
Competition Robotics FIRST

WPILib

אפר' 27, 2024

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Changelog

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API

documentation. class Python and C++, Java,

Java

C++

Python

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.Tool Imaging roboRIO Dashboards, Station, Driver FRC articles View

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Reference Quick Light Status

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1.1 חדשים בתכנות?

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LabVIEW Learn NI •

Python 1.1.4

Python learn to guides various of List •

מאפס לרובוט 1.2

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התוכן המופיע כאן הוא חלק מהפרויקט של ה-FRC, המיועד להעברת הידע והמיומנות של הקבוצה אל הקהילה.

Wiring Robot FRC to Introduction 2.1

התוכן המופיע כאן הוא חלק מהפרויקט של ה-FRC, המיועד להעברת הידע והמיומנות של הקבוצה אל הקהילה. This document details the basic wiring of the board electronics for the kitbot or to allow basic drivetrain testing.

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

סקירה כללית 2.1.1

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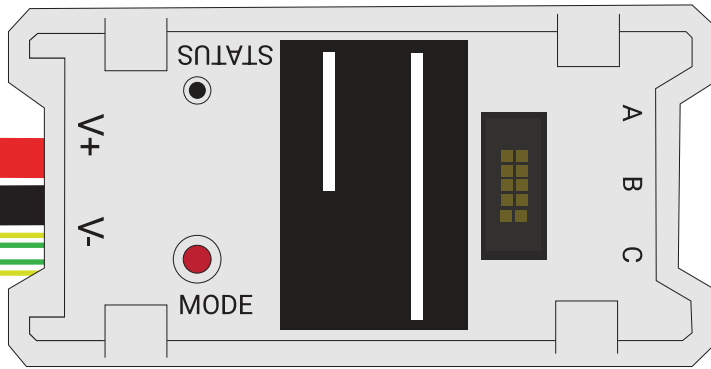
CTR

Materials Gather 2.1.2

Locate the following control system components and tools

Materials: Kit •

- *PDP* (Panel Distribution Power / *PDH* (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

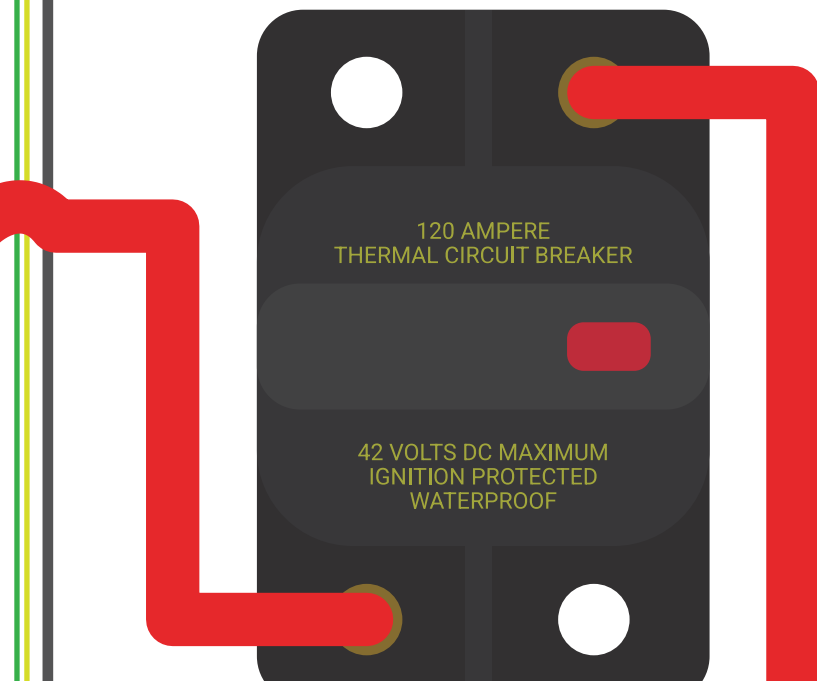


Spark MAX

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



Voltage
Regulator
Module
(VRM)

Radio

POE Injector

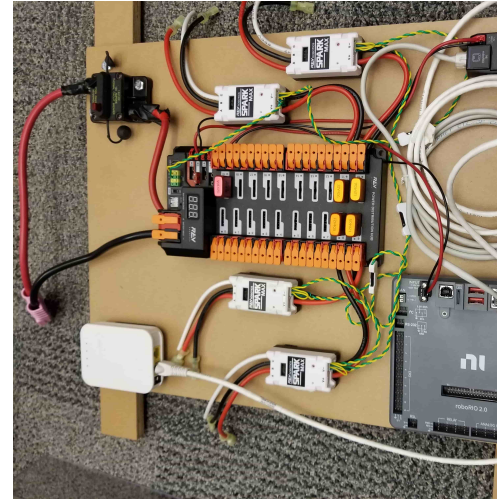
)*RSL*(*Light Signal Robot* -
controllers motor other or MAX SPARK 4x -
cables- *PWM* 2x -
breaker Circuit 120A -
breaker Circuit 40A 4x -
wire Red) mm^2 (16 AWG 6 -
wire Red/Black) mm^2 (6 AWG 10 -
wire Red/Black) mm^2 (1 AWG 18 -
cable *CAN* twisted Yellow/Green) mm^2 (0.5 AWG 22 -
ring (16x terminals 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

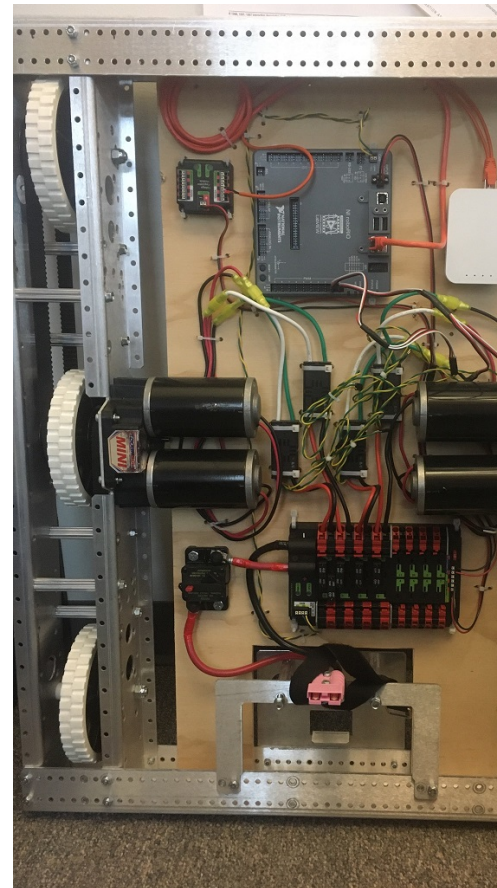
approximately plastic) or (wood material mm) 12(6- 1/2" or 1/4" of piece cut board, test a For
supporting the see board control Build Quick Robot a For cm). 40 x (60 16" x 24"
configuration. chassis chosen the for board size proper the for documentation

Components System Control Core the Layout 2.1.4

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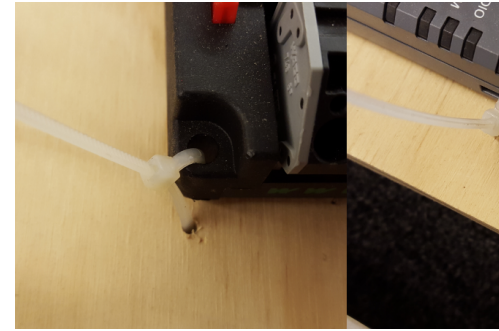


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above. image the in shown is layout example An board. the on components the out Lay

Components Fasten 2.1.5



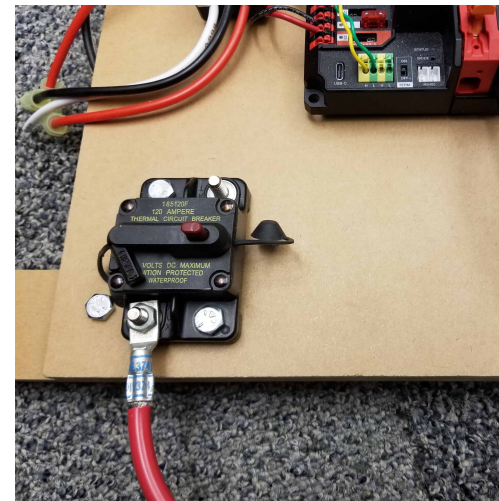
FRC many in that Note board. the to components all fasten hardware, or Lock Dual the Using up stand to unlikely is alone Lock Dual and substantial be may contact robotto-robot- games fasteners bolt and nut use to wish may Teams components. electronic many for fastener a as to devices secure to Lock Dual 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

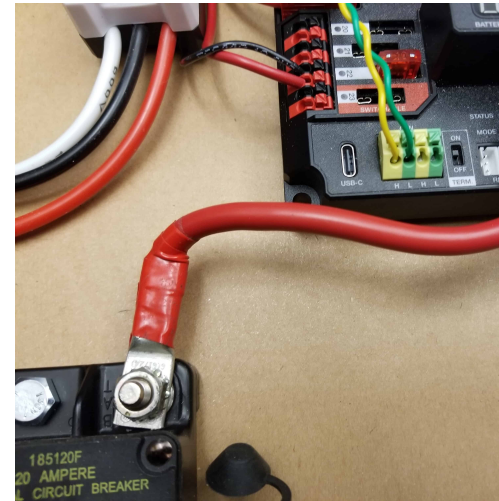
7/16" Allen, mm 5 Allen, 1/16" lugs, terminal)mm² (16 AWG 6 Connector, Battery Requires:
end Box mm) (11

connector. battery to lugs terminal Attach

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

Distribution Power to Breaker Wire 2.1.7

REV



(11 7/16" lugs, terminal)mm² (16 AWG 6 1x wire, red)mm² (16 AWG 6 Requires:
wrench mm)

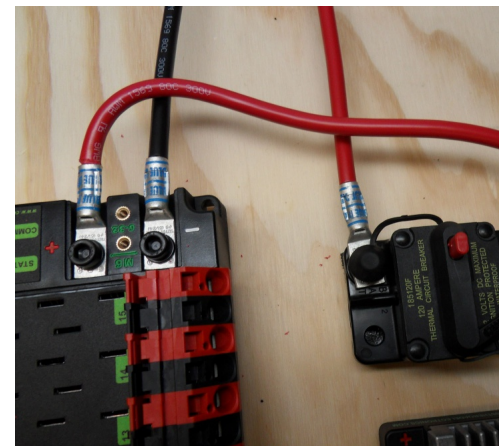
7/16" the Using wire. red)mm² (16 AWG 6 the of end the to lug terminal one Secure
and breaker main 120A the of side "AUX" the from nut the remove wrench, mm) (11
remove to wish may (you nut the secure Loosely stud. the over terminal the place
wire of length the out Measure wire). the of end other the strip and cut to shortly it
PDH. the of terminal positive the reach to required

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

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

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

CTR



(11 7/16" Allen, mm 5 lugs, terminal)mm² (16 AWG 6 2x wire, red)mm² (16 AWG 6 Requires:
end box mm)

(11 7/16" the Using wire. red)mm² (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.)mm² (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 2.
breaker.

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

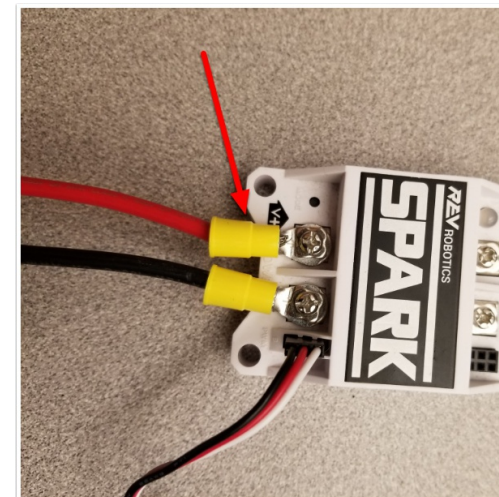
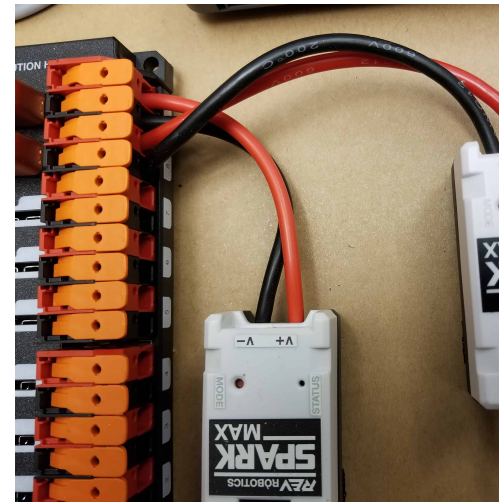


tape Electrical Allen, 1/16" Requires:

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



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 12 or 10 ,

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

Wago the of one from reach to length appropriate to wire black and red Cut 1.
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 length the

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.

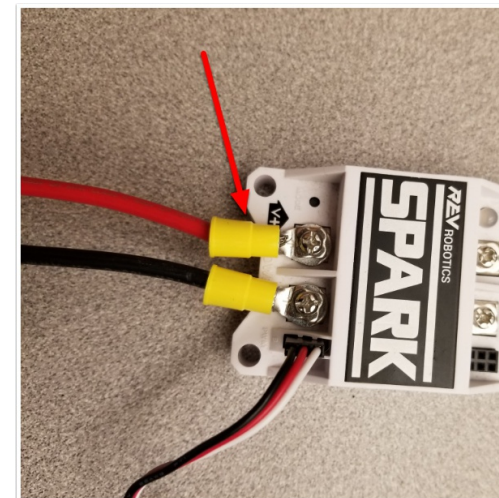
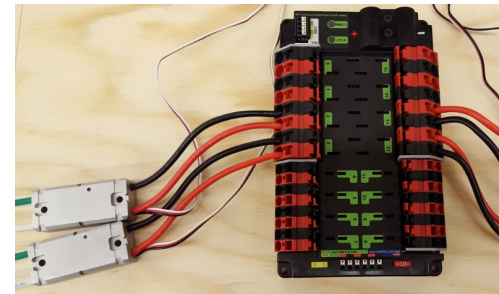
to black +, to (red terminals input controller motor the to terminal the Attach 4.
)-

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 connector. Wago the into inserting before twisted) not ideally (and



(4 AWG 12 or 10 only: Controllers Terminal Screwdriver, Flat Small Stripper, Wire Requires: crimp 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

Wago (larger) 40A the of one from reach to length appropriate to wire black and red Cut 1. 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

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.

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

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1. Requires: 1 AWG 18 screwdriver, flat small very stripper, Wire fuse, mini 10A Black and Red

2. Insert the 10A fuse into the PDH channel of the switchable non-fused channels. (20-22).

3. Strip (~8 ~5/16") the black and red wires (1 AWG 18) and connect them to the terminals corresponding to the installed fuse.

4. Measure the length required for the wires to reach the roboRIO. Leave enough length for cable management. Do not strain the wires or the battery.

5. Cut the strip wire.

6. Using a flat small screwdriver, connect the wires to the roboRIO. Connect the black wire to the negative terminal and the red wire to the positive terminal. Securely screw down the connector.

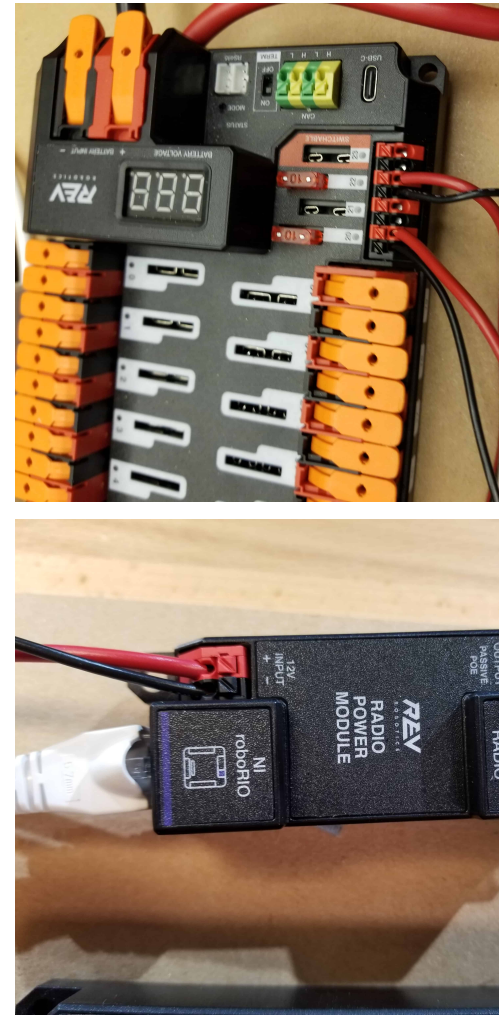
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- 1mm^2 (1 AWG 18 screwdriver, flat small very stripper, Wire fuses, mini 10A/20A Requires: Black and Red
- screen silk the on shown locations the in PDP the in fuses mini 20A and 10A the Insert 1.
above) image the in (and
- to connect and wire 1mm^2 (1 AWG 18 black and red the both on mm) ($\sim 8 \sim 5/16$ " 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



and red)mm² (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:
wire: black

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

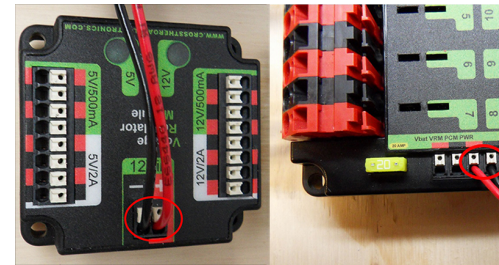
wire)mm² (1 AWG 18 black and red the of end the on mm) (~8 ~5/16" Strip 2.
PDH. the on terminals corresponding the to wire the connect and

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

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)mm² (1 AWG 18 (optional), screwdriver flat small stripper, Wire Requires:

1. wire.)mm² (1 AWG 18 black and red the of end the on mm) (~8 ~5/16" Strip
2. the on PWR" PCM VRM "Vbat labeled pairs terminal two the of one to wire the Connect PDP.
3. to care Take VRM. the on terminals "12Vin" the reach to required length the Measure 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
4. wire. the of end the from mm) (~8 ~5/16" strip and Cut
5. terminals. 12Vin VRM the to wire the Connect

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



VRM. the of section 12V/2A the on terminals

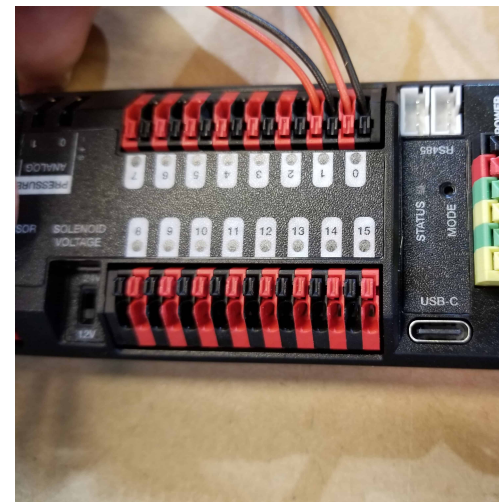
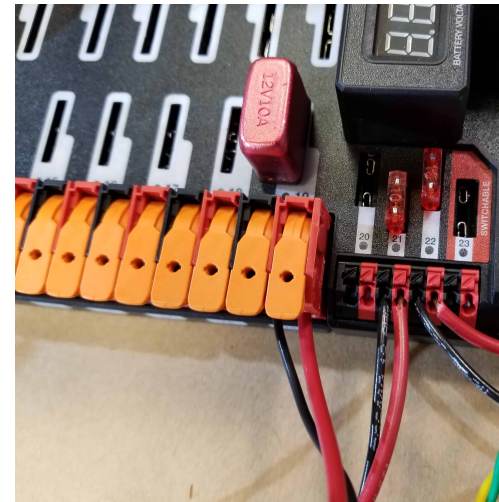
POE) 24v18- (labeled connector barrel the to closest

1. Insert the ferrules of the passive PoE cable into the corresponding colored terminals

2. Connect the Ethernet RJ45 plug (end of the cable) into the Ethernet port on the radio

(Optional) Power Pneumatics 2.1.13

REV



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

the on pneumatics controlling for used component optional an is Hub Pneumatics The :□□□□ robot.

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.

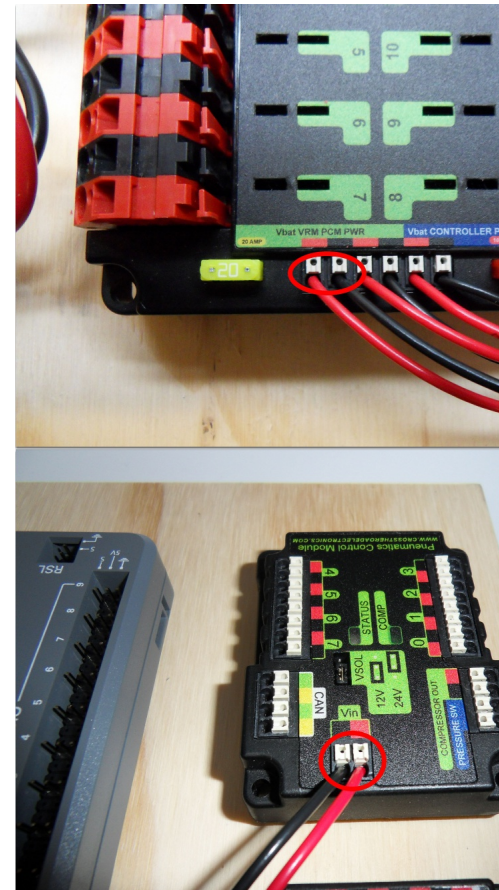
above described ways two the of one in PDH the to wire the Connect 2.

labeled PH the of end short the on terminals red the reach to required length the Measure 3. 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

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:

robot. the on pneumatics controlling for used component optional an is PCM The :□□□□

1. wire.) mm^2 (1 AWG 18 black and red the of end the on mm) (~8 ~5/16" Strip
2. the on PWR" PCM VRM "Vbat labeled pairs terminal two the of one to wire the Connect PDP.
3. leave to care Take PCM. the on terminals "Vin" the reach to required length the Measure and battery the as such components other any around wires the route to length enough management. cable or relief strain any for allow to
4. wire. the of end the from mm) (~8 ~5/16" strip and Cut
5. terminals. 12Vin PCM the to wire the Connect

Cables Ethernet 2.1.14

REV



cables Ethernet 2x Requires:

1. Connect an Ethernet cable from the RJ45 socket of the roborIO to the port.
2. Connect an Ethernet cable from the RJ45 socket of the radio to the closest barrel connector (labeled 24v18- POE) to the WiFi Radio on the RPM.

CTR



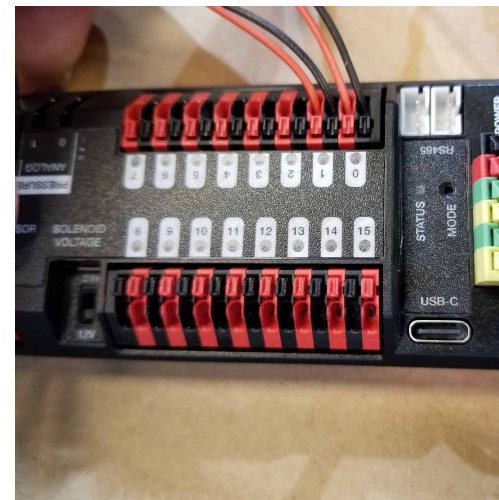
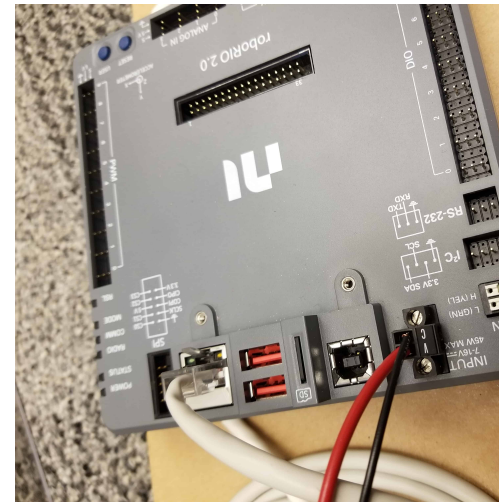
cable Ethernet Requires:

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

CAN מכשירי 2.1.15

CAN Pneumatics to roboRIO

REV

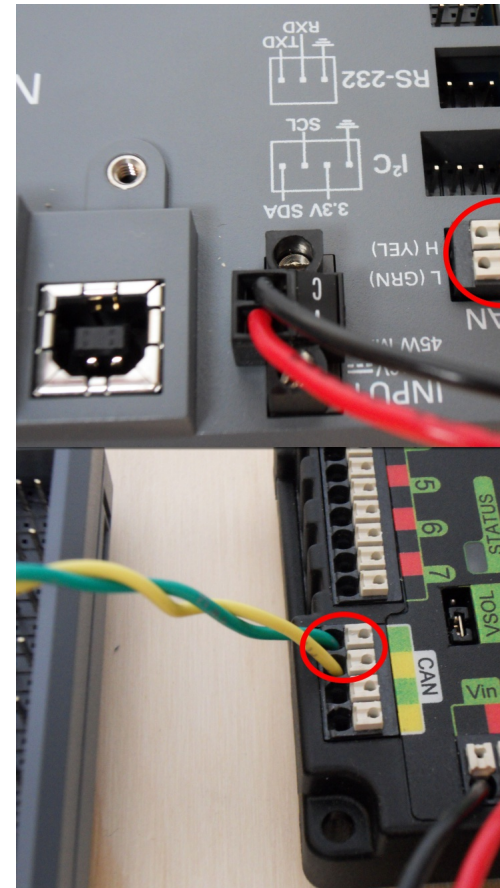


cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

you If robot. the on pneumatics controlling for used component optional an is PH The : step) this in (shown roboRIO the from directly connection CAN the wire PH, the using not are step). next the in (shown PDH the to

- 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



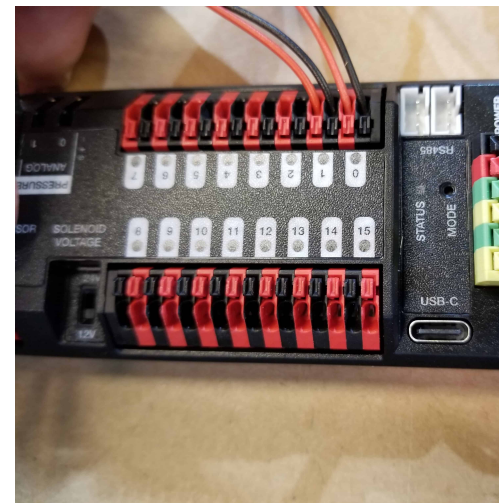
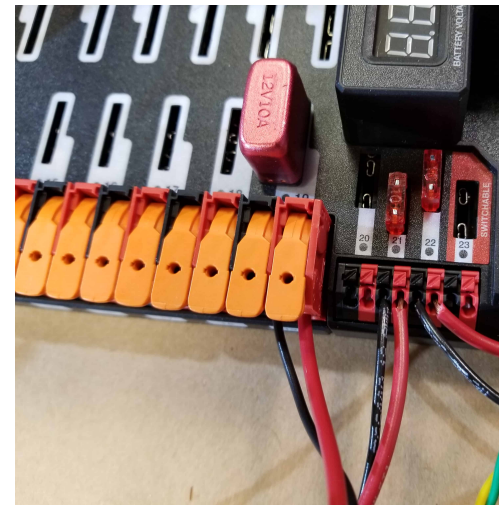
cable CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:

If robot. the on pneumatics controlling for used component optional an is PCM The :□□□□ in (shown roboRIO the from directly connection CAN the wire PCM, the using not are you step). next the in (shown PDP the to step) this

1. wires. CAN the of each of off mm) (~8 ~5/16" Strip
2. >YEL,(Yellow- roboRIO the on terminals CAN appropriate the into wires the Insert >GRN).Green-
3. two the of (either PCM 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 PCM. the on terminals CAN coded color appropriate the into wires the Insert out. or in defined no is there PCM, the on pairs terminal Yellow/Green the of either use

CAN PD to Pneumatics

REV



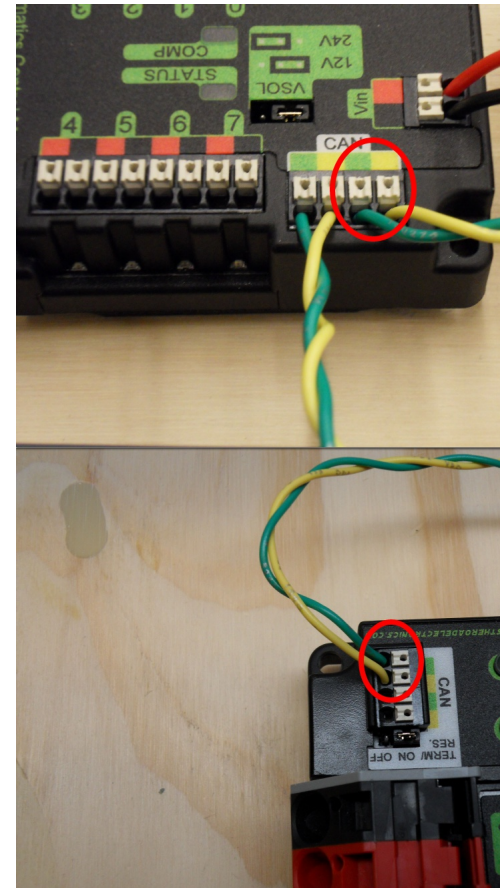
CAN twisted yellow/green (optional), screwdriver flat small stripper, Wire Requires:
cable

the on pneumatics controlling for used component optional an is PH The :□□□□
the from directly connection CAN the wire PH, the using not are you If robot.
step). this in (shown PDH the to step) above the in (shown roboRIO

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

somewhere bus CAN the terminate to need you if *Basics Wiring CAN* the See :□□□□
PDP. the than other

CTR



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

If robot. the on pneumatics controlling for used component optional an is PCM The :□□□□
the in (shown roboRIO the from directly connection CAN the wire PCM, the using not are you
step). this in (shown PDP the to step) above

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

other somewhere bus CAN the terminate to need you if *Basics Wiring CAN* the See :□□□□

Wires Signal Controller Motor 2.1.16

PWM



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

a with adapter (small MAX SPARK the to adapter PWM the attach MAX, SPARK using If 1. wires). black/white with connector pin 3

controller the On adapter. or controller the to cables extension PWM attach needed, If 2. wiring, green/yellow have may controllers (some markings or colors the match side, black). to connect should green

outside the towards wire black the with roboRIO the to cable the of end other the Attach 3. 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

a with adapter (small MAX SPARK the to adapter PWM the attach MAX, SPARK using If 1. wires). black/white with connector pin 3

PWM the and adapter or controller the between cables extension PWM attach needed, If 2. have may controllers (some markings or colors the match side, controller the On cable.Y- black). to connect should green wiring, green/yellow

side each controlling controllers the for cables PWM 2 the to cableY- PWM 1 Connect 3. PWM the on wire black the match should cableY- the on wire brown The robot. the of cable.

be should wire brown The roboRIO. the on ports PWM the to cablesY- PWM the Connect 4. 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

1. wires both strip and cable pin 2 the of off end one Cut
2. terminal. the tighten and terminal "N" center, the into wire black the Insert
3. the tighten and terminal "La" the into insert and wire red) mm^2 (1 AWG 18 the Strip terminal.
4. terminal "Lb" the into insert to wire) mm^2 (1 AWG 18 the of end other the strip and Cut
5. (1 AWG 18 the with terminal "Lb" the into cable pin two the from wire red the Insert terminal. the tighten and wire red) mm^2
6. should wire black The roboRIO. the on port RSL the to connector pintwo- the Connect 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

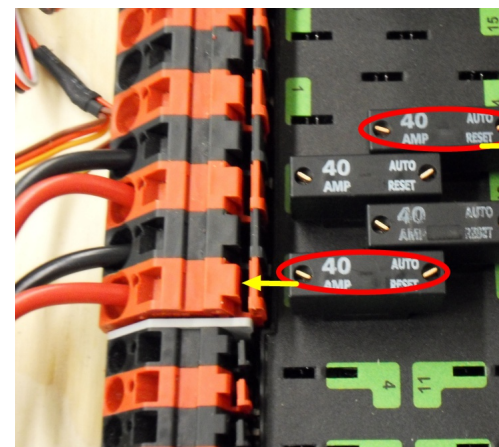
REV



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

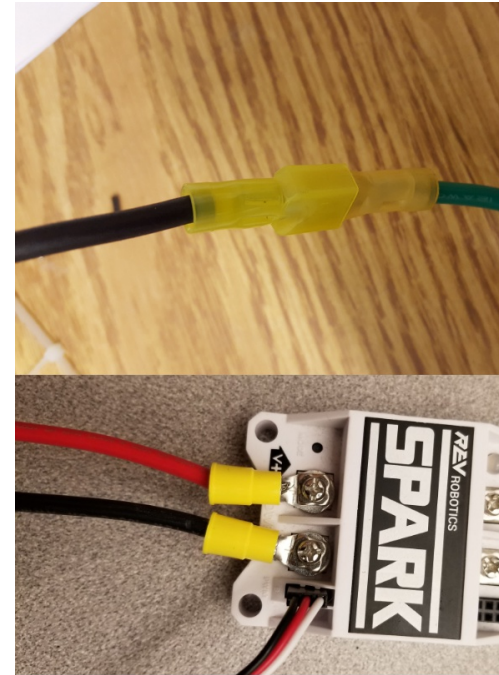


breakers circuit 40A 4x Requires:

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

SPARK (the controller the from wires) green and white (or wires black and red the Strip 1.
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

with controllers (for wires output controller matching the to wires motor the Connect 2.
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

התקנת התוכנה להפעלה offline.

3.1 הכנת להתקנה Offline

התקנת התוכנה להפעלה offline מתבצעת באמצעות התקנת התוכנה להפעלה offline.

התקנת התוכנה להפעלה offline מתבצעת באמצעות התקנת התוכנה להפעלה offline.

התקנת התוכנה להפעלה offline מתבצעת באמצעות התקנת התוכנה להפעלה offline.

3.1.1 תיעוד

התקנת התוכנה להפעלה offline מתבצעת באמצעות התקנת התוכנה להפעלה offline.

3.1.2 מתקנים (Installers)

כל הקבוצות

Installers“) Offline “Individual for link on Click (Note: Tools Game FRC 2024 •
Israel Utility Configuration Radio FRC 2024 or Utility Configuration Radio FRC 2024 •
Version

קבוצות LabVIEW

Installers”) Offline ”Individual for link on Click (Note: [Installer Base LabVIEW](#) •

קבוצות Java או C++

[Installer WPILib Java/C++](#) •

page. the of middle the in section download the to scroll page, releases GitHub the on Once

WPILib 2024.1.1 Release Draft

This is the kickoff release of WPILib for the 2024 season.

The documentation for WPILib is located at <https://docs.wpilib.org/> (if you have trouble accessing <https://frcdocs.wpi.edu/en/stable/> is an alternate location with the same content).

If you're new to FRC, start with [Getting Started](#).

System Requirements: WPILib requires 64-bit Windows 10 or 11, Ubuntu 22.04, or macOS 12. Note that Visual Studio 2022 is required for desktop builds. Mac users will need to have the JDK installed before running the installer. This can be done by running `xcode-select --install`.

If you're returning from a previous season, check out [what's new for 2024](#). You will need a new IDE to install WPILib is available via the [FRC 2024 Game Tools](#). Follow the [WPILib installation guide](#) to install WPILib.

If you're starting from a 2023 robot project, you will need to [import your project](#) to create a new project. This process is important, as it will make a few automated corrections for some breaking changes. It is also necessary to import vendor libraries again, since last year's vendor libraries must be updated for this year's projects.

A complete list of known issues with this release can be found [here](#).

WPILib is [developed by a small team of volunteers and the FIRST community](#).

Downloads

For 2024, we have changed the location for WPILib downloads due to GitHub file size limitations. To download the installer package for your platform.

- [WPILib 2024.1.1 - Windows](#) (2.0 GB)
- [WPILib 2024.1.1 - Mac \(Arm\)](#) (2.1 GB)
- [WPILib 2024.1.1 - Mac \(Intel\)](#) (2.2 GB)
- [WPILib 2024.1.1 - Linux](#) (2.3 GB)

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

התהליך להתקנת WPILib, Java/C++ (installer) מתבצע באמצעות קובץ ההתקנה. יש להוריד את הקובץ מתוך אתר ה-FIRST Robotics Competition. לאחר ההורדה, יש להפעיל את הקובץ ולהתאים את ההתקנה לסביבת ה-Code VS שלכם. יש להשתמש בקובץ ה-`install offline for computers/OSes` כדי להתקין את WPILib ללא אינטרנט. *other with share to zip Code VS Create* *User this for Install* *install offline for computers/OSes*.

