordep Romi the by provided are classes following The

- `RomiGyro`
- `RomiMotor`
- `OnboardIO`

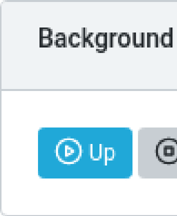
## UI Web Romi The 37.5

accessible is It image. Pi Raspberry WPILibPi the of part as installed comes UI Web Romi The UI. Web WPILibPi main the of bar navigation the in tab Romi the on clicking by



describe and UI Web Romi the of parts various the through walk will section this of rest The functionality. relevant the

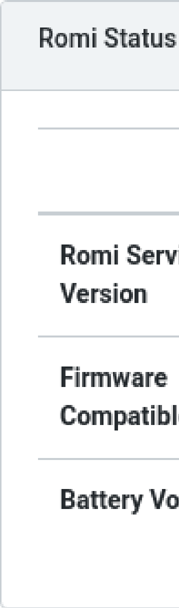
### Status Service Background 37.5.1



Web Romi running currently the about information provides UI Web Romi the of section This bring to controls provides UI The Romi). the to talk to WPILib allows what is (which Service service. web the of uptime current the shows as well as up/down service the

useful be can it but often, section this in functionality the use to need not will Users :□□□□ troubleshooting. for

### Status Romi 37.5.2


Romi Status

Romi Serv
Version

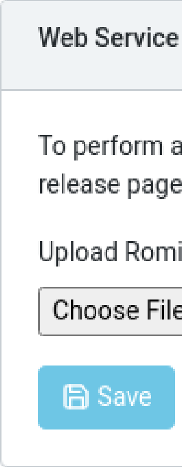
Firmware
Compatibl

Battery Vo

battery version, service the including Romi, the about information provides section This is board 32U4 Romi the on firmware installed currently the not or whether and voltage, service. web the of version current the with compatible

*Romi your Imaging* on section the see compatible, not is firmware the If :□□□□

### Update Service Web 37.5.3


Web Service

To perform a
release page

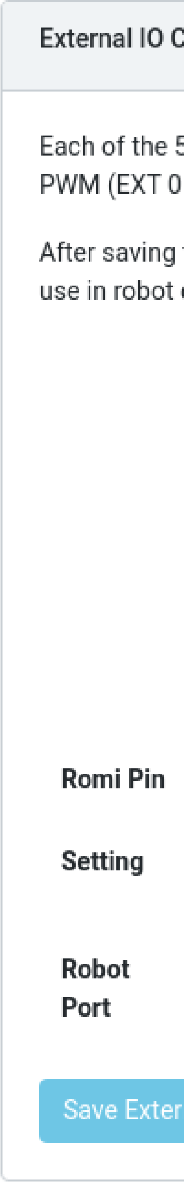
Upload Romi

work. to section this for mode **Writable** in be must Pi Raspberry The :□□□□

web Romi the of version time) publication (at latest the with ships image WPILibPi Romi The
allows section this service, web Romi the of versions newer to upgrading support To service.
GitHub service web Romi the via obtained be can that bundle builtpre- a upload to users
.page releases

page. Releases GitHub the from file .tgz appropriate the download upgrade, an perform To
will bundle service web updated The .*Save* click and file .tgz downloaded the select Next,
Status Romi the moment, short a After installed. be and Pi, Raspberry the to uploaded be
information. version latest the with itself update should section

## Configuration IO External 37.5.4

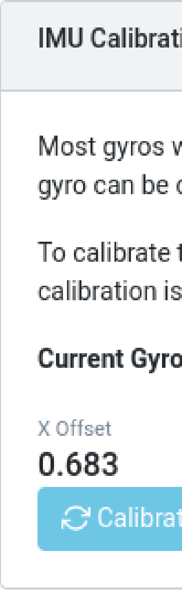


Romi. the on channels GPIO external 5 the configure to users allows section This work. to section this for mode **Writable** in be must Pi Raspberry The :□□□□

the from option appropriate an select channel, GPIO a of configuration the change To
and In Analog IO, Digital support 0) EXT of exception the (with channels All lists. dropdown
*IO External Save* on click made, are selections appropriate the Once types. channel as PWM
configuration. IO new the up pick and restart then will service web The .*Configuration*

GPIO configured each for mapping WPILib appropriate the provides row Port“ ”Robot The
in accessible be will and channel, IO Digital a as configured is 0 EXT example, For channel.
8. channel DigitalOutput) (or DigitalInput a as WPILib

## Calibration IMU 37.5.5



work. to section this for mode **Writable** in be must Pi Raspberry The :□□□□

sort some have usually Gyros Romi. the on gyro the calibrate to users allows section This
in it use and offset the calculate to Romi the allows calibration and error, offsetzero- of
calculations.

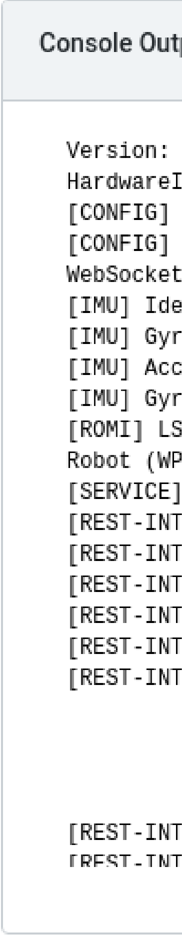
*Gyro Calibrate* the click Then, surface. stable flat, a on Romi the place calibration, begin To
calibration Once process. calibration current the showing appear, will bar progress A button.
Romi the with registered and screen on displayed be will values offset latest the complete, is
service. web

reboots. between persist and disk to saved are values offset These

## Firmware 37.5.6

Romi your *Imaging* on section the See :□□□□

## Output Console 37.5.7



```
Console Out

Version:
HardwareI
[CONFIG]
[CONFIG]
WebSocket
[IMU] Ide
[IMU] Gyr
[IMU] Acc
[IMU] Gyr
[ROMI] LS
Robot (WP
[SERVICE]
[REST-INT
[REST-INT
[REST-INT
[REST-INT
[REST-INT
[REST-INT



[REST-INT
[REST-INT
```

web Romi the that output console raw the view to users allows section this enabled, When out find to just or Romi, the with issues troubleshooting for useful is This provides. service scenes. the behind on goes what about more

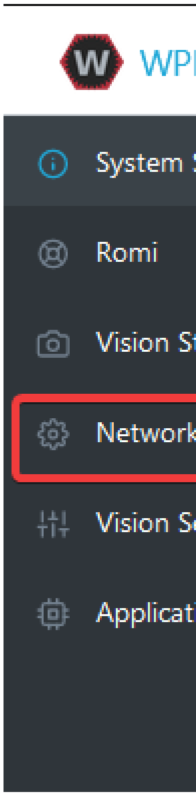
## Mode Bridge 37.5.8

an as acting of instead network WiFi a to connect to robot Romi your allows mode Bridge use can you as environments, learning remote in useful especially is This (AP). Point Access hardware. extra without Romi the using while internet the

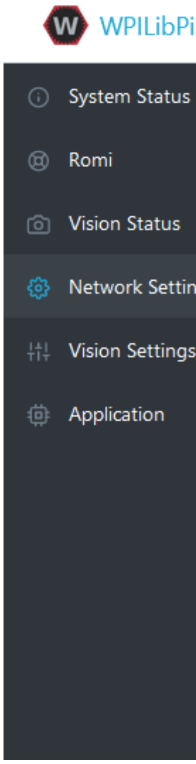
environments network restricted in properly work to likely not is mode Bridge **:□□□□** Institutions). (Educational

menu. top the in *Writable* Enable 1.

.*Settings Network* on Click 2.



applied: be must settings network following The 3.



- DHCP :**Ethernet**
- Bridge :**Mode WiFi**
- network your of (name) SSID :**SSID**
- network wifi your of Password :**Passphrase WPA2**
- DHCP :**Address WiFi**

to navigate to able be now should You Romi. the reboot please applied, are settings the Once network. specified your to connected while browser web your in `wpilibpi.local`

## Romi Access to Unable

few a have we it, access to unable are you and settings bridge correct the has Romi the If workarounds.

- Romi the into Ethernet
- Romi the Reimage

can you resolving, Romi the of hostname the with interfere can networks restricted Some address. IP the find to Scanner IP Angry using by this workaround

> on devices pings it as spyware as antivirus some by flagged is Scanner IP Angry **:□□□□□□** application! safe a is It network! your

## Romi the Programming 37.6

robot. FRC regular a for program a writing to similar very is Romi the for program a Writing be can etc) SmartDashboard, Station, Driver Code, Studio (Visual tools same the all fact, In Romi. the with used

### Program Romi a Creating 37.6.1

the to similar program, FRC normal a creating like is Romi a for program new a Creating steps. programming *Robot To Zero*

TimedRobot, on based one including projects, Romi for templates two with comes WPILib which provided is project example an Additionally, template. project BasedCommand- a and through walk will article This Romi. the of functionality inbuilt- the of some showcases example. this from project a creating

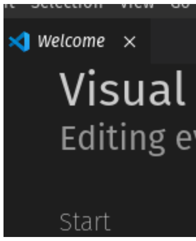
---

must compiler desktop C++ compatible a C++, using Romi the program to order In **:□□□□** .*Dependency C++ Additional - Simulation Robot* See installed. be

---

#### Project Romi WPILib New a Creating

project“ ”New type and ,`Ctrl+Shift+P` with palette command Code Studio Visual the up Bring command: project“ new a ”Create the Select prompt. the into



project a ”Select on click here, From Window“. Creator Project ”New the up bring will This appears: that prompt the from ”Example“ pick and Template), or (Example type

”RomiReference“ the find to list the through Scroll appear. will examples of list a Next, example:

to Project“ ”Generate click and Creator“ Project ”New the in fields the of rest the out Fill project. robot new the create

## Program Romi a Running

builtpre- a has project The run. to ready essentially is it generated, is project robot the Once using around Romi the drive you lets that command default associated and class `Drivetrain` joystick. a

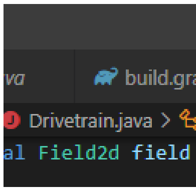
code the that is project robot FRC regular a from differs project Romi a where aspect One development your on runs project Romi a Instead, Romi. the to directly deployed not is Romi the with communicate to framework simulation WPILib the leverages and computer robot.

the to connect Next, on. powered is Romi your that ensure first, program, Romi a run To network Romi the changed you If Romi. the by broadcast network WiFi `><number-WPILibPi` address IP the change may you network) WiFi own your to it connect to example, (for settings and file `build.gradle` the open this, do To Romi. the to connect to uses program your that address. IP appropriate the to line `wpi.sim.envVar` the update