3.1.3 ספריות ותוכנות של צד שלישי

יש להודיע על שינויים בתוכנות וספריות של צד שלישי. יש להודיע על שינויים בתוכנות וספריות של צד שלישי.

3.2 התקנת LabVIEW עבור FRC (בלבד)

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

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

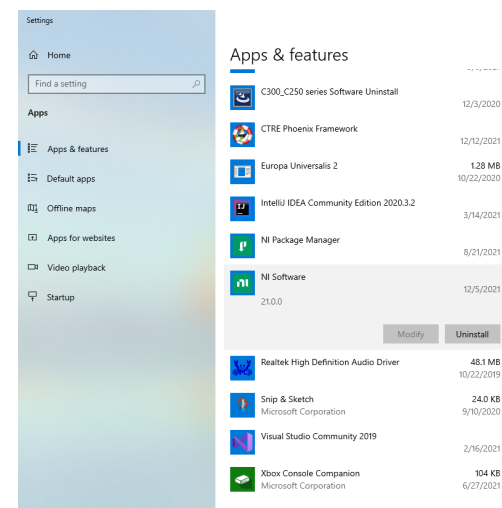
3.2.1 דרישות

11) 10, (Windows higher or 10 Windows •

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

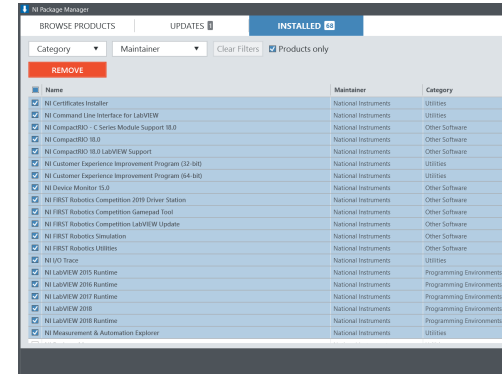
versions. old any remove to recommended is it LabVIEW of version new the installing Before
 with done been has testing all but version, old the with existco- likely will version new The
 Data" "User\LabVIEW the in located code team any up back to sure Make only. 2024 FRC
 the Locate Programs. Remove or Add >> Start click Then installing.un- before directory
 Uninstall. select and Software", "NI labeled entry



בחרו רכיבים להסרה

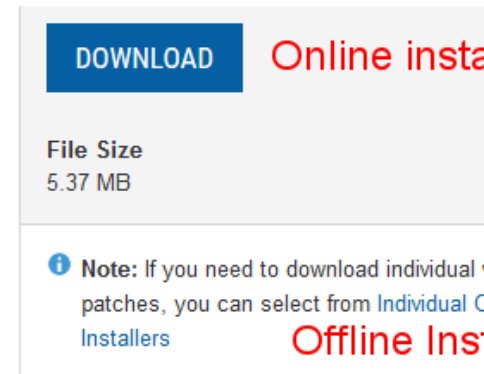
selectde- to is this do to way easiest The entries. all select appears, that box dialog the In Remove. Click "Name". of left the to boxcheck- the select and boxcheck- Only" "Products the prompted. if reboot and complete to uninstaller the for Wait

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



installer LabVIEW Getting 3.2.3

version correct the select to sure Be NI. from installer 2024 FRC for LabVIEW the Download down.drop- the from



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

connection internet fast a use to recommended is It (~10GB). download large a is This :□□□□ interrupted. if resume to download the allow to Downloader NI the use to and

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

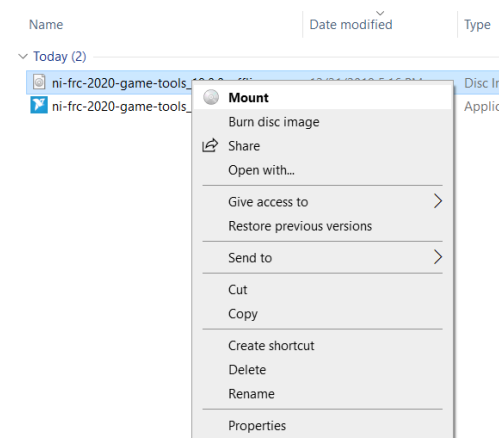
Installer Online

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

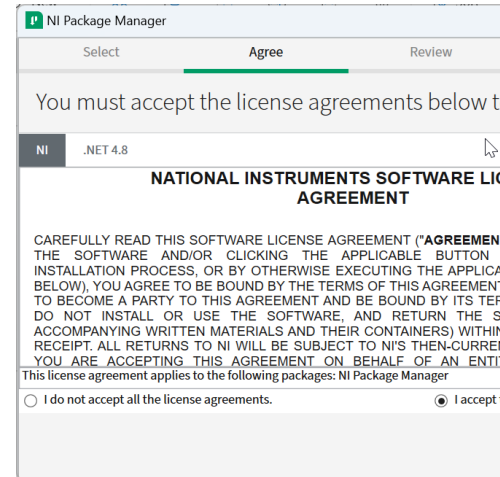
(+10 (Windows Installer Offline

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-

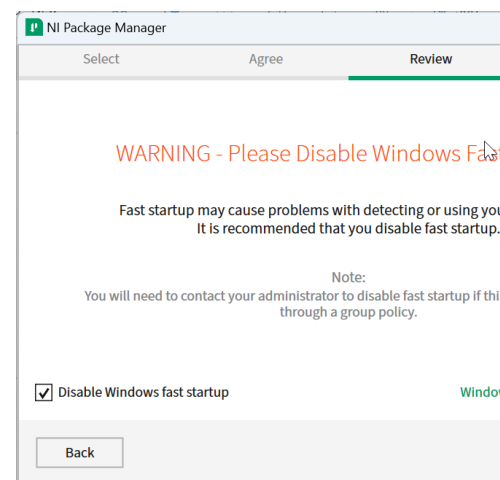


רישיון NI Manager Package



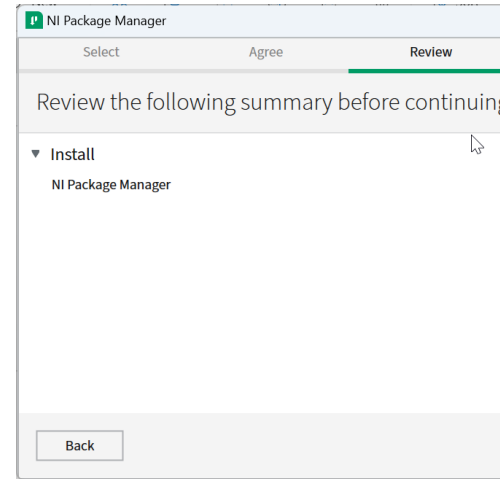
Next click screen, this see you If

ביטול ההפעלה המהירה של Windows



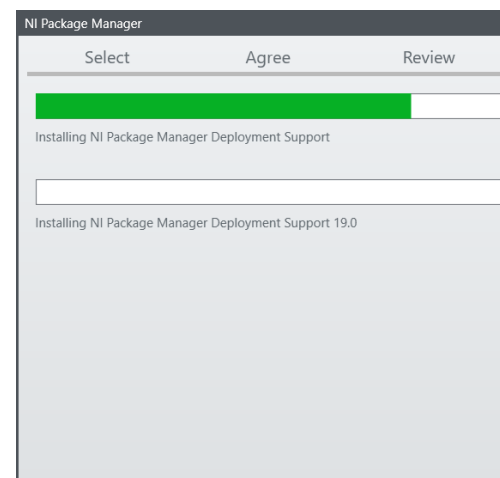
Next click screen, this see you If

סקירת NI Package Manager



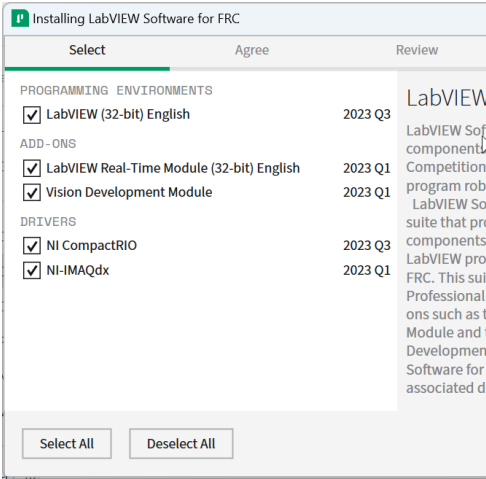
Next click screen, this see you If

התקנת NI Package Manager



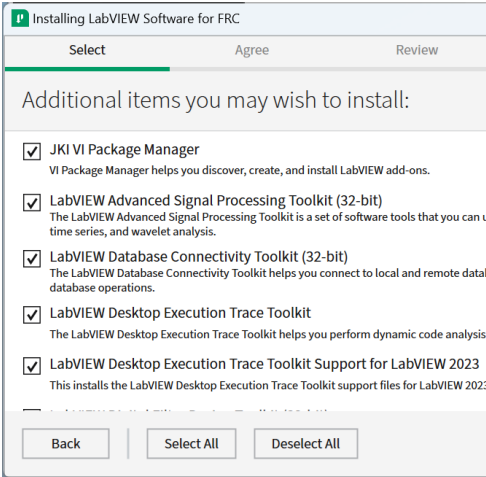
Installation progress of NI Package Manager will be tracked in this window

List Product



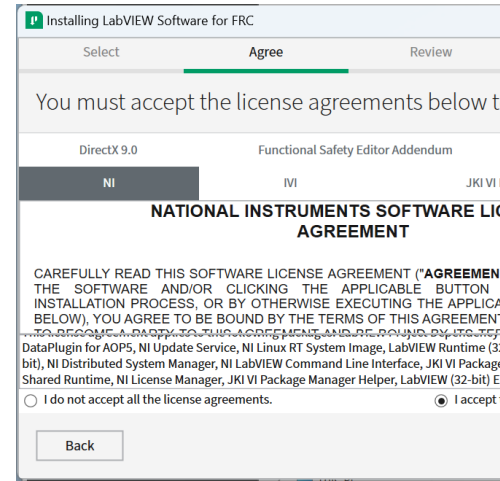
Next Click

Packages Additional



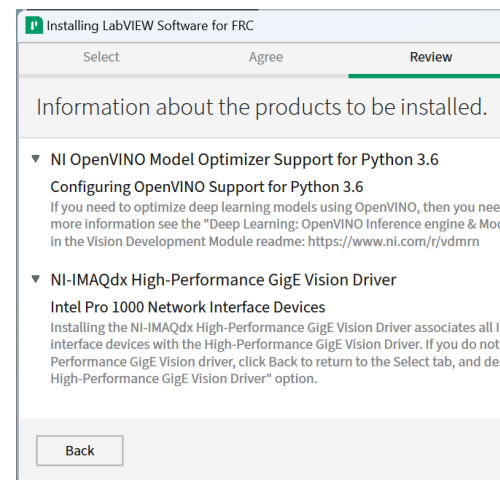
Next Click

agreements License



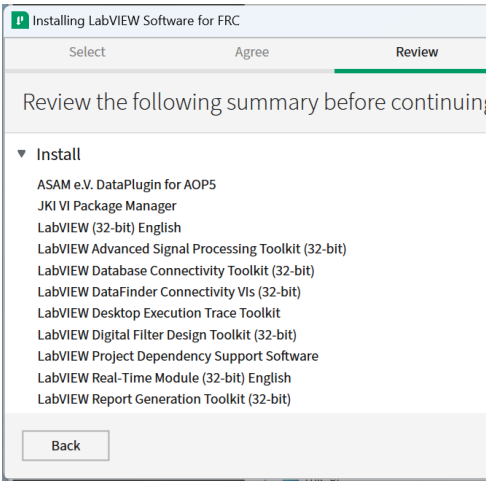
Next Click then accept... "I Check

Information Product



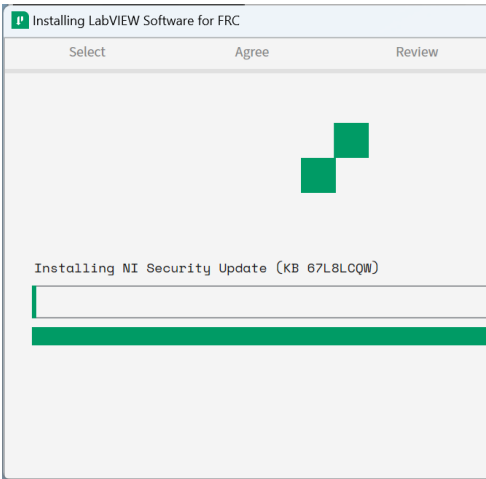
Next Click

Installation Start



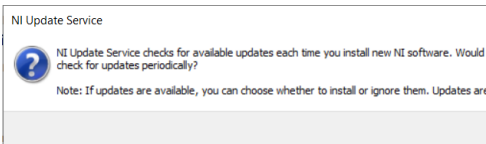
Next Click

Progress Overall



window this in tracked be will progress installation Overall

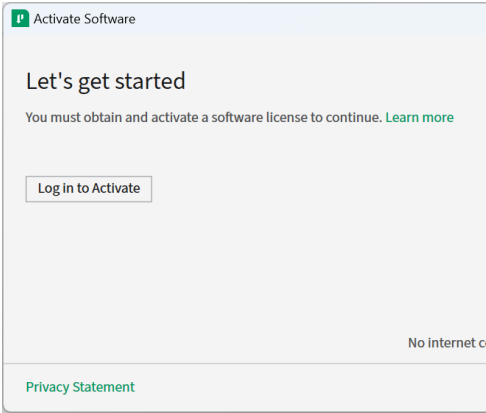
Service Update NI 3.2.5



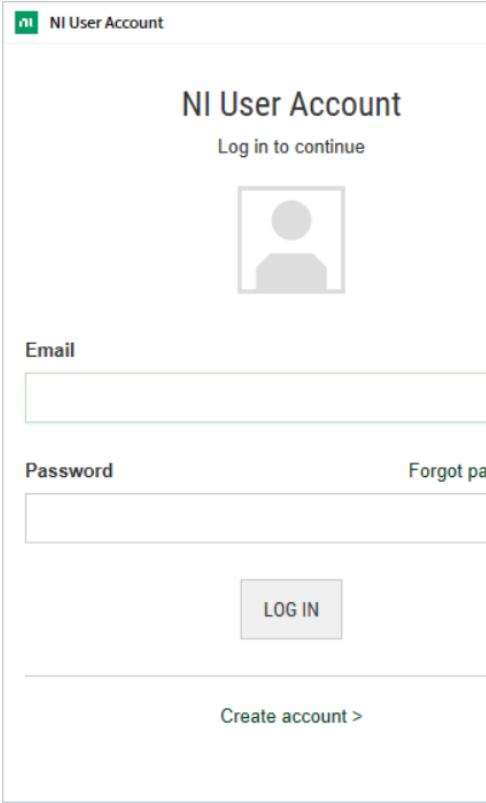
enable not to choose can You service. update NI the enable to whether prompted be will You service. update the

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

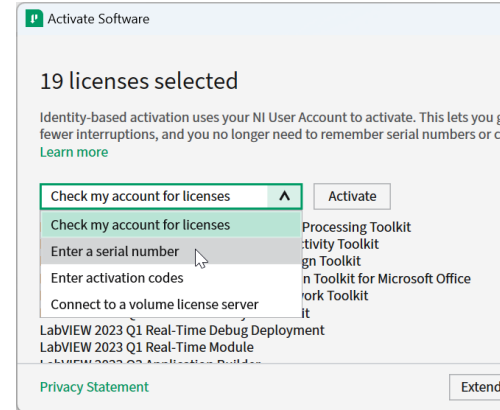
Wizard Activation NI



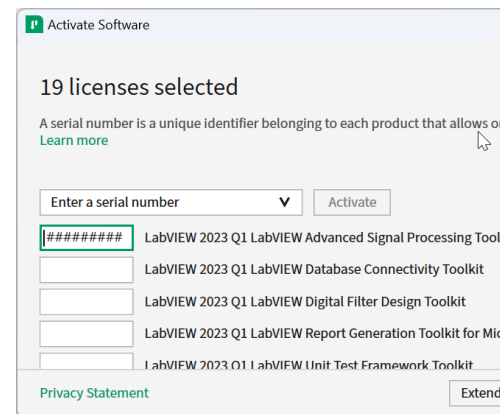
button. *Activate to in Log* the Click



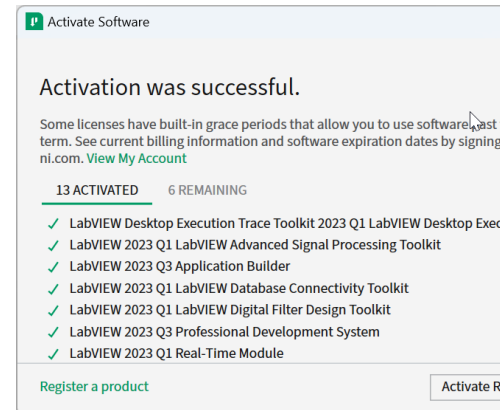
create to *account Create* select account, an have don't you If account. ni.com your into Log
account. free a



number serial a enter select down,drop- the From

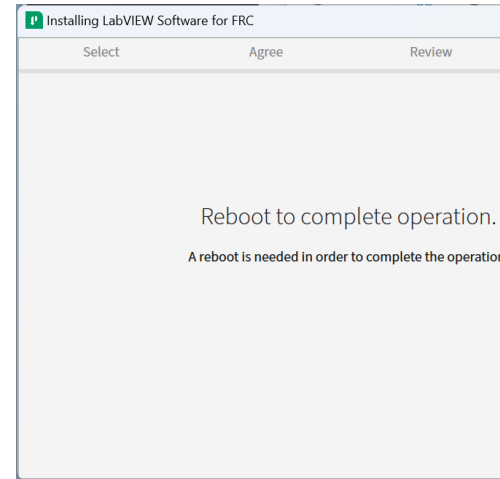


.Activate Click boxes. the all in number serial the Enter



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

3.3 התקנת ה-Tools Game FRC

התקנת ה-Tools Game FRC®:

• LabVIEW

• Station Driver FRC

• Images and Tool Imaging roboRIO FRC

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

התקנת ה-Tools Game FRC: No components from the LabVIEW Software for FRC package are required for running either the Station Driver or Tool Imaging.

3.3.1 דרישות

• Windows 10 or higher (Windows 11).

• Download the Tools Game FRC from NI.

[DOWNLOAD](#)

[Online install](#)

File Size

5.37 MB

Note: If you need to download individual patches, you can select from [Individual C](#)

[Installers](#)

[Offline Ins](#)

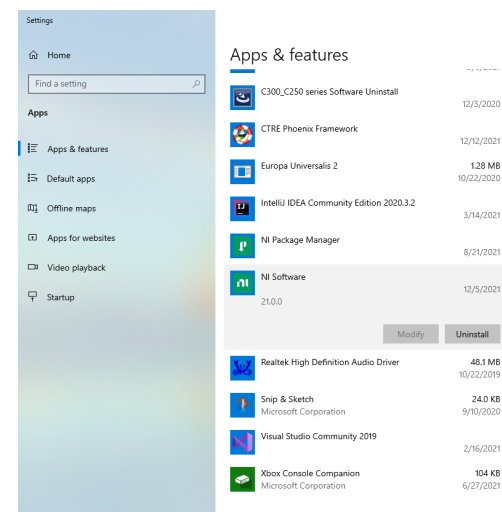
התקנת *Installers Offline Individual* היא פשוטה, והתהליך מתבצע באופן אוטומטי. לאחר מכן, עליך ללחוץ על *Download* כדי להוריד את התוכנית.

3.3.2 הסרת גרסאות ישנות (מומלץ)

לפני שתתקין את LabVIEW 2024, עליך להסיר את הגרסאות הקודמות. להלן הדרכה כיצד לעשות זאת:

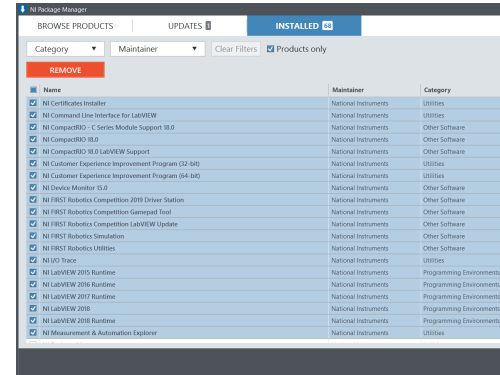
Before installing the new version of FRC Game Tools, remove the old versions. The old versions will be overwritten. Start by clicking on the "Programs and Features" link in the Windows Settings app. Then, click on "Uninstall or change these programs".

It is necessary to uninstall previous versions of the tools before installing the new version. For example, if you have the 2021 version installed, you must uninstall it before installing the 2022 version. This applies to all versions of the tools.



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



3.3.3 התקנה

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.

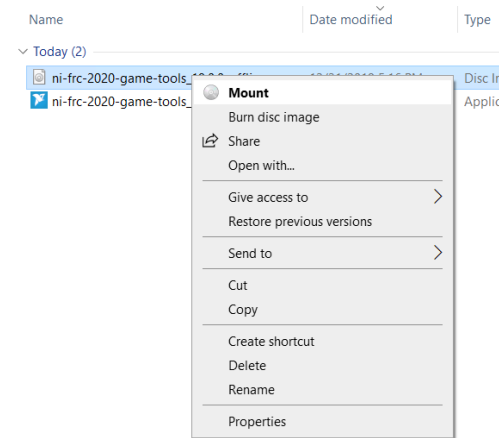
חילוץ

מצב מקוון

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

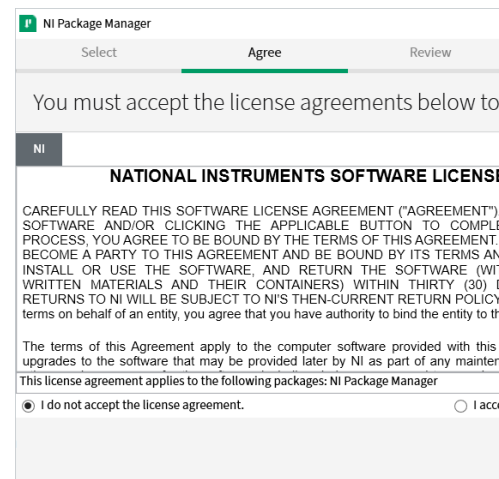
(+10 (Windows Offline

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.



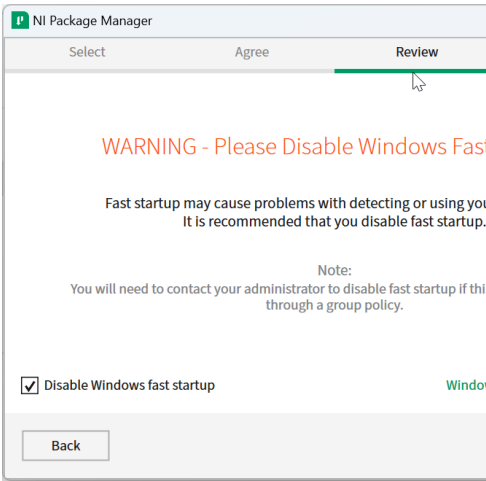
not may option *mount* the and files iso with associate may programs installed Other :
install then file, iso the extract or mount to option the give not does software that If appear.
iso. the extract to that use and Zip7-

רישיון NI Manager Package



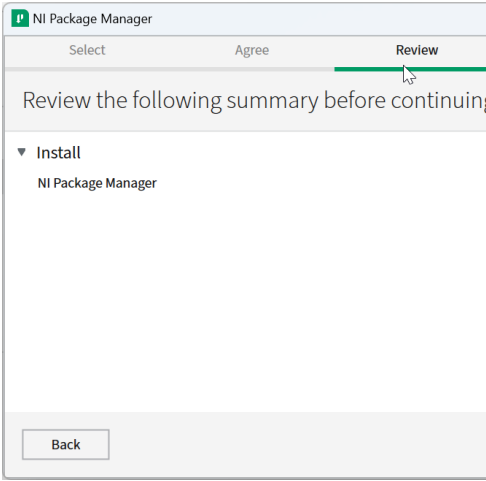
Package NI 00 00000000 000000 000000 0000 0000 00 0000 .*Next* 00 0000 ,00 0000 000000 0000 000000
Manager.

ביטול ההפעלה המהירה של Windows



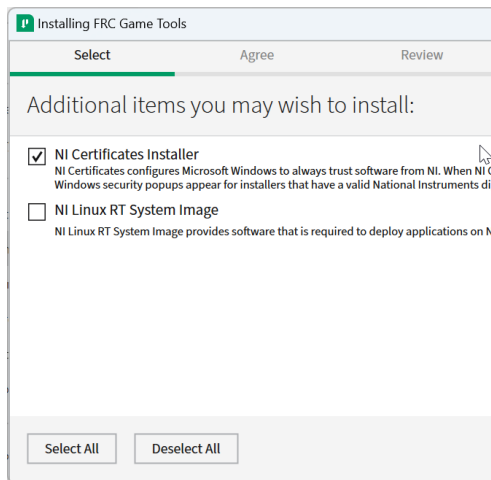
הפעלה מהירה של Windows היא תכונה המאפשרת למערכת להתעורר במהירות. כדי להתקין את NI Package Manager, עליך לבטל את ההפעלה המהירה של Windows. *Next* תוכלו להתקין את roboRIO.

Review Manager Package NI



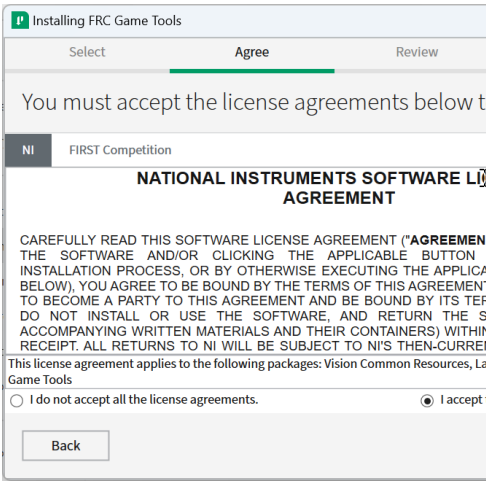
Next תוכלו להתקין את roboRIO.

□□□□□□ □□□□□ **2:** □□□ **3.** □□□



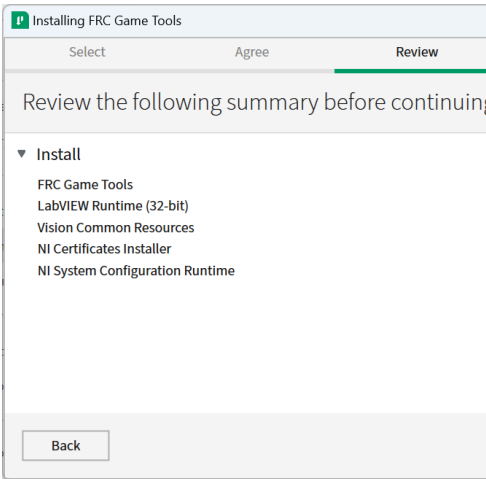
Next □□□□ ,□□ □□□ □□□□□ □□□□ □□□□□

הסכמי רישיון



Next ☐ accept... I ☐

Summary Review



.Next ☐

3.4.1 דרישות מקדימות

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
- higher or 12 macOS requires C++ Java. for Arm and Intel both higher, or 11 macOS
- 14. Xcode with

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

3.4.2 Downloading

Installer WPILib

Downloads 2024 14, March - Release 2024.3.2 WPILib
platforms other for Downloads

Notes Release

.GitHub from installer the of release latest the download can You
section. Downloads the to scroll page, releases GitHub the on Once

WPILib 2024.1.1 Release Draft

This is the kickoff release of WPILib for the 2024 season.

The documentation for WPILib is located at <https://docs.wpilib.org/> (if you have trouble accessing <https://frcdocs.wpi.edu/en/stable/> is an alternate location with the same content).

If you're new to FRC, start with [Getting Started](#).

System Requirements: WPILib requires 64-bit Windows 10 or 11, Ubuntu 22.04, or macOS 12. note that Visual Studio 2022 is required for desktop builds. Mac users will need to have the installed before running the installer. This can be done by running `xcode-select --install`.

If you're returning from a previous season, check out [what's new for 2024](#). You will need a new is available via the [FRC 2024 Game Tools](#). Follow the [WPILib installation guide](#) to install WPILib.

If you're starting from a 2023 robot project, you will need to [import your project](#) to create a process is important, as it will make a few automated corrections for some breaking changes also necessary to import vendor libraries again, since last year's vendor libraries must be updated year's projects.

A complete list of known issues with this release can be found [here](#).

WPILib is [developed by a small team of volunteers and the FIRST community](#).

Downloads

For 2024, we have changed the location for WPILib downloads due to GitHub file size limitations to download the installer package for your platform.

- [WPILib 2024.1.1 - Windows](#) (2.0 GB)
- [WPILib 2024.1.1 - Mac \(Arm\)](#) (2.1 GB)
- [WPILib 2024.1.1 - Mac \(Intel\)](#) (2.2 GB)
- [WPILib 2024.1.1 - Linux](#) (2.3 GB)

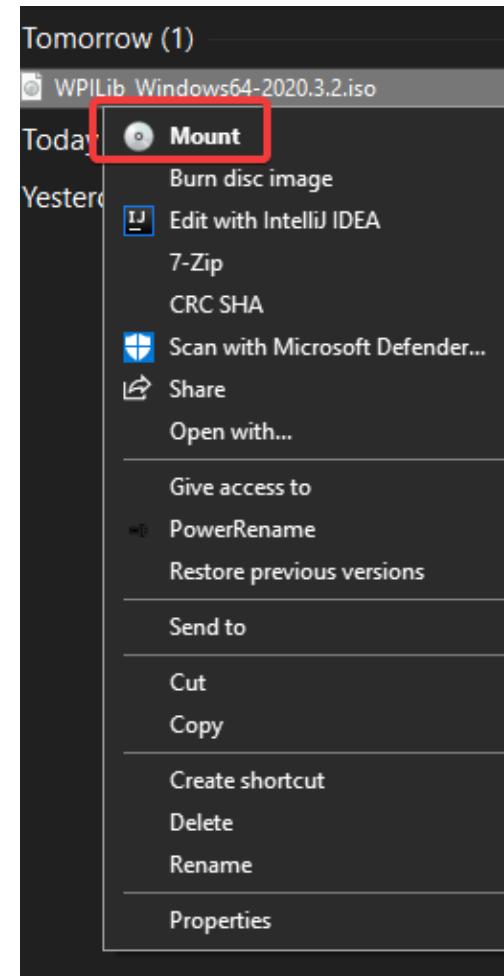
download. the begin to architecture and OS your for binary correct the on click Then

3.4.3 חילוף המתקין

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macOS. DMG 可移植, 可移植 可移植 tar.gz.

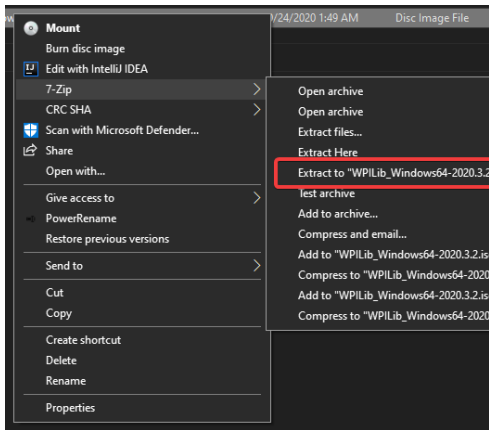
+10 Windows

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



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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

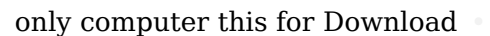
installed Tools Line Command Xcode the have to need will users macOS release, this For release. future a in requirement this removing on working are we installer; the running before Terminal. the in install - - select-xcode running by done be can This

manually to necessary it's 2024.1.1, or release beta 2024 a from upgrading When : and ~/wpilib/2024/tools to Navigate installer. the running before AdvantageScope delete AdvantageScope. delete

"WPILibInstaller" "DMG"- macOS .



.Code VS و Code .VS دو محیط کدنویسی هستند که در این مقاله به بررسی آن‌ها خواهیم پرداخت.

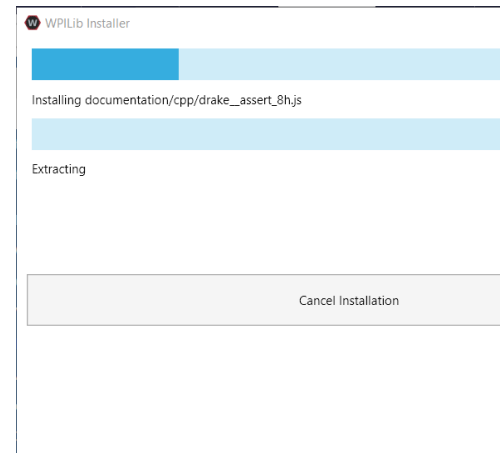


Code VS use don't and Skip

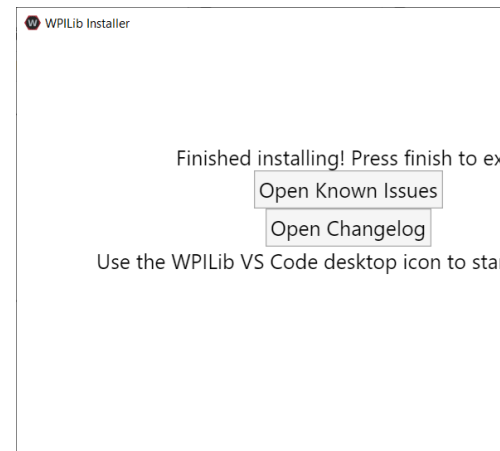
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.00000000

3.4.5 לאחר ההתקנה

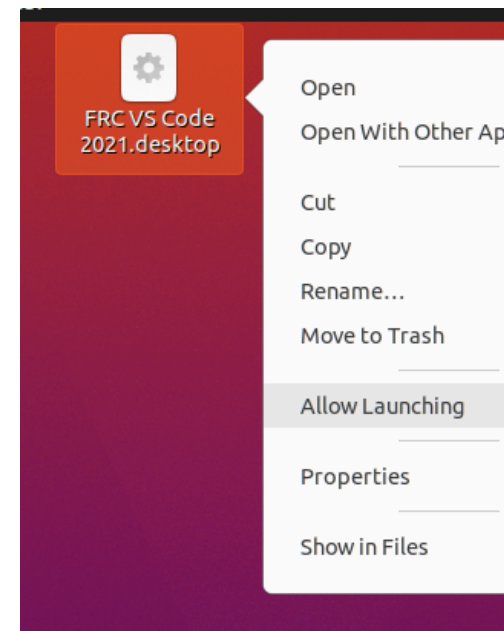
התקנתם את הכלים הנדרשים? הנה כמה טיפים שיסייעו לכם להתחיל.

macOS

התקנתם את Code VS? הנה כמה טיפים שיסייעו לכם להתחיל. Code VS WPILib-ה התקנתם? הנה כמה טיפים שיסייעו לכם להתחיל. WPILibInstaller התקנתם? הנה כמה טיפים שיסייעו לכם להתחיל.

לינוקס

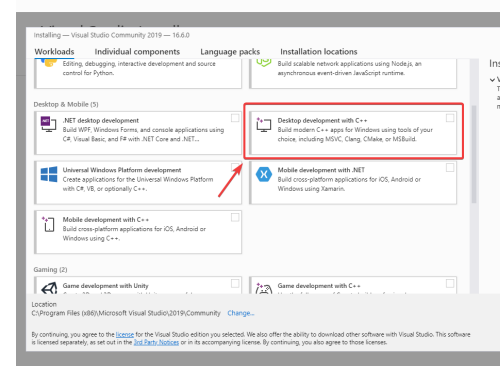
התקנתם את Ubuntu (20.04) ואת הכלים הנדרשים? הנה כמה טיפים שיסייעו לכם להתחיל. Launching. Allow התקנתם? הנה כמה טיפים שיסייעו לכם להתחיל.



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3.4.6 Simulation for Installation C++ Additional

would this Windows, For installed. be to compiler native a that requires simulation robot C++ ,later or 14 Xcode requires macOS Code), VS **not**(later or 17.9 version 2022 Studio Visual be package. essential-build the requires (Ubuntu) Linux and installer Studio Visual the in checked is option C++ with Development Desktop the Ensure support. simulation for



3.4.7 מה הותקן?