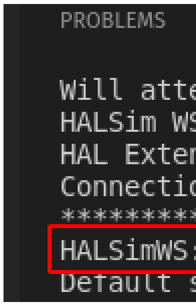
```
                                   host. remote client websocket the Sets//

                   true = defaultEnabled.)(addWebsocketsServer.sim.wpi
                   true = defaultEnabled.)(addWebsocketsClient.sim.wpi
```

)`Ctrl+Shift+P` (type Palette Command WPILib the open code, robot Romi your start to Now .F5 press or Code“, Robot ”Simulate select and



WebSocket ”HALSimWS: reads that output console the in line a see should you well, goes all If Connected“:



```
PROBLEMS

Will atte
HALSim WS
HAL Exter
Connectio
*********
HALSimWS:
Default s
```

running! now is code Romi Your

## (LabVIEW) Romi the Programming 37.7

regular a for program a writing to similar very is Romi the for program LabVIEW a Writing Romi. the with used be can tools same the all fact, In robot. based roboRIO

### Project Romi a Creating 37.7.1

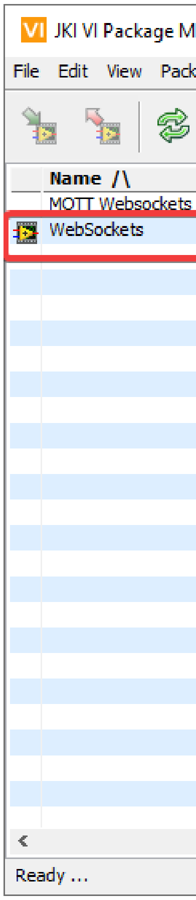
program, |reg| FRC normal a creating than different no is Romi a for program new a Creating separate a create to wish may you Initially, steps. programming *Robot To Zero* the to similar ports different to connected be may hardware Romi the as Romi the just on use for project robot. roboRIO your on than

respectively. side right and left for 1 and 0 ports PWM used Robot Romi The

#### VI WebSockets the Installing

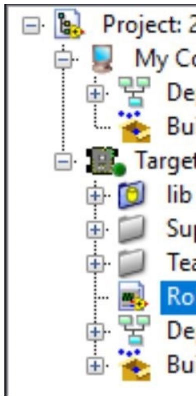
the that is project robot |reg| FRC regular a from differs project Romi a where aspect One development your on runs project Romi a Instead, Romi. the to directly deployed not is code Romi the with communicate to framework simulation WPILib the leverages and computer, Romi. the with converse to uses LabVIEW that protocol the is WebSockets robot.

top the in box search the into `websockets` Type application. *Manager Package VI* the Open .*Network Tools LabVIEW* by VI the Select right.



## Target Project the Changing

target the change to is Romi the on program LabVIEW your run to needed step primary The Explorer Project the in VI Main Robot the locate target, project the change To Desktop. the to section. `Computer My` the to section `Target` the from it drag and click and



### IP Target the Setting

address IP the with Romi a to connect to attempt will program LabVIEW your default, By `Driver` the to input an as it specify can you IP, different a use to wish you If .`10.0.0.2` of for terminal input pink the Locate .`Main Robot` inside `VI Communication Start Station` filledpre- constant a create to *Constant Create* select and clickright- then `URL Simulation` to care taking text, the of portion address IP the modify then can You value. default the with same. the end) the (at suffix and port and beginning) the (at section protocol the leave


ws://10.0.0.2 33

### Program Romi a Running

to connect you Once on. powered is Romi your that ensure first, program, Romi a run To start to arrow *Run* white the press Romi, the by broadcast network `><number-WPILibPi` the computer. your on program Romi the running

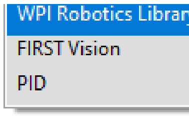
either to connect to attempt automatically will program The running! now is code Romi Your IP. an specified not have you if default the or specified, have you IP the

LabVIEW the as computer same the on software Station Driver the run to recommended is It automatically will it Station, Driver the to connects successfully program your Once code. Station Driver the allowing Desktop, the on running is code the that Station Driver the notify need you'll Next, Station. Driver the inside information any changing you without connect to `127.0.0.` to number team the setting by done is This Romi. your to Station Driver the point to enable/disable and mode robot the set to Station Driver the in controls the use then can You .1 normal. as

### Encoder or Gyro the Using

is This functions. RomiGyro the using available is Romi the on available is that gyro The under located

```
                Library Robotics WPI -
                          Sensors -
                 Libraries Party Third -
                       RomiGyro -
```



are: ports DIO The function. encoder standard the using used be can encoders The

- 5) (4, Left
- 7) (6, Right

# 83

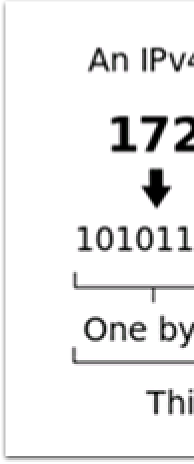
[redacted]

.roboRIO Station Driver [illegible]

## Basics Networking 38.1

### Address? IP an is What 38.1.1

device each identifies that periods by separated numbers, of string unique a is address IP An
255.0- from ranging (octets) sections 4 into up divided is address IP Each network. a on



$^{32}$2 are there meaning address bit32- a is address IP each that means this above, shown As used are these of most However, possible. addresses 4,300,000,000 nearly or addresses, servers. web like things for publicly

have must network the on device Each Addressing: IP of **point key first** our up brings This will collisions otherwise address, IP same the have can devices two No address. IP unique a occur.

computers billion 4 than more are there and addresses, billion 4 only are there Since addresses. IP out giving with possible as efficient as be to need we internet, the to connected addresses. private vs. public to us brings This

### Addresses IP Private vs Public 38.1.2

implemented. was Ranges“ IP ”Reserved of idea the Addresses, IP using with efficient be To web to assigned be never will that Addresses IP of ranges are there that means this short, In house. your in those as such networks, local for used be only will and servers,

modem basic provider’s internet your to connecting directly are you Unless :**#2 point Key** means This ranges. these of one in Address IP an have will device your function), router (no 99% will device your etc., home, office, work school, your as: such network, local any at that below: listed range a in address IP an have time the of

| Class | Bits | Address Start | Address End | Addresses of Number |
|---|---|---|---|---|
| A | 24 | 10.0.0.0 | 10.255.255.255 | 16,777,216 |
| B | 20 | 172.16.0.0 | 172.31.255.255 | 1,048,576 |
| C | 16 | 192.168.0.0 | 192.168.255.255 | 65,536 |

and house, entire an to Address“ IP ”unreserved one assign us let ranges reserved These to computer one than more connect to range reserved a in addresses multiple use then Address (Network **NAT** as known router internet home’s the on process A internet. the using data, requesting is IP private which track keeping of process the handles Translation), back data returned the passing then and internet, the from data that request to IP public the for addresses IP reserved same the use to us allows This it. requested that IP private the to presented is process this of image An conflicts. any causing without networks, local many below.

use to us allows range This range. `10.0.0.0` the use will we networks, FRC® the For :□□□□ would networks C or B Class the using whereas addresses, IP for format `10.TE.AM.xx` the be would formatting this of example An format. the follow to teams of subset a allow only 1750. Team FRC for `10.17.50.1`

## assigned? addresses these are How 38.1.3

for use will we addresses IP which and are, addresses IP what of basics the covered We've the to assigned get will addresses these how discuss to need we now so competition, FRC the same the on devices two have can't we that above stated already We network. our on devices receives device every that sure be to way a need we so Address, IP same the with network Statically or (automatic), Dynamically done be can This overlapping. without address an (manual).

### Dynamically

manage network the on device a letting are we that means addresses IP assigning Dynamically Protocol Configuration Host Dynamic the through done is This assignments. address IP the think will we document, this of scope the for but it, to components many has DHCP (DHCP). device new a in plug you Whenever network. the manages automatically that service a as it of IP available an with it provides then device, new the sees service DHCP the network, the to can This communicate. to device the for required settings network other the and address device. each of address IP exact the know not do we times are there that mean

### server? DHCP a is What

devices new for network the monitor to service DHCP the runs that device a is server DHCP A DHCP the running computer dedicated a be could this businesses, larger In configure. to networks, FRC networks, home For server. DHCP the be would computer that and service case, this in router; the on running usually is service DHCP the networks, smaller other and server. DHCP the is router the

server DHCP a have to need you where situation a into run ever you if that means This home closest the finding as simple as it's devices, network your to addresses IP assigning in. it plugging and router,

### Statically

the on device each telling manually are we that means addresses IP assigning Statically setting a through happens configuration This have. to it want we address IP which network we manually, addresses the assigning and network the on DHCP disabling By device. each on because but network, the on device each of address IP exact the knowing of benefit the get we addresses, IP used the of track keeping service no is there and manually one each set we careful be must we addresses, IP setting statically While ourselves. this of track keep to have settings network other the setting are we sure be must and addresses, duplicate assign to not device. each on correctly gateway) default and mask subnet as (such

### local?link- is What 38.1.4

can This network. a on communicate cannot it then address, IP an have not does device a If
a from address its acquire dynamically to set is that device a have we if issue an become
when be would this of example An network. the on server DHCP no is there but server, DHCP
an acquire dynamically to set are both and roboRIO a to connected directly laptop a have you
the on devices two only the are they since and server, DHCP a is device Neither address. IP
automatically. addresses IP assigned be not will they network,

device a if to back“”fall- can we that addresses of set standard a us give addresses localLink-
will device the happens, this If address. an acquire to able not is dynamically acquire to set
address. locallink- a is this range; address `169.254.xx.yy` the in address IP an itself assign
been haven’t they realize will devices both above, example computer and roboRIO our In
both are they Once address. locallink- a themselves assign and address IP an assigned
will and network same the in be will they range, `169.254.xx.yy` the in addresses assigned
not did server DHCP a and dynamic to set were they though even communicate, to able be
addresses. assign

### FRC for Addressing IP 38.1.5

information. more for *Article Networking IP* the See

#### Configurations Static and Dynamic Mixing

in statically set devices having with issues any notice not should team the field, the on While
no are there as long as addresses DHCP assign field the having and range, `10.TE.AM.xx` the
above. section the in to referred as conflicts address IP

following the for devices DHCP and Static mixing with issues encounter may team a pits, the In
`169.254.xx.`( address locallink- a to back fall will devices DHCP above, mentioned As reason.
the If same. the be always will address IP the devices, static For present. isn’t server a if )yy
locallink- to back fall laptop and station, driver roboRIO, the and present not is server DHCP
network different a in be will range 10.TE.AM.xx the in devices set statically the addresses,
provided is this of description visual A addresses. locallink- with those to visible not and
below:

> is configuration *Forwarding Port* a roboRIO, the to USB via connected When **:□□□□□** shown network green the (on radio OpenMesh the to connected devices access to required above).