: 0000 000000 00 0000 0000 000 000000

2019-년 1월 1일부터 IDE-인 Code Studio Visual Studio Code VS 2019년 1월 1일부터 WPILib, Code VS 2019년 1월 1일부터 WPILib-인 Code VS-인

roboRIO- C++ - **Compiler C++**

Java 与 C++ 的 编译 选项 / 选项 Gradle 的 选项 - Gradle

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 JDK-0 00000000 00 00 0000 00000000 00 .(0000 00000000 000000) Java 00000000 00000000 0000 00
 JAVA HOME. 00000000 00 000000 000000 00000000

OutlineViewer, RobotBuilder, Shuffleboard, SmartDashboard, - **Tools WPILib**
 Setter, Number Team roboRIO Tool, Log Data SysId, Glass, PathWeaver,
 AdvantageScope

OpenCV, WPIlib - Dependencies WPIlib

code robot for extensions Java/C++/Python and WPILib - **Extensions Code VS**
Code VS in development

Java/C++/Python and documentation docsfr- this of copies Offline - **Documentation** APIs

3.4.8 הסרת ההתקנה

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macOS

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לינוקס

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

3.4.9 פתרון בעיות

Repository-\ 2.

Guide Installation Python 3.5

. WPILib to skip can teams C++ and Java teams. Python for intended is guide This
 . (LabVIEW FRC LabVIEW to skip can teams LabVIEW

Prerequisites 3.5.1

currently We system. operating supported a on Python of version supported a install must You
 roboRIO. the for available is 3.12 only but 3.8/3.9/3.10/3.11/3.12, Python support

Architectures: and Systems Operating Supported

supported not are Arm and bit 32 only. bit 64 11, & 10 Windows •
 higher or 12 macOS •
 but work, may 2.35 >= glibc with distributions Linux Other bit. 64 22.04, Ubuntu •
 unsupported are
 by distributed installers Python official the using recommend we macOS, and Windows On
 python.org.

Windows for Python •

macOS for Python •

RobotPy Install 3.5.2

development your on RobotPy install to pip use can you Python, installed have you Once computer.

Windows

first should you RobotPy, of version beta 2024 or 2024pre- a installed previously you If :
upgrading. before robotpy uninstall pip m- py via RobotPy uninstall

be to required is package redistributable 2019 Studio Visual the Windows, On :
installed.

packages: RobotPy core the install to Powershell or cmd from command following the Run

```
robotpy install pip m- 3- py
```

this: run can you upgrade, To

```
robotpy upgrade-- install pip m- 3- py
```

use either computer, your on rights administrative have don't you If
directory: package site- user the to install can you or or ,winvirtualenv/virtualenvwrapper-

```
robotpy user-- install pip m- 3- py
```

macOS

first should you RobotPy, of version beta 2024 or 2024pre- a installed previously you If :
upgrading. before robotpy uninstall pip m- python3 via RobotPy uninstall

Terminal the from command following the run just installed, pip has that system macOS a On
rights): admin require (may application

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robotpy install pip m- python3
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this: run can you upgrade, To

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robotpy upgrade-- install pip m- python3
```

use either computer, your on rights administrative have don't you If
directory: package site- user the to install can you or ,virtualenv/virtualenvwrapper

```
robotpy user-- install pip m- python3
```


first should you RobotPy, of version beta 2024 or 2024pre- a installed previously you If :
upgrading. before robotpy uninstall pip m- python3 via RobotPy uninstall

```
version-- pip m- python3 |
```

```
g++-12=CXX gcc-12=CC export
```

roboRIO for RobotPy Download 3.5.3

commands of variety a are there computer, your on project robotpy the installing After module. robotpy the via line command the from ran be can that available

```
:~$
```

subcommands robotpy for Documentation

to needed pieces the download to that use can you project, robot RobotPy a have already you If directory empty an in command this running project, a have don't you If roboRIO. the on run project: robot new a initialize will

Windows

```
init robotpy m- 3- py
```

macOS

```
init robotpy m- python3
```

Linux

```
init robotpy m- python3
```

be should file pyproject.toml The file. pyproject.toml and robot.py a create will This things. other among code, robot your run to needed requirements the details and customized

```
:~$
```

installed RobotPy of version the contains only you for created pyproject.toml default The packages python other install or packages vendor enable to want you If computer. your on

documentation pyproject.toml our see PyPI, from

will: which subcommand, sync robotpy the run Next

roboRIO for compiled Python Download •

pyproject.toml your by specified as packages python compatible roboRIO Download •

environment local your into pyproject.toml your by specified packages the Install •

robotpy the privileges, administrative have don't and virtualenv a using aren't you If :~\$ package-site-specific-user- the to install to argument user-- a accepts command sync directory.

Windows

```
sync robotpy m- 3- py
```

macOS

```
sync robotpy m- python3
```

Linux

```
sync robotpy m- python3
```

install automatically will *subcommand deploy the* roboRIO, the to code your deploy you When
deploy the of part as roboRIO the on requirements project robot your and needed) (if Python
process.

3.6 השלבים הבאים

בסעיף 3 באתר! בסעיף 2 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר!
VS- בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר!
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:באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר!

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

באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר!
באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר! בסעיף 4 באתר!

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



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 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.zip
FRC_roboRIO2_2021_v3.0.zip

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 •

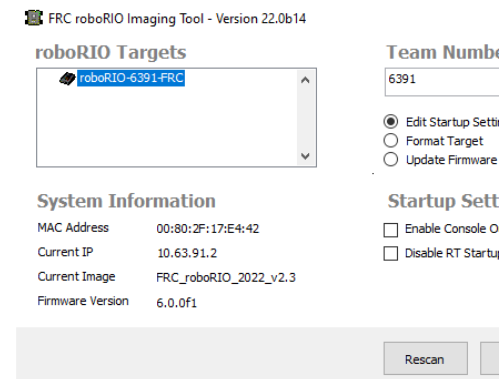
Imager Pi Raspberry with image the Writing

- .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

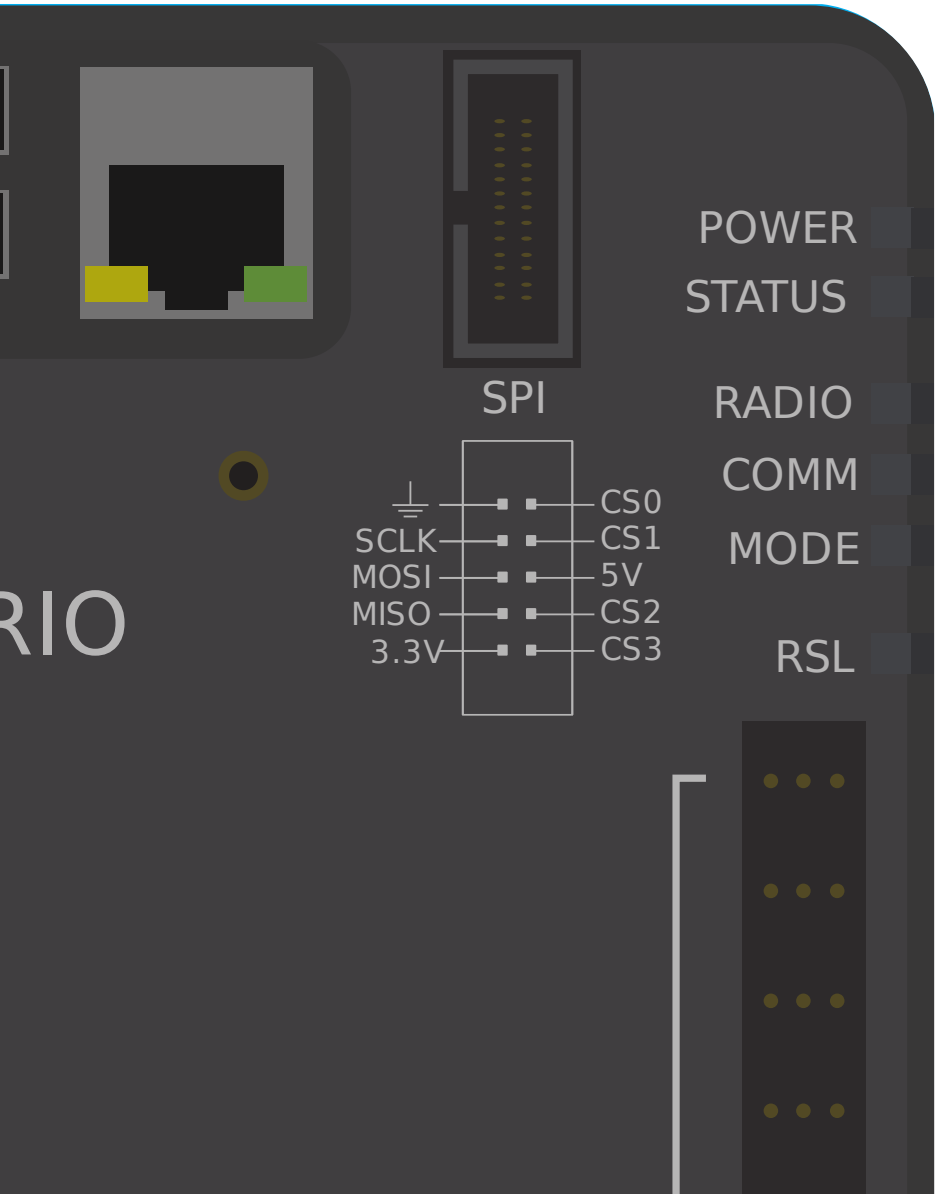
the of installation completed have must you roboRIO, your imaging Before :□□□□□
Power the to wired properly power roboRIO the have must also You .*Tools Game FRC*
the that and secure are roboRIO the to wires power the sure Make Panel. Distribution
check). to screws total (4 roboRIO the to firmly secure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

the for instructions imaging The instructions. imaging different uses 2 roboRIO The :□□□□
.here are 2.0 roboRIO NI

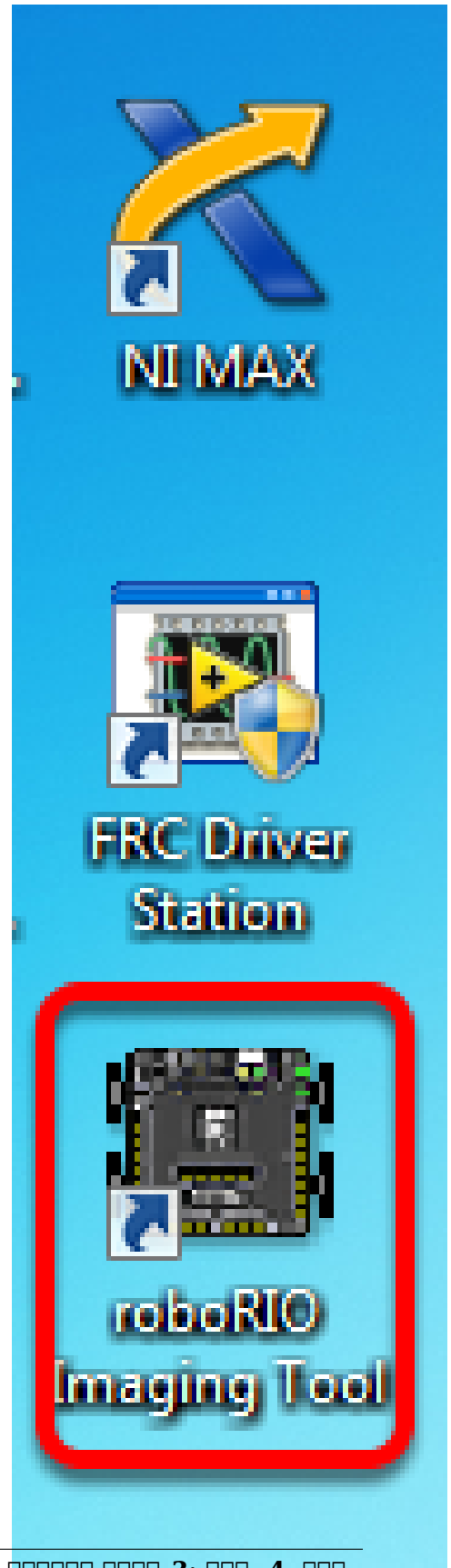
roboRIO the Configuring 4.2.1

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

Connection USB



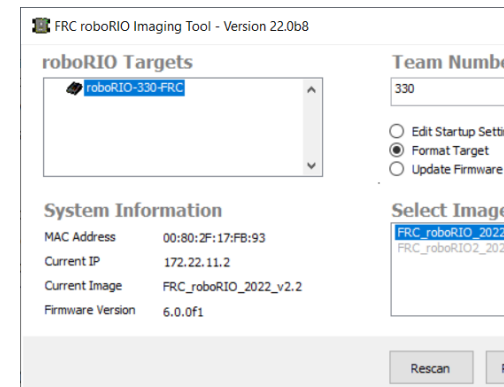
Tool Imaging the Launching 4.2.2



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 clicking right- 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\2023 LabVIEW\Instruments

Tool Imaging roboRIO 4.2.3

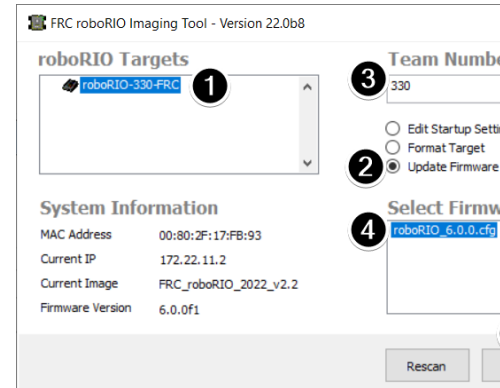


any indicate and roboRIOs available for scan will Tool Imaging roboRIO the launching, After the for settings and information show will box left bottom The box. left top the in found roboRIO the modifying for controls contains pane hand right The selected. currently roboRIO settings:

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

Firmware Updating

not is It roboRIO. new brand a on firmware the update to necessary only is It :
below. conditions the meet doesn't it unless firmware the update to recommended



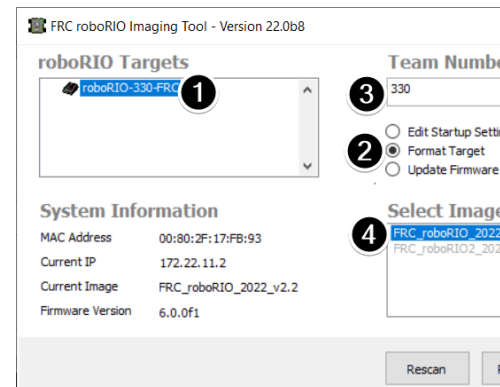
roboRIO your If image. later or 2019 the with work to v5.0 least at be must firmware roboRIO to need not do you tool) imaging the of left bottom the in shown (as 5.0 version least at is update.

It years. the over schemes numbering version different had has firmware roboRIO :□□□□ of variations or 23.5 22.5, 8, 6, 5, version has it if firmware the update to necessary isn't safe in utilized only is firmware The 8). of variation a is 8.8.0f0 (e.g. numbers version those operations. normal in used not is it ,mode

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

roboRIO the Imaging 4.2.4

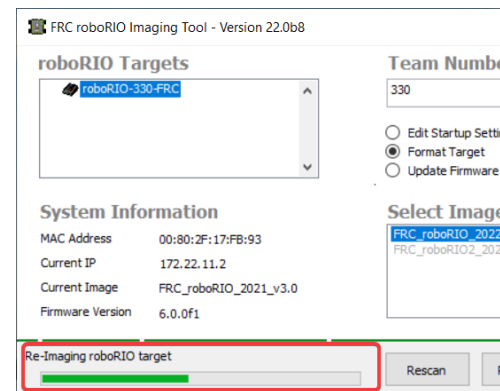
yearly. updated be must and firmware, the then different is image roboRIO The :□□□□□



2 step per *Target Format* select you until show not will versions image available The :□□□□ below.

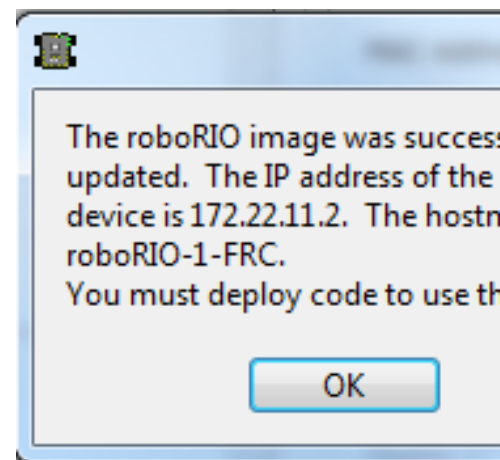
- pane left top the in selected is roboRIO the sure Make 1.
- pane right the in *Target Format* Select 2.
- box *Number Team* the in number team a Enter 3.
- box. the in version image latest the Select 4.
- process. imaging the begin to *Reformat* Click 5.

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

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 •
the or it, in number or),- dash (e.g. character special a has using you're computer
11, Windows On PC). different a using (or computer the renaming Try long. too is name
PC this Rename click and About > System > Settings to go PC, the rename to
- 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 •
- the follow failed, mode safe in imaging and flashing, constantly is LED status the If •
instructions recovery roboRIO
- available: isn't version image roboRIO correct the If
- Target Format* selected you've Ensure •
- Tools Game FRC* latest the installed you've ensure shown, is version older an If •
- and *Tools Game Uninstall* Tools, Game installing after shown still version wrong the If •
install.re- then

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), administratoron- 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

24.0.1 Configuration Radio FRC

Version Israel 24.0.1 Configuration Radio FRC

OM5PAC IL :
.

:

adapters network other all Disable 1.

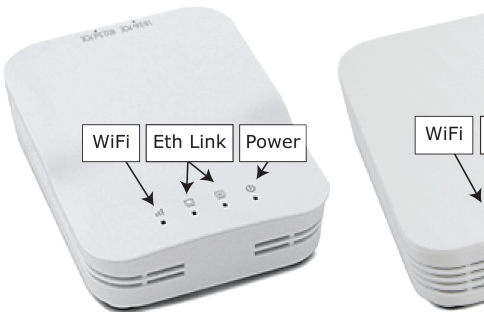
the to closest port ethernet bridge wireless the into computer your from directly Plug 2.
If ethernet. via computer your to connected are devices other no sure Make jack. power
the of side socket the into PC the from cable Ethernet an plug PoE, via radio the powering
configuring issues experience you 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.

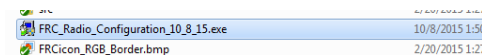
only: home At

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 :□□□□□

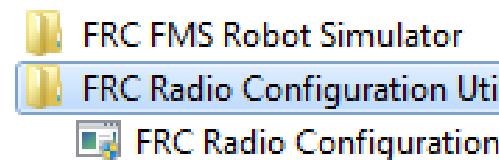
Software the Install 4.3.3



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

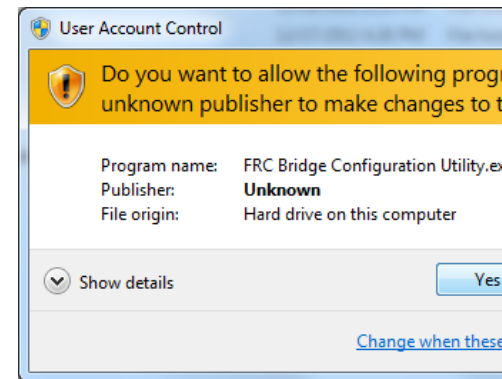
software the Launch 4.3.4



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

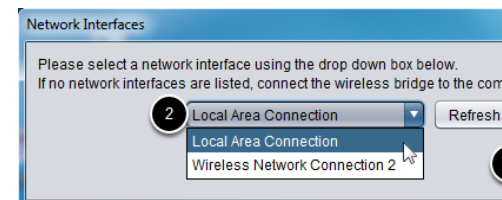
FRC\(\x86) Files Program\C: to installed is it program, the locate to need you If :
 FRC\Files Program\C: is path the machines bit32- For .Utility Configuration Radio
 Utility Configuration Radio

prompted if changes, make to program the Allow 4.3.5



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

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

interfaces. available for scanre- to *Refresh* click listed, are interfaces ethernet no If 1.

list. dropdown- the from use to want you interface the Select 2.

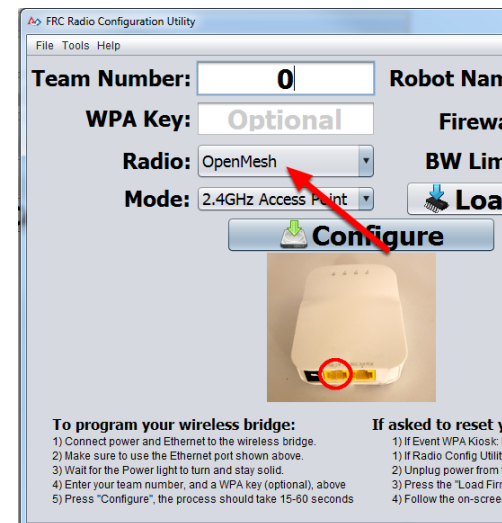
.OK Click 3.

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

2024 the configuring, before updated be to need **not do** 20232019- in used Radios :□□□□□
firmware. 2019 same the uses tool

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

the select and program the launch software, the install to above instructions the Follow 1.
interface. Ethernet

dropdown. Radio the in selected is radio Mesh Open the sure Make 2.

Ethernet. via PC the to connected is radio the sure Make 3.

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

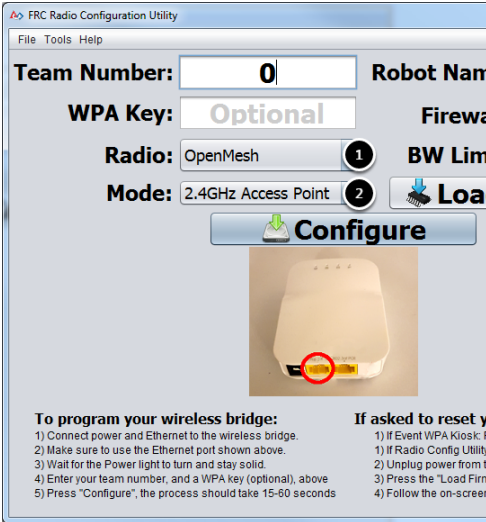
button Firmware Load the Press 5.

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

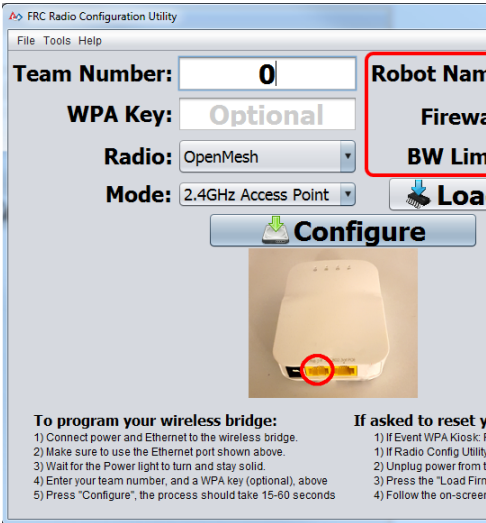
Locale the setting or PC provided KOP the on as such OS, English an using try OS, language .page this on described as "en_us" to setting

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

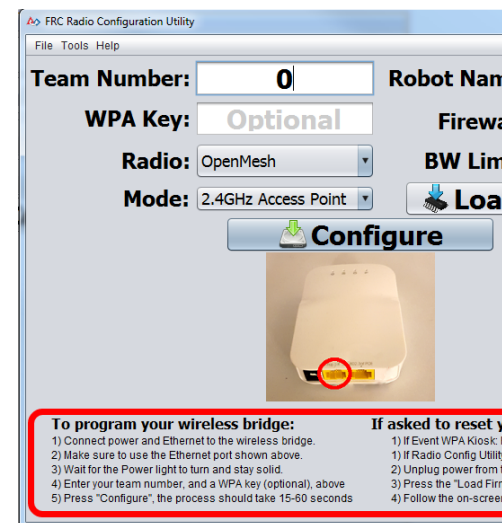
mimic to attempt to configured be will firewall radio the checked, is box this If **Firewall:** 2.
open of list a For field. FRC the on present firewall the of behavior blocking port the
Manual. Game FRC the see please ports,

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 this 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

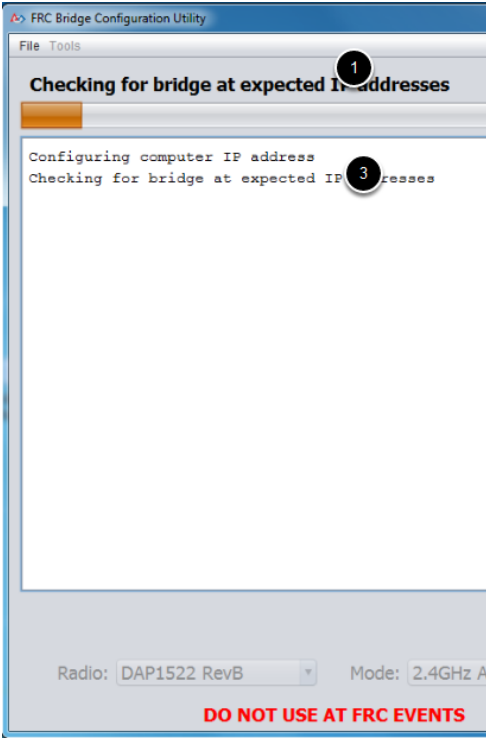
means This firewall. field the emulate to radio the configures option "Firewall" The :□□□□□
useful is This enabled. option this with wirelessly code deploy to able be not will you that
competitions. at exist may that ports blocked simulating for

Process Configuration the Starting 4.3.11



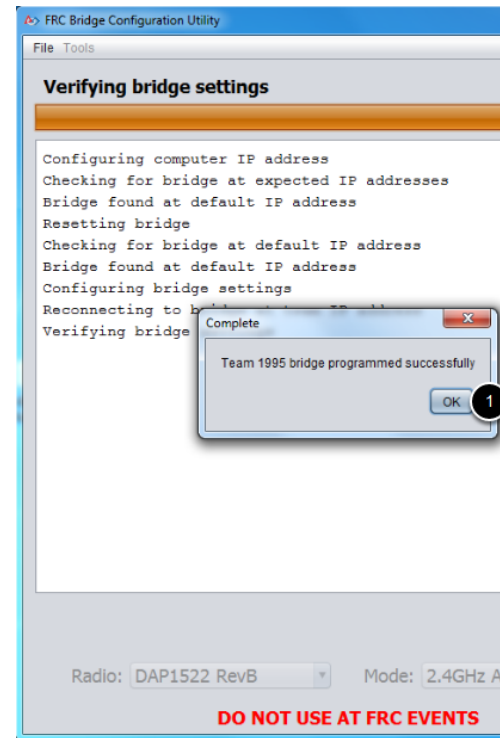
settings the entering bridge, wireless your preparing for instructions screenon- the Follow
screenon- These process. configuration the starting and with, configured be will bridge the
chosen. mode operating and model bridge the match to update instructions

Progress Configuration 4.3.12



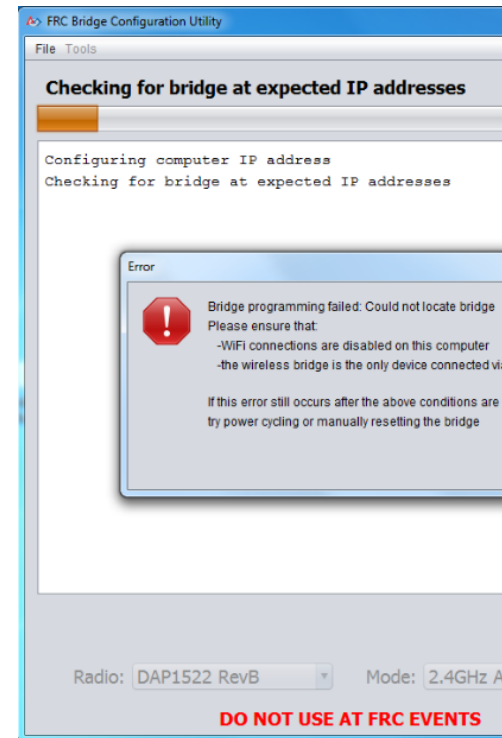
indicate: will window the process, configuration the Throughout
executed. being currently step The 1.
process. configuration the of progress overall The 2.
far. so executed steps All 3.

Completed Configuration 4.3.13



complete: is configuration the Once
 window. dialog the on *OK* Press 1.
 screen. settings the to return to window main the on *OK* Press 2.

Errors Configuration 4.3.14



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

פתרון בעיות 4.3.15

- *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*
- *because failure configuration a face may Teams USnon- incompatibles, Unicode to Due*
- name adapter network the change case, that In reading. interface network incorrect of
- retry. and English in name another to
- 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

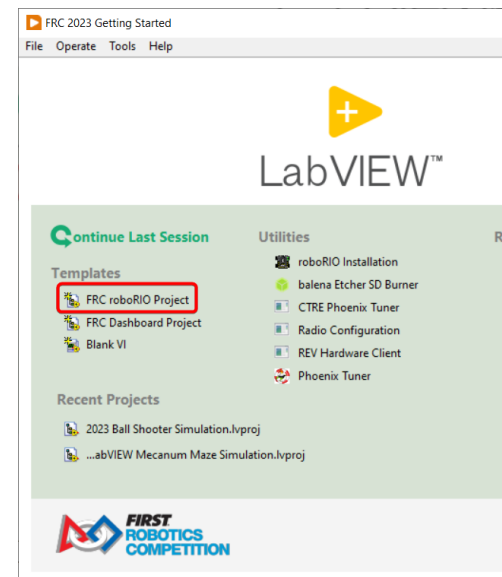
computer. different a try fails, else all If •



(LabVIEW) Program Drivetrain Test your Creating 5.1

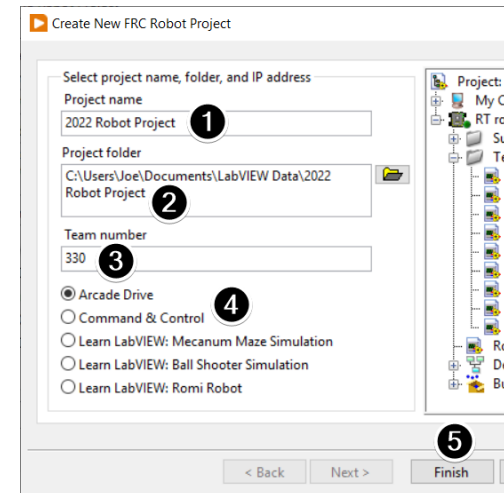
program LabVIEW FRC® basic a load and build create, to how covers document This :□□□□
LabVIEW installed have you that sure make beginning, Before roboRIO. a onto drivetrain a for
as roboRIO your imaged and configured have you that and Tools Game FRC the and FRC for
.tutorial Robotto-Zero- the in described

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



Dialog: Project FRC New Create the in Fill

project your for name a Pick 1.

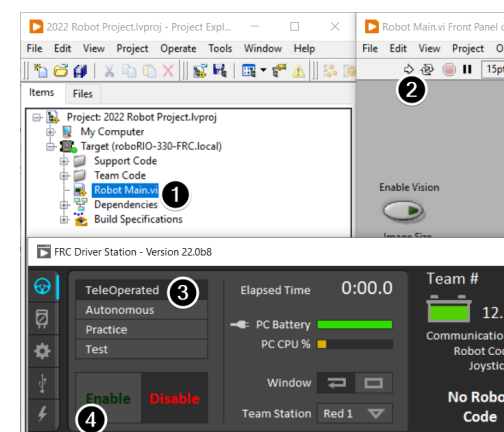
in. project the place to folder a Select 2.

Team number 330 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.

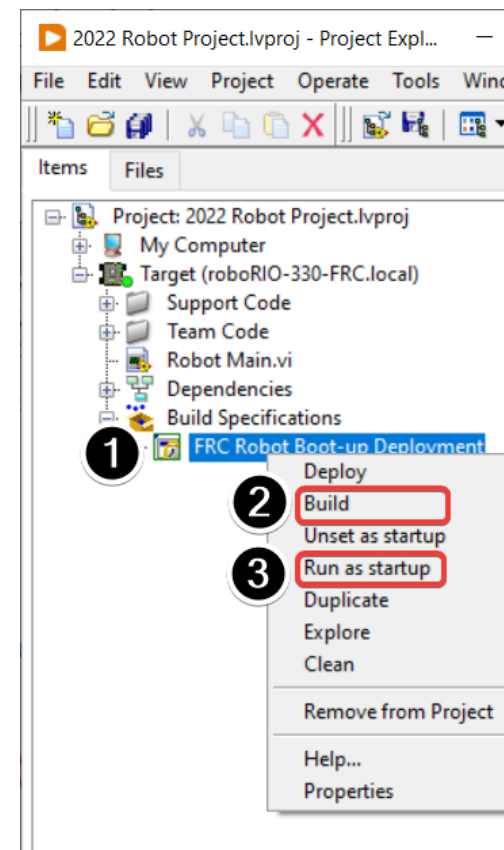
on information more For Mode. Teleop in robot the put software, Station Driver the Using 3.
Software Station Driver FRC the see software, Station Driver the using and configuring
article.

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

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

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

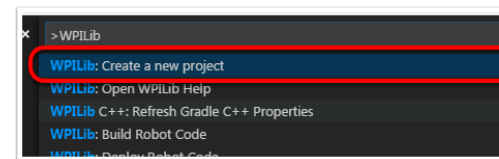
(Java/C++) Project WPILib New a Creating •

(Python) Project WPILib New a Creating •

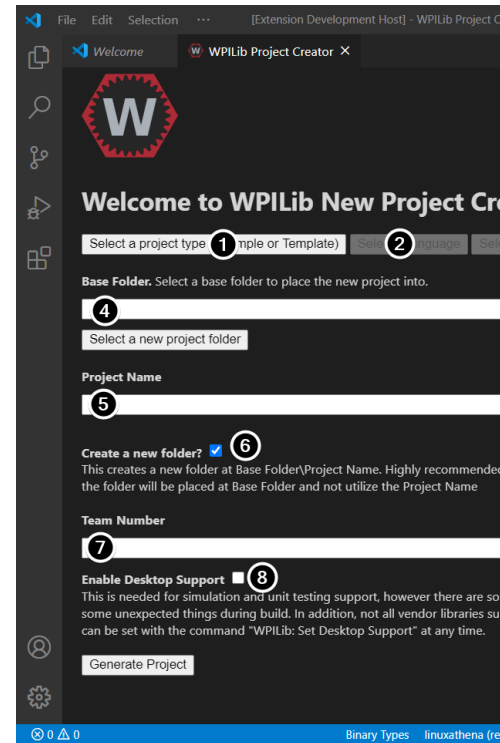
convenience the for hardware vendor involve that examples code includes guide This :□□□□
The KOP. the in included controller motor the to refers *PWM* document, this In user. the of
similar is usage but motor), 500 (Falcon controller motor FX Talon the references tab CTRE
a controlling MAX SPARK CAN 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

(Java/C++) 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

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
box Folder New Create the if given be will folder project checked. not is this and empty
checked. is

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

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
this check not do example, this For it. support libraries all and needed is simulation or
box.

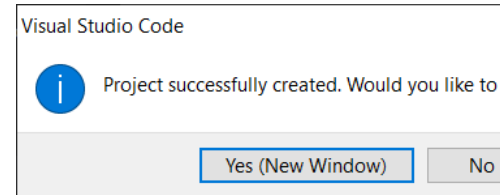
will project robot the and Project“ "Generate click configured, been have above the all Once
created. be

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

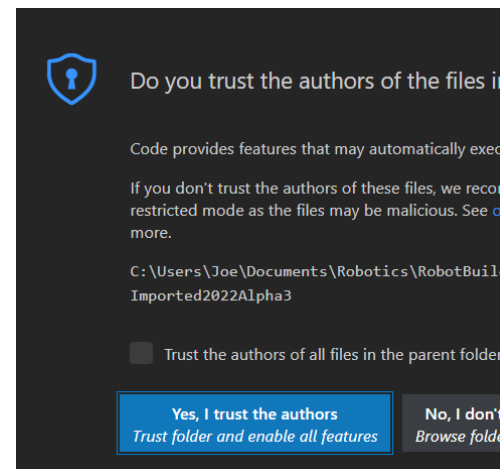
screen.

interferes caching OneDrive's as supported not is OneDrive on projects Creating :
folders Desktop and Documents the put installations Windows Some system. build the with
default. by OneDrive on

5.2.2 פתיחת הפרויקט החדש

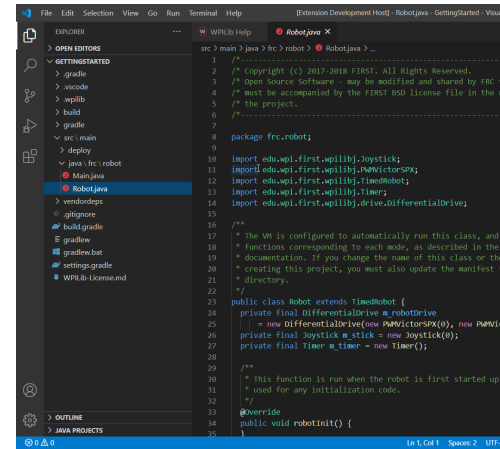


project the opening of option the give will Code VS project, your creating successfully After
just (or Ctrl+0 then Ctrl+K typing by later or now that do to choose can We above. shown as
project. our saved we where folder the select and macOS) on Command+0



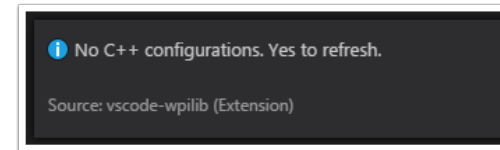
.authors the trust I Yes Click

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"



(Python) Project WPILib New a Creating 5.2.4

project: robot new a initialize will command init robotpy the Running

Windows