### Ports Network Available

ports. network available regarding information for Manual Game 2023 the of R704 see Please

## mDNS 38.1.6

the from benefit to us allows that protocol a is System Name Domain multicast or mDNS, let’s clearer, this make To network. the on server DNS a having without DNS, of features is. DNS what about talk and back step a take

### DNS? is What

we paper, this of scope the for but topic, complex a become can System) Name (Domain DNS DNS explanation, basic most the In DNS. of overview levelhigh- the at look just to going are and Addresses, IP to devices network for names friendlyhuman- relate to us allows what is change. they if addresses IP those of track keep

`172.217.` is site this for address IP The `.www.google.com` site the at look Let’s 1: Example remember! to friendlyuser- very not is that however `,164.132`

DNS the contacts computer the computer, their into `www.google.com` types user a Whenever `www.google.` for file on address IP the is what asks and DHCP!) by provided setting (a server to that use to able is computer the then and address IP the returns server DNS The `.com` website. Google the to connect

to want you that `MYCOMPUTER` named server a have you network, home your On 2: Example of Address IP the know don’t you so DHCP uses network Your laptop. your from to connect Additionally, name. `MYCOMPUTER` the using by just connect to you allows DNS but `,MYCOMPUTER` address, different a with up end may `MYCOMPUTER` refresh, assignments DHCP the whenever address, IP specific a of instead name `MYCOMPUTER` the using by connecting you’re because but connect. to able still you’re and updated was record DNS the

reference we if DNS, With FRC. for relevant most the and DNS to benefit second the is This our in anything change to have don’t we Address, IP of instead name friendly their by devices new the return and changes the of track keep will DNS changes. Address IP the if program changes. ever it if address

### FRC for DNS

lookups the perform to us allows that server DNS no is there pits, the in and field the On
remembering not of benefits the have to like still we'd but website, Google the for do we like
different a assigns DHCP if address device's every at guess to having not and Address, IP every
picture. the into comes mDNS where is This expect. we than address

way a in implemented just is but DNS, traditional as benefits same the us provides mDNS
friendly a using device a to connect to asks user a Whenever server. a require not does that
The itself. identify to name that with device the asking message a out sends mDNS name,
on devices all so address IP its including message return a sends then name the with device
roboRIO our to refer to us allows what is mDNS information. their update can network the
network. DHCP a on connect it have and `FRC.local-TEAM-roboRIO` as

---

Address IP an assigned be will it then mDNS, support not does FRC for used device a If **:□□□□**
connect to address exact the know won't we but range, 10.TE.AM.255 - 10.TE.AM.20 the in
need would device the case, this In before. like name friendly the use to able be won't we and
Address. IP static a have to

---

### Principles - mDNS

hostnames of resolution for allows which system a is (mDNS) System Name Domain Multicast
a hostname a resolve To server. name dedicated no with networks small on addresses IP to
device The device. the for querying network the to message multicast a out sends device
store can network the on Devices IP. its containing message multicast a with responds then
the from resolved be can address this for requests subsequent so cache a in information this
query. network the repeating without cache

### Providers - mDNS

some are Here PC. your on installed be to required is implementation mDNS an mDNS, use To
platform: major each for implementations mDNS common

Windows:

- Tools Game FRC NI the with Installed **Responder: mDNS NI**
- iTunes with Installed **Bonjour: Apple**

OSX:

- default by Installed **Bonjour: Apple**

Linux:

- variants Linux some on default by enabled and Installed **mDNS/Avahi/Zeroconf:nss-**
  Arch) as (such others on enabled or installed be to need May Mint). or Ubuntu as (such

### Firewalls - mDNS

is section this required, be may changes no configuration, PC your on Depending **:□□□□** troubleshooting. with assist to provided

network the Because firewall. your through pass to allowed be must mDNS properly work To IDE, or Station Driver the from directly not and implementation mDNS the from comes traffic resolve to ways main two are There sufficient. be not may through applications those allowing issues: firewall mDNS

- mDNS (NI implementation mDNS the for exception application/service an Add `\Responder mDNS\Shared\Instruments National\Files Program\C:` is Responder `)nimdnsResponder.exe`
- Ranges: IP 5353. UDP to/from traffic for exception port a Add
  - `10.255.255.255 - 10.0.0.0`
  - `172.31.255.255 - 172.16.0.0`
  - `192.168.255.255 - 192.168.0.0`
  - `169.254.255.255 - 169.254.0.0`
  - `224.0.0.251`

### support Browser - mDNS

web roboRIO the access to address mDNS the utilize to able be should browsersweb- Most Edge, Microsoft include browsers These installed. is provider mDNS an as long as server Chrome. Google and Firefox,

## USB 38.1.7

*Game FRC-□ □□□□□* the need do (you required is setup network no interface, USB the using If automatically will driver roboRIO The Driver). USB roboRIO the provide to installed *Tools* listed software the and roboRIO and computer) (your host the of address IP the configure roboRIO. your utilize and locate to able be should above

## Ethernet/Wireless 38.1.8

case use home the in radio OpenMesh the on server DHCP the enable will □□□□□□ □□□□□ The can you router, a using and mode bridge in OpenMesh the putting are you if mode), (AP address IP basedteam- same the to set is bridge The router. the on addressing DHCP enable `.10.TE.AM.199` to `10.TE.AM.20` from address DHCP out hand will and `)10.TE.AM.1(` before as range. IP same the in addresses out hand also will FMS field, the to connected When

### Summary 38.1.9

these FRC, For network. a on devices with communicate to us allow what are Addresses IP server DHCP a to connected are we if range 10.TE.AM.xx the in be to going are addresses are devices the if range `169.254.xx.yy` locallink- the in or statically, assigned are they if or work, Addresses IP how on information more For present. server no is there but DHCP, to set Microsoft. by article this see

referred and DHCP to set be can devices all then mDNS, support network the on devices all If support not do devices some If ).`FRC.local-TEAM-roboRIO` (ex. names friendly their using to addresses. static use to set be to need will they mDNS,

the settings), static correct (with assignments IP Static or DHCP use to set are devices all If If needed. changes any without field the on and pit the both in work should communication connect will devices Static the then devices, DHCP some and Static some of mix a are there devices all setting either by resolved be can This pit. the in connect not will but field, the on pit. the in server DHCP a providing and settings current the leaving or settings, static to

## Configurations IP 38.2

---

in and fields the on both events, at used configuration IP the describes document This :[illegible] configurations. workaround and issues potential pits, the

---

### Notation IP TE.AM 38.2.1

notation This document. this in places numerous in IPs of part as used is TE.AM notation The octets. address IP the for pairs digit two into number team digit four your splitting to refers

`10.TE.AM.2` Example:

`10.0.12.2` - 12 Team

`10.1.22.2` - 122 [illegible]

`10.12.12.2` - 1212 [illegible]

`10.12.2.2` - 1202 Team

`10.12.20.2` - 1220 Team

`10.34.56.2` - 3456 [illegible]

### על המגרש 38.2.2

.[illegible]

### למגרש DHCP הגדרת

addresses out hand will that team each for pools with server DHCP a runs Network Field The a and ,`255.255.255.0` of mask subnet a with `10.TE.AM.199` to `10.TE.AM.20` of range the in DHCP a runs Radio Team the event, an for configured When .`10.TE.AM.4` of gateway default range the in addresses out hand will that robot the onboard devices for pool a with server of gateway a and 255.255.255.0, of mask subnet a with 10.TE.AM.219 to 10.TE.AM.200 of 10.TE.AM.1.

- Kiosk by programmed `10.TE.AM.1` Static - radio ACOM5P- or ANOM5P- OpenMesh
- `10.TE.AM.2`-□ Radio Robot-□ □□□ □□ □□□□□□□ - roboRIO
- by assigned 10.TE.AM.X automatically“) address IP an (”Obtain DHCP - Station Driver field
- Radio Robot by assigned `10.TE.AM.Y` DHCP - used) (if camera IP
- Radio Robot by assigned `10.TE.AM.Z` DHCP - used) (if devices Other

### Configuration Static Field the On

software or devices accommodate to devices your on IPs static configure to possible also is It that addresses avoid to sure make to want you so doing When mDNS. support not do which for `10.TE.AM.1` are addresses These network. field the on is robot the when use in be will `10.TE.AM.` than greater anything and router, field the for `10.TE.AM.4` radio, OpenMesh the roboRIO The reserved. else or DHCP for configured device a to assigned be may which `20` webdashboard. the from set be can configuration network

- Kiosk by programmed `10.TE.AM.1` Static - radio OpenMesh
- `255.255.` of mask subnet choice, reasonable a be would `10.TE.AM.2` Static - roboRIO (default) `255.0`
- be **must** mask subnet choice, reasonable a be would `10.TE.AM.5` Static - Station Driver additionally without Server, FMS and robot the both reach to DS the enable to `255.0.0.0` is mask subnet the and assigned is address static a If gateway. default the configuring .`10.TE.AM.4` to configured be must gateway default the then ,`255.255.255.0` to set
- `255.255.` subnet choice, reasonable a be would `10.TE.AM.11` Static - used) (if Camera IP fine be should `255.0`
- subnet present) not camera if (.11 `19.`-`12.` or `10.`-`10.TE.AM.6` Static - devices Other `255.255.255.0`

## Pits the In 38.2.3

---

Robot the of side wired the on running server DHCP a now is There **2018: for New** :□□□□ configuration. event the in Radio

---

### Configuration DHCP Pits the In

- Kiosk. by programmed `10.TE.AM.1` Static - radio OpenMesh
- Radio Robot by assigned ,`10.TE.AM.2` - roboRIO
- by assigned ,`10.TE.AM.X` automatically“), address IP an (”Obtain DHCP - Station Driver
Radio Robot
- Radio Robot by assigned ,`10.TE.AM.Y` DHCP, - used) (if camera IP
- Radio Robot by assigned ,`10.TE.AM.Z` DHCP, - used) (if devices Other

### Configuration Static Pits the In

software or devices accommodate to devices your on IPs static configure to possible also is It
that addresses avoid to sure make to want you so doing When mDNS. support not do which
the for `10.TE.AM.1` are addresses These network. field the on is robot the when use in be will
router. field the for `10.TE.AM.4` and radio OpenMesh

## Troubleshooting Network roboRIO 38.3

connectivity. network for (DHCP) addresses IP dynamic use tools FRC® and roboRIO The
PC your between connectivity networking troubleshooting for steps describes article This
roboRIO your and

### mDNS using roboRIO the Ping 38.3.1

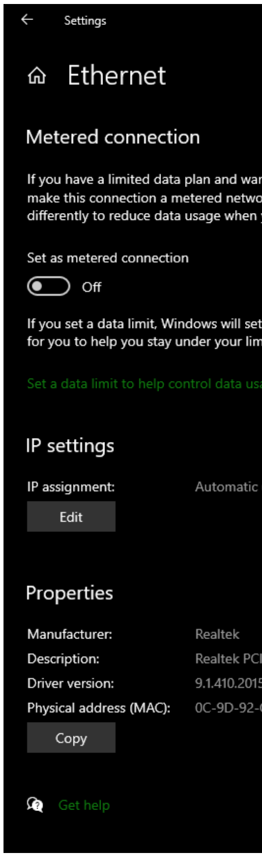
application an is it if isolate to is issues networking roboRIO identifying to step first The
to **Enter press >- cmd type >- Start** click this, do To issue. network general a or issue
team your is #### where `FRC.local-####-roboRIO ping` Type prompt. command the open
with likely is issue the succeeds, ping the If enter. press and zeroes) leading no (with number
check and application, the in configuration number team your verify application, specific the
configuration. firewall your

### Address IP roboRIO the Ping 38.3.2

command the using )*Notation IP TE.AM*( `10.TE.AM.2` pinging try response, no is there If
address mDNS the resolving issue an have you works, this If above. described as prompt
the on installed resolver mDNS an having not are causes common most two The PC. your on
using address .local the resolve to trying is that network the on server DNS a and system
DNS. regular

- is this Windows, On system. your on installed resolver mDNS an have you that Verify
resolvers, mDNS on information more For Tools. Game FRC NI the by fulfilled typically
.*article Basics Network* the see
- OM5P- the have you sure make and networks other any from computer your Disconnect
Removing .*Utility Configuration Radio FRC* the using point, access an as configured AN
causing server DNS a not is there that verify help will system the from routers other any
issue. the

### Fails Ping 38.3.3



Settings

Ethernet

Metered connection

If you have a limited data plan and war
make this connection a metered netwo
differently to reduce data usage when

Set as metered connection

Off

If you set a data limit, Windows will set
for you to help you stay under your lim

Set a data limit to help control data us

IP settings

IP assignment: Automatic

Properties

Manufacturer: Realtek
Description: Realtek PC
Driver version: 9.1.410.2015
Physical address (MAC): 0C-9D-92-

network the with issue an have may you fails, directly address IP the pinging If this, check To .**Automatic** to configured be should PC The PC. the of configuration select network, your on Depending .*Internet & Network* >- *Settings* >- *Start* click **settings IP** to down Scroll network. connected your on click Then .*Ethernet* or *Wifi* selected. is option *(DHCP) Automatic* the ensure and *Edit* click and

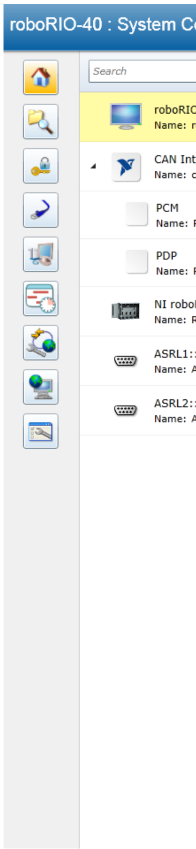
### Troubleshooting Connection USB 38.3.4

IP roboRIO's the pinging try connection, USB the troubleshoot to attempting are you If as configured be should it PC, the to connected roboRIO one only is there as long As address. and powered, and connected roboRIO the have you sure make fails, ping this If 172.22.11.2. drivers roboRIO the installs tools game The Tools. Game FRC NI the installed have you that needed for the USB connection.

is hostname roboRIO the either that likely is it fails, ping .local the but succeeds, ping this If resolve to attempting is which server DNS a to connected are you or incorrectly, configured address. .local the

- .*2 roboRIO 1 roboRIO* number: team your for imaged been has roboRIO your that Verify
  mDNS. by used hostname the sets This
- *adapters network other all Disable*

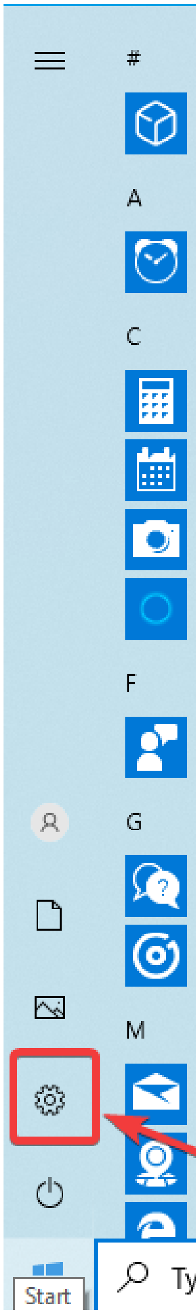
### Connection Ethernet 38.3.5



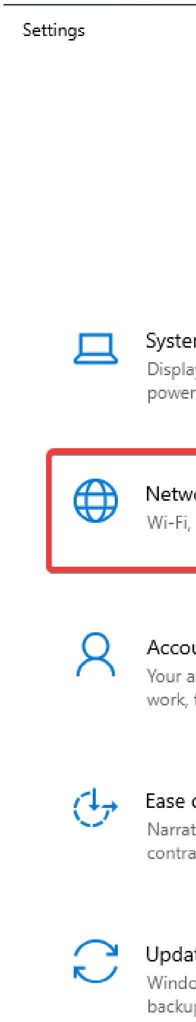
that sure make first to helpful be may it connection, Ethernet an troubleshooting are you If open connection, USB the Using connection. USB the using roboRIO the to connect can you ethernet the on address IP an has roboRIO the that verify and *webdashboard roboRIO* the `169.*.` assignedself- a be should this directly roboRIO the to tethering are you If interface. form the of address an be should it radio, ANOM5P- the to connected are you if address, `*.*` is here address IP only the If number. team FRC digit four your is TEAM where `10.TE.AM.XX` connection. ethernet roboRIO physical the verify address, USB the

### Adapters Network Disabling 38.3.6

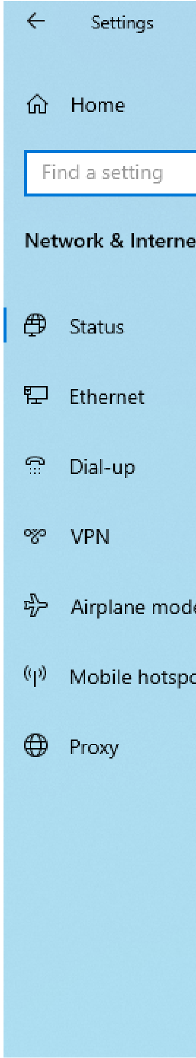
the putting or button physical a with off adapters the turning as same the always not is This adapters. disable to how on detail more provide steps following The mode. airplane into PC



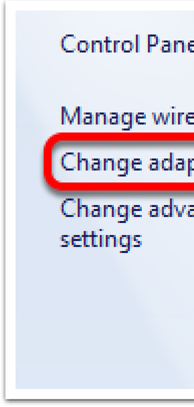
icon. settings the on clicking by application Settings the Open



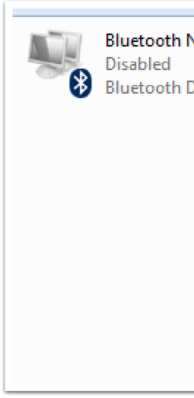
category. *Internet & Network* the Choose



.*options adapter Change* on Click



.*Settings Adapter Change* click pane, left the On



Bluetooth N
Disabled
Bluetooth D

and adapter the on click right radio, the to connected one the than other adapter each For menu. the from *Disable* select

### Proxies 38.3.7

- networking. roboRIO the with issues cause may enabled proxy a Having Proxies.

## Configuration Firewall Windows 38.4

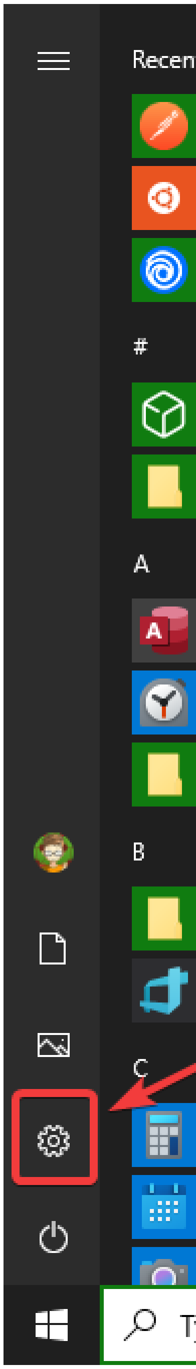
reasons. various for access network need FRC® in used tools programming the of Many with interfere potentially may Firewall Windows the configuration, exact the on Depending programs. these of more or one for access this

### Firewall Windows Disabling 38.4.1

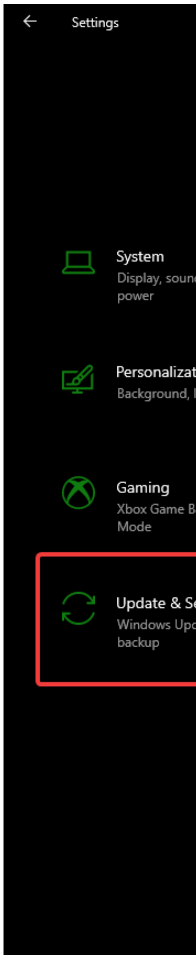
**:□□□□** note Additionally PC. the to privileges administrator requires firewall your Disabling internet. the to connect that computers for recommended not is firewall the disabling that

does this that beware should Teams Firewall. Windows the disable to is solution easiest The internet. the to connecting if attacks malware to vulnerable more potentially PC the make

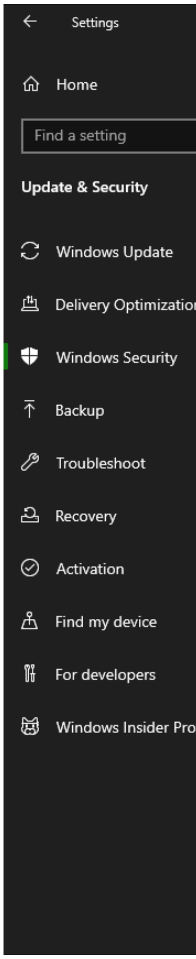
*Settings* >- *Start* Click



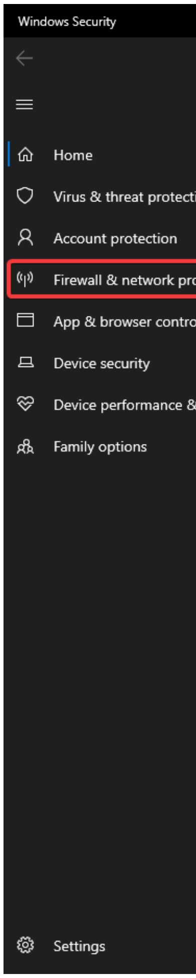
*Security & Update* Click



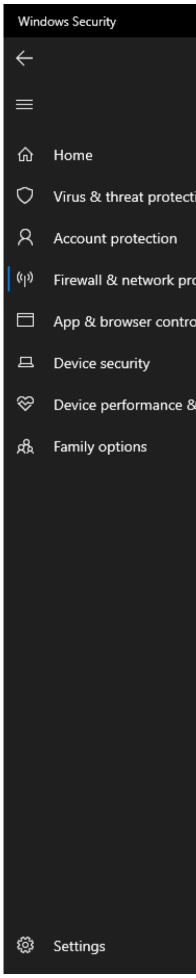
*Security Windows Open* select pane, right the In