```
init robotpy m- 3- py
```

macOS

```
init robotpy m- python3
```

Linux

```
init robotpy m- python3
```

file. existing an overwrite not will but file, pyproject.toml and robot.py a create will This
are which project, your for requirements the contains file pyproject.toml The
command. sync robotpy the via installed and downloaded
class. Robot your the put will you where is file robot.py The

```
:~ ~
```

roboRIO for RobotPy Download

example Drivetrain Basic 5.2.5

motors controlled PWM with Drivetrain a for like look can code simple a what is here First,
SparkMax). as (such

<https://github.com/robotpy/examples/tree/main/> from is below example Python the :~ ~
GettingStarted

JAVA

```
contributors. WPILib other and FIRST (c) Copyright //
of terms the under it share and/or modify can you Software; Source Open //
project. this of directory root the in file license BSD WPILib the //
```

```
;edu.wpi.first.wpilibj.examples.gettingstarted package
```

```
;edu.wpi.first.util.sendable.SendableRegistry 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
```

```
;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import
```

```
*/
```

functions the call to and class, this run automatically to configured is VM The *
to corresponding
of name the change you If documentation. TimedRobot the in described as mode, each *
or class this
in file manifest the update also must you project, this creating after package the *
resource the
directory. *

```
*/
```

```
{ TimedRobot extends Robot class public
```

```
);0PWMSparkMax( new = m_leftDrive PWMSparkMax final private
```

```
);1PWMSparkMax( new = m_rightDrive PWMSparkMax final private
```

```
= m_robotDrive DifferentialDrive final private
```

```
m_rightDrive::set); DifferentialDrive(m_leftDrive::set, new
```

```
);0XboxController( new = m_controller XboxController final private
```

page) next on (continues

(0000 0000 0000)

```

Timer(); new = m_timer Timer final private
{ ()Robot public
m_leftDrive); (m_robotDrive,addChildSendableRegistry.
m_rightDrive); (m_robotDrive,addChildSendableRegistry.
}

**/
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.
}

*/ 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.
}
}

*/ 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.
}

*/ 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
}

```

```

    contributors. WPILib other and FIRST (c) Copyright //
of terms the under it share and/or modify can you Software; Source Open //
project. this of directory root the in file license BSD WPILib the //

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

    { TimedRobot: frc public : Robot class
      :public
      { Robot()
        m_left);& m_robotDrive,&AddChild(: SendableRegistry: wpi
        m_right);& m_robotDrive,&AddChild(: SendableRegistry: wpi

        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 m_right.SetInverted(
        ms);_100m_robotDrive.SetExpiration(
        m_timer.Start();
      }

    } 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(
        }
      }

    }{ override TeleopInit() void

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

    }{ override TestInit() void

    }{ override TestPeriodic() void

      :private
        system drive Robot //
        ;}m_left{ PWMSparkMax: frc
        ;}m_right{ PWMSparkMax: frc
        m_robotDrive{ DifferentialDrive: frc
        ,} m_left.Set(output); { output) double]}(&

```

page) next on (continues

(C++ Program Drivetrain Test your Creating)

```

;}} m_right.Set(output); { output) double](&[
;}}m_controller{ XboxController::frc
m_timer; Timer::frc
;}}
RUNNING_FRC_TESTS ifndef#
{ ()main int
();>Robot::StartRobot::frc return
}
endif#

```

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PYTHON

```

python3 usr/bin/env/#!/#
#
contributors. WPILib other and FIRST (c) Copyright #
of terms the under it share and/or modify can you Software; Source Open #
project. this of directory root the in file license BSD WPILib the #
#
wpiLib import
drive.wpiLib import

TimedRobot):.(wpiLibMyRobot class
):self(robotInit def
"""
and startup program upon called is function This
code. initialization any for used be should
"""
)PWMSparkMax(.wpiLib = leftDrive self
) PWMSparkMax(.wpiLib = rightDrive self
DifferentialDrive(.drive.wpiLib = robotDrive self
rightDrive self leftDrive, self
)
)XboxController(.wpiLib = controller self
Timer() wpiLib = timer self

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.setInverted( rightDrive self

):self(autonomousInit def
mode.""" autonomous enters robot the time each once run is function This"""
restart().timer self

):self(autonomousPeriodic def
autonomous.""" during periodically called is function This"""

seconds two for Drive #
:2.0 < get().timer self if

off squaring input turn to sure make speed, half forwards Drive #

```

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page) next on (continues

Python

```
wpiLib import 8
drive.wpiLib import 9
```

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#
```

PYTHON

```
joysticks the get to Used #
class DifferentialDrive the for Used #
library CTRE #
wpiLib import
drive.wpiLib import
ctre import
```

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#
```

PYTHON

```
joysticks the get to Used #
class DifferentialDrive the for Used #
library REV #

wpiLib import
drive.wpiLib import
rev import
```

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 5.2.7

PWM

Java

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

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 //
);true m_right.SetInverted(
ms);_100m_robotDrive.SetExpiration(
m_timer.Start();
}
```

```

                                :private
                                system drive Robot //
                                ;}m_left{ PWMSparkMax::frc
                                ;}m_right{ PWMSparkMax::frc
                                m_robotDrive{ DifferentialDrive::frc
                                ,} m_left.Set(output); { output} double](&[
                                ;}} m_right.Set(output); { output} double](&[
                                ;}m_controller{ XboxController::frc
                                m_timer; Timer::frc
                                ;}

```

Python

```

TimedRobot):.(wpilibMyRobot class
):self(robotInit def
"""
and startup program upon called is function This
code. initialization any for used be should
"""
)PWMSparkMax(.wpilib = leftDrive.self
) PWMSparkMax(.wpilib = rightDrive.self
DifferentialDrive( drive wpilib = robotDrive self
rightDrive self leftDrive,.self
)
)XboxController(.wpilib = controller.self
Timer() wpilib = timer.self

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.setInverted( rightDrive.self

```

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

```

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 //
        );true m_right.SetInverted(
        ms);_100m_robotDrive.SetExpiration(
        m_timer.Start();
    }

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

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

Python

```

        TimedRobot):.(wpilibMyRobot class
        ):self(robotInit def
        """
        and startup program upon called is function This
        code. initialization any for used be should
        """
        )1WPI_TalonFX(.ctre = leftDrive self
        )2WPI_TalonFX(.ctre = rightDrive self
        DifferentialDrive(.drive.wpilib = robotDrive.self
        rightDrive.self leftDrive, self
        )
        )3XboxController(.wpilib = controller.self
        Timer() wpilib = timer.self
        """
        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.setInverted( rightDrive self
    
```

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); ↵
    
```

page) next on (continues

(0000 0000 0000)

```
); XboxController( new = m_controller XboxController final private
Timer(); new = m_timer Timer final private
```

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 //
); true m_right.SetInverted(
ms); _100m_robotDrive.SetExpiration(
m_timer.Start();
}
```

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

Python

```
TimedRobot): (wpilib MyRobot class
): self(robotInit def
and startup program upon called is function This
code. initialization any for used be should
kBrushless) MotorType CANSparkMax.rev ,1 CANSparkMax(.rev = leftDrive self
kBrushless) MotorType CANSparkMax.rev ,2 CANSparkMax(.rev = rightDrive self
DifferentialDrive( drive wpilib = robotDrive self
rightDrive self leftDrive, self
)
) XboxController( wpilib = controller.self
Timer() wpilib = timer.self
voltage 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 setInverted( rightDrive self
```

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 5.2.8

Java

```

        @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++

```

    }{ ()RobotInit void
    
```

Python

```

    ):self(robotInit def
    
```

constructor. the after but up, starting is program robot the when run is method RobotInit The
 on Depending drivetrain. the of side right the inverts program sample our for RobotInit The
 instead. side left the invert to need might you setup, drive your

above. constructor Robot () the in handled is inversion drive the C++, In :

Example Autonomous Simple 5.2.9

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 */
    
```

page) next on (continues

(0000 00000 0000)

```

                                @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(arcadeDrive m_robotDrive.
                                    { else }
                                    robot stop // ();stopMotor m_robotDrive.
                                    }
                                }

```

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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(
    }
}

```

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PYTHON

```

):self(autonomousInit def
mode.""" autonomous enters robot the time each once run is function This"""
    restart().timer.self

):self(autonomousPeriodic def
autonomous.""" during periodically called is function This"""

    seconds two for Drive #
    :2.0 < get().timer.self if
off squaring input turn to sure make speed, half forwards Drive #
    )False=squareInputs ,0 ,0.5arcadeDrive( robotDrive.self
    :else
    robot Stop # stopMotor().robotDrive.self

```

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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 5.2.10

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());
    }

```

PYTHON

```

mode." teleoperated enters robot the time each once called is function This""
):self(teleopInit def
mode."" teleoperated during periodically called is function This""
arcadeDrive(.robotDrive.self
getRightX()).controller.self- getLeftY(),.controller.self-
)

```

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 5.2.11

JAVA

(0000 00000 0000)

```

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

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78
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C++

```

        {} override ()TestInit void
        {} override ()TestPeriodic void
    
```

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PYTHON

```

        ):self(testInit def
        mode.""" test enters robot the time each once called is function This"""
        ):self(testPeriodic def
        mode.""" test during periodically called is function This"""
    
```

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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 5.2.12

code Java/C++ Deploy •
code Python Deploy •

Program Test your Running 5.3

סקירה כללית 5.3.1

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

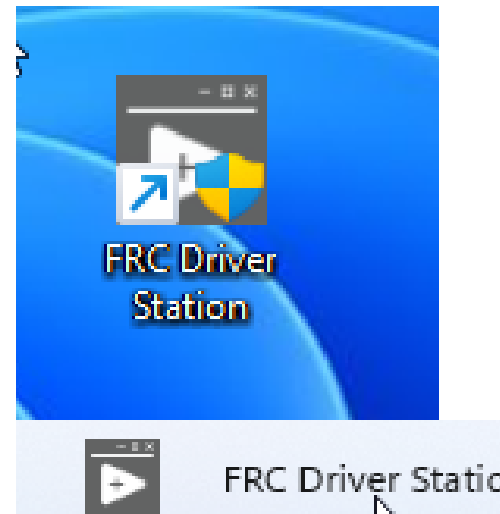
C++/Java/Python
LabVIEW

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

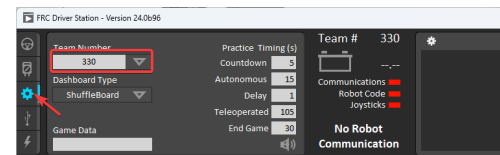
USB. or Ethernet over PC the to connected and on powered be should roboRIO The

Station Driver FRC the Starting 5.3.3



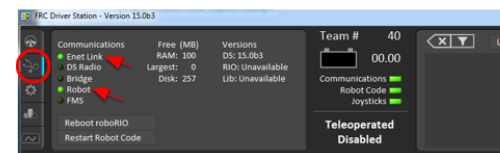
by or Desktop the on icon the clickingdouble- by launched be can Station Driver FRC® The
Station. Driver >FRCPrograms- >AllStart- selecting

Station Driver the Up Setting 5.3.4



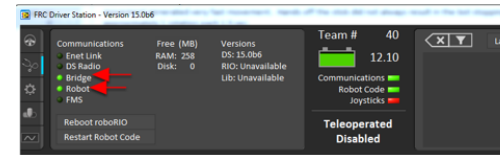
do to order In robot. your to connect to order in number team your to set be must DS The
return Press box. number team the in number team your enter then tab Setup the click this
effect. take to setting the for box the outside click or
already, robot the to connect to DS the for settings network correct the have typically will PCs
.DHCP to set is adapter Network your sure make not, if but

Connectivity Confirm 5.3.5



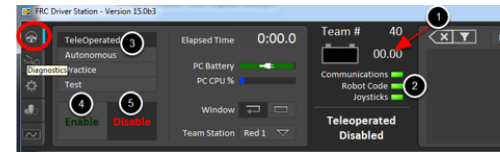
Tethered 1: Fig.

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.

Robot the Operate 5.3.6



Tab Operation the Click

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

Operation Wireless 5.3.7

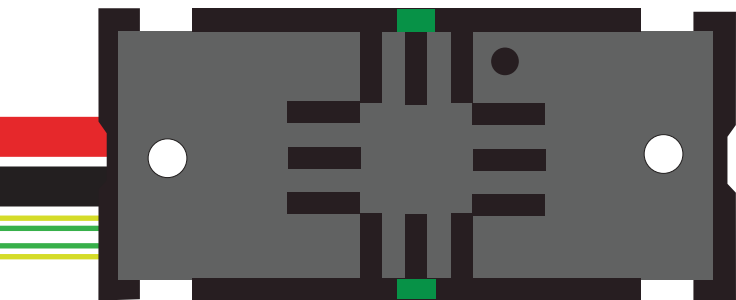
as confirmed been have should operation tethered operation, wireless attempting Before
Driver the to connected while program test your Running . *Operation Tethered* in described
configured. properly is point access the that confirm will WiFi via Station

Point Access the Configuring

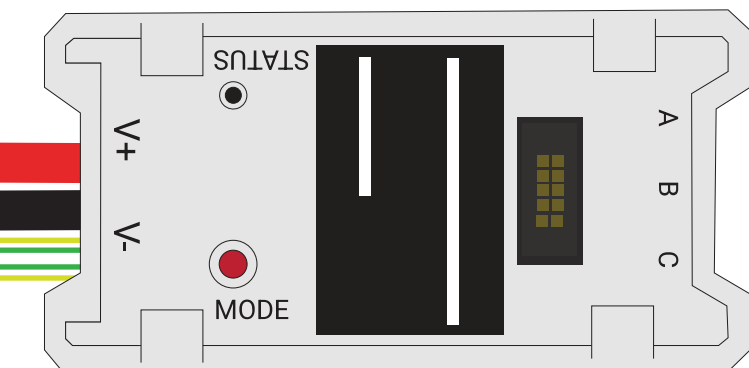
as use for radio robot the configuring on details for *radio your Programming* article the See
point. access an

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

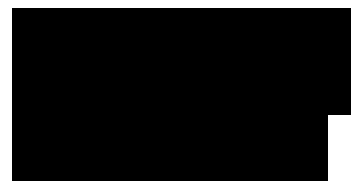
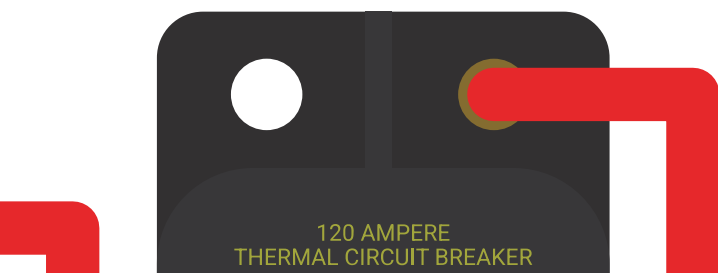


Spark MAX

DISCRETE MOTOR CONTROLLERS (CAN/PWM Controlled)

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

120A Breaker

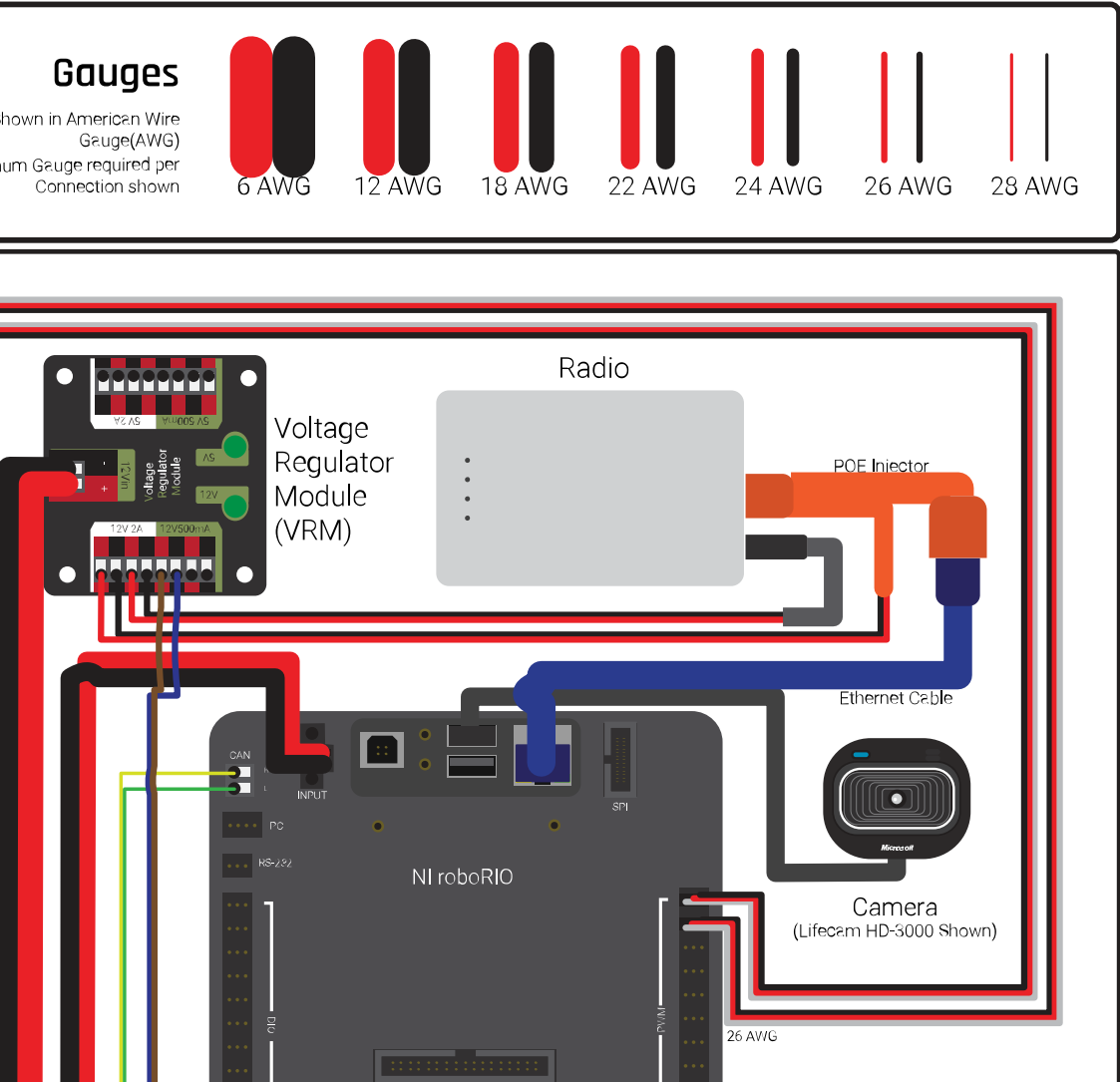


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00 000 000000 0000 0000

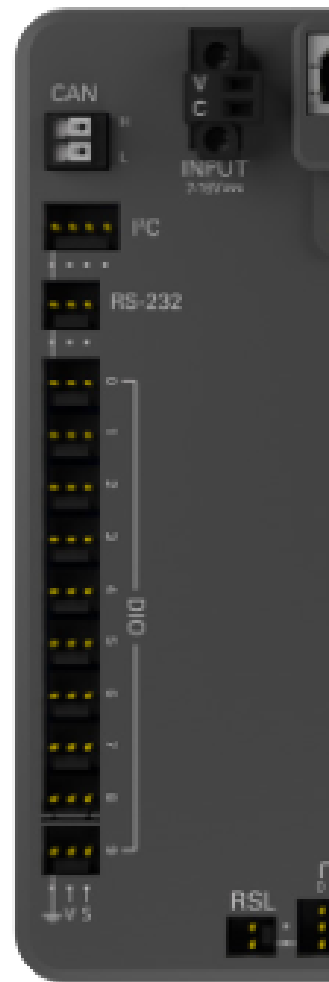
0000: 00000000 00 0000

6.1 סקירה כללית

REV



roboRIO NI 6.2



"brain" the as serves roboRIO The FRC. for used controller robot main the is *roboRIO NI*- 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 resetting auto- 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

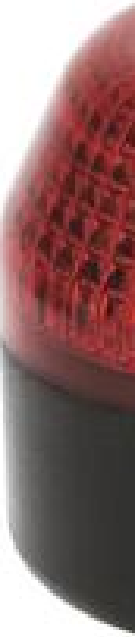


battery, (SLA) Acid Lead Sealed 18Ah 12V single a is robot FRC an for supply power The the see information, more For robot. FRC an of demands current high the meeting of capable *page. Battery Robot*

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

Light Signal Robot 6.11

BradleyAllen-



B12ME522855PB- BradleyAllen- 1: Fig.

AndyMark

or B12ME522855PB- BradleyAllen- either be to required is (RSL) Light Signal Robot The and enabled when flash will and roboRIO the by controlled directly is It 3583.am- AndyMark disabled. while solid stay



3583am- AndyMark 2: Fig.

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

SPX Victor 6.14.2



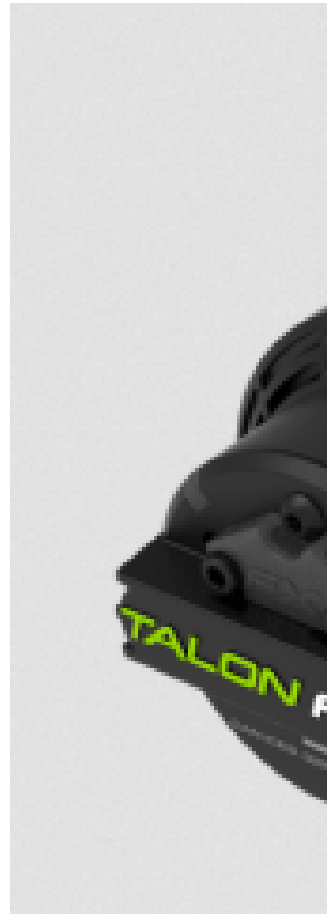
The Cross from controller motor controlled PWM or CAN a is Controller Motor SPX Victor The the to connection easy allow to connectorized is device The Robotics. Electronics/VEX Road entering from debris prevent to sealed is case The bus. CAN a or connectors PWM roboRIO .Guide User SPX Victor the see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

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

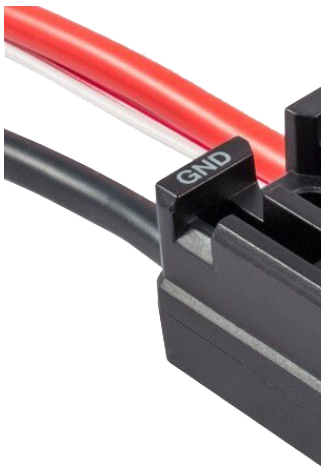
Controller Motor SPARK 6.14.5



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

The SPARK Motor Controller is a low-cost, brushless DC motor controller from REV Robotics. It is designed to be used with a variety of DC motors, including the popular FRC 3960 motor. The controller is easy to use and can be configured to operate in a variety of modes, including PWM, Limit, and Travel. For more information, see the SPARK User's Manual.

SP Victor 6.14.6



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



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

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

Module Power Servo 6.16



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

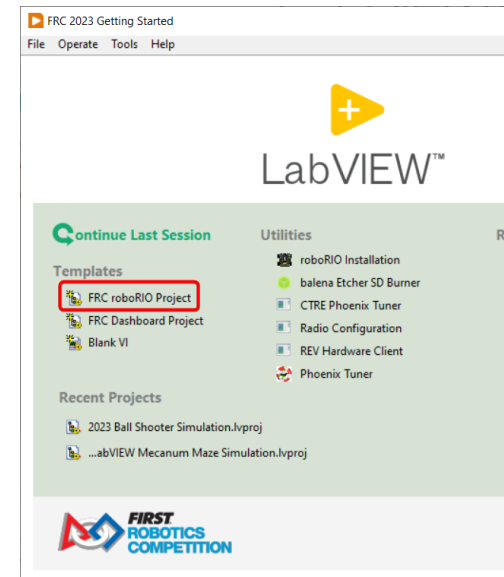


components. optional and mandatory of variety wide a of consists software FRC® The of debugging and development, design, the in you assist to designed are elements These feedback provide to and operation robot control with assist as well as code robot your brief a provide will document this component 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

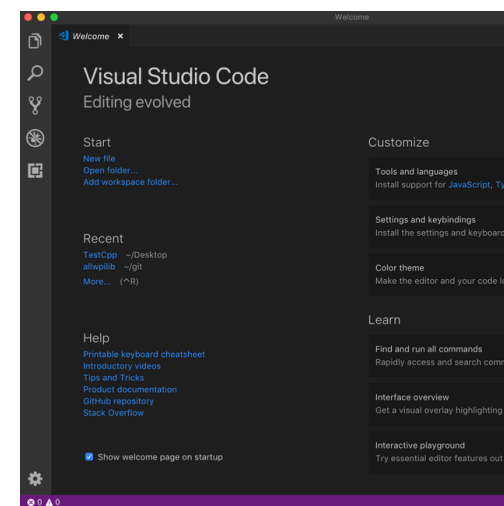
software FRC required All Windows. is components FRC for OS supported primary The 11. & 10 Windows on tested been have components macOS on tested and supported also are programming C++/Java/Python for tools the of Many these using develop to able be should C++/Java/Python in programming Teams Linux. and Station, Driver the as such operations onlyWindows- the for system Windows a using systems, Tool. Imaging roboRIO and Utility, Configuration Radio

7.2 Windows FRC LabVIEW (בלבד)



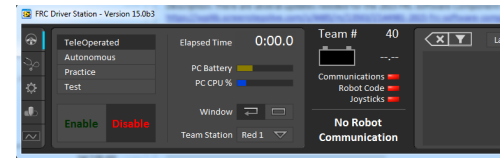
three the of one is Professional, LabVIEW of version recent a on based FRC, LabVIEW graphical, a is LabVIEW robot. FRC an programming for languages supported officially VIs, called icons, of collection a of consist programs LabVIEW language. drivendataflow-is installer FRC LabVIEW The VIs. the between 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

7.3 Code Studio Visual



to guide A Java. C++, for environment development supported the is Code Studio Visual of configuration and installation the including FRC, for C++ and Java with started getting .*here* found be can Code Studio Visual

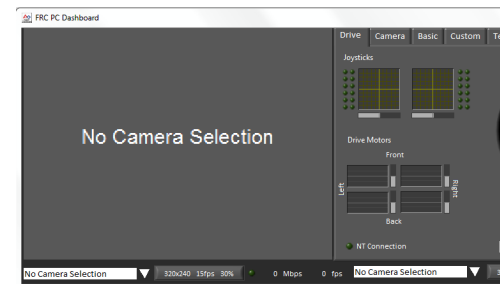
(Windows LabVIEW NI by Powered Station Driver FRC 7.4 (בלבד)



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

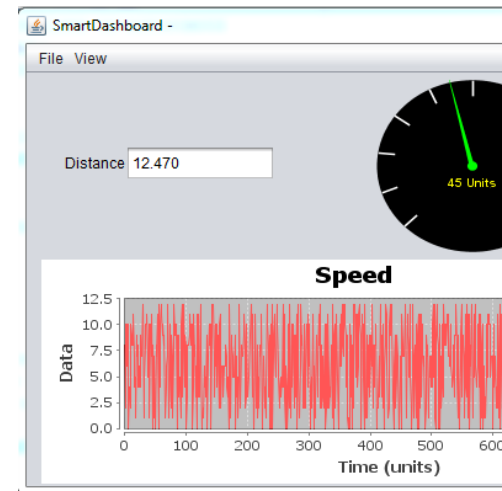
Options Dashboard 7.5

Only) (Windows Dashboard LabVIEW 7.5.1



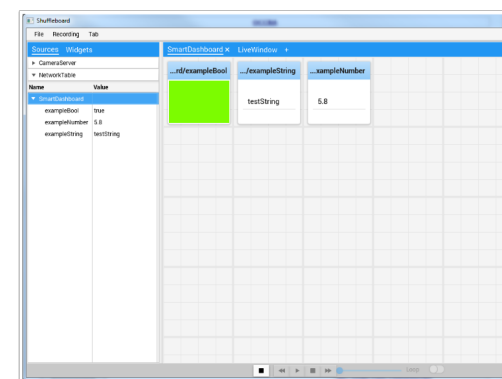
default. by Station Driver FRC the by launched automatically is Dashboard LabVIEW The using robot the of operation the about feedback provide to is Dashboard the of purpose The Default FRC the about information More features. in built of variety a with display tabbed .*here* found be can software Dashboard

SmartDashboard 7.5.2



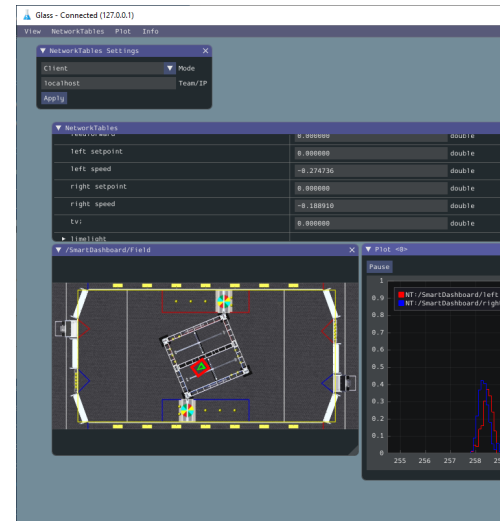
customizable creating automatically by data robot your view to you allows SmartDashboard documentation Additional robot. your from sent data of piece each for specifically indicators [.here](#) found be can SmartDashboard on

Shuffleboard 7.5.3



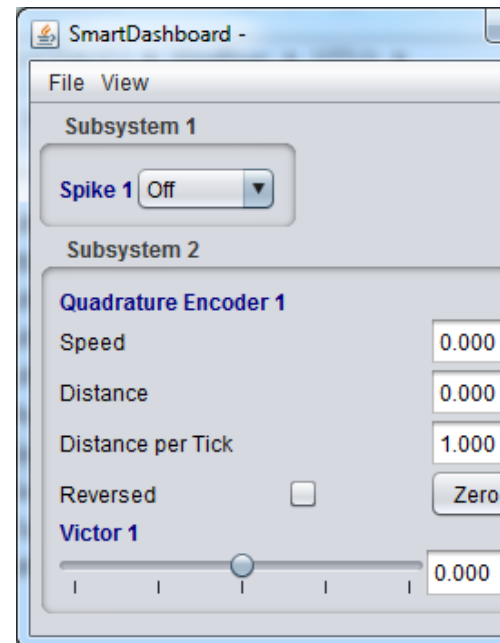
and setup the on improves also It SmartDashboard. as features same the has Shuffleboard less being of cost the at design modern a and features new with data your of visualization [.here](#) found be can Shuffleboard on documentation Additional efficient. resource

Glass 7.5.4



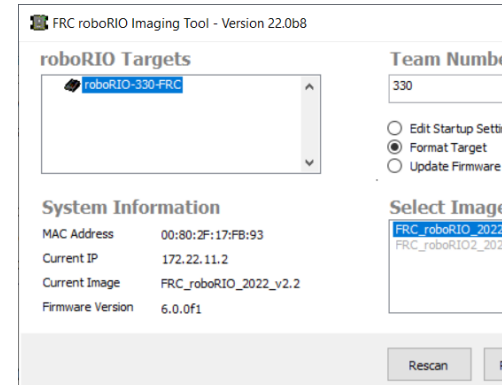
primary The debugging. for tool programmer's a being on focused Dashboard a is *Glass* tools. plotting signal advanced and visualization pose view, field the are advantages

LiveWindow 7.6



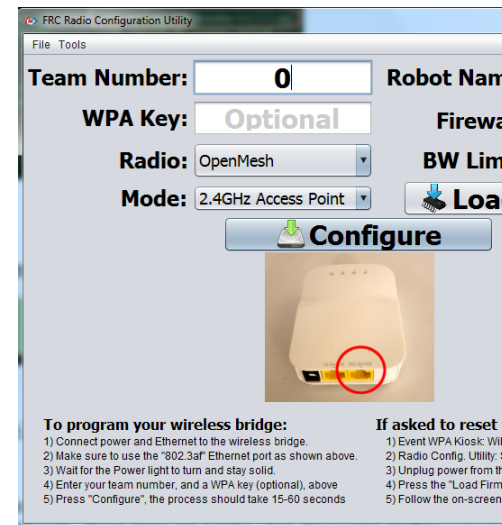
Test the with use for designed Shuffleboard, and SmartDashboard of feature a is LiveWindow the on sensors from feedback see to user the allows LiveWindow Station. Driver the of Mode about information More code. user written the of independent actuators control and robot *.here* found be can LiveWindow

Only) (Windows Tool Imaging roboRIO FRC 7.7



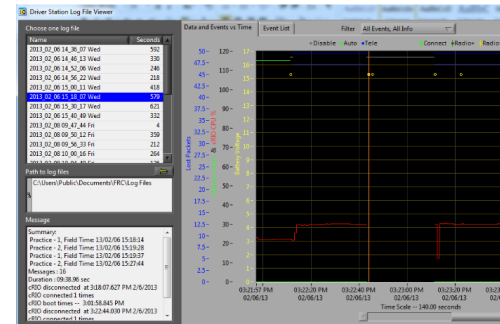
can instructions Installation FRC. in use for roboRIO a setup and format to used is tool This found be can tool this using roboRIO your imaging on instructions Additional [.here](#) found be [.here](#)

Only) (Windows Utility Configuration Radio FRC 7.8



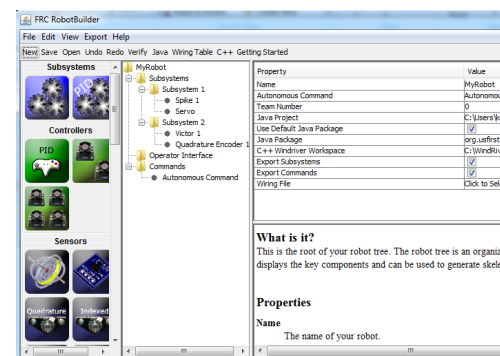
practice for radio standard the configure to used tool a is Utility Configuration Radio FRC The the of experience the mimic to settings network appropriate the sets tool This home. at use installer standalone a by installed is Utility Configuration Radio FRC The field. playing FRC [.here](#) found be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

Only) (Windows Viewer Log Station Driver FRC 7.9



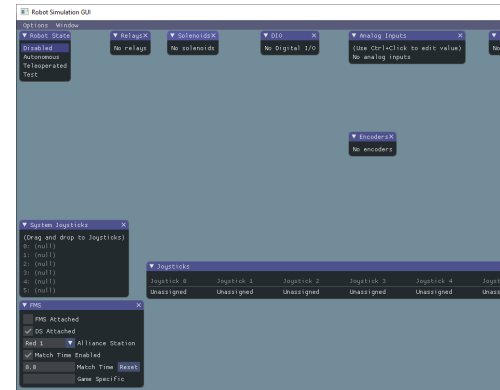
Station. Driver FRC the by created logs view to used is Viewer Log Station Driver FRC The happened what understanding for important information of variety a contain logs These Station Driver FRC the about information More match. FRC or session practice a during *here* found be can logs the understanding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

RobotBuilder 7.10



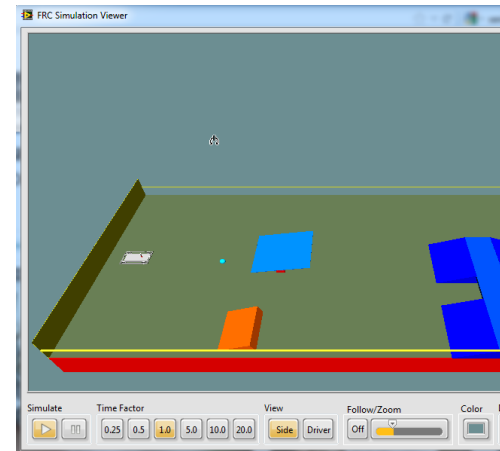
robot Based Command a of structuring and setup in aid to designed tool a is RobotBuilder enter to you allows RobotBuilder supported). currently not (Python Java or C++ for project what define and interface operator and subsystems robot your of components various the in structural generate then will RobotBuilder structure. tree graphical a in are commands your *here* found be can RobotBuilder about information More started. you get to code template *here* found be can architecture programming Based Command the about information More

7.11 סימולציית רובוט



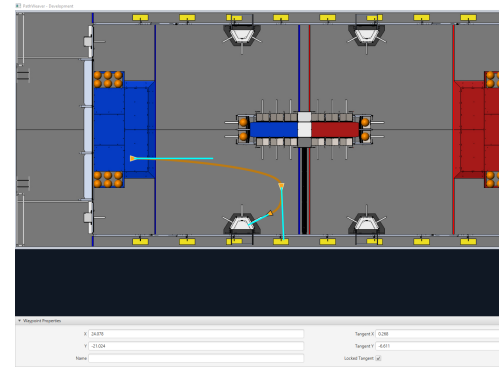
robot actual their verify to teams Python and C++, Java, for way a offers Simulation Robot from directly launched be can simulation This environment. simulated a in working is code more For on. movement robot's their visualize can users that field 2D a includes and Code VS .*section Simulation Robot*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

Only) (Windows Simulator Robot LabVIEW FRC 7.12



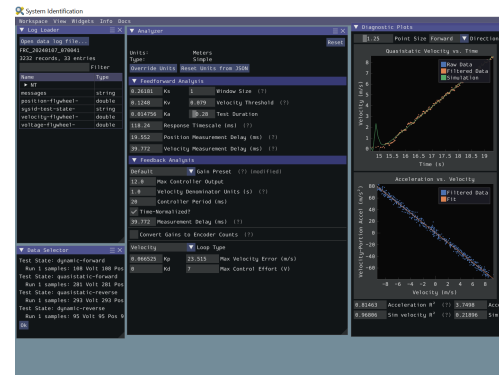
that environment programming LabVIEW the of component a is Simulator Robot FRC The and/or code test to environment simulated a in robot predefined a operate to you allows *here* found be can Simulator Robot FRC the using on Information functions. Station Driver Explorer. Project LabVIEW the in file Readme.html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

PathWeaver 7.13



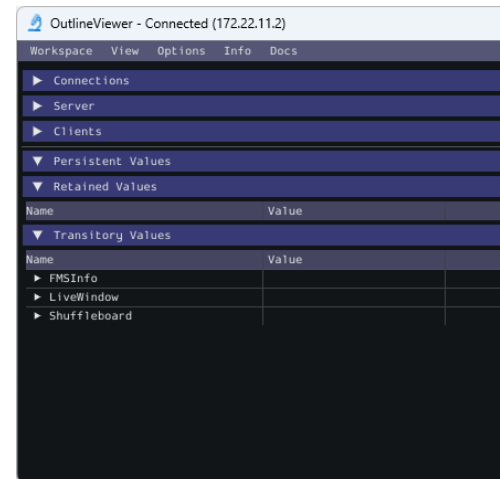
autonomous advanced for paths configure and generate quickly to teams allows PathWeaver robot their navigate quickly to team the allowing curves smooth have paths These routines. *.section PathWeaver* the see information more For field. the on points between

Identification System 7.14



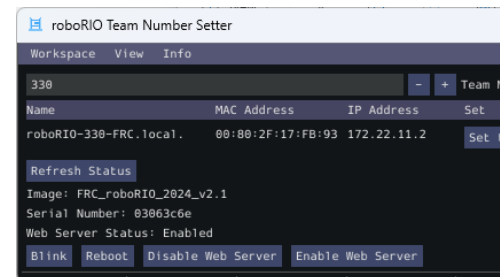
the describe to used be can that constants calculate automatically teams helps tool This following, trajectory simulation, robot like features in use for robot your of properties physical .*section Identification System* the see information more For control. PID and

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*

Setter Number Team roboRIO 7.16



team the set to used be can that utility platformcross- a is Setter Number Team roboRIO The team the setting for tool imaging roboRIO the to alternative an is It roboRIO. the on number *.section Setter Number Team roboRIO* the see information more For number.

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- three the of each for one WPILib, of versions three are There considerable A Python. for RobotPy and C++, for WPILibC and Java, for WPILibJ languages: not are features library - languages these between parityfeature- maintain to made is effort to able C++ the (with C++ and Java both for supported reasonably be can they unless added kept are names method and class the possible when and Python), for pybind by wrapped be supportedofficially- the for chosen were Python and C++, Java, similar.highly- or identical high- and industry both in ubiquity and abstractionof-level- appropriate their to due languages classes. science computer school

effort user increased of cost the at performance, endhigh- better offers C++ general, In user ensure to much do not does compiler C++ the and manually, handled be must (memory greater much but performance, lesser offer Python and Java runtime). at crash not will code and typos that ensure to program their test to care take should users Python convenience. users New/inexperienced interpreted. is Python as crashes, robot cause don't issues other Java. use to encouraged are

documentation and code Source 8.2

reponono- allwpilib the in is code source Java and C++ the - library sourceopen- an is WPILib can code source C++ and Java The repo.mono- mostrobotpy the in is code source python and directories: source WPILibC and WPILibJ the in found be

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

code source Java •

code source C++ •

[code source Python](#) •

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
RobotPy: and WPILibC and WPILibJ for pages documentation

[documentation Java](#) •

[documentation C++](#) •

[documentation Python](#) •



9.1 בעיות ידעות

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

9.1.1 בעיות פתוחות

macOS on Installer WPILib by updated isn't AdvantageScope

was "WPILibInstaller" saying uppop- a Installer, WPILib the running When **Issue:** version remains AdvantageScope and Mac. your on apps modifying from prevented WPILib or WPILib of version beta a when WPILib, upgrading when occurs issue This 3.0.1. macOS. on installed was 2024.1.1

Installer. WPILib the runre- and ~/wpilib/tools from AdvantageScope Delete **Workaround:**

disabled randomly Station Driver

against protect to 2024 in mechanisms safety tighter contains Station Driver The **Issue:** disable. to robot the cause this seen have teams Some issues. control

mechanisms. safety the tripping for causes potential multiple are There **Workaround:**

.FMS the to connected when robot the disable *not* will mechanisms safety new The :□□□□

controls safety the to update an contains 1 Patch 2024 Tools Game from 24.0.1 Station Driver version this with seen still is issue the If circumstances. certain in issue the resolve may that below. steps troubleshooting the with continue please installed,

The this. cause could that delays packet control for tools new has software Station Driver The the of screenshots post issue this experience that teams that requests team system control <https://github.com/wpilibsuite/allwpilib/issues/6174> to window Timing Station Driver

when not but wirelessly, operated is robot the when only happen this seen have teams Some mitigations: potential Some tether. ethernet or USB via operated

from away and robot the in (high location better a to radio robot the relocating Try 1.
metal). of amounts large or motors
bandwidth Mbps 4 the to margin have you ensure and *bandwidth robot's your Measure* 2.
limit
5 the As *.Analyzer WiFi like tool a using congested is environment FiWi-* the if See 3.
to radio robot the switching crowded, less is and channels more has spectrum WiFi ghz
communication. WiFi improve likely will ghz 5 at operate
computer. the for drivers FiWi- the Update 4.
router a up setting mode, point access in proximity close in robots multiple operate you If 5.
points access wireless of number the reduce will mode bridge in radios the operating and
communications improve may and
(such station driver the on running is that software to due happen this seen have teams Some
mitigations: potential Some Discord). or updater Autodesk as
computer station driver the Reboot 1.
background the in running is that software Close 2.
Practices Best Station Driver the Follow 3.
or processor roboRIO the oversaturates that code robot by caused be can this rare, While
of one with running try can you fail, steps troubleshooting other all If connection. network
occurs. still problem the if see to programs example WPILib the
<https://github.com/toitpost/pleasestationdriverwithinterferessoftwareidentifyyouifwpilibsuite/allwpilib/issues/6174>

Available is then RAM Free Less Reports Station Driver

This low. misleadingly is that RAM free reports screen diagnostic Station Driver The **Issue:**
relinquish then but memory, in data cache will Linux caches. memory of use Linux's to due is
memory reports only Station Driver The memory. more requests programs robot the when
caches. by used isn't that
proc// file the in available is program robot the to available memory true The **Workaround:**
.proc/meminfo/ cat run and ,*robot the to connect to ssh Use .meminfo*

kB 250152	MemTotal:
kB 46484	MemFree:
kB 126956	MemAvailable:

driver the what is (which MemFree then rather MemAvailable, as is look to value proper The
reporting). is station

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

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

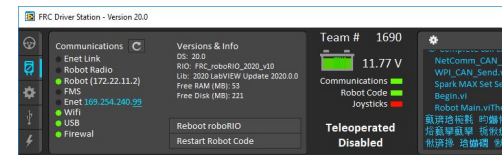
```
└─'2020.3.2'] version: 'edu.wpi.first.GradleRIO', [id: plugin requested apply not Could
    'edu.wpi.first.GradleRIO' id with plugin a provide not does it as └─
```

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

תווים סיניים ב-Log Station Driver

.Windows 7 64-bit 32-bit 64-bit 32-bit Station Driver- 32-bit Log- ,Windows 7 64-bit 32-bit 64-bit 32-bit Windows 7 64-bit 32-bit 64-bit 32-bit



:..... 2 :.....
 Notepad, 1.
 Windows- 2.

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:

- open Code VS leave but Code, VS in files all Close 1.
- exists it if folder, .vscode the in file c_cpp_properties.json Delete 2.
- Code. VS in command Intellisense" C++ "Refresh the Run 3.
- 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 Smartdashboard •
- upstart- on crash will Simulation Robot •

Pack Feature Media the Install **Solution:**

2024.2.1 WPILib in Fixed 9.1.2

Dependency Unresolved Reports Code Studio Visual

org.junit.platform dependency: Unresolved report will programs Java **Issue:** fail will tests unit use that Programs build.gradle. on launcherJava(0)-platform-junit explorer, Code Studio Visual the in red highlighted be to build.gradle causes This build. to squiggle. red a have to build.gradle in line plugins the and

the do it, fix To tests. unit running aren't you if ignored safely be can This **Workaround:** following:

powershell: in following the execute Windows On

```
https://repo.maven.apache.org/maven2/org/junit/jupiter/junit- Uri- Invoke-WebRequest
C:\Users\Public\wpilib\2024\ OutFile- jupiter/5.10.1/junit-jupiter-5.10.1.module →
maven\org\junit\jupiter\junit-jupiter\5.10.1\junit-jupiter-5.10.1.module →
https://repo.maven.apache.org/maven2/org/junit/junit-bom/5.10. Uri- Invoke-WebRequest
C:\Users\Public\wpilib\2024\maven\org\junit\ OutFile- 1/junit-bom-5.10.1.module →
junit-bom\5.10.1\junit-bom-5.10.1.module →
```

following: the execute Linux/macOS On

```
https://repo.maven.apache.org/maven2/org/junit/jupiter/junit-jupiter/5.10.1/ curl  
wpilib/2024/maven/org/junit/jupiter/junit-jupiter/~ o- junit-jupiter-5.10.1.module →  
5.10.1/junit-jupiter-5.10.1.module →  
https://repo.maven.apache.org/maven2/org/junit/junit-bom/5.10.1/junit-bom-5.10.1. curl  
wpilib/2024/maven/org/junit/junit-bom/5.10.1/junit-bom-5.10.1.module/~ o- module →
```

the up pick to it for Code VS in intellisense Java refresh to need you'll those, running After
command Workspace Server Language Java Clean the running by so do can You files. new
Code. VS in

1 Patch 2024 Tools Game in Fixed 9.1.3

tags and error print with issue internal Station Driver

and error print with issue internal print occasionally will Station Driver The **Issue:**
with intermixed side its on message a reports DS the when caused is message The .tags
code. robot affect not does and by caused not is it robot; the from messages
known no is There release. Tools Game next the in fixed be will This **Workaround:**
workaround.

2024 for New 9.2

This 2024. 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 2023 any ,*2024 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

- robots XRP* for support Added •
- features 17 Java supporting to default now Projects •
- and reliability improved for improvements networking NetworkTables Multiple •
- protobuf using support data structured and robustness
- performance improve should this roboRIO; the on default by GC Serial the uses now Java •
- programs robot most for usage memory reduce and

- libraries throughout usage memory caseworst- reduced and improvements Performance •
- yet) WPILib of part main the by used (not Java for system unit typesafe a Added •
- Test in LiveWindow Enabling See See default. by Mode Test in LiveWindow Disabled* •
- it. enable to *Mode*
- logging data with Replaced generation; project remove to rewritten been has SysId •
- program robot team within

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 12 macOS •

20.04, & 18.04 Ubuntu 11, macOS supported: longer no are Oses following The :□□□□□
Windows. bit32- any and 8.1, Windows 7, Windows

WPILib 9.2.3

הספרייה הכללית

Commands: •

- Commands to factory proxy Added -
- IdleCommand Added -
- twice end() calling RepeatCommand Fixed -
- decorators onlyIf() and onlyWhile() Added -
- ConditionalCommand.getInterruptBehavior() Implemented -
- callbacks onCommandInterrupt to parameter interruptor Added -
- Subsystem.defer() and ,Commands.defer() ,DeferredCommand Added -
- Commands.idle() to parameter requirements Add -
- order parameter CommandXboxController.leftTrigger() Java Fix -
- generic SelectCommand Java Make -
- lambda argzero- with finallyDo Add -

NetworkTables: •

- robustness and reliability improved for improvements Networking -
- checking aliveness connection dashboard basedweb- improve to subprotocol Added -
- usage) memory case worst (reduced improvements stability and Bugfixes -
- code robot from updated continuously values for behavior update Improved -
- behavior) button command (improves

Logging: Data •

MB 5 than less if logging stops (now conditions space free low of handling Improved - free)

1 RoboRIO on storage inbuilt- to logging about warning Added -

usage memory case worst Reduced -

DS by updated is it after time system use only to functionality rename file Improved -

captured now are started is log the before created publishers NT -

DataLogTool to functionality download without delete Add -

organization better for subdirectory logs to location log default Changed -

interfaces: Hardware •

faster ~10x now is timestamps Getting -

functionality temperature CPU and disable rail power Exposed -

clock base timestamp CAN Exposed -

timings LED addressable documented and Fixed -

behavior reset DutyCycleEncoder Fixed -

state *RSL* the read to function Added -

units microseconds uses now *PWM* *Raw* -

bitfield faults REVPH Fixed -

Java match to pulse per distance default Counter Fix C++: -

Math: •

code less have to internals estimator pose and odometry, kinematics, Refactored -

Odometry and Kinematics the via drivetrains custom implement can you duplication; class. PoseEstimator the and interfaces

per ms 2.33 (from construction faster for solver DARE faster a use controllers LTV -

roboRIO) a on C++ in ms 0.188 and Java in ms 0.432 to roboRIO a on solve

in doubles using by improvement speed 100x a got Rotation3d.rotateBy() (Java) -

vectors EJML of instead Quaternion

C++ the calling by improvement speed a got Pose3d.log() and Pose3d.exp() (Java) -

matrices EJML using of instead JNI through version

,getZ(),getY(),getX()(calculations angle Euler Rotation3d of accuracy Improved -

lock gimbal near yaw)pitch-roll- aka

overload Transform3d CoordinateSystem.convert() Fixed -

for instances new creating require not to API TrapezoidProfile Modified -

cases use like-ProfiledPIDController

support profile motion Exponential Added -

from creation Transform3d and Transform2d easier for overloads constructor Add -

coordinates Z Y, X,

to relative robot from convert to fromRobotRelativeSpeeds ChassisSpeeds Add -

relative field

a from example for kV, and kA from LinearSystem a create to method Add -

mechanism characterized

class SimulatedAnnealing Add -
 desaturate() MecanumDriveWheelSpeeds Fixed -
 number team assigned the get to function RobotController Added •
 units and docs GetMatchTime Updated •
 connection DS for wait to function Added •
 helper cleanup based reflection Added •
 yet) performed actually is preloading (no preloader class Java Added •
 planned) is replacement (no interfaces Gyro and Accelerometer Deprecated •
 3.11.2 to JSON C++ and 0.43.1 EJML and 4.8.0 OpenCV to Updated •
 class PS5Controller Add •
 dimensions field and origin AprilTagFieldLayout for accessors Add •
 handling output max Fix ArcadeDrive: •
 Controller Motor PWMSparkFlex Add •
 axes three all accessing allow ADIS16470: •
 method addFollower() PWMMotorController Use .MotorControllerGroup Deprecated •
 following. of method their use controllers motor CAN using if or
 The .MecanumDrive and DifferentialDrive to inteface functional Added •
 with coupling reduce to future the in removed be may interface MotorController
 method following the objects, MotorController passing of Instead libraries. vendor
 used: be can expressions lambda or references
 DifferentialDrive(m_leftMotor::set, new = drive DifferentialDrive Java: -
 m_rightMotor::set);
 m_leftMotor. { output) m_drive{[&](double frc::DifferentialDrive C++: -
 } }; m_rightMotor.Set(output); { output) [&](double }, Set(output);

Changes Breaking

example See [value.optional](#) return to `DriverStation.getAllianceStation()` Changed •
 usage
 an of instead class base a now is (Command Command into CommandBase Merged •
 interface)
 consistent order scheduling command made breaking: Potentially •
 functions: and classes command deprecated various Removed •
 (use Command.perpetually() and PerpetualCommand -
 instead) repeatedly()/RepeatCommand
 Command.SetGrouped() and only), (C++ Command.IsGrouped() ,CommandGroupBase -
 Commands to moved been have factories static the only); (C++
 Command.withInterrupt() -
 ProxyScheduleCommand -
 instead) Trigger (use Button -

**,whileActiveOnce() ,whenActive() functions: Trigger styleOld-
 ,toggleWhenActive() ,whenInactive() ,whileActiveContinuous()
 variants; False and True both has type binding Each .cancelWhenActive()
 here: listed are variants True the only brevity, for**

rising on schedule):whenPressed() and whenActive() (replaces onTrue() *
 edge.

cancel edge, rising on schedule):whileActiveOnce() (replaces whileTrue() *
 edge. falling on

schedule edge, rising on):toggleWhenActive() (replaces toggleOnTrue() *
 scheduled. if cancel and unscheduled if

described better is which case use niche fairly a is this :cancelWhenActive() *
 condition end an as)Trigger.rising()(edge rising trigger's the having as
).Command.until() (using command the for

no- the on relied this common, however :whileActiveContinuously() *
 more The command. scheduledalready- an scheduling of behavior op
 is edge falling the before ends it if command the repeat to way correct
 only the - RunCommand a or RepeatCommand/Command.repeatedly() using
 to likely more is that but interrupted, is command the if is difference
 the achieve than other each canceling perpetually commands two in result
 like binding schedulingblindly- a implementing Manually behavior. desired
 intuitive. be not might though possible, still is whileActiveContinuously()

CommandScheduler.clearButtons() -

only) (Java CommandScheduler.addButtons() -

instead) ProxyCommand (use SelectCommand of constructor supplier Command -

instead) isEnabled() (use function Compressor.enabled() Removed •

camera the on setResolution() (use function CameraServer.setSize() Removed •
 instead) object

methods SPI broken and deprecated Removed •

SlewRateLimiter to constructor argument2- Removed •

existed) already frc::PIDController(alias frc2::PIDController Removed •

exception unchecked an throws now loadAprilTagFieldLayout() use, of ease For •
 exception checked a of instead

height starting for constructor ElevatorSim for parameter new Add •

gains PID negative on error Report •

סימולציה 9.2.4

robot with consistent be to values Raw and Position, Speed, simulation PWM Unified •
 behavior

API DutyCycleEncoderSim Expanded •

sims mechanism of state starting set to ability Added •

sims physics to overloads SetState specificmechanism- Added •

SmartDashboard 9.2.5

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

- the Fixes file. save the processing after occurs always now robot the to Connection •
- chooser a before happens robot the to connection if up show don't Choosers that problem •
- processed is file save the in •
- from them creating when widget subsystem containing to widgets LiveWindow Added •
- file save the •
- SmartDashboard. with SmartDashboard on Scheduler the putting handles properly Now •
- putData() •

GUI Simulation / OutlineViewer / Glass 9.2.6

- background Field2D for images field standard Include •
- views NetworkTables in support array Enhanced •
- plots glass to selector color background Added •
- settings NT for tooltips Added •
- message bar title Improved •
- monitor second on window maximized a loading Fixed •
- workspace existing clearing when crash Fixed •
- closes window after closing not dialogs file Fixed •
- support ProfiledPIDController add •

GradleRIO 9.2.7

- default by GC Serial Java Use •
- usage) memory startup (reduces arguments Java from AlwaysPreTouch Remove •
- XRP for support Added •
- vendor year prior using (prevents frcYear correct set dependencies vendor that Enforces •
- dependencies) •
- 8.4 Gradle to Upgraded •
- issues causes that as OneDrive, in isn't project that Check •

Installer One in All WPILib 9.2.8

- 1.85.1 Code VS to Update •
- 1.26.0 javaext 1.19.1, cpptools updates: extension Code VS •
- download/install Code VS for files zip separate Use •
- 8 .NET use to Update •
- installer the by bundled now is AdvantageScope •

Code Studio Visual הרחבת 9.2.9

- to possible it makes This file. jar deployed the into bundled now is code source Java •
- program. robot deployed a from code source recover •
- support XRP Added •
- issues causes that as OneDrive, in created isn't project that Check •

RobotBuilder 9.2.10

- POVButton Add •
- aliasing constants Fixed •
- PH REV of addition for export wiring and references PCM Updated •

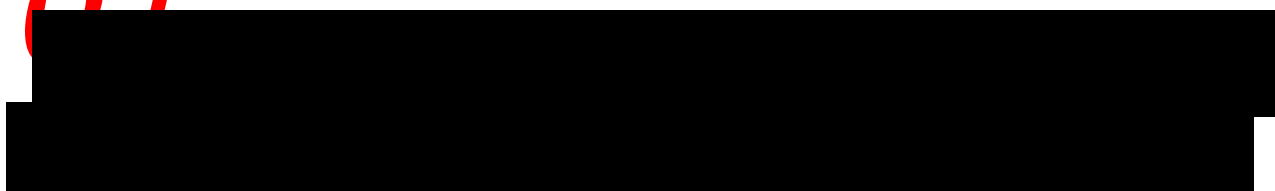
SysId 9.2.11

- program robot team within logging data with Replaced generation; project Removed •

Teams Returning for Start Quick 9.3

- current the to update to need that teams veteran for point launching a as serves section This software. year's •
- season. the for *issues known* and *changelog* the through read teams **all** that advised is It •
- only) teams (LabVIEW *LabVIEW Install* 1. •
- Tools Game Install* 2. •
- only) teams C++ / (Java *WPILib Install* 3. •
- libraries party third Update* 4. •
- 2 roboRIO or 1 roboRIO Reimage* 5. •
- only) teams C++ / (Java *project robot Import* 6. •
- changelog* the in described changes the on based software Update 7. •

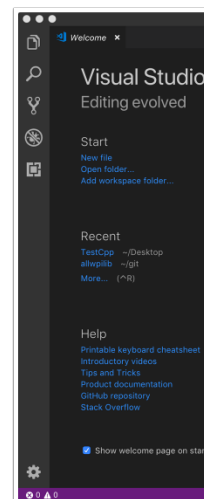
01



10.1 יסודות Code Studio Visual והרחבת WPILib

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



המסך הראשוני של Visual Studio Code, המכונה 'מסך הפתיחה', מציג את המערכת ואת האפשרויות השונות. המסך כולל את האפשרויות הבאות: 'Start' (הפעלה), 'Recent' (היסטוריה) ו-'Help' (עזרה). המסך גם כולל את האפשרות 'Show welcome page on start' (הצגת מסך הפתיחה על מנת להתחיל).

המסך הראשוני של Visual Studio Code, המכונה 'מסך הפתיחה', מציג את המערכת ואת האפשרויות השונות. המסך כולל את האפשרויות הבאות: 'Start' (הפעלה), 'Recent' (היסטוריה) ו-'Help' (עזרה). המסך גם כולל את האפשרות 'Show welcome page on start' (הצגת מסך הפתיחה על מנת להתחיל).

10.1.2 ממשק משתמש

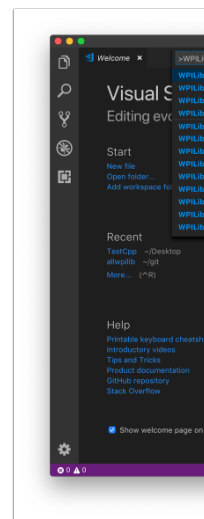
הממשק המשתמש של Visual Studio Code (VS Code) הוא ממשק משתמש פשוט וקל לשימוש. הממשק כולל מסלול עבודה אחד, המכיל מסלול קוד, מסלול תצוגה ופנל פקודות. הממשק תומך גם במערכת FRC. הממשק Code Studio

10.1.3 לוח הפקודות

הממשק המשתמש של Visual Studio Code (VS Code) כולל מסלול עבודה אחד, המכיל מסלול קוד, מסלול תצוגה ופנל פקודות. הממשק תומך גם במערכת FRC. הממשק Code Studio

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10.1.4 הרחבת WPILib



הממשק המשתמש של Visual Studio Code (VS Code) כולל מסלול עבודה אחד, המכיל מסלול קוד, מסלול תצוגה ופנל פקודות. הממשק תומך גם במערכת FRC. הממשק Code Studio

- הממשק המשתמש של Visual Studio Code (VS Code) כולל מסלול עבודה אחד, המכיל מסלול קוד, מסלול תצוגה ופנל פקודות. הממשק תומך גם במערכת FRC. הממשק Code Studio
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10.2 פקודות WPIlib ב-Code Studio Visual

הנה פקודות Code VS שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות:

הנה פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: Ctrl+Shift+P פקודות, הנה פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות:

GradleRIO פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: **- Code Robot Build WPIlib:**

הנה פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: **- 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

הנה פקודות WPIlib פונקציות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: **- tasks running currently Cancel WPIlib:**

הנה פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: **- Setting Deploy On Save Auto Change WPIlib:**

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. הנה C++ הנה פקודות שיש להן WPIlib פונקציות שונות כדי להקל על העבודה עם הקוד. הנה פקודות: **- 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:** deployment 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.- Deploy - **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
- you help to wizard a Open - **Project Gradle 20232020- WPILib a Import WPILib:** •
Further 2022.2020- from project Gradle Code VS existing a from project new a create
project gradle importing at is documentation
- (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
- 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
- Number Team Set WPILib:** •
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

```

;edu.wpi.first.wpilibj.TimedRobot import
    /**
    _functions the call to and class, this run automatically to configured is VM The *
    to corresponding →
    _of name the change you If documentation. TimedRobot the in described as mode, each *
    or class this →
    _build.gradle the update also must you project, this creating after package the *
    the in file →
    project. *
    */
    { TimedRobot extends Robot class public

```

page) next on (continues

(□□□□ □□□□ □□□□)

```

    /**
     * for used be should and up started first is robot the when run is function This *
     * any ↩
     * code. initialization *
     */
    @Override
    {} { ()robotInit void public
    }

    @Override
    {} { ()robotPeriodic void public
    }

    @Override
    {} { ()autonomousInit void public
    }

    @Override
    {} { ()autonomousPeriodic void public
    }

    @Override
    {} { ()teleopInit void public
    }

    @Override
    {} { ()teleopPeriodic void public
    }

    @Override
    {} { ()disabledInit void public
    }

    @Override
    {} { ()disabledPeriodic void public
    }

    @Override
    {} { ()testInit void public
    }

    @Override
    {} { ()testPeriodic void public
    }

    @Override
    {} { ()simulationInit void public
    }

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

```

C++

```

Robot.h" include#
5
6
    {} { ()Robot::RobotInit void
7
    {} { ()Robot::RobotPeriodic void
8
    {} { ()Robot::AutonomousInit void
9
    {} { ()Robot::AutonomousPeriodic void
10
11
    {} { ()Robot::TeleopInit void
12
    {} { ()Robot::TeleopPeriodic void
13
14

```

page) next on (continues

(0000 0000 0000)

```

15         }{ ()Robot::DisabledInit void
16     }{ ()Robot::DisabledPeriodic void
17
18         }{ ()Robot::TestInit void
19     }{ ()Robot::TestPeriodic void
20
21         }{ ()Robot::SimulationInit void
22     }{ ()Robot::SimulationPeriodic void
23
24         RUNNING_FRC_TESTS ifndef#
25             { ()main int
26         ();>Robot StartRobot :frc return
27             }
28         endif#
29

```

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 :0000
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 :0000
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.

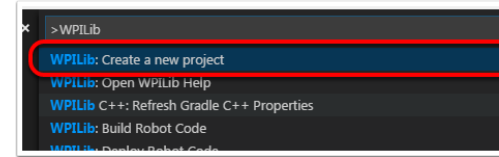
Class Base a Using Not

`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 flow. program their over control absolute have to

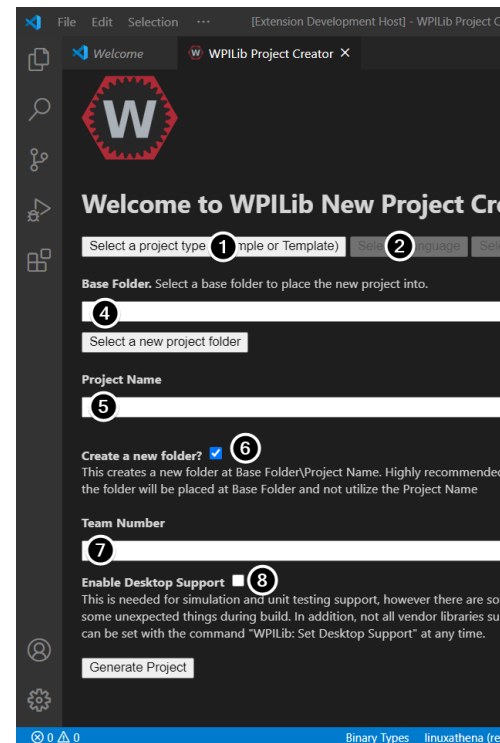
are they unless program robot a of method `main()` the modify *not* should Users :`|||||`
doing. are they what of sure absolutely

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

1. **Type Project**: The kind of project we wish to create. Examples include TimedRobot, TimedRobot, and TimedRobot. Each of these projects has a specific template provided by WPILib. Additionally, there are base robot classes that exist, such as *basedCommand*, which include additional features but are based on the TimedRobot class. The robot program is highly recommended for new teams.
2. **Language**: This is the language (C++ or Java) that will be used for this project.
3. **Folder Base**: If this template specifies the type of template that will be used.
4. **Location Project**: This determines the folder in which the robot project will be located.
5. **Name Project**: The name of the robot project. This also specifies the name of the project. If the 'Create New Folder' checkbox is checked, a new folder will be created.

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

0000000 00000000 0000000 000000 000000 ,00000000 0000 0000000 0000 **:Number Team** 7.
.0000 00 Deploying 000000 000 0000000

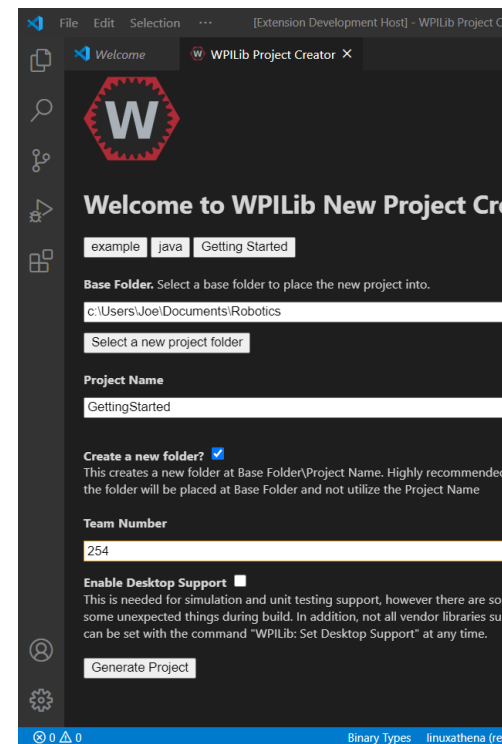
supports WPILib While simulation. and test unit Enables **:Support Desktop Enable** 8.
then desktop, support not do libraries If not. may libraries software party third this,
testing unit unless unchecked left be should It crash. may or compile not may code your
it. support libraries all and needed is 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 **:00000**
screen.

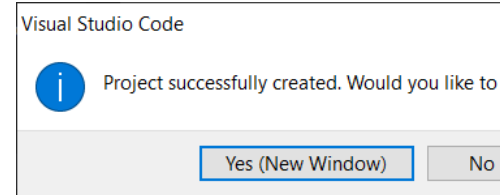
interferes caching OneDrive’s as supported not is OneDrive on projects Creating **:000000**
folders Desktop and Documents the put installations Windows Some system. build the with
default. by OneDrive on

below. shown is selected are options all after example An

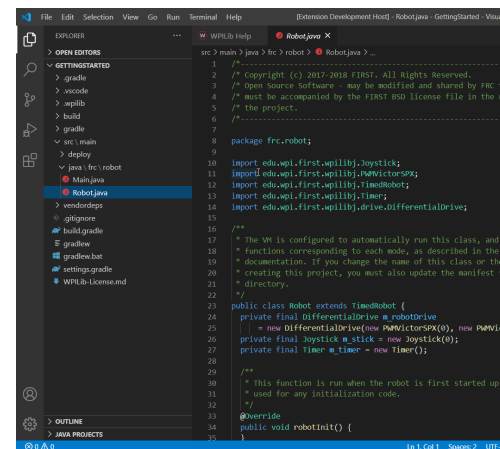


10.3.3 פתיחת הפרויקט החדש

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

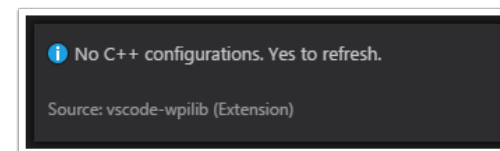


will file the on clicking Double left. the on hierarchy project the see will we opened Once editor. the in file that open



10.3.4 קונפיגורציות 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 oppop- a get should we IntelliSense. up set to "Yes"



10.4 ספריות צד שלישי

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

Dependencies? Vendor Are What 10.4.1

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

Dependencies Vendor Managing 10.4.2

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\2023 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 VI. other any like just above mentioned folder

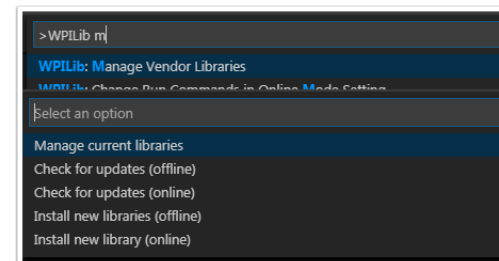
Python - Work? It Does How

python) pure (if PyPI to uploaded and wheels Python into packaged are libraries party Third the adding by either dependencies as them enable can Users artifactory. WPILib's and/or dependency explicit an adding by or (recommended) robotpy_extras to name component is sync robotpy when downloaded are dependencies The .requires in package PyPI the for executed. is deploy robotpy when roboRIO the on installed and executed,

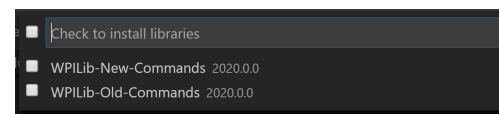
Libraries Installing

Java/C++

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*

(Offline) Updates for Checking

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

(Online) Updates for Checking

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

Dependency Library a Removing

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.

Python

additional add can You .pyproject.toml in specified are dependencies project RobotPy All by: either dependencies specificvendor-

robotpy_extras to name component the Adding •

requires to name package PyPI the Adding •

:□□ □□□

usage pyproject.toml

ספריות 10.4.3

Libraries WPILib

Library Command

WPILib the by installed is It library. vendor a into split been has *library command* WPILib The installation. offline for installer

Java/C++

Library Command New

Python

```
v2-commands-robotpy or robotpy[commands2] package: PyPI •
["commands2"] = robotpy_extras :pyproject.toml In •
```

Library Romi

the in used are that classes helper several contain to created been has Library Romi A example. RomiReference

Java/C++

.Vendordep Romi

Python

```
romi-robotpy or robotpy[romi] package: PyPI •
["romi"] = robotpy_extras :pyproject.toml In •
```

Library XRP

the in used are that classes helper several contain to created been has Library XRP An example. XRReference

Java/C++

.Vendordep XRP

Python

```
xrp-robotpy or robotpy[xrp] package: PyPI •
["xrp"] = robotpy_extras :pyproject.toml In •
```

Libraries Vendor

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.