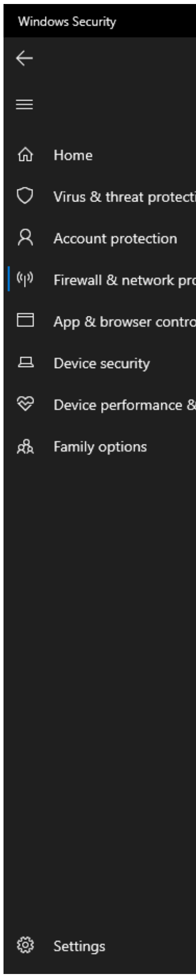
*protection network and Firewall* select pane, left the In



options highlighted the of **each** on Click



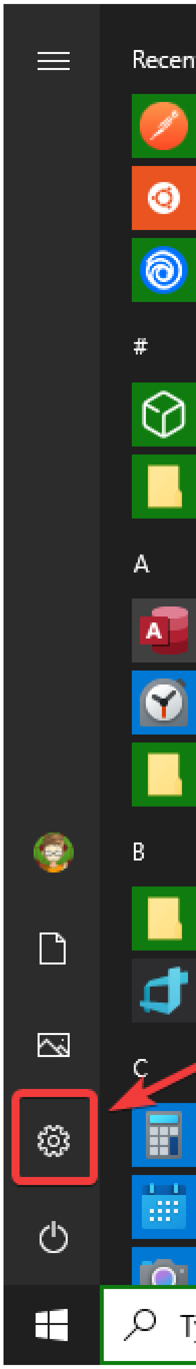
off. it turn to toggle **On** the on click Then



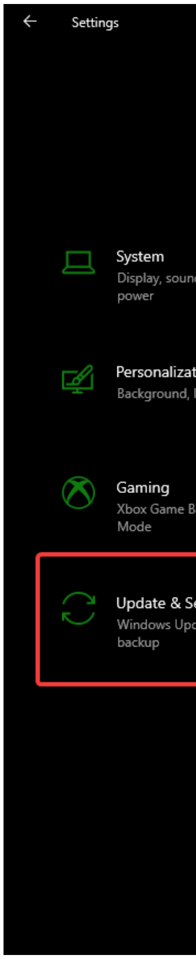
## Apps Whitelisting 38.4.2

having are you programs FRC any for Firewall the to exceptions add can you Alternatively, with. issues

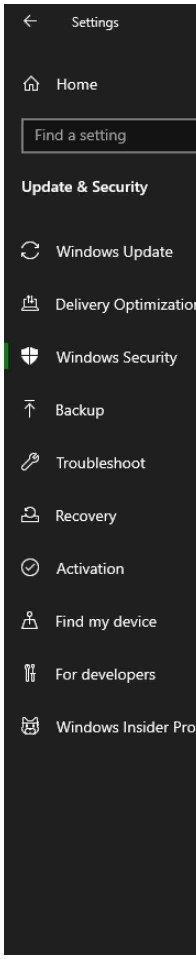
*Settings* >- *Start* Click



*Security & Update* Click



*Security Windows Open* select pane, right the In



Settings

Home

Find a setting

Update & Security

Windows Update

Delivery Optimizatio

Windows Security

Backup

Troubleshoot

Recovery

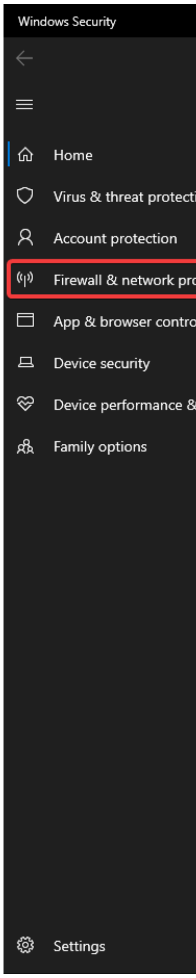
Activation

Find my device

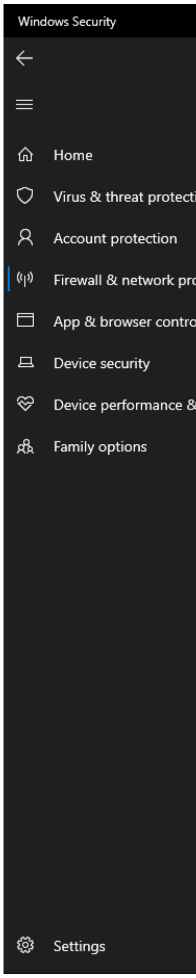
For developers

Windows Insider Pro

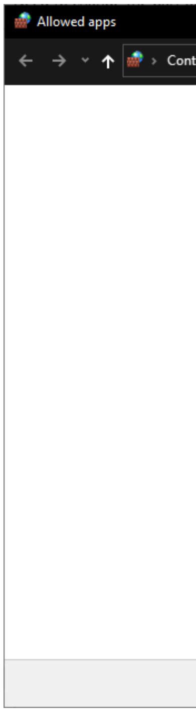
*protection network and Firewall* select pane, left the In



*firewall through app an Allow* select window, the of bottom the At



list the in appears it that sure make with, issue an having are you program FRC each For made you setting, a change to need you If columns. 3 the of each in check a has it that and the If settings. the changing before right top the in button *settings Change* the click to need the to browse and button *program... another Allow* the click all, at list the in not is program it. add to program the of location



## Usage Bandwidth Measuring 38.5

2023 the in R704 (see bandwidth network limited allocated is team each Field FRC® the On bandwidth the determining on information more provides Whitepaper FMS The manual). bandwidth overall their measure to wish may teams some but camera, Axis the of usage measurement. that make to how details document This consumption.

---

Bridge FRC the using home at throttling bandwidth the simulate can Teams :□□□□ checked. checkbox bandwidth the with Utility Configuration

---

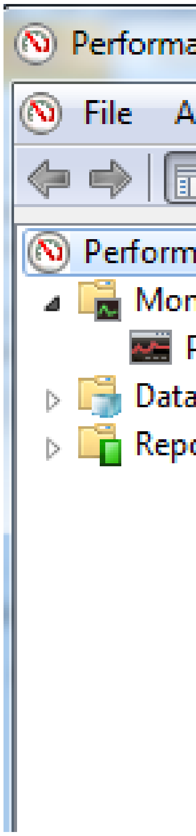
### (Win Monitor Performance the Using Bandwidth Measuring 38.5.1 (7/10

monitor to used be can that Monitor Performance the called tool inbuilt- a contains Windows interface. network a over usage bandwidth the

#### Monitor Performance the Launching

Enter. press and `perfmon.msc` type box, search the in and `Start` Click

## Monitor TimeReal- Open



monitor. timereal- the display to `Monitor Performance` click pane, left the In

## Counter Network Add

counter a add to screen the of top the near plus green the Click 1.

it select to `Interface Network` on click and locate pane, left top the In 2.

to instances All use (or interface network desired the locate pane, left bottom the In 3.
interfaces) all monitor

pane. right the to counter the add to `>>Add` Click 4.

graph. the to counters the add to `OK` Click 5.

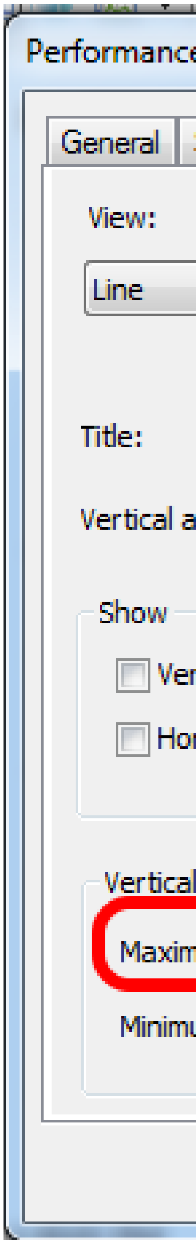
## Counters Extra Remove

`Delete` the press and `Total/sec Bytes` than other counter each select pane, bottom the In
pane. the in remaining entry only the be should entry `Total/sec Bytes` The key.

## Properties Data Configure

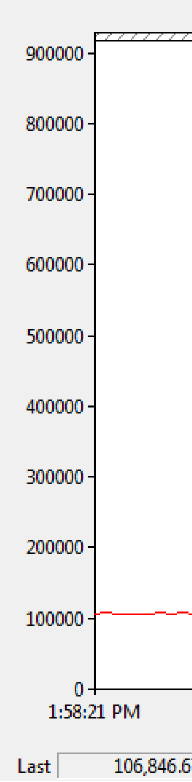
and `Scale` to next dropdown the on Click  window. Properties the up bring to `Ctrl+Q` Press
tab. `Graph` the on click Then .`1.0` select

### Properties Graph Configure



to converted Megabits 7 is (this 917504 enter `Scale Vertical` under `Box Maximum` the In the close to `OK` click Then box. the checking by grid horizontal the on turn desired, If Bytes). dialog.

### Usage Bandwidth Viewing



Last 106,846.6

haven’t you (if interface selected the over normal as robot your to connect now may You with connection, the of usage bandwidth total the show will graph The already). so done also are values Max and Min Average, Last, The graph. the of top the at cap bandwidth the meaning Bytes/Second in are values these that Note graph. the of bottom the at displayed ~100000 at line flat a see should you open Station Driver the just With 917,504. is cap the Bytes/Second.

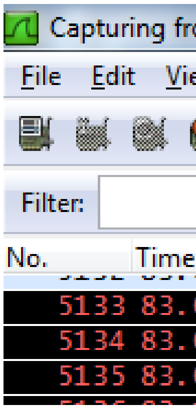
## Wireshark using Usage Bandwidth Measuring 38.5.2

monitor to program party 3rd a install to need will you monitor, performance use not can you If Download Wireshark. is purpose this for used be can that program One usage. bandwidth is installation After Windows. of version your for Wireshark of version latest the install and Driver the open robot, your to computer your Connect Wireshark. open and locate complete, using. be may you programs custom or Dashboard any and Station

### capture Start and interface the Select

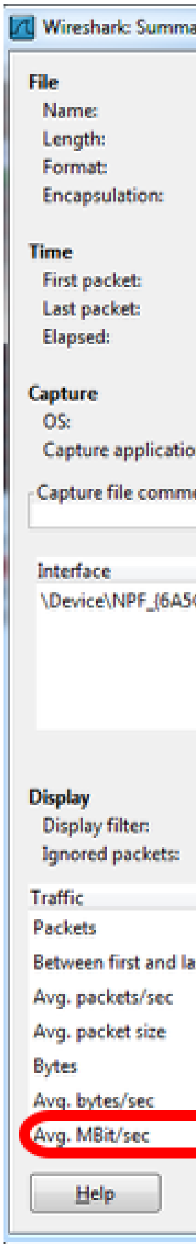
the to connect to using are you interface the select side, left the on program Wireshark the In .`Start` click and robot

### Summary Statistics Open



.`Summary` then `Statistics` click then minute, 1 least at for run capture the Let

## Usage Bandwidth View



summary the of bottom the near displayed is Megabits/Second in usage, bandwidth Average window.

# Modification Radio ACOM5P- 38.6

and shocks same the to it subject not does radio ACOM5P- the for case use intended The pressure significant to subjected is radio the If environment. FRC® the in sees it as forces at shield metal a shorting by reboot radio a cause to possible is it case, the of bottom the on article This board. the of bottom the on leads metal exposed some to radio the of bottom the scenario. this prevent to radio the to modification a details

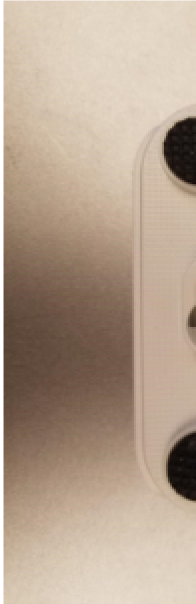
reboot a cause to case the of bottom the to applied pressure significant takes It :□□□□□ some in path power the to traced be can issues reboot radio FRC Most manner. this in than rather radio the of mounting strategic via risk this mitigating recommend We form. components): internal delicate damaging risk (and radio the modifying and opening

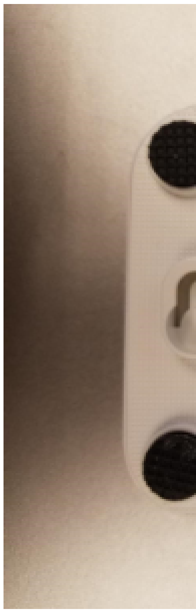
- radio. the of bottom the on features tab“ ”mounting the using Avoid
- a go can little A absorption. shock some for allow to radio the mount to wish may You with surface robot a to or fastener loop and hook using radio the mounting way, long the reduce significantly can etc.) sheet, metal sheet or (plastic flex of amount small a radio. the by experienced forces

## Radio the Opening 38.6.1

Users device. serviceable user a be to designed not is ACOM5P- OpenMesh The :□□□□ avoid to carefully and slowly work to sure Make risk. own their at modification this perform cables. antenna radio as such components internal damaging

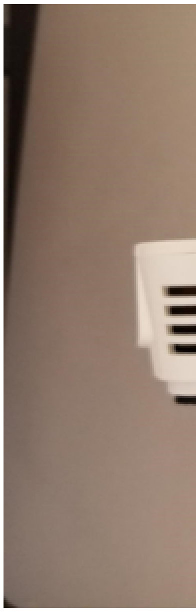
### Screws Case





using radio the off them pry then radio the of side front the on feet rubber two the Locate
two the remove screwdriver, Phillips small a Using etc. screwdriver, flat small fingernails,
feet. the under screws

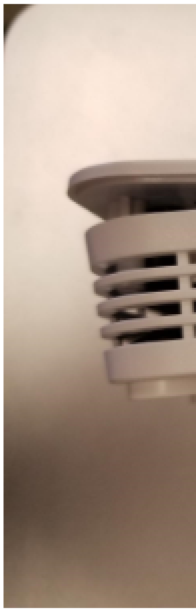
### Latches Side



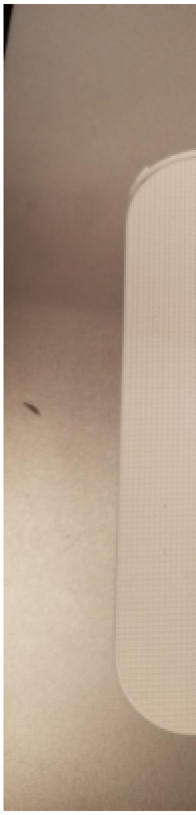
see can (you edge long each of middle the near radio the of lid the on latch small a is There
slide tool, thin very or fingernail a Using picture). next the in clearly more latches these
radio, the of middle the towards back to front from case and lid the between gap the along
(note: side other the on Repeat radio. of middle the near you as pop small a hear should you
are sides both sure make this, doing while side first the latchre- accidentally to hard not it’s
as side front the on open slightly be now should lid radio The proceeding). before unlatched
above. image the in shown

### Lid Remove

Look pads. heatsink the to due it remove you as lid the to stick may board The :□□□□□
it, with coming is board the if see to lid the remove you as radio the of vents the through
the from it separate to down board the hold to tool small a insert to need may you is it if
applied vents, the through fits that tool similar or screwdriver small a recommend We lid.
scroll can You hole. screw the above right side, jack barrel the on corner front the through
area. this in like looks board the what see to removed lid the with picture the to down

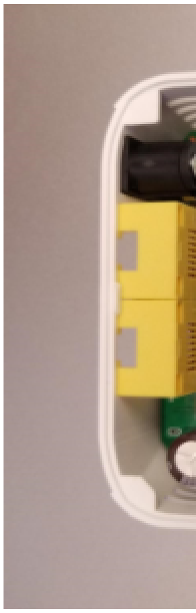


case the hit holders screw the until slightly) (lifting forward it slide lid, the removing begin To
front (you may need to apply pressure on the latch areas while doing this.

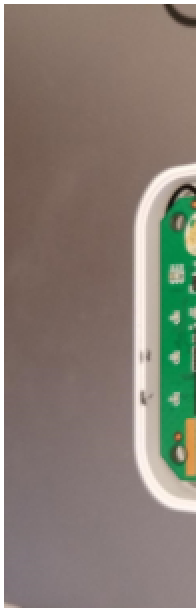


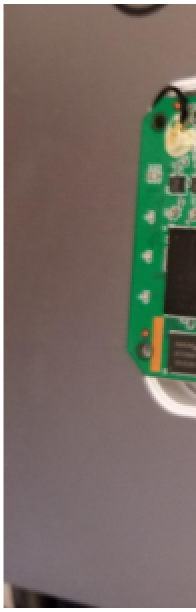
continuing while shown as side, jack barrel the from away slightly lid the rotating begin Next, Continue corner. right top the in visible triangle small the from lid the unhook will This lift. to jack barrel the towards corner left top the pushing while direction this in slightly rotate to Then corner. left top the in feature similar a unhook to step) this in further lift to try (don’t lift the body. the from away completely lid the

### Board Remove



their and wires, These above. image the in shown wires antenna the Note :□□□□□
steps. next the performing while them damage to not care take fragile, are connectors,





fingers your with ports network both or one grasping recommend we board, the remove To
network the until upward and radio) the of front the (toward inward pushing and shown) (as
case. the from free are jack barrel and ports

shield metal the expose to cable) antenna grey short the (towards up board the Tilt
underneath.

the on button reset small a is there that notice may you step, this perform you When :□□□□
reset the pressing that Note case. the in hole the than larger is that board the of underside
is radio the of case the drilling that and effect no has installed firmware FRC the with button
modification. permitted a not

### Tape Apply 38.6.2

network the of inside just area the in shield metal the to tape electrical of piece a Apply
board the of underside the on leads exposed the prevent will This openings. jack port/barrel

plate. this on circuiting short from

### Radio assembleRe- 38.6.3

it: open to instructions the reversing by radio the assembleRe-

- and front the near holes screw the with aligns it sure making down, back board the Lay securely seats
- Take left. to right from in it moving by feature retaining left back the onto lid the Slide area this in capacitor the of care
- in feature retaining right back the slide and downwards press lid, the Rotate
- latches the seat to lid the of front/middle the on firmly down Press
- feet front in screws 2 Replace
- feet front Replace

# 93

[redacted]

## Forwarding Port 39.1

useful is This host/port. another to ports local forward to way easy an provides class This
the to tethered computer a from devices connectedEthernet- access to way a provide to
forward can you means this forwarder, port TCP raw a as acts class This port. USB roboRIO
SSH. as such connections

### Port Remote a Forwarding 39.1.1

The robot. their controlling for roboRIO the to directly connect to wish may teams Often
for connection Pi Raspberry the forward to used be can )C++ ,Java( class PortForwarding
remote the between bridge a establishes class PortForwarding The times. these during usage
`String port, PortForwarder.add(int` do simply Java, in port a forward To client. the and
`.remotePort) int remoteName,`

Java

```
                                        @Override
                               { ()robotInit void public
  );80 ,"wpilibpi.local" ,8888(addPortForwarder.
                                                    }
```

C++

```
                               { RobotInit::Robot void
  );80 ,"wpilibpi.local" ,8888GetInstance().Add(::PortForwarder::wpi
                                                    }
```

Python

```
  )80 ,"wpilibpi.local" ,8888add(.getInstance().PortForwarder.wpiutil
```

---

important also is It port. forwarded local your as 1024 than less port a use **not can** You :□□□□
IP use only should and )`http://wpilibpi.local`( URLs full use **not can** you that note to

names. DNS or Addresses

### Port Forwarded a Removing 39.1.2

port the being port with `port) remove(int` call simply port, specified a on forwarding stop To happen. will nothing forwarded, being not is that port a on `remove()` call you If number.

Java

```
                                          @Override
                         { ()robotInit void public
                 );8888(removePortForwarder.
                                                  }
```

C++

```
                              { RobotInit::Robot void
);8888GetInstance().Remove(::PortForwarder::wpi
                                                    }
```

Python

```
)8888remove(.getInstance().PortForwarder.wpiutil
```

[redacted]

## 40.1 הנחיות תרומה

to unfamiliar are you If project. docsfrc- the for guidelines contribution the to Welcome
.here it on up read please format, reStructuredText the in writing

---

[illegible]: *FIRST* ® [illegible]. [illegible]
[illegible]/[illegible] [illegible] Commits-[illegible] GitHub-[illegible].

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### 40.1.1 הצהרת משימה

[illegible] WPILib [illegible] *FIRST* [illegible] - [illegible], [illegible]. [illegible] [illegible]/[illegible] [illegible], [illegible] [illegible]. [illegible] Parts of Kit-[illegible] [illegible]. [illegible] C++, (Java, [illegible] NI), [illegible] LabVIEW-[illegible] [illegible].