2.0, Pigeon IMU, Pigeon CAnDle, CAnifier, CAnCoder, Contains - Framework Phoenix CTRE configuring for program Tuner Phoenix and Libraries SPX Victor and SRX, Talon FX, Talon devices CAn CTRE

Java/C++

electronics.com/release/com/ctre/phoenix6/-https://maven.ctr (v6): Phoenix latest.json-frc2024-latest/Phoenix6

electronics.com/release/com/ctre/phoenix/-https://maven.ctr (v5): Phoenix latest.json-frc2024-Phoenix5

support, v5 Phoenix need also you If library. (v6) Phoenix the use should users All :☐☐☐☐ library. vendor v5 the install additionally

Python

package: Vendor's

phoenix6 or robotpy[phoenix6] package: PyPI •

["phoenix6"] = robotpy_extras :pyproject.toml In •

packages: Community

ctre-robotpy or robotpy[phoenix5] package: PyPI •

["phoenix5"] = robotpy_extras :pyproject.toml In •

and Canandcoder the including devices Redux all for Library - ReduxLib Robotics Redux Canandcolor

Java/C++

https://frcsdk.reduxrobotics.com/ReduxLib_2024.json

Python

available yet Not

motor/controller Venom the including devices PWF all for Library - Driver Fusion With Playing

Java/C++

<https://www.playingwithfusion.com/frc/playingwithfusion2024.json>

Python

packages: supportedCommunity-
playingwithfusion-robotpy or robotpy[playingwithfusion] package: PyPI •
["playingwithfusion"] = robotpy_extras :pyproject.toml In •
Fusion Sensor and Micro,NavX- MXP,NavX- for Libraries - Labs Kauai

Java/C++

<https://dev.studica.com/releases/2024/NavX.json>

Python

packages: supportedCommunity-
navx-robotpy or robotpy[navx] package: PyPI •
["navx"] = robotpy_extras :pyproject.toml In •
and MAX, SPARK Flex, SPARK including devices REV all for Library - REVLlib Robotics REV
V3 Sensor Color

Java/C++

2024.json-metadata.revrobotics.com/REVLlib-<https://software>

Python

packages: supportedCommunity-
rev-robotpy or robotpy[rev] package: PyPI •
["rev"] = robotpy_extras :pyproject.toml In •

ספריות מהקהילה

software CV PhotonVision for Library - PhotonVision

Java/C++

[https://maven.photonvision.org/repository/internal/org/photonvision/
1.0.json-json-json/1.0/photonlib-photonlib](https://maven.photonvision.org/repository/internal/org/photonvision/1.0.json-json-json/1.0/photonlib-photonlib)

Python

photonlibpy package: PyPI •
["photonlibpy"] = requires :pyproject.toml In •
PathPlanner for Library - PathPlanner

Java/C++

<https://3015rangerrobotics.github.io/pathplannerlib/PathplannerLib.json>

Python

pathplannerlib package: PyPI •
["pathplannerlib"] = requires :pyproject.toml In •
Choreo by generated trajectories following and reading for Library - ChoreoLib

Java/C++

<https://sleipnirgroup.github.io/ChoreoLib/dep/ChoreoLib.json>

Python

available Not
configuration any of Drives Swerve for Library - YAGSL

Java

Lib/yagsl/yagsl.json-<https://broncbotz3481.github.io/YAGSL>

Python

available Not

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

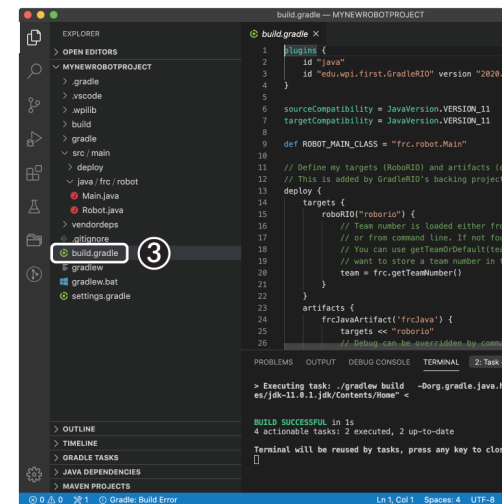
of: one do project, robot a deploy and build To

Code" Robot "Build enter/select and Palette Command the Open 1.

Code VS the of corner right top the in ellipses the by indicated menu shortcut the Open 2.

Code" Robot "Build select and window

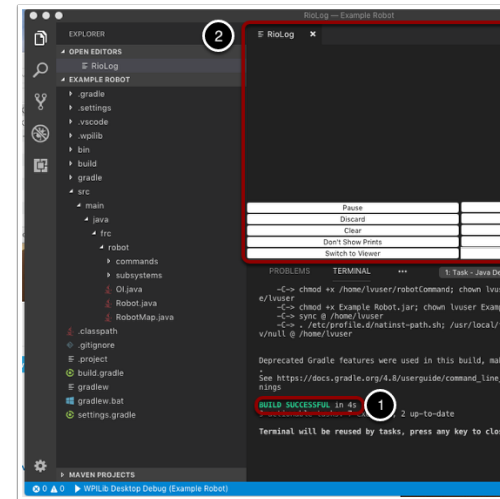
Code" Robot "Build select and hierarchy project the in file build.gradle the on clickRight- 3.



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



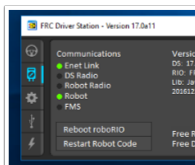
Output Console Viewing 10.6

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 Code. VS in plugin Riolog the and Station Driver FRC the in Viewer

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

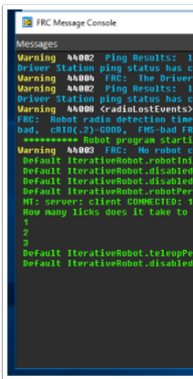
Viewer Console 10.6.1

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

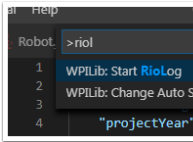


gear The green. in program robot our from output the displays window Viewer Console The displayed. messages of level the set and window the clear can right top the in

Plugin Code VS Riolog 10.6.2

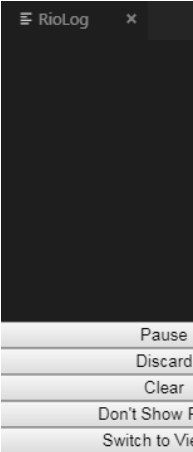
VS in output NetConsole the view to used be can that view Code VS a is plugin Riolog The FRC1511). Stoeckl, Manuel version: Eclipse original the for (credit Code

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

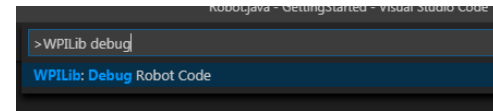
Program Robot a Debugging 10.7

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

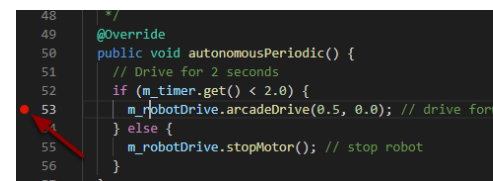


Command the open to *Item Menu WPILib* the on click or WPILib type and Ctrl+Shift+P Press item menu Code Robot Debug the select and Debug Type populated. pre- WPILib with palette debugging. begin and roboRIO the to download will code The debugging. start to

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.out System.
```

```
;"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

Code Robot Year's Last Importing 10.8

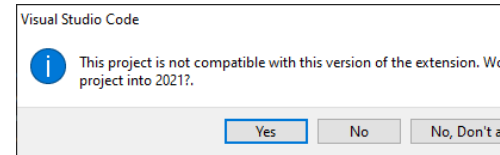
years previous a for files build the update to necessary is it project, the in changes to Due vendor year's last since again, libraries vendor import to necessary also is It project. Gradle projects. year's this with compatible be to updated be must libraries

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

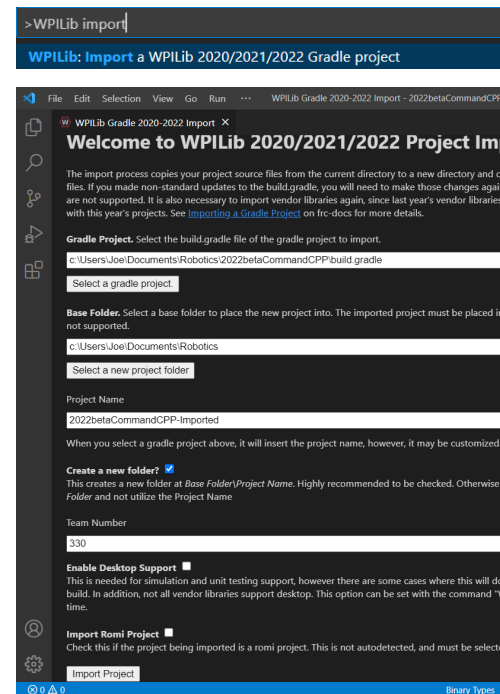
new a to directory current the from files source project your copies process import The :
the for code the updates it Additionally, files. gradle the regenerates completely and directory you ,build.gradle the to updates standardnon- made you If 2023. in made changes package supported. not are upgrades 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



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 20232020-



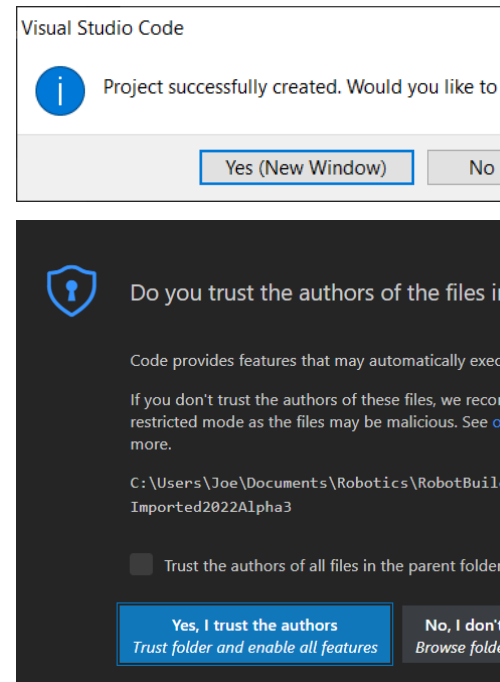
of process the to similar is This window. Importer Project WPILib the with presented be You'll contains window This below. shown are steps the and window the and project new a creating elements: following the

1. build.gradle the select should Users imported. be to project the Selects **:Project Gradle** project. gradle the of directory root the in file
2. located. be will project robot the which in folder the determines This **:Location Project**
3. the that name the specifies also This project. robot the of name The **:Name Project** a be must This checked. is box Folder New Create the if given be will folder project location. original the from directory different
4. 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 checked. not is this and empty
5. 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

enabled. is support test unit and simulation checked, is this If **:Support Desktop Enable** 6.
 addition, In things. unexpected some do will this where cases some are there However,
 do. libraries all not which support desktop need libraries vendor all
 gradle Romi the using imported is project the checked, is this If **:Project Romi Import** 7.
 projects. Romi for checked be only should This template.

interferes caching OneDrive's as supported not is OneDrive on projects Creating : folders Desktop and Documents the put installations Windows Some system. build the with default. by OneDrive on

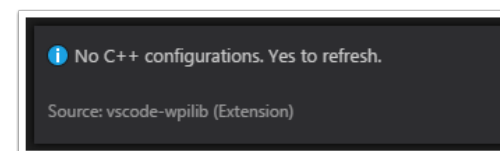
then can You directory. project new the into copied and upgraded be will project gradle The
the using later it open or below uppop- the using immediately project new the open either
shortcut. macOS) for Command+O (or Ctrl+O



.authors the trust I Yes Click

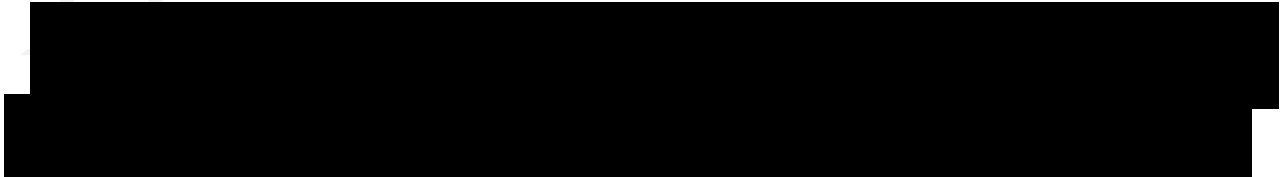
Only) (C++ Configurations C++

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 uppopen- a get should you IntelliSense. up set to Yes



Libraries Party 3rd

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



Dashboard a Choosing 11.1

your of operation the about information display and retrieve to used program a is dashboard A programmer and driver need: may teams that dashboards of types main two are There robot. purposes. both accommodate to try will dashboards Some dashboards.

Dashboard Driver 11.1.1

robot. the from information get to dashboard this use will team drive the competition During by accomplished best often is This instantly. information key conveying on focus should It this use also will teams Most elements. visual understand to easy and colorful, large, using routine. autonomous their select to dashboard

another is there if and dashboard this on be to *needs* what consider carefully to caution Take (especially team drive the of members Any information. that communicating of way better to *LEDs* Using match. the from away focus their takes dashboard the at looking driver) the information useful communicate to way a of example good a is robot your of state the indicate robot. the off eyes their take to having without driver the to

Dashboard Programming 11.1.2

supports It robot. the from data analyzing and code debugging for designed is dashboard This utility and function prioritizing simultaneously, information of variety wide a of monitoring the visualization data complex includes often functionality This use. of ease or simplicity over amount overwhelming an is there where scenarios In periods. extended across graphing and past examine to capability The challenging. becomes analysis timereal- review, to data of data log may dashboards some While beneficial. extremely be to proves it replay and data process. the simplifies class DataLog the using *telemetry roboton-* them, to transmitted

newest) to (oldest Dashboards Specific 11.1.3

However, teams. FRC aiding of history long a have Shuffleboard and SmartDashboard :□□□□ improvements. or fixes bug receiving not are so them maintain to person a have not do they certain under machines some on issues performance experience may Shuffleboard Notably, reviewed. be will contributors external from PRs scenarios.

features of lot a provides and use to easy - Programming) / (Driver *Dashboard LabVIEW* It feedback, joystick and selection, autonomous streams, camera like: box the of out straight *used be can* it While project. Dashboard new a creating by LabVIEW using customized be can be can which Shuffleboard or SmartDashboard prefer generally they teams, C++ or Java by language. respective their in customized

computer few relatively uses that dashboard efficient and simple - (Driver) *SmartDashboard* it but has, Shuffleboard features the of some or look fancy the have not does It resources. station driver the down bogging without widgets of variety a with data tables network displays computer.

displays It dashboard. customizable easily and straightforward - (Driver) *Shuffleboard* with controlled and positioned be can that widgets of variety a using data tables network advanced and playback, / recording tabs, like: features extra many includes It code. robot widgets. custom

of that to similar extremely is GUI Its tool. visualization data robot - (Programming) *Glass* rather tool programmer's a as used be to meant is it state, current its In *.GUI Simulation* the performance high on focus a with environment, competition a in dashboard proper a than plotting. time real

data and review/analysis, log diagnostics, robot - (Programming) *AdvantageScope* Log Station Driver and)wpilog.(Log Data WPILib the reads It application. visualization viewing. data robot live plus formats, file)dsevents. / dslog.(

Dashboards Party Third 11.1.4

standalone a as installed be can that dashboard basedweb- A - (Driver) *Components Web FRC* solutions. dashboard custom for package JavaScript a as or application,

meant is It 353. Team by made alternative Shuffleboard modern and simple - (Driver) *Elastic* draggable features It testing. for used be also can but competition for dashboard a as serve to widgets. card resizable and

dashboard. footprintlow- performance,high- reliable, as described - (Driver) *QFRCDashboard* possible. as resources few as use to designed specifically been has QFRCDashboard

Shuffleboard 11.2

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

Started Getting - Shuffleboard 11.2.1

Shuffleboard of Tour

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

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

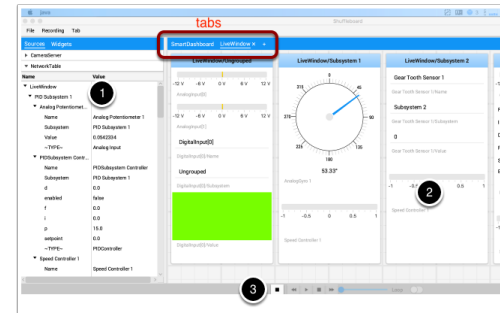
graph a onto data drag can you and **data numeric for available are widgets Graph** •
scale. same the on and time same the at points multiple see to

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.

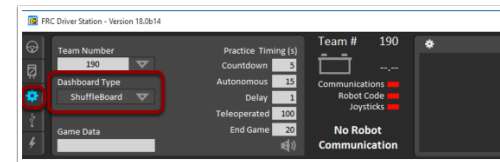
from values choose can you which from sources data are Here **area: Sources** 1.
tabs the of one into value a dragging by display to sources other or NetworkTables

this In sources. other or robot the from displayed is data you where is This **panes: Tab** 2.
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

the playback can you where controls likemedia- of set **controls: Record/playback** 3.
data historical see to session current



Shuffleboard Starting



ways: four of one in Shuffleboard start can You

“Dashboard the setting by starts Station Driver the when it start automatically can You 1.
above. picture the in shown as tab settings the in Shuffleboard to Type”

folder *tools WPILib YEAR* the in icon Shuffleboard the clickingdouble- by it run can You 2.
Desktop. Windows the on

“WPILib” type and Ctrl+Shift+P pressing by Code Studio Visual with from start can You 3.
Select Palette. Command WPILib the launch to right top the in logo WPILib the click or
.Shuffleboard select then ,Tool Start

on vbs. is XXX (where file shuffleboard.XXX the on clickingdouble- by it run can You 4.
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

on shuffleboard command: the typing by line command the from it start can You 5.
~/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

```
(());get joystick1. , "value X Joystick" (putNumber SmartDashboard.
```

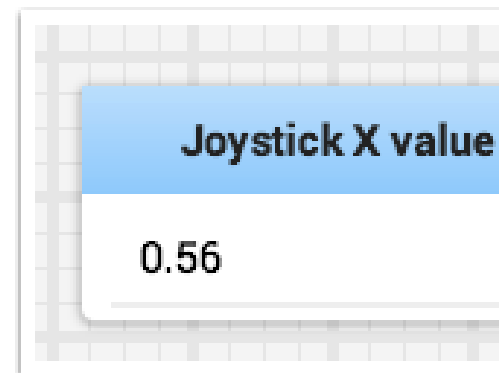
C++

```
joystick1.getX()); , "value X Joystick" PutNumber (:: SmartDashboard :: frc
```

PYTHON

```
SmartDashboard import wpilib from  
getX()) joystick1 , "value X Joystick" putNumber ( SmartDashboard
```

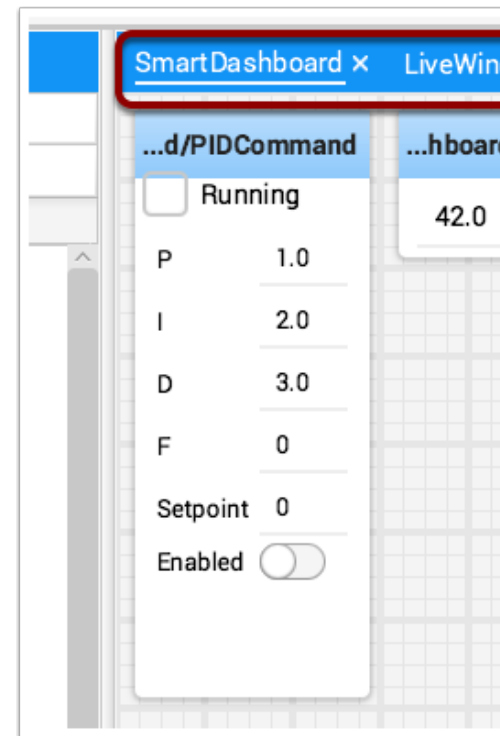
of value X the of value a and value" X "Joystick label the with displayed field a see to to sent be will value joystick new a executed, is code of line this time Each joystick. the an see to want you whenever value joystick the write must you Remember: Shuffleboard. value the display only will program 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"(putBoolean SmartDashboard.
        ());getPositionbridgeTipper. , "Angle Bridge"(putNumber SmartDashboard.
        ());getSwerveAngle drivetrain. , "Angle Swerve"(putNumber SmartDashboard.
        ());getLeftEncoder drivetrain. , "Encoder Drive Left"(putNumber SmartDashboard.
        ());getRightEncoder drivetrain. , "Encoder Drive Right"(putNumber SmartDashboard.
        ());getCurrentAngle turret. , "Pot Turret"(putNumber SmartDashboard.
        ());getAverageVoltage turret. , "Voltage Pot Turret"(putNumber SmartDashboard.
        ());getRPM shooter. , "RPM"(putNumber SmartDashboard.
    }
    
```

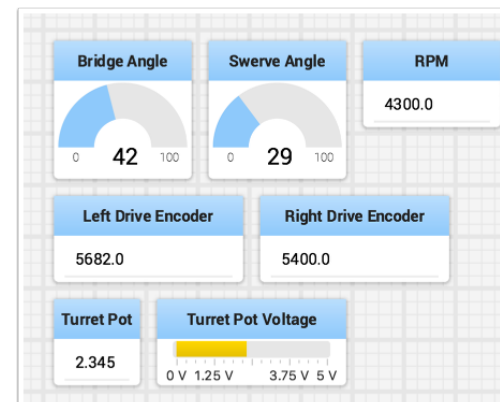

C++

```
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
```

PYTHON

SmartDashboard import wpilib from

```
atBridge() bridgeTipper , "Limit Bridge"putBoolean( SmartDashboard
getPosition() bridgeTipper , "Angle Bridge"putNumber( SmartDashboard
getSwerveAngle() drivetrain , "Angle Swerve"putNumber( SmartDashboard
getLeftEncoder() drivetrain , "Encoder Drive Left"putNumber( SmartDashboard
getRightEncoder() drivetrain , "Encoder Drive Right"putNumber( SmartDashboard
getCurrentAngle() turret , "Pot Turret"putNumber( SmartDashboard
getAverageVoltage() turret , "Voltage Pot Turret"putNumber( SmartDashboard
getRPM() shooter , "RPM"putNumber( SmartDashboard
```

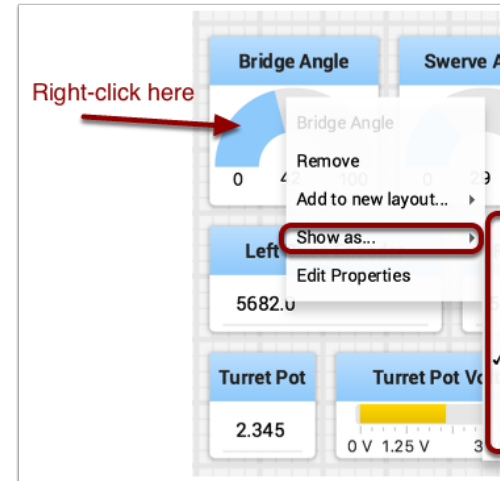


correct the calling simply by Shuffleboard to values String or Numeric, Boolean, write can You is code additional no data, the of value the and name the including and type the for method required.

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

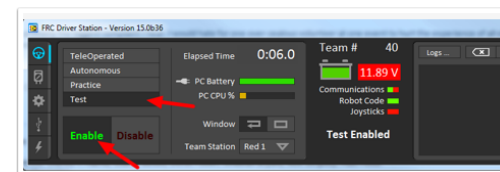
change often can you Shuffleboard to sent being values the of type data the on Depending displayed were values number that see can you example previous the In format. display the the for view voltage a as and angles, represent better to dial a numbers, decimal either as as...". "Show select and tile 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

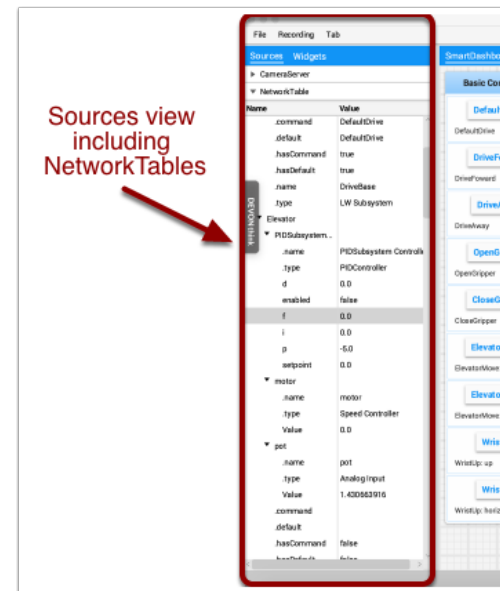
mode test Setting



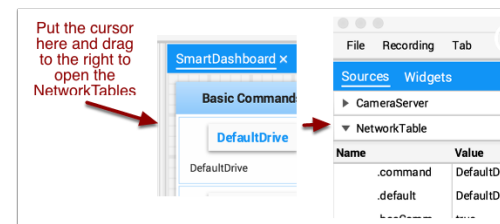
"Enable" setting and button "Test" the on clicking by Station Driver the in Mode Test Enable and actuators any of status the display will Shuffleboard this, doing When robot. the on subsystem. by organized program your by used sensors

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 the 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

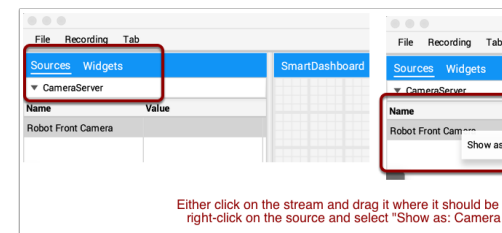


Streams Camera Displaying

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

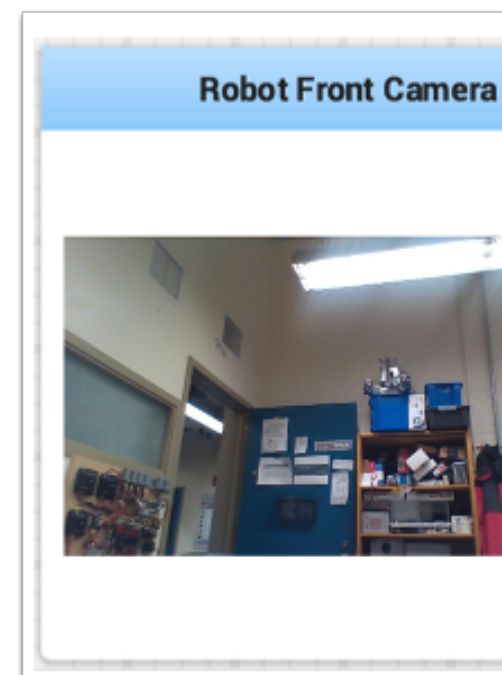
Stream Camera a Adding

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

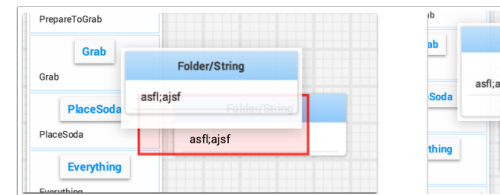


widgets with Working

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,

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

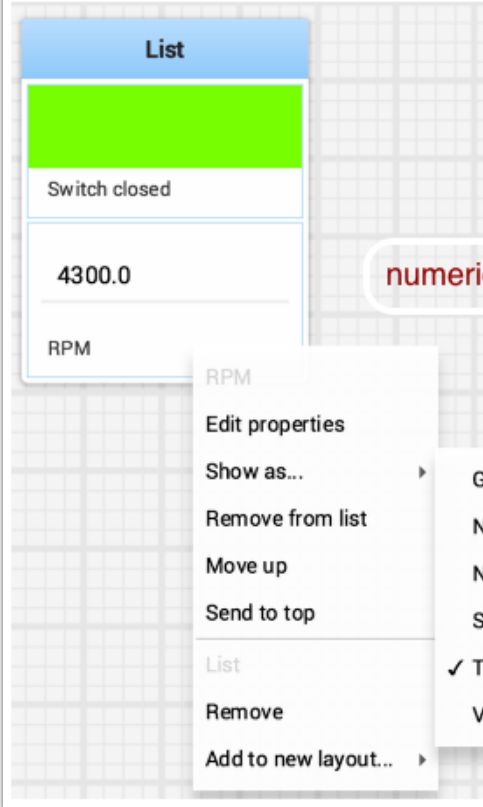
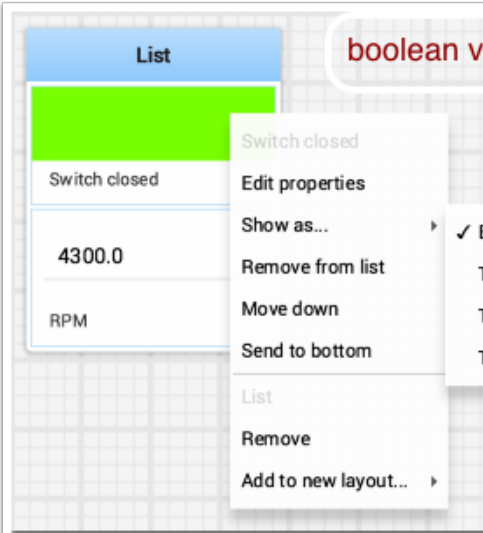
within labels smaller have instead they labels; header individual have don't lists in Tiles • entries. list their

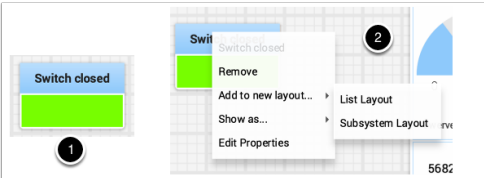
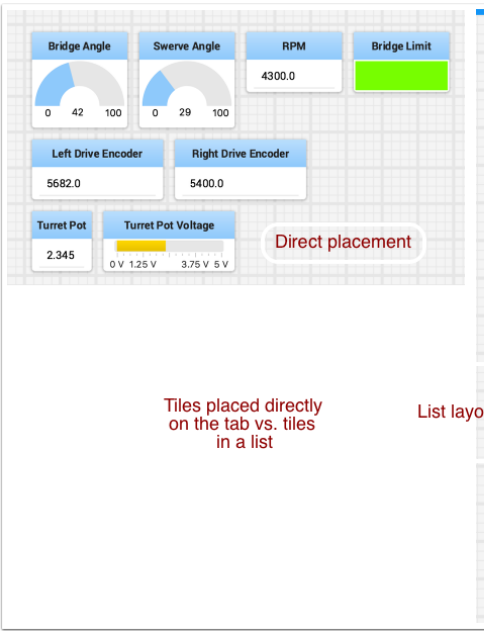
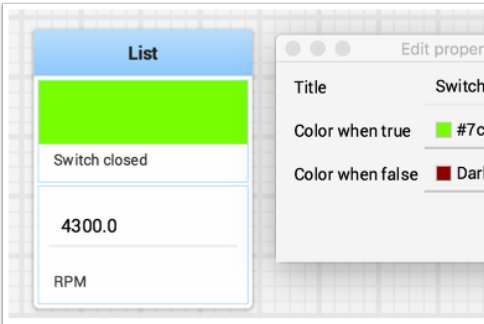
gaps smaller have lists another; one between gaps create together placed tiles Individual • tiles. between

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

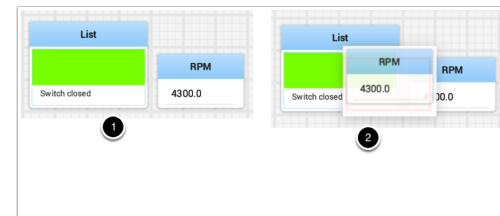




list a from tiles to/removing tiles Adding

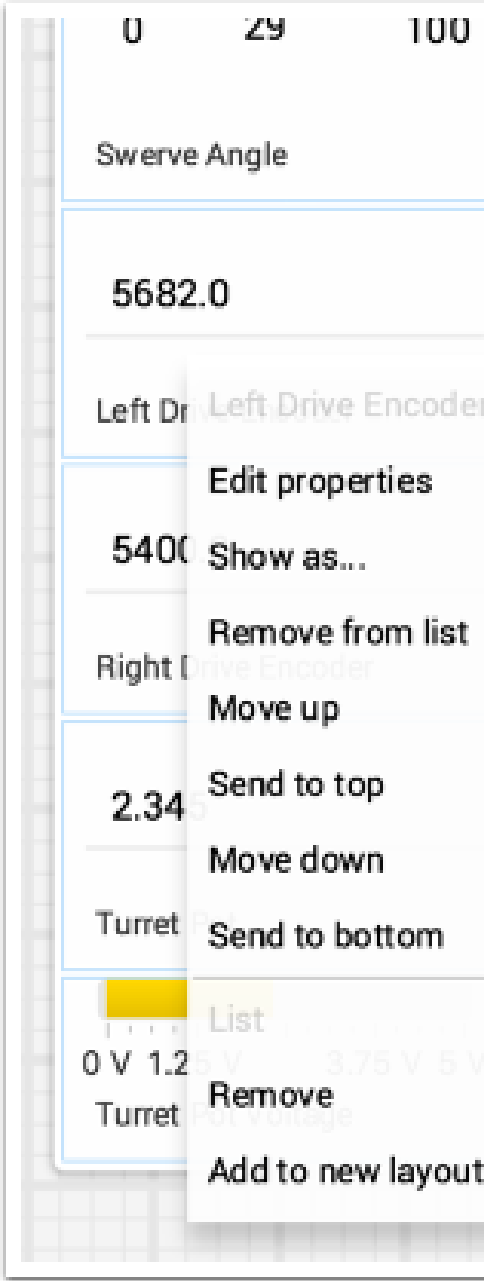
follows: as list existing an to **added** be can tile A
 added. be to tile the and list the Identify 1.
 list. the onto tile new the Drag 2.
 tile the it, show to small too is size list current the If list. the to added be will tile The 3.
 already not if added be will scrollbar vertical a and screenoff- 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.



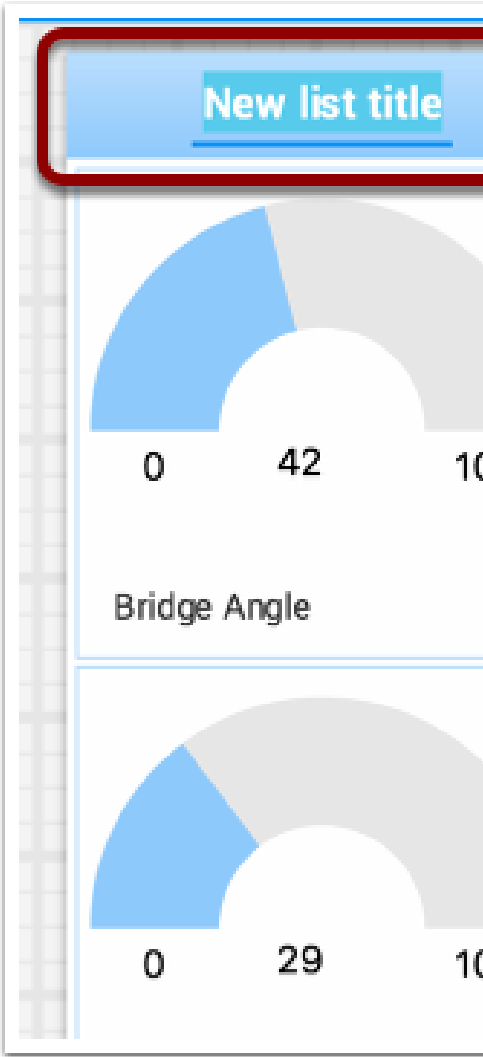
list a in tiles Rearranging

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

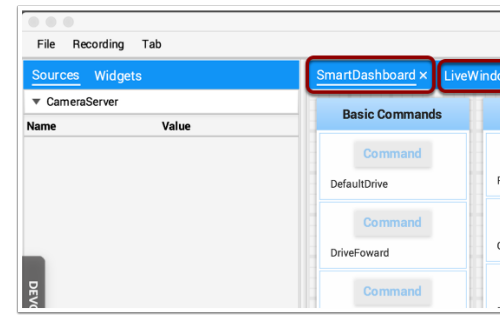


tabs manipulating and Creating

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



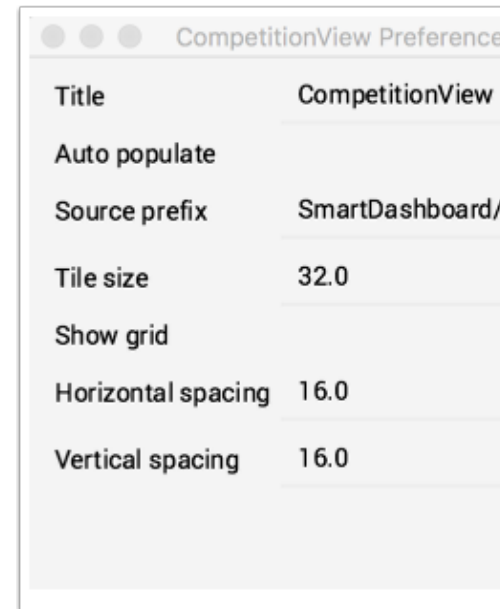
the using written are that values the all tab SmartDashboard the On autogenerated the all tab LiveWindow the On methods. of set SmartDashboard.putType() shown. are values debugging

tabs between Switching

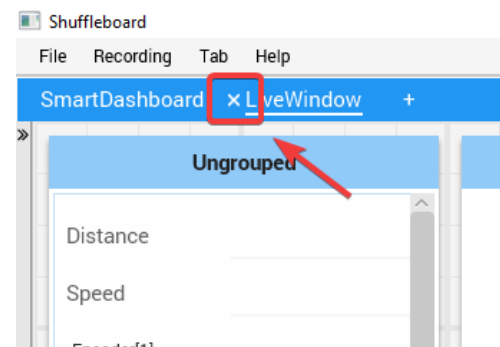
case the In window. the of top the at label tab the on clicking tabs between switch can You associated are that values the see to LiveWindow or SmartDashboard on click simply above, tab. each with

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. (hgap, gap vertical and

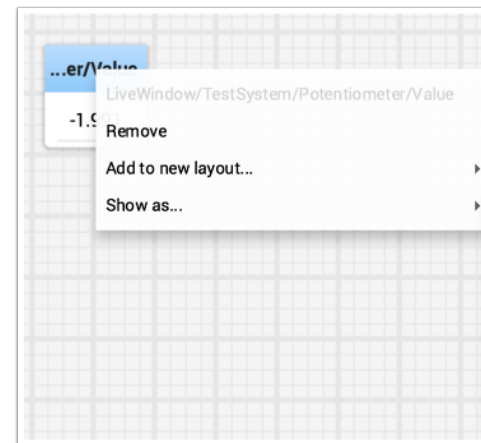
tabs between widgets Moving

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

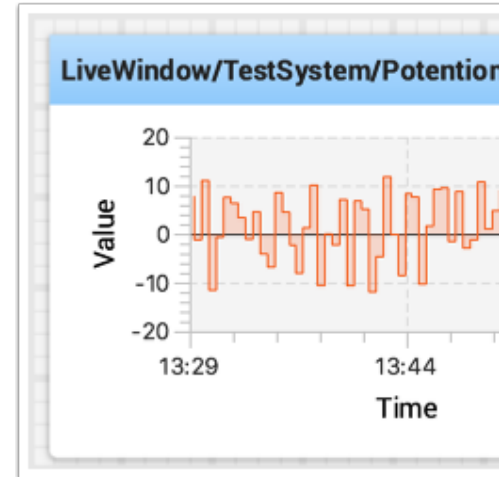
Graphs with Working

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..."

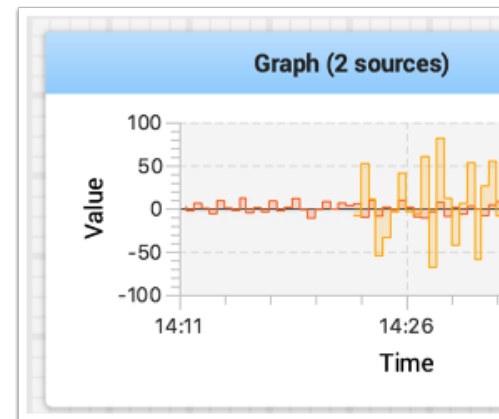


set automatically will It selected. you that value the of plots line shows widget graph The can You seconds. 30 be will show will graph the that interval time default the and scale the below). (see graph the for setting the in that change

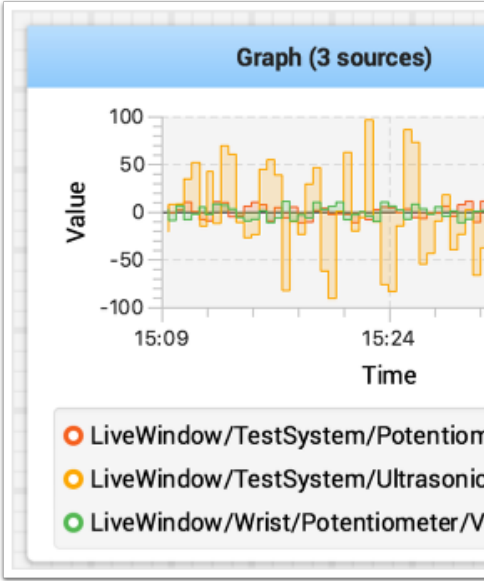


Values Data Additional Adding

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.

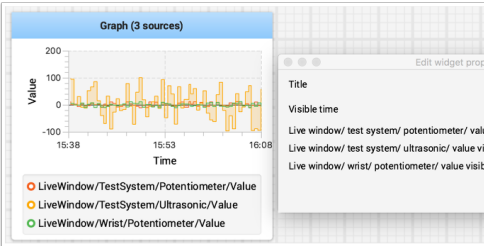


the in shown as displayed not is it if legend the view to vertically graph the resize can You plot. the in used are that sources the all shows legend The below. image



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).

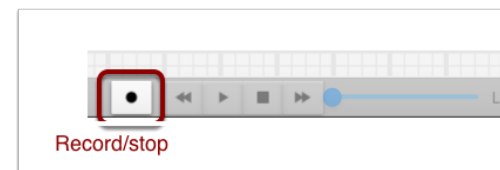


Playback and Recording

"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

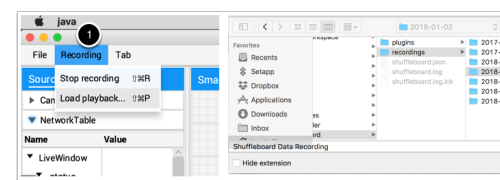
Recording a Creating

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
 playback". "Load click then menu "Recording" the Selecting 1.
 date by grouped are Recordings shown. directory the from the from recording a Choose 2.
 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

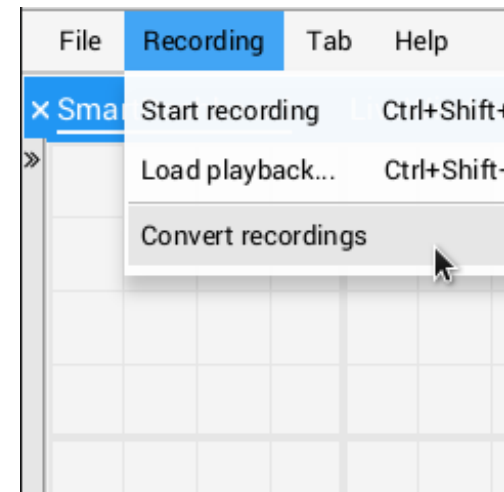
the playing is recording the While file. that of playback begin will file recoding the Selecting to option the as well as recording the within time current the show will controls recording "transport" the back played being is recording the When it. watching while recording the loop controlled. be to playback the allow will controls



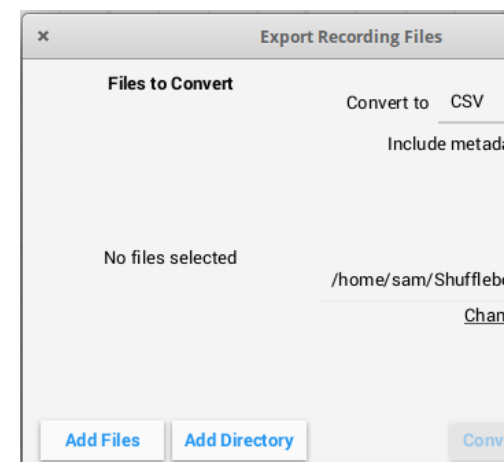
follows: as work controls The

point data changed last the to playback the up backs button arrowdouble- left The 1.
 playback the stops and starts controls play/pause The 2.
 values robot current showing resumes and playback stops button stop square The 3.
 value data changed next the to forward skips arrowdouble- right The 4.
 the of parts different view to time in point any to positioning direct for allows slider The 5.
 recording
 over and over run will playback the is, that looping, playback on turns switch loop The 6.
 stopped until
 recording the of time total the and recording the within point current the shows time The 7.

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

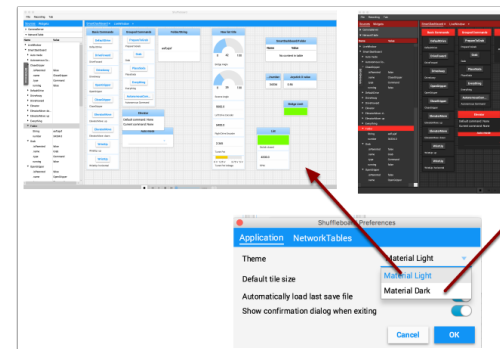
where through playing is it if but timeline the scrubbing while properly display won't Graphs
 run. original the in as display will they then graph the by captured be can history graph the

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

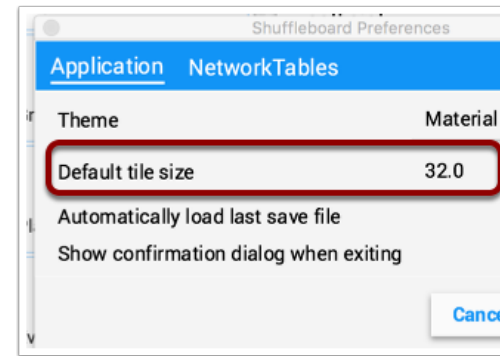
theme the Setting

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



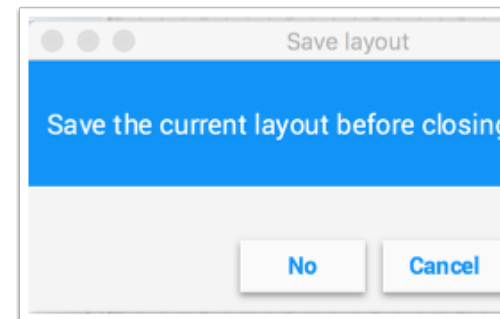
size tile default the Setting

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

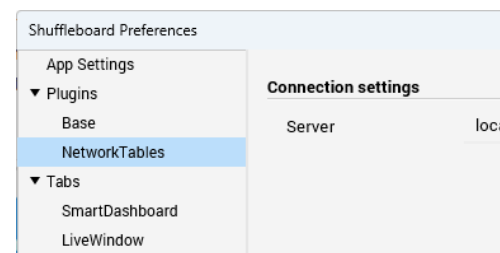


files save layout the with Working

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



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

Bugs, requests. pull accepting are we but Shuffleboard, of maintainer active no is There
an creating by page GitHub Shuffleboard the on added be can requests feature and issues,
aren't you sure make to ones new creating before issues existing at look to try Please issue.
find can You planned. is that work or reported been already has that something duplicating
.page GitHub Shuffleboard the on issues the

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

Application	the run systems	Windows (for Command file) gradlew.bat
Shuffleboard Running		:app:run ./gradlew
for classes utility and APIs the Building		:api:shadowJar ./gradlew
creation plugin		
file jar application complete the Building		:app:shadowJar ./gradlew

Code with Layouts - Shuffleboard 11.2.2

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
```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from  
)"Title Tab"getTab( Shuffleboard = tab
```

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
```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from  
)"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 willselectTab("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.