[illegible] *FIRST* Robotics Competition. [illegible] [illegible].

- [illegible]. [illegible]
- [illegible], [illegible]. [illegible], [illegible]
- [illegible]. [illegible] Competition Robotics *FIRST*-[illegible]

[illegible] [illegible].

## Process Release 40.1.2

the and `stable//` site main the handling for process release special a uses docsfrc- below. detailed is flow This .`latest//` site development

Season: During

- branch `main` to made Commit
  - website the on `latest//` and `stable//` Updates

Season: of End

- purposes archival for year, with tagged is Repository

Season:Off-

- commit seasonon- last the to locked is branch `stable`
- branch `main` to made Commit
  - site documentation the on `latest//` updates Only

## PR a Creating 40.1.3

branch `main` the to point should They GitHub. on repo docsfrc- the to made be should PRs .`stable` *not* and

## Content New Creating 40.1.4

know should you things couple a are There project! docsfrc- the to contributing for Thanks started! getting before

### articles? place to Where

that articles Standalone subject. opinionated pretty a be can articles new for location The category subject mentioned into placed be should category subject already an into well fall section). simulation the into placed be should simulation about something on (documentation two references or combines article an when complicated pretty get can things However, the on issue an open to author the advise we situation, this In sections. existing separate PR. the opening before going discussion get to repository

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### sections? place to Where

to author the advise We content. of amount large a contain they as tricky, quite are Sections PR. a up opening before discussion gather to issue an open

### Articles Other Linking

the article, another in described is that content references article the that instance the In reference. first the upon article that to link to effort best make should author

tutorial: drivetrain a in content following the have we Imagine

```
␣competition. a of outside code robot their test to need often may Teams
␣this. achieve to means a is `link-to-simulation:simulation>< Simulation`:ref: ↪
␣ever without code robot their test and test unit to way a teams offers Simulation ↪
robot. a needing ↪
```

author the structure the is This linked. is Simulation of instance first the only how Notice you If content. of topics different has article linked a where times are There follow. should reference new each to link should you article, the in content of types different the reference otherwise). appropriate it deemed has author the where situations in (except once

## 40.2 הנחיות סגנון

[illegible] [illegible] docs.frc- [illegible] RST/Sphinx [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] WPILib [illegible] ,[illegible] [illegible] [illegible] GitHub-ב [illegible] WPILib

### 40.2.1 שמות הקבצים

.([illegible]) - [illegible] ,[illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible]

,[illegible] .[illegible] [illegible] [illegible] "Software" [illegible] "Hardware" [illegible] ,[illegible] [illegible]/[illegible] [illegible] [illegible] [illegible] .hardware.rst-ultrasonics

.rst. [illegible] [illegible] [illegible] [illegible]

---

[illegible]: text recommended the extension, rst. the with files editing issues having are you If editor is Code VS with the rST extension.

---

### 40.2.2 טקסט

function wrapword- the use readability, need you If line. same the on be should content text All editor. your of

:[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

- RoboRio) [illegible] roboRio, RoboRIO, [illegible]) roboRIO
- LabView) [illegible] labview [illegible]) LabVIEW
- ([illegible] code, vs VScode, vscode, [illegible]) Code) (VS Code Studio Visual

- (□□□□□ OS, Mac Mac, X, OS Mac OSX, Mac OS, Mac □□) macOS
- (□□□□□ Github, github, □□) GitHub
- (□□□□□ Powershell, powershell, □□) PowerShell
- linux) □□) Linux
- java) □□) Java

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in items reference can You .*FRC □□□□□□ □□□□□□* the to added be should terms used Commonly .`` `deprecated`:term: `` using by glossary the

## Whitespace 40.2.3

### הזחה

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spaces. *3* be should `toctree:: ..` line new as directives content of Indentation

### שורות ריקות

be *should* There titles. section and blocks text basic separating line blank 1 be should There 1 blank line separating text blocks *and* content directives.

### פנימי Whitespace

.□□□□□□□ □□□□ □□□□ □□□□□□ □□□□□□□

## כותרות 40.2.4

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headings. for case title Use

### 40.2.5 רשימות

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.[illegible]

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   one Block -
   two Block -
 three Block -

       1 Sub -
       2 Sub -

  four Block -
```

### 40.2.6 בלוקי קוד

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1. .text -[illegible] .[illegible] :[illegible]

[illegible] ,[illegible] Java.-[illegible] ++ C [illegible] WPILib [illegible]
Java.-[illegible] C++-[illegible] [illegible]

### Include) Literal (Remote RLI 40.2.7

lines code pulls This used. be should RLI an blocks, code using of instead possible, When keeps automatically This programs. example the using commonly most GitHub, from directly is: RLI an of format The made. are that changes any with date to up code the

```
                                                          Java ::group-tab ..

        https://raw.githubusercontent.com/wpilibsuite/allwpilib/v2023.4.3/ ::rli ..
     wpilibjExamples/src/main/java/edu/wpi/first/wpilibj/examples/ramsetecontroller/ ↪
                                                                        Robot.java ↪
                                                              java :language:
                                                             44-61 :lines:
                                                                   :linenos:
                                                          44 :lineno-start:

                                                           C++ ::group-tab ..

        https://raw.githubusercontent.com/wpilibsuite/allwpilib/v2023.4.3/ ::rli ..
             wpilibcExamples/src/main/cpp/examples/RamseteController/cpp/Robot.cpp ↪
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## 40.2.8 אזהרות

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```
warning! a is This ::warning ..
```

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```
::warning ..
warning! a is This
```

## 40.2.9 קישורים

### Links Internal

section and filename ReStructuredText the on based generatedauto- be will Links Internal title.

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the use must You section. document a reference to format this Use `apis/sensors/-docs/software/hardware`:ref:` document. the of path absolute .*ultrasonics Analog* to renders `` `ultrasonics software:Analog-ultrasonics ``

underscore. single the Note document. same the of section a reference to format this Use .*Images* to renders `` _`Images` ``

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actual the surrounding by text displayed the customize may you `:doc:` or `:ref:` using When the and ` backtick first the between text custom the adding and >< brackets angle with link `apis/-<docs/software/hardware text custom`:ref:` example For .< bracket angle first .*text custom* to renders `` `>ultrasonics software:Analog-sensors/ultrasonics ``

### Links External

note to thing important The hyperlinks. anonymous as links external format to preferred is It used, is underscore one only that situation the In text. the appending underscores **two** the is document. the compiling when arise may issues

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cool! pretty s'it and __`https://example.com>< link a is this` there, Hi
```

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```
cool! pretty s'it and _`link a is this` there, Hi

https://example.com link: a is this_ ..
```

## תמונות 40.2.10

.[illegible] 1 [illegible]

[illegible] .[illegible] 500-[illegible] ([illegible]) [illegible] .[illegible]

```
images/my-article/my-image.png ::image ..
image. the describing here text alt add Always :alt:
```

### קבצי תמונה

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[illegible] gif. [illegible] .jpg. [illegible] png. [illegible] .[illegible]

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.:alt: [illegible] ![illegible] :[illegible]

```
images/my-document/my-image.png ::image ..
image example An :alt:
```

---

### תמונות וקטוריות

Sphinx. [illegible] svg2pdfconverter [illegible] SVG [illegible]

.[illegible]

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500KB. [illegible] :[illegible]

---

```
images/my-document/my-image.svg ::image ..
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```

### Draw.io תרשימי

,drawio. [illegible]-[illegible] [illegible] svg [illegible] [illegible] [illegible] )diagrams.net [illegible] [illegible] [illegible]) Draw.io [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] svg-[illegible] [illegible] [illegible] .[illegible]

.[illegible] [illegible] [illegible] [illegible] ,[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

```
diagrams/my-document/diagram-1.drawio.svg ::image ..
image. the describing here text alt add Always :alt:
```

### Draw.io קבצי

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.*Draw.io* [illegible] [illegible] [illegible] [illegible] ,[illegible]-[illegible] [illegible] svg. -[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

> ,drawio.svg.-[illegible] [illegible] [illegible] diagrams [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] :[illegible] [illegible] ,[illegible] [illegible] [illegible]-[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] draw.io, [illegible] [illegible] [illegible] .[illegible] [illegible] [illegible] [illegible] [illegible]

## 40.2.11 סיומות הקבצים

:[illegible] [illegible] ,[illegible] .[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

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``png.``
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:[illegible]

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png.
png"."
"``png.``"
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## 40.2.12 תוכן עניינים

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source/index. at located file index root the to added be then can file index.rst category The .rst

### 40.2.13 דוגמאות

```
                                                  Title
                                                  =====
                         article example an is This

                                     java ::code-block ..

                         );"World Hello"(println.outSystem.

                                                Section
                                                -------
                                   section! a is This
```

### 40.2.14 הערה חשובה!

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## 40.3 הנחיות בנייה

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### 40.3.1 דרישות מקדימות

`clone  git` using by cloned is repository docsfrc- the that and installed is Git that Ensure
`.docs.git-https://github.com/wpilibsuite/frc`

#### IDE / Editors Text

reStructuredText the with along Code VS use you that recommend we development, For
work. will editor text any However, .extension

#### Windows

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required only are they HTML, building for required not are `convert-rsvg` and MikTeX  :□□□□
builds. PDF Windows for

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- 3.9 Python
- PDF) □□□□□□ □□□□□ □□ □□□□□) MiKTeX
- Perl
- convertrsvg-

Python. □□□□□□ □□□ **PATH to Python Add** □□□□□□ □□□ □□ □□□□ Path-□ □□□□ Python □□ □□□□

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:powershell□ □□□□ □□□□□□□ □□ □□□□ □□□ docsfrc- □□□□□□□□ □□□□□□□ □□□ MikTex □ □□□□□□ □□ □□□□ `packages.txt-require=@miktex-- verbose-- mpm`

### (Ubuntu) Linux

```
                                                update apt sudo $
                                     python3-pip python3 install apt sudo $
                               wheel setuptools pip U- install pip m- python3 $
                             source/requirements.txt r- install pip m- python3 $
 texlive- texlive-fonts-recommended texlive-latex-recommended y- install apt sudo $
texlive-fonts- texlive-xetex texlive-luatex texlive-lang-greek latexmk latex-extra ↪
                                               librsvg2-bin dvipng extra ↪
```

## 40.3.2 בנייה

docs.frc- □□□□□□□ □□□□□□□ Terminal □□ Powershell □□□□ □□□□

```
                                          USERPROFILE%\Documents"%" cd > PS
https://github.com/wpilibsuite/frc-docs.git clone git C:\Users\Example\Documents> PS
                                                     ...'frc-docs' into Cloning
                                              done. 217, objects: Enumerating remote:
                                        done. (217/217), 100% objects: Counting remote:
```

page) next on (continues

([illegible] [illegible] [illegible])

```
                         done. (196/196), 100% objects: Compressing remote:
      2370 pack-reused 21), (delta 68 reused 50), (delta 2587 Total remote:
         done. MiB/s, 20.32 | 42.68MiB (2587/2587), 100% objects: Receiving
                                   done/ (1138/1138), 100% deltas: Receiving
                                  frc-docs cd C:\Users\Example\Documents> PS
                                     C:\Users\Example\Documents\frc-docs> PS
```

### בדיקת Lint

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`lint make\.` :[illegible] ,[illegible]

### בדיקת קישורים

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`linkcheck make\.` [illegible] ,[illegible] [illegible]

### בדיקת גודל התמונות

**will** check This 500KB. below are images all that verify to `sizecheck make\.` run Please the to added are and basis case by case a on allowed are Exclusions fails. it if CI fail file. configuration the in list `IMAGE_SIZE_EXCLUSIONS`

### בדיקת הפניות

`redirects.txt` [illegible] 404)-[illegible] [illegible] [illegible]) [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
.``source``[illegible]

Run file. redirects the to files renamed/moved add automatically will writer redirect The `.rediraffewritediff make\.`

---

to it add not will writer redirect the changed, substantially and moved both is file a if :[illegible]
the `redirects.txt` file, and the `redirects.txt` file will need to be manually updated.

---

the fail **will** This files. all for redirects valid are there that sure makes checker redirect The are files all verify to `rediraffecheckdiff make\.` run check, To pass. not does it if buildbot redirect files all that ensure to ran be to need may build HTML an Additionally, redirected. properly.

#### HTML בניית

-□ □□□□□□ `build/html` □□□□□□□ □□□□□□ HTML. □□□□□ □□□□□□ □□□□ `html make\.` □□□□□□□ □□ □□□□□□ Repository.

### PDF בניית 40.3.3

> □□□□□□: SVG for images distorted in result may Windows on build PDF that note Please content. This is due to a lack of binlibrsvg2- support on Windows.

the in located is PDF The content. PDF generate to `latexpdf make\.` command the Type `build/latex` directory at the root of the repository.

### EPUB בניית 40.3.4

the in located is EPUB The content. EPUB generate to `epub make\.` command the Type `build/epub` directory at the root of the repository.

### libraries PartyThird- Python Adding 40.3.5

□□□□□: be must `requirements.txt` way, any in dependencies docsfrc- modifying After `source/ output-- requirements.txt f- export poetry` running by regenerated `requirements.txt hashes-without--` repo. the of root the from

reproducible. are builds sure make to dependencies its manage to Poetry uses docsfrc-

□□□□□: poetry □□ □□□□□□ □□□□ □□□□□□ □□□□□□□ □□□□□□ docs.frc- □□□□ □□□□□ □□ □□□□□□□ □□□□□□□.

#### Poetry התקנת

.`poetry install pip` command: following the Run installed. is Poetry that Ensure

#### הוספת תלות

Make .`pyproject.toml` of section `[tool.poetry.dependencies]` the to dependency the Add `lock poetry` command: following the run Then, version. exact an specify to sure .`update-no--`

### Dependency LevelTop- a Updating

`pyproject.` of section `[tool.poetry.dependencies]` the in version dependency’s the Update `.toml` ,Then run the following command: `.update-no-- lock poetry`

### עדכון תלות נסתרת

`.lock poetry` command: following the Run

## 40.4 הנחיות שמירת Draw.io

> **:□□□□□□** Make sure you don’t modify any file that is in a `diagrams` folder, or ends in `.` `drawio.svg` in any program other than draw.io; otherwise you might risk breaking the metadata of the file, making it uneditable.

XML □□□□□□ □□□□-□□□ □□□□□□□□ ,`svg` □□□□ □□□□□□□□ □□□□ )diagrams.net □□□ □□ □□□□) Draw.io □□ □□□□□□ □□□□□□□□ □□□□□□ □□ □□□ )`.drawio.`-□ □□□ □□□□□ □□□□□□□) draw.io □□ □□□□□□ □□□□□ □□□□□ .□□□□□ `svg` □□□□□□ □□□□□□ □□□□□□ □□□□ ,□□□□□□□ □□□□□□ □□□□□□□□□□ □□ □□□□□□ □□□□□

export the using but metadata, embedded the with diagram a save to methods few a are There they otherwise diagram; the in images any embed to us allows it because preferred is menu docs. the on properly render not might

.diagrams.net □□□□□□□ □□□□□□□□□□ □□□□□ □□ □□□□ draw.io □□ desktop-□ □□□□□ □□ □□ □□□□ □□ □□□□

□□□□□□ `diagram my of copy a Include`-□ □□□□□ `.SVG... - as Export - File` □□ □□□□□ ,□□□□□□□ □□□□□□ □□□□□□□ □□□□□□□ □□□□□□ □□ □□□□□□ `Images Embed` □□□□ ,□□□□□□□ □□ □□□□□-□□□□□ □□ □□□□□□□ □□□□ □□□□□ □□□□□□ □□□□□□ □□□□ `Background Transparent` □□□□□□□□ □□ □□□□□ ,□□□□□□ .□□□□□□□□ □□□□□□□□□ .□□□□□□

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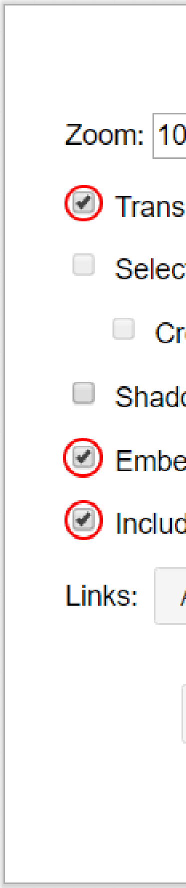

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## 40.5 תרגומים

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## 40.5.1 זרימת עבודה

docs.frc- [illegible]

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2. team. WPILib the with communication of means direct a is This !discussions GitHub Join fashion. streamlined and fast a in questions us ask to this use can You
3. [illegible] docs.frc- [illegible]
4. ![illegible]

## 40.5.2 קישורים

the replace can you link, a translate To syntax. original their in preserved be must Links appropriate the with title) English the with replaced be will (this text ME TRANSLATE translation.

:[illegible]

```
␣FRC the Wiring`:doc: the see please instructions/diagrams, wiring complete For
.`document> System Control FRC the Wiring< Document System Control ↪
```

.[illegible] Document System Control FRC the Wiring [illegible]

```
TEXT TRANSLATED`:doc: the see please instructions/diagrams, wiring complete For
.`document> System Control FRC the <Wiring ↪
```

:[illegible]

```
docs/< TEXT TRANSLATED`:ref: the see please instructions/diagrams, wiring complete For
`Robot> FRC an Wire to zero-to-robot/step-1/how-to-wire-a-simple-robot:How ↪
```

## 40.5.3 פרסום התרגומים

.[illegible] Transifex-[illegible]

## 40.5.4 דיוק

[illegible] ,[illegible] .[illegible] .[illegible] .docsfrc- [illegible] Repository-[illegible] Issue [illegible] PR

## 40.6 מתרגמים מובילים

### 40.6.1 סינית

- Dhc 8192
- Zhang Atlus
- Gong Jiangshan
- Keseterg
- Zhao Michael
- Huang Ningxi
- Xin Ran
- 5308 Team
- Wu Tianrui
- Zhang Tianshuang
- Sun Xun
- Zhao Yitong
- Li Yuhao
- □ □□
- □ □□
- □ □□
- □ □□
- □ □□
- □ □□
- Sherry □

### 40.6.2 צרפתית

- Schneider Alexandra
- Theberge Andre
- Chang Andy
- Shalit Austin
- Smith Dalton
- Renaud Daniel
- Beaulac Étienne
- Giffard Félix
- Kenwell Kaitlyn
- Bedard Luna Laura

- Regimbald Martin
- Bekale Regis
- D.G.- Sami
- Lavoie Sidney
- Marcellus Youdlain

### 40.6.3 פורטוגזית

- Wilmsen Carolina Amanda
- Oliveira Bibiana
- Osio Bruno
- Toso Bruno
- Silveira Gabriel
- Ribeiro Amaral Do Tomaz Gabriela
- Steinmeier Günther
- Souza De Maciel Karana
- Carvalho Luca
- Francisco Fontes Lucas
- Gisse Grabin Eduarda Maria
- Chanan Timm Heitor Matheus
- Grabin Meg
- Dias Nadja
- Tristão Feijó Natan
- Santiago Nathany
- Pellicioli Dias Henrique Pedro
- Silva Almeida De Dias Tales
- Castro Vinícius

### 40.6.4 ספרדית

- Shalit Austin
- Ernesto Cesar
- Ramos Diana
- Rangel Lozano Diego
- Reveles Fernanda
- Soltero Fernando
- Verástegui Gibrán

- Sepúlveda Heber
- Gutierrez Heriberto
- Espino Hugo
- Eng Lian
- Luis_Hernández
- Adame León De Angel Miguel
- Gutiérrez Ariel Óscar
- Maynez Paulina
- Cote Pierre
- Lozano Ranferi
- Acosta Rodrigo
- Fernandez Sofia
- Moreno Zara

### 40.6.5 טורקית

- Bilgin Hasan
- Alkaya Müfit
- Özemre Esra
- Oktemer Ceren
- T Demet
- Tumkaya Demet
- Aldeniz Melis
- Serdaroğlu Lal
- Uslu Çağan
- Ünlü Duru
- Ünay Arhan
- Akdoğan Doruk
- Zagyapan Ada
- Alkaya_3390 Müfit
- Şengel Mayra
- Hatipoğlu Duru
- Yiğit Ece
- Akın Elif
- Özer Tuna
- Köşkeroğlu Serra Nesrin

### 40.6.6 עברית

- Radzin Aric
- Smith Dalton
- Ziv Itay
- Ashery Ofek
- Grossman Shai
- Starlight220
- Shlomi Yotam

[redacted]

. FRC® [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] WPILib. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] :[illegible]

.allwpilib Repository-[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

## Start Quick 41.1

using and publishing building, cloning, through you guide that instructions of list a is Below replacement a as intended not is start quick This project. robot a in binaries allwpilib local document. this in listed further is that information the for

- `https://github.com/wpilibsuite/allwpilib.` `clone git` with repository the Clone `git`
- you if `cache-build-- build gradlew/.` or `build gradlew/.` with repository the Build connection internet an have
- `publish gradlew/.` running by locally artifacts the Publish
- artifacts the use to `build.gradle` project's robot your Update

## ליבה Repository 41.2

## NetworkTables 41.3