סרונות

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 : frc  
);3.14 , "Pi"Add(.
```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from  
)3.14 , "Pi"add(."Title Tab"getTab(.Shuffleboard
```

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"(getTab Shuffleboard. = tab ShuffleboardTab private
        = distanceEntry GenericEntry private
        )0 ,"target to Distance"(addtab.
        );getEntry.

        { ()calculate void public
        ;... = distance double
        (distance);setDouble(distanceEntry.
        }
    }

```

PYTHON

```

Shuffleboard import shuffleboard.wpilib from

    ):self(robotInit def
    )"Vision"getTab(.Shuffleboard = tab
getEntry().)0 ,"target to Distance"add(.tab = distanceEntry.self

    ):self(teleopPeriodic def
    getDistance() encoder.self = distance
    setDouble(distance).distanceEntry.self

```

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"(getTab Shuffleboard.
);1.0 ,"Speed Max"(addPersistent.

```


C++

```
    )"Drive"GetTab(: Shuffleboard : frc
); 1.0 , "Speed Max"AddPersistent(.

```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from
    )"Drive"getTab( (Shuffleboard
))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.

```

C++

```
    )"Title Tab"GetTab(: Shuffleboard : frc
mySendable); , "Title Sendable"Add(.

```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from
    )"Title Tab"getTab( (Shuffleboard
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"(getTab Shuffleboard. = tab ShuffleboardTab private
        = maxSpeed GenericEntry 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(getDouble maxSpeed. = max double
    max); * right max, * (left tankDrive robotDrive.
        }
    }

```

PYTHON

```

        commands2 import
        drive.wpilib import
    Shuffleboard import shuffleboard.wpilib from

    SubsystemBase): (commands2DriveSubsystem class
        :None >- )self( init__ def
        ()init__().()super

        ) "Drive"getTab( Shuffleboard = tab
    getEntry() )1, "Speed Max"add( tab = maxSpeed.self

        ... = robotDrive.this

        ):float right: ,float left: ,self(drive def
    dashboard the from speed maximum the Retrieve #
        )1.0(getDouble( maxSpeed.self = max
    )max * right ,max * tankDrive(left.robotDrive.self

```

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.
```

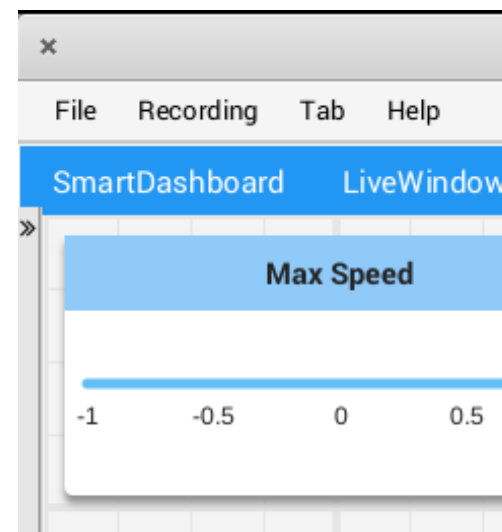
C++

```
        )"Drive"GetTab(: Shuffleboard :frc  
                )1,"Speed Max"Add(.  
here widget the specify // kNumberSlider)::BuiltInWidgets:WithWidget(frc.  
                GetEntry();.
```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from  
BuiltInWidgets import shuffleboard.wpilib from  
  
        )"Drive"getTab( (Shuffleboard  
                )1,"Speed Max"add(  
here widget the specify # kNumberSlider) withWidget(BuiltInWidgets  
                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({.
        }),MakeDouble(:Value: nt,"min"{
        })MakeDouble(:Value: nt,"max"{
        })
        GetEntry();.

```

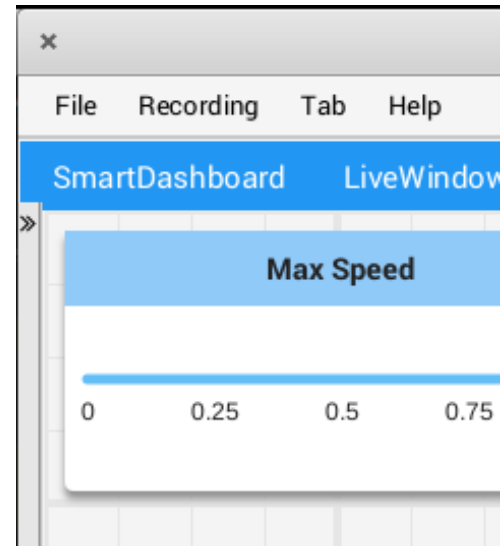
PYTHON

```

Shuffleboard import shuffleboard.wpilib from
BuiltInWidgets import shuffleboard.wpilib from

        )"Drive"getTab( (Shuffleboard
            )1,"Speed Max"add(
kNumberSlider) withWidget(BuiltInWidgets
here properties widget specify # ))1,"max",0,"min"(mapwithProperties(
            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 ,WithPosition(.
```

PYTHON

```
Shuffleboard import shuffleboard.wpiLib from  
        )"Pre-round"getTab( (Shuffleboard  
        autoModeChooser) ,"Mode Auto"add(.  
        2x1 widget the make # )1 ,2withSize(.  
        corner top-left the in it place # ))0 ,withPosition(.
```

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.
```

C++

```

        properties{ >>Value::nt<shared_ptr::std::StringMap::wpil
    )) "HIDDEN" MakeString(::Value::nt , "position Label" make_pair(::std
    };

) "Commands" GetTab(::Shuffleboard::frc = elevatorCommands &ShuffleboardLayout::frc
    kList)::BuiltInLayouts::frc , "Elevator" GetLayout(.
        ) 2 , 2 WithSize(.
        WithProperties(properties));

ElevatorDownCommand(); new = elevatorDown *ElevatorDownCommand
ElevatorUpCommand(); new = elevatorUp *ElevatorUpCommand

elevatorDown); , "Down Elevator" elevatorCommands.Add(
    elevatorUp); , "Up Elevator" elevatorCommands.Add(

```

PYTHON

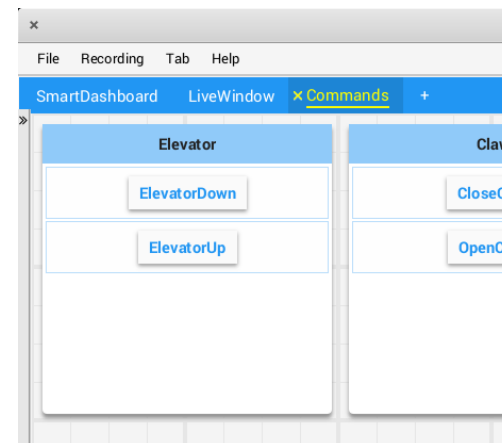
```

Shuffleboard import shuffleboard.wpilib from
BuiltInLayouts import shuffleboard.wpilib from

) "Commands" getTab(. Shuffleboard = (elevatorCommands
    kList). BuiltInLayouts , "Elevator" getLayout(.
        ) 2 , 2 withSize(.
    commands for labels hide # ))) "HIDDEN" , "position Label" (map withProperties(.

add(ElevatorDownCommand()) elevatorCommands
add(ElevatorUpCommand()) elevatorCommands

```



Usage Advanced - Shuffleboard 11.2.3

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.
```

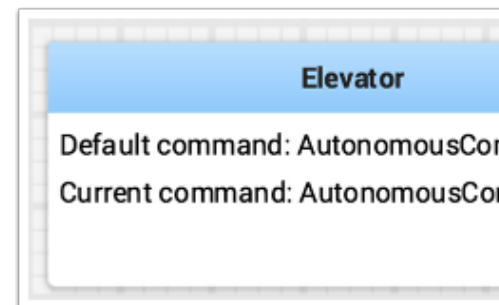
C++

```
pointer); PutData(subsystem: SmartDashboard
```

PYTHON

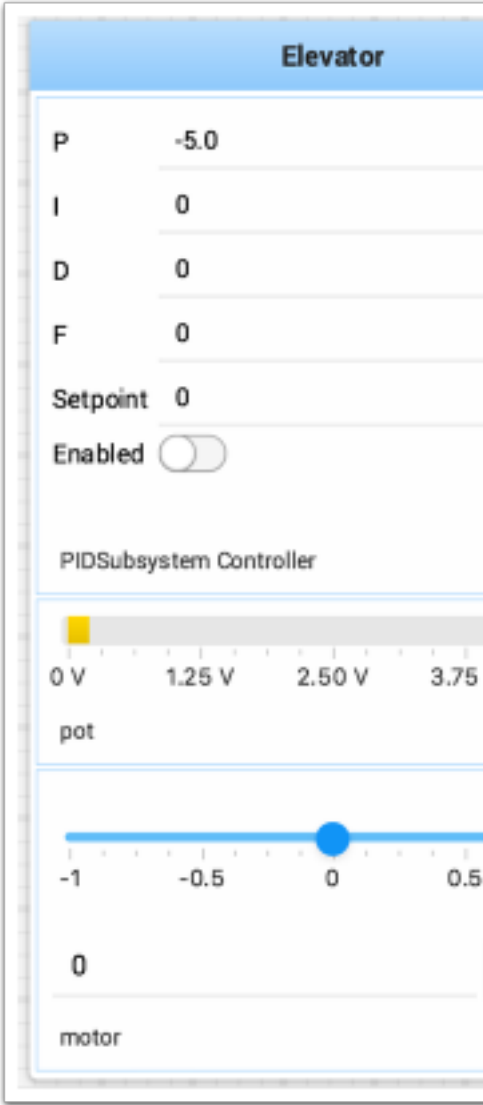
```
SmartDashboard import wpilib from  
reference) putData(subsystem SmartDashboard
```

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.
```

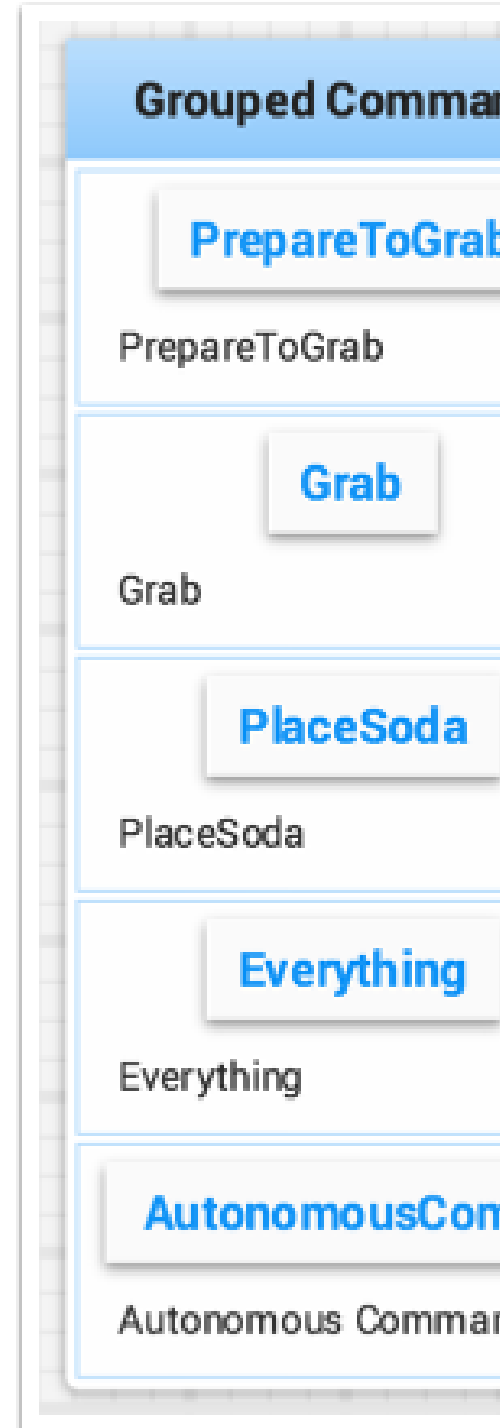
C++

```
));2.7ElevatorMove( new , "up ElevatorMove:'PutData(:SmartDashboard
```

PYTHON

```
SmartDashboard import wpilib from
));2.7ElevatorMove( , "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

desired the from mechanism or robot the far how determine to values sensor Reading 1.
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

The value). desired the and value sensor the between difference (the error an Compute 2.
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

a and direction correct the in motor the drive to used then is speed motor resultant The 3.
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

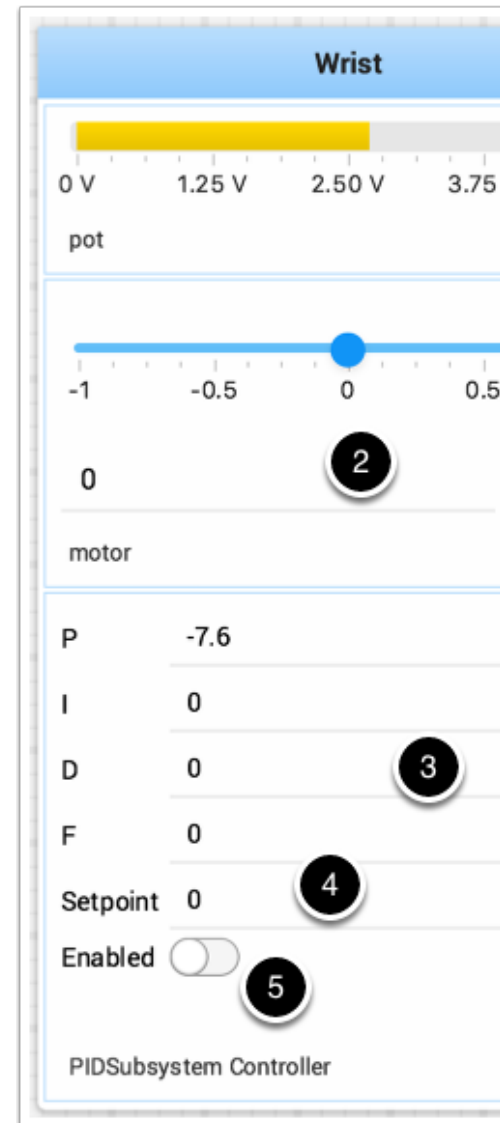
a generate will (Kp) constant a by multiplied when that term a is this - (proportional) P 1.
speed. and direction correct the in motor the move help will that speed motor

the exists error the longer The errors. successive of sum the is term this - (integral) I 2.
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

down slow to used is It errors. the of change of rate the is value this - (differential) D 3.
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 :`enable`
 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" (getTab Shuffleboard. = tab ShuffleboardTab
    ()); getEntry().false, "Enable Shooter" (add tab. = shooterEnable GenericEntry

    PIDSubsystem a in be to assumed Example Command //
    InstantCommand(m_shooter::enable)); new (on True NetworkButton(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 & GenericEntry : int

    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(),
    }
  
```

PYTHON

```
Shuffleboard import shuffleboard.wpilib from
) "Shooter"getTab( Shuffleboard = tab
getEntry().false) ,"Enable Shooter"add(.tab = shooterEnable

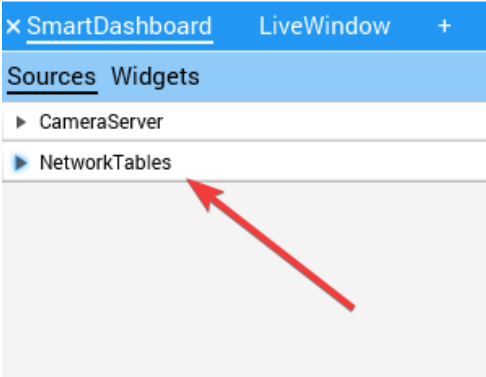
PIDSubsystem a in be to assumed Example Command #
enable())) .onTrue(InstantCommand(m_shooter.NetworkButton(shooterEnable)

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(),.calculate(encoder set(pid motor
```

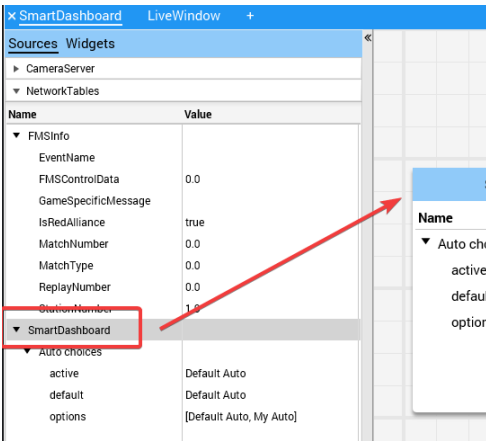
Data of Hierarchies Viewing

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 11.2.4

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

Since the `NetworkTables` plugin provides data sources backed by `ntcore`. The `LiveWindow` data is sent 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 `Plugin` `Shuffleboard` widget for displaying it can be found *here*.

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

```
import edu.wpi.first.shuffleboard.api.plugin.Description;
import edu.wpi.first.shuffleboard.api.plugin.Plugin;

= 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

shuffleboard the in folder *pluginsexample*- the utilize 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

Loaded Plugins		
Plugin	Loaded	Version
edu.wpi.first.shuffleboard.Base	<input checked="" type="checkbox"/>	1.1.8
edu.wpi.first.shuffleboard.NetworkTables	<input checked="" type="checkbox"/>	2.2.5
edu.wpi.first.shuffleboard.CameraServer	<input checked="" type="checkbox"/>	3.0.0

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
        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.this MyPoint2D( 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
    );class Double. (NAME,super
    }

```

page) next on (continues

(0000 00000 0000)

```

        @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
        };class MyPoint2D. (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 StackPanels 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
    
```

page) next on (continues

(0000 0000 0000)

```

        */
        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, *
        */

```

```

        )class MyPoint2D. = 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

        )class MyPoint2D. = 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

        )class MyPoint2D. = dataTypes , "MyPoint2D" = (name@Description
        ) "Point2DWidget.fxml" (@ParametrizedController
        { >MyPoint2D<SimpleAnnotatedWidget extends Point2DWidget class final public

        @FXML
        root; StackPane private

        @FXML
        xSlider; Slider private

```

page) next on (continues

(0000 00000 0000)

```

        @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

        )class MyPoint2D. = 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().valueProperty,xSlider.
                (MyPoint2D::getY));map(dataOrDefault.bind().valueProperty,ySlider.
            }

            @Override
            { ()getView Pane public
                root; return
            }
        }
    }
}

```

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().valueProperty<Slider.  
(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/stylesheets/" , "path/to/stylesheets" ↵
@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/resources/edu/wpi/first/shuffleboard/api/material.css> • `_material.css`
- <https://github.com/wpilibsuite/shuffleboard/blob/main/api/src/main/resources/edu/wpi/first/shuffleboard/api/base.css> • `_base.css`
- <https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/resources/edu/wpi/first/shuffleboard/app/light.css> • `_light.css`
- <https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/resources/edu/wpi/first/shuffleboard/app/dark.css> • `_dark.css`
- <https://github.com/wpilibsuite/shuffleboard/blob/main/app/src/main/resources/edu/wpi/first/shuffleboard/app/midnight.css> • `_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
64B5F6;# :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
<code>AbstractWidget</code>	<code>titleProperty()</code> and <code>getSources()</code> <code>getProperties()</code> Implements
<code>><TSingleTypeWidget</code>	type data single a support only that widgets for properties Adds
<code>AnnotatedWidget</code>	for <code>getDataTypes()</code> and <code>getName()</code> for implementations default Adds
<code>SingleSourceWidget</code>	support widgets default, (by source single a only with widgets For
<code>><TSimpleAnnotatedWidget</code>	and <code>AnnotatedWidget</code> <code>><TSingleTypeWidget</code> Combines
	<code>SingleSourceWidget</code>

widgets: define help to annotations two also are There

Name	Description
<code>@ParametrizedController</code>	defined views JavaFX for controllers FXML be to widgets Allows
<code>@Description</code>	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

```

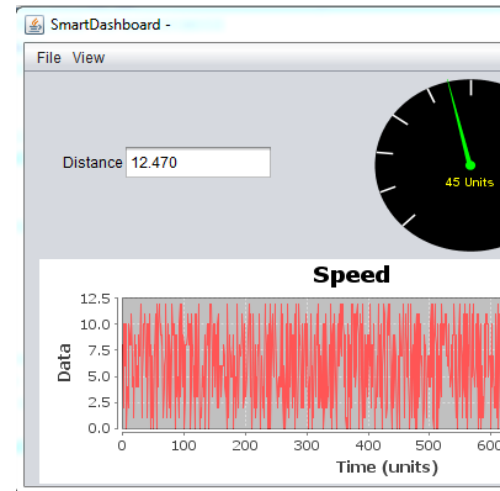
@Description

single a by defined types data supported and name their have to widgets allows This .AnnotatedWidget alongside used when annotation,

SmartDashboard 11.3

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 11.3.1



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

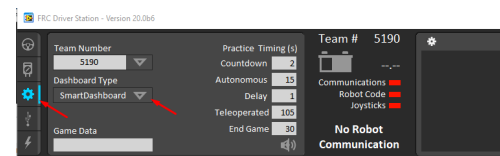
and commands executing currently the as such program robot the of state the Displays •
 subsystems any of status the

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

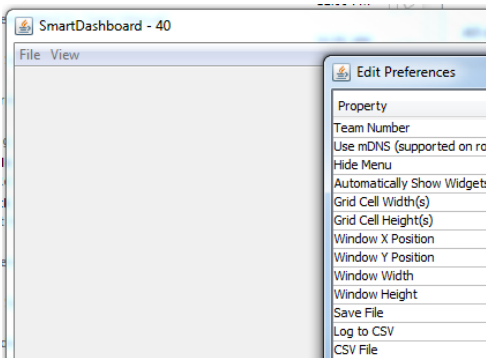
robot, the from sent is data the as timereal- in formatted automatically is data displayed The
 screen new the save then and types widget display the or format the change can you but
 use. to simple extremely still is it options, these all with And later. again used be to layouts
 with methods SmartDashboard the of one call simply dashboard, the on data some display To
 screen. dashboard the on appear automatically will value the and name its and data the

SmartDashboard the Installing



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

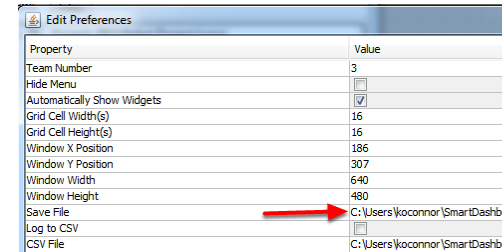
Location Server NetworkTables Custom a Setting

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!

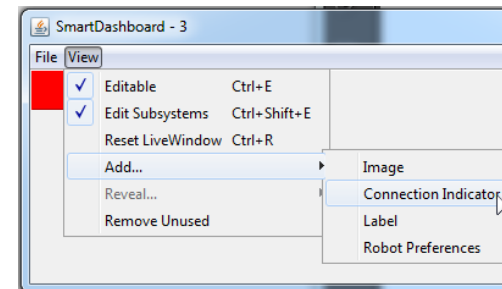
Edit Preferences	
Property	Value
Team Number	localhost
Hide Menu	
Automatically Show Widgets	<input checked="" type="checkbox"/>
Grid Cell Width(s)	16
Grid Cell Height(s)	16
Window X Position	723
Window Y Position	432
Window Width	317
Window Height	200
Save File	/example
Log to CSV	<input type="checkbox"/>
CSV File	/example

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 11.3.2

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 updated, are values As program. your on based constructed automatically is that GUI a to numbers catch to try to need no is there - value changes element GUI corresponding the screen. the on by streaming

SmartDashboard to Values Writing

JAVA

```

        { ()execute void protected
        ());atBridgebridgeTipper. , "Limit Bridge"(putBoolean SmartDashboard.
        ());getPositionbridgeTipper. , "Angle Bridge"(putNumber SmartDashboard.
        ());getSwerveAngledrivetrain. , "Angle Swerve"(putNumber SmartDashboard.
        ());getLeftEncoderdrivetrain. , "Encoder Drive Left"(putNumber SmartDashboard.
        ());getRightEncoderdrivetrain. , "Encoder Drive Right"(putNumber SmartDashboard.
        ());getCurrentAngleturret. , "Pot Turret"(putNumber SmartDashboard.
        ());getAverageVOLTageturret. , "Voltage Pot Turret"(putNumber SmartDashboard.
        ());getRPMshooter. , "RPM"(putNumber SmartDashboard.
        }

```

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. , "Encoder Drive Right"PutNumber( SmartDashboard: frc
        GetRightEncoder()); ↵
        Turret.GetCurrentAngle()); , "Pot Turret"PutNumber( SmartDashboard: frc
        Turret.GetAverageVoltage()); , "Voltage Pot Turret"PutNumber( SmartDashboard: frc
        Shooter.GetRPM()); , "RPM"PutNumber( SmartDashboard: frc
        }

```

PYTHON

```

SmartDashboard import wpilib from

    atBridge() bridgeTipper , "Limit Bridge"putBoolean( SmartDashboard
    getPosition() bridgeTipper , "Angle Bridge"putNumber( SmartDashboard
    getSwerveAngle() drivetrain , "Angle Swerve"putNumber( SmartDashboard
    getLeftEncoder() drivetrain , "Encoder Drive Left"putNumber( SmartDashboard
    getRightEncoder() drivetrain , "Encoder Drive Right"putNumber( SmartDashboard
    getCurrentAngle() turret , "Pot Turret"putNumber( SmartDashboard
    getAverageVoltage() turret , "Voltage Pot Turret"putNumber( SmartDashboard
    getRPM() shooter , "RPM"putNumber( SmartDashboard

```

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

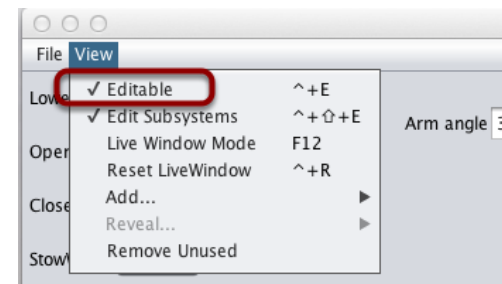
is it values, current showing are OutlineViewer and SmartDashboard the that ensure To old way, That time. same the at robot and clients NetworkTables the restart to necessary others. the to replicated get won't holding is one that values

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 11.3.3

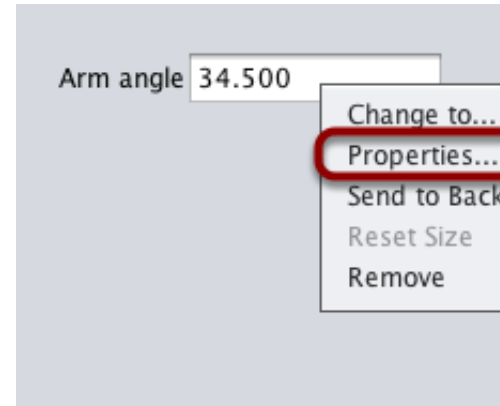
it's way the effect that properties of set a has SmartDashboard with displayed value Each displayed.

mode editing into display SmartDashboard the Setting



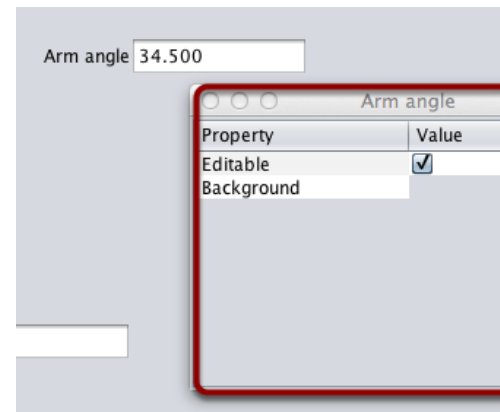
edit In mode. edit and mode display in, operate can it modes two has SmartDashboard The the put To properties. their edit and screen the on widgets around move can you mode on turn to "Editable" select then menu, "View" the click mode, edit into SmartDashboard mode. edit

widget a of editor properties the Getting



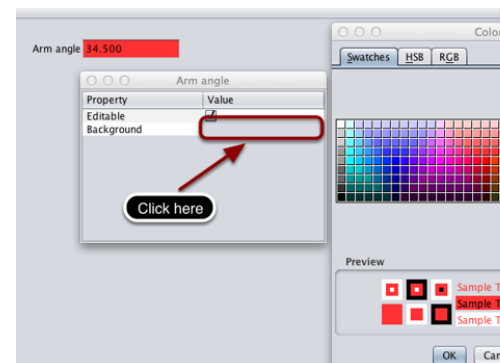
the on clickRight- widget. a for properties the edit and display can you mode, edit in Once "Properties...". select and widget

field a on properties the Editing



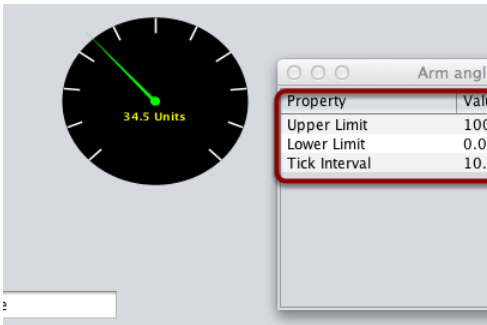
right- widgets the on item menu "Properties..." the to response in shown be will box dialog A menu. context click

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

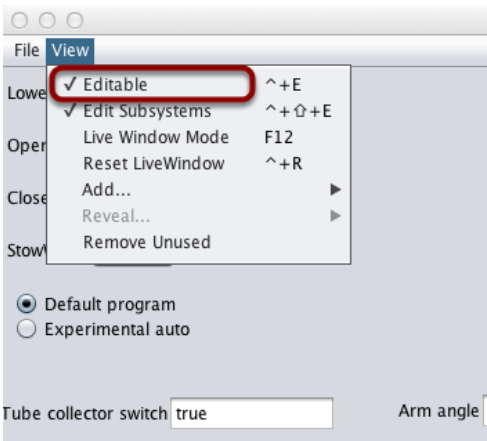


appearance. the change to properties editable of sets different have types widget Different changeable are interval tick the and dial the of limits lower and upper the example, this In parameters.

Value a for Type Widget Display the Changing 11.3.4

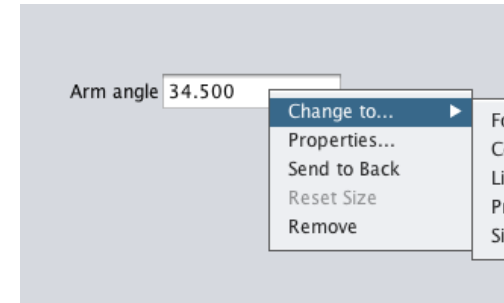
The SmartDashboard. the with values displays that widget of type the change can One displayed. being value the of type the on depend widgets allowable

Mode Edit Setting



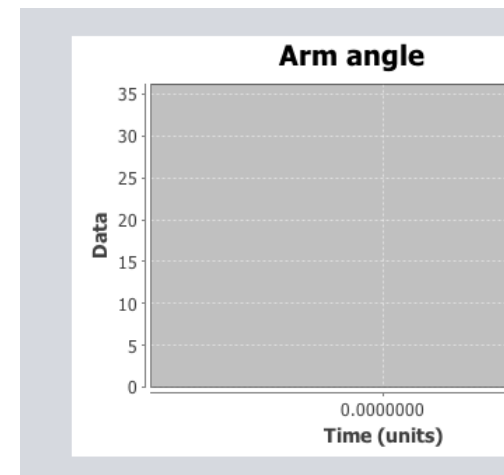
from Editable selecting by done is This mode. edit in is SmartDashboard the that sure Make .menu View the

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 11.3.5

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
```

Python

```
wpilib import
    "Default" = defaultAuto self
    ; "Auto My" = customAuto self
SendableChooser().wpilib = chooser.self
```

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"(setDefaultOption m_chooser.
        kCustomAuto); , "Auto My"(addOption m_chooser.
        m_chooser); , "choices Auto"(putData SmartDashboard.
    }

```

C++

```

        { ()Robot::RobotInit void
kAutoNameDefault); m_chooser.SetDefaultOption(kAutoNameDefault,
        kAutoNameCustom); m_chooser.AddOption(kAutoNameCustom,
        m_chooser);& , "Modes Auto"PutData( SmartDashboard::frc
    }

```

Python

```

SmartDashboard import wpilib from
defaultAuto).self , "Auto Default"setDefaultOption( .chooser.self
        customAuto).self , "Auto My"addOption( .chooser.self
        chooser).self , "choices Auto"putData( SmartDashboard

```

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
            ();getSelected m_chooser. = m_autoSelected
            m_autoSelected); + " selected: Auto"(println.out System.
        }

        /* 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
            }
        }

```

page) next on (continues

(0000 00000 0000)

```
}  
}
```

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 //  
        }  
    }
```

Python

```
        ):self(autonomousInit def  
getSelected() chooser.self = autoSelected.self  
autoSelected).self + " selected: Auto"(print  
  
        ):self(autonomousPeriodic def  
autoSelected: self match  
customAuto: self case  
        here code auto custom Put #  
        : _ case  
        here code auto default Put #
```

BasedCommand-

project example HatchbotTraditional the of part are below shown snippets code The :
(Python ,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

```

Python

```

    then and distance, specified a forward drives that routine auto simple A #
                                                                    stops. →
        DriveDistance( = simpleAuto.self
drive.self kAutoDriveSpeed,.constants kAutoDriveDistanceInches,.constants
    )

    drives then and hatch, a drops forward, drives that routine auto complex A #
                                                                    backward. →
        hatch).self drive,.selfComplexAuto( = complexAuto.self

        Chooser #
        SendableChooser().wpilib = chooser.self

```

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(

```

Python

```

chooser command autonomous the to commands Add #
simpleAuto).self , "Auto Simple"setDefaultOption(.chooser.self
complexAuto).self , "Auto Complex"addOption(.chooser.self

```

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

```

Python

```

SmartDashboard import wpilib from
dashboard the on chooser the Put #
putData(chooser) SmartDashboard

```

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

(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
}
}

```

Python

```

Command: commands2 >- )self(getAutonomousCommand def
getSelected() chooser.self return

:None >- )self(autonomousInit def
your by selected command autonomous the runs autonomous This""
class."" RobotContainer →
getAutonomousCommand().container.self = autonomousCommand.self

autonomousCommand:.self if
schedule().autonomousCommand.self

```

Autonomous during Scheduler the Running

every (about period update station driver every scheduler the run will this ,Robot.java In runs scheduler the Python In run. to command autonomous selected the cause and 20ms) used. is TimedCommandRobot when automatically

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 //
{ )nullptr =! (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
}
}

```

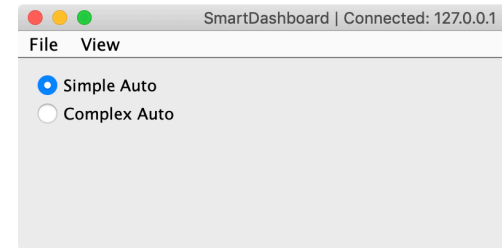
Python

```

:None >- )self(teleopInit def
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 #
autonomousCommand: self if
cancel() autonomousCommand.self

```

Display SmartDashboard

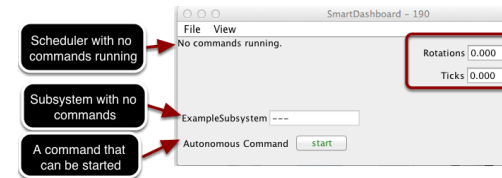


automatically are SendableChooser the from choices the run, is SmartDashboard the When the and begins period autonomous the before option an pick simply can You displayed. run. will command corresponding

Subsystems and Commands of Status the Displaying 11.3.6

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

are there when like look would screen the what see you'll examples, following the In display. this produces that code the and running, commands

Status Scheduler the Displaying

JAVA

```
());getInstance(CommandScheduler.putDataSmartDashboard.
```

C++

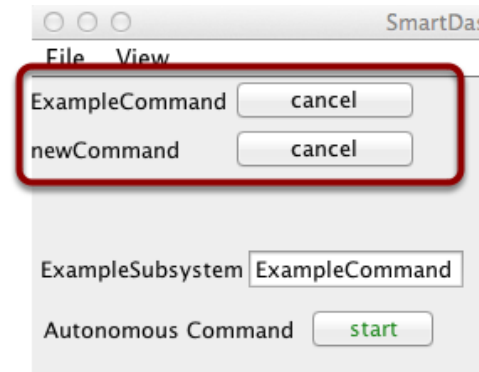
```
GetInstance());::CommandScheduler::PutData(frc2::SmartDashboard::frc
```

PYTHON

```
SmartDashboard import wpilib from
CommandScheduler import commands2 from

getInstance().putData(CommandScheduler SmartDashboard
```

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.
```

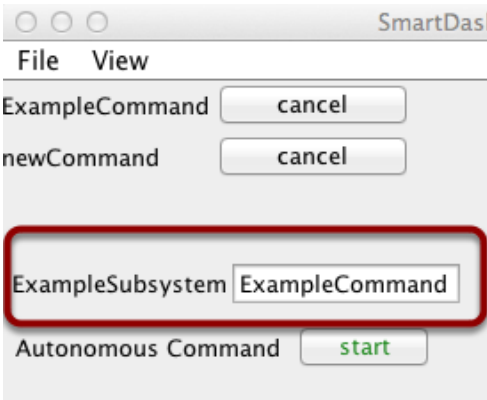

C++

```
exampleSubsystem);&PutData(::SmartDashboard::frc
```

PYTHON

```
SmartDashboard import wpilib from  
putData(exampleSubsystem) SmartDashboard
```

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.
```

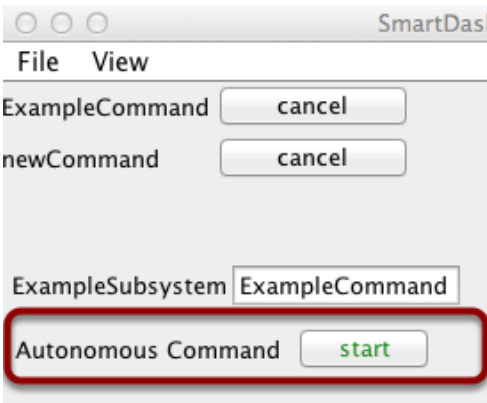
C++

```
exampleCommand);& , "Command Autonomous"PutData(::SmartDashboard::frc
```

PYTHON

```
SmartDashboard import wpilib from  
exampleCommand) , "Command Autonomous"putData( SmartDashboard
```

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

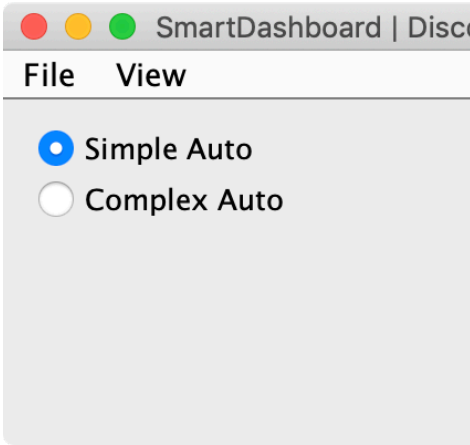


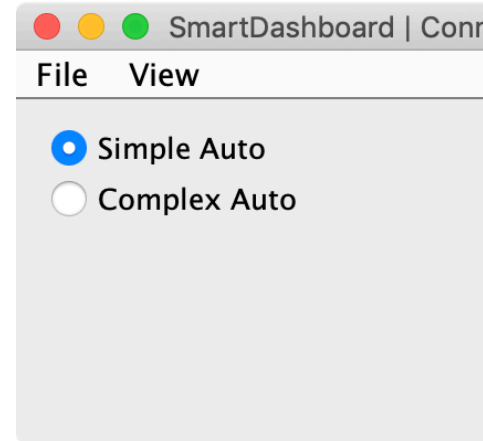
button this Pressing .Command Autonomous labeled button a see can you example this In
time a at one commands testing of way excellent an is and command associated the run will
each for buttons Adding program. robot your to code test awaythrow- add to having without
time. a at command one program, the test to simple it makes command

working is SmartDashboard Verifying 11.3.7

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

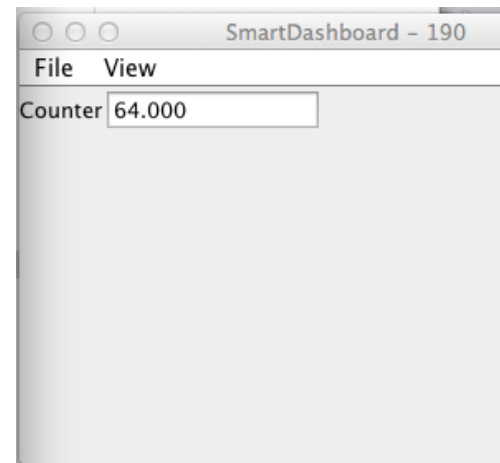
{ ()Robot::TeleopPeriodic void
);++counter , "Counter"PutNumber(:SmartDashboard::frc
}
```

PYTHON

```
SmartDashboard import wpilib from
0.0 = counter self
:None >- )self(teleopPeriodic def
)l += counter.self , "Counter"putNumber( SmartDashboard
```

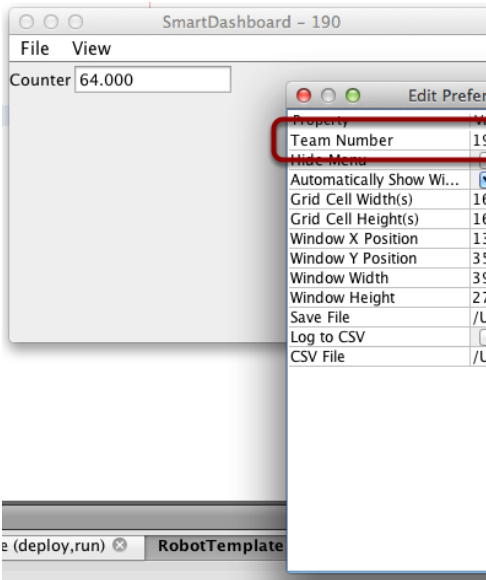
simply It SmartDashboard. the to value a writes that program robot minimal a is This
However, working. is connection the that verify to second per times 50 counter a increments
times 10 to updates the throttle will default by NetworkTables usage, bandwidth minimize to
second. per

Program Sample the for Output SmartDashboard



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

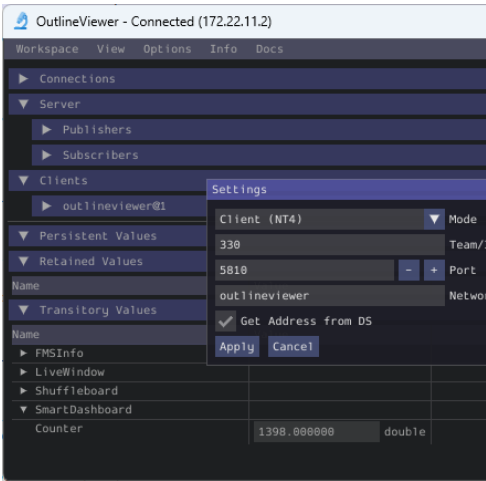


set correctly is number team the that verify appearing, not is value the of display the If then ,File selecting by viewed be can dialog preferences The picture. this in shown as .Preferences

OutlineViewer using Program Verifying

the using by values SmartDashboard generating is program robot the that verify can You .program OutlineViewer

the to written variable the is Counter value The row. SmartDashboard the Expand increasing value the see should you runs program the As NetworkTables. via SmartDashboard something for look OutlineViewer, the in variable this see don't you If case). this in 1398.0(configuration. network the or program robot the with wrong



Namespace SmartDashboard 11.3.8

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

/SmartDashboard/Arm position in degrees	52.0	1
/SmartDashboard/Autonomous Command/~TYPE~	Command	
/SmartDashboard/Autonomous Command/isParented	false	
/SmartDashboard/Autonomous Command/name	Autonom	
/SmartDashboard/Autonomous Command/running	false	
/SmartDashboard/Chooser/~TYPE~	String Ch	
/SmartDashboard/Chooser/default	defaultA	
/SmartDashboard/Chooser/options	[defaultA	
/SmartDashboard/Program Version	V1.2	4

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

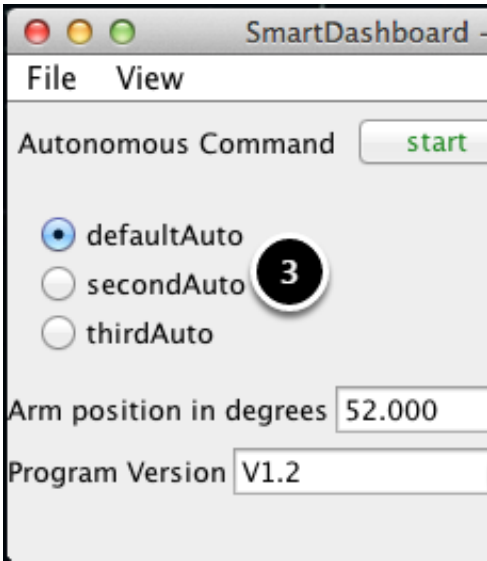
```

        SendableChooser(); new = chooser
AutonomousCommand(); new , "defaultAuto" (setDefaultOptionchooser.
AutonomousCommand(); new , "secondAuto" (addOptionchooser.
AutonomousCommand(); new , "thirdAuto" (addOptionchooser.
        chooser); , "Chooser" (putData SmartDashboard.
    ); 52.0 , "degrees in position Arm" (putNumber SmartDashboard.
    ); "V1.2" , "Version Program" (putString SmartDashboard.

```

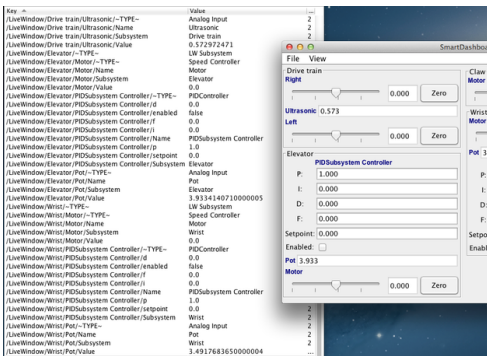
written is AutonomousCommand The call. putNumber() the with created is position Arm The code above the in shown not is that command) Command", putData("Autonomous a with Program value, string the and object SendableChooser a as created is chooser The fragment. call. putString() the with created is Version

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



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

```
); PWMVictorSPX( new = drivetrainLeft
); "Left" , "train Drive"(setName drivetrainLeft.

); PWMVictorSPX( new = drivetrainRight
; "Right" , "train Drive"(setName drivetrainRight.
```

page) next on (continues

(0000 00000 0000)

```
drivetrainRight); DifferentialDrive(drivetrainLeft, new = drivetrainRobotDrive
);false(setSafetyEnableddrivetrainRobotDrive.
);0.1(setExpirationdrivetrainRobotDrive.
);3AnalogInput( new = drivetrainUltrasonic
);"Ultrasonic" , "train Drive"(setName drivetrainUltrasonic.
);6PWMVictorSPX( new = elevatorMotor
);"Motor" , "Elevator"(setName elevatorMotor.
);4AnalogInput( new = elevatorPot
);"Pot" , "Elevator"(setName elevatorPot.
);2AnalogInput( new = wristPot
);"Pot" , "Wrist"(setName wristPot.
);3PWMVictorSPX( new = wristMotor
);"Motor" , "Wrist"(setName wristMotor.
);5PWMVictorSPX( new = clawMotor
);"Motor" , "Claw"(setName clawMotor.
```

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: 11.3.9

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, setName SendableRegistry.

); Jaguar( new = elbow Jaguar
); "Elbow" , "Arm" (elbow, setName SendableRegistry.

); Victor( new = wrist Victor
); "Wrist" , "Arm" (wrist, setName SendableRegistry.
```

C++

```
;2 ,1Ultrasonic{ Ultrasonic::frc
); "Ultrasonic" , "Arm" SetName(ultrasonic, : SendableRegistry

}; Elbow{ Jaguar::frc
); "Elbow" , "Arm" SetName(elbow, : SendableRegistry

}; Wrist{ Victor::frc
); "Wrist" , "Arm" SetName(wrist, : SendableRegistry
```

PYTHON

```
Victor Ultrasonic, Jaguar, import wpilib from
SendableRegistry import wpiutil from

)2 ,1Ultrasonic( = ultrasonic
) "Ultrasonic" , "Arm" setName(ultrasonic, SendableRegistry

) Jaguar( = elbow
) "Elbow" , "Arm" setName(elbow, SendableRegistry

) Victor( = wrist
) "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(

);1Jaguar( new = elbow Jaguar
    elbow); , "Elbow"addChild(

);1Victor( 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(
```

PYTHON

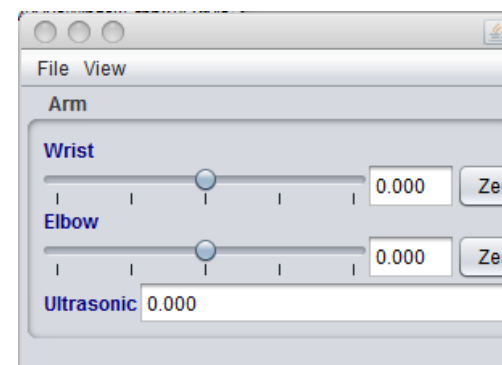
```
Victor Ultrasonic, Jaguar, import wpilib from
    SubsystemBase import commands2 from

)2 ,1Ultrasonic( = ultrasonic
    ultrasonic) , "Ultrasonic"addChild( SubsystemBase

)1Jaguar( = elbow
    elbow) , "Elbow"addChild( SubsystemBase

) Victor( = wrist
    wrist) , "Wrist"addChild( SubsystemBase
```

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 not is robot the whenever Station Driver the from selected be can This mode. Test in is robot designed is mode Test this). do to how on details for *Mode Test Enabling* (see field the on 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 switch will display SmartDashboard the mode, Test in enabled is robot the When code. your by used sensors and actuators any of status the display will and (LiveWindow) mode test to program. your

mode! Test in default by enabled not is LiveWindow 2024, Since :□□□□

Mode Test in LiveWindow Enabling

class: Robot the in needed is code following the Mode, Test in LiveWindow run To

JAVA

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

C++

```
{ ()Robot::RobotInit void
);trueEnableLiveWindowInTest(
}
```

PYTHON

```
:None >- )self(robotInit def
enableLiveWindowInTest(true)
```

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
        };1rightDrive{ PWMSparkMax::frc
        accel{}; BuiltInAccelerometer::frc
        };3arm{ PWMVictorSPX::frc

        { ()Robot::RobotInit void
            );"Arm" , "SomeSubsystem" arm, &SetName( : SendableRegistry: wpi
            );"Accelerometer" , "SomeSubsystem" accel, &SetName( : SendableRegistry: wpi
        }

```

PYTHON

```

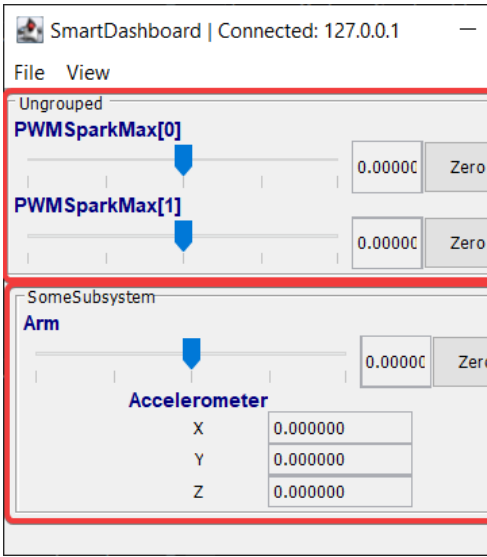
PWMVictorSPX PWMSparkMax, BuiltInAccelerometer, import wpilib from
SendableRegistry import wpiutil from

:None >- )self(robotInit def
    )0PWMSparkMax( = leftDrive
    )1PWMSparkMax( = rightDrive
    )2PWMVictorSPX( = arm
    BuiltInAccelerometer() = accel
    )"Arm" , "SomeSubsystem" setName(arm, SendableRegistry
    )"Accelerometer" , "SomeSubsystem" setName(accel, SendableRegistry

```

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 defined programmer- case which actuators. and sensors those defining explicitly illustrates example This clearer. program

mode Test in displayed is what Understanding

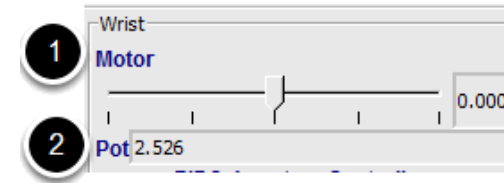


In mode. test into placed is robot the when display SmartDashboard the in output the is This WPILib by created implicitly were Ungrouped as listed objects the above shown display the subsystem a in contained are objects These created. were objects corresponding the when this in (PWMSparkMax type device 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

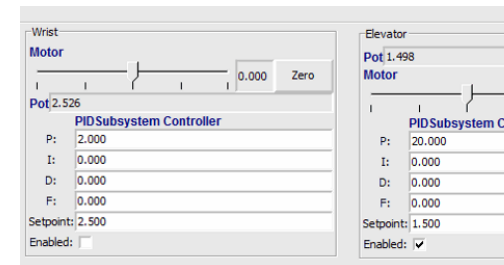
speed motor the determining for algorithm an is Differential) Integral, (Proportional, PID The with robot a example, For possible. as quickly as setpoint a reach to feedback sensor on based possible as fast as there move should position predetermined a to moves that elevator an to controller PID the 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

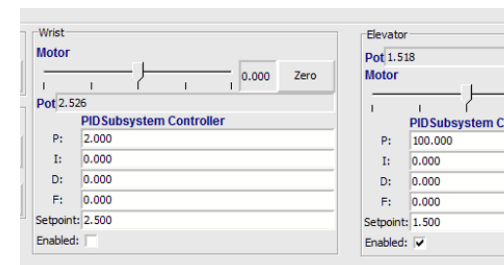
LiveWindow in PIDController the Viewing



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



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 11.4

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

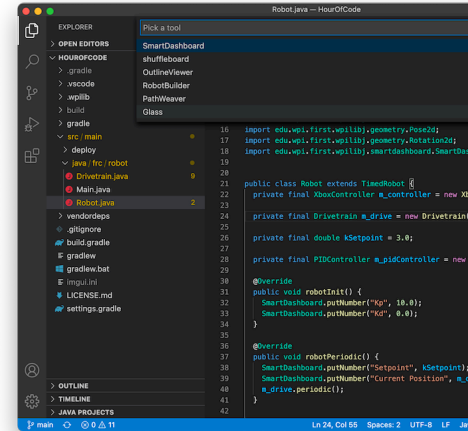
Station. Driver NI the in dashboards of list the within available be not will Glass :`----`

Glass to Introduction 11.4.1

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

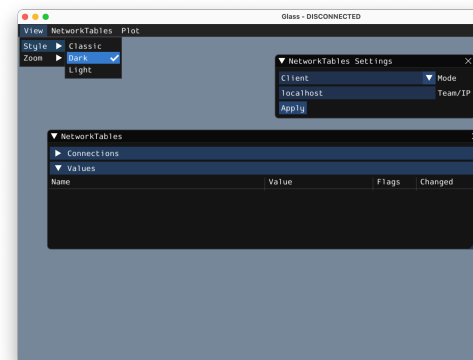
Tool Start on clicking Code, VS in)...(menu ellipsis the selecting by launched be can Glass .*Glass* choosing then and



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

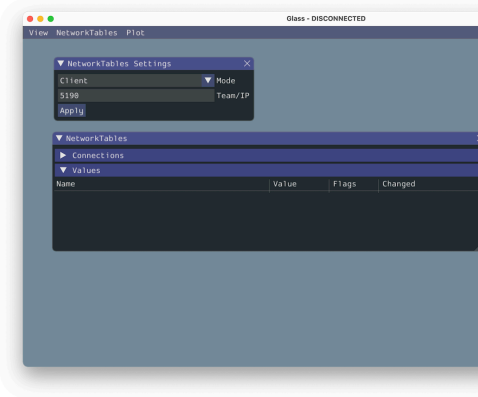
- .%APPDATA% in located is file configuration the Windows, On
 - ~/.Library/Preferences in located is file configuration the macOS, On
 - the if ~/.config or \$XDG_CONFIG_HOME in located is file configuration the Linux, On
 - exist. not does former
- slate". "clean a to Glass restore to deleted be simply can file configuration glass.ini The

Connections NetworkTables Establishing 11.4.2

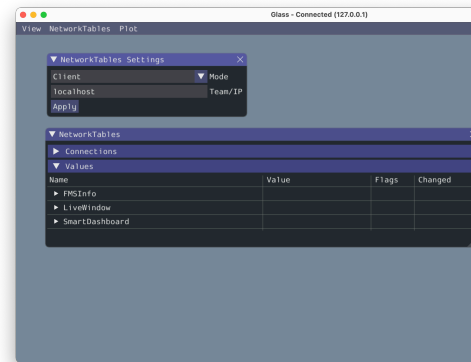
It program. robot your with connection a establish to protocol *NetworkTables* the uses Glass robot. the from and to data receive and transmit to used also is

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*



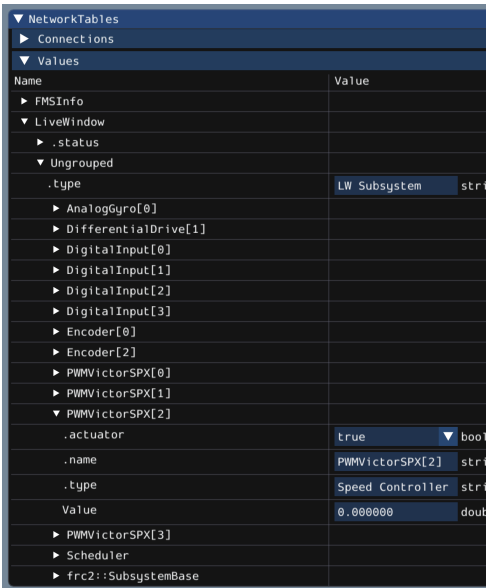
(including computer your on simulation in running is that robot a to connect also can You box. *Team/IP* the into localhost in typing by robots) Romi



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 11.4.3

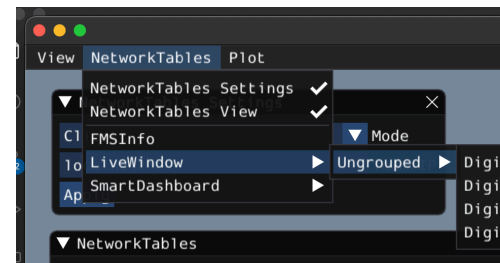
include These code. robot in exist that types certain for available are widgets Specialized or instances, SendableChooser as such NetworkTables over sent manually are that objects .LiveWindow over sent automatically is that hardware

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"(putData SmartDashboard. |
```

C++

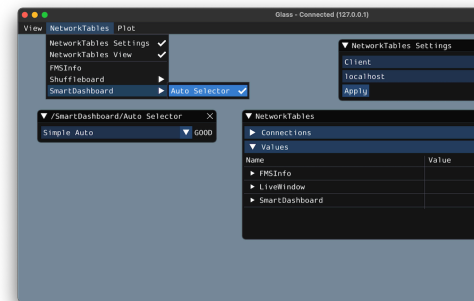
```
m_selector);& , "Selector Auto"PutData(::SmartDashboard::frc |
```

PYTHON

```
SmartDashboard import wpilib from
selector) , "Selector Auto"putData( SmartDashboard
```

.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

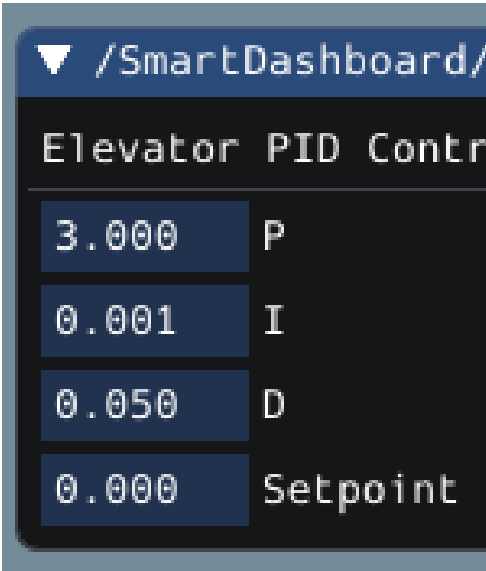
```
m_elevatorPIDController); , "Controller PID Elevator"(putDataSmartDashboard.
```

C++

```
m_elevatorPIDController);& , "Controller PID Elevator"PutData(::SmartDashboard::frc
```

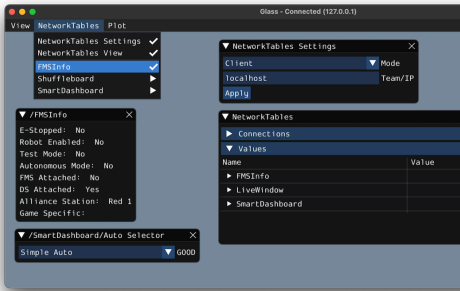
PYTHON

```
SmartDashboard import wpilib from  
elevatorPIDController) , "Controller PID Elevator"putData( SmartDashboard  
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 11.4.4

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"(putData SmartDashboard.
```

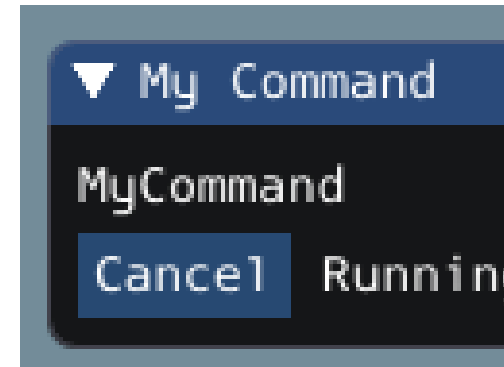
C++

```
frc/smartdashboard/SmartDashboard.h>< include#
...
command{...}; MyCommand
command);& , "Command My"PutData(::SmartDashboard :frc
```

PYTHON

```
SmartDashboard import wpilib from
) ... MyCommand( = command
command) , "Command My"putData( SmartDashboard
```

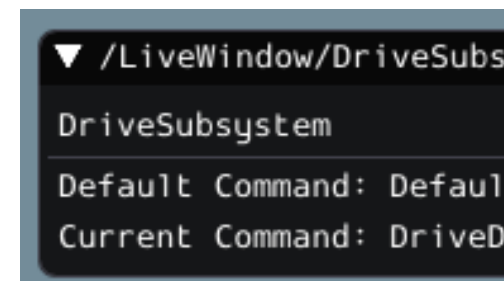
or API NetworkTables levellower- a using sent be also can instance MyCommand The : the that meaning used, was API SmartDashboard the case, this In . *API Shuffleboard* the using name. table SmartDashboard the under appear will widget *Selector Command*



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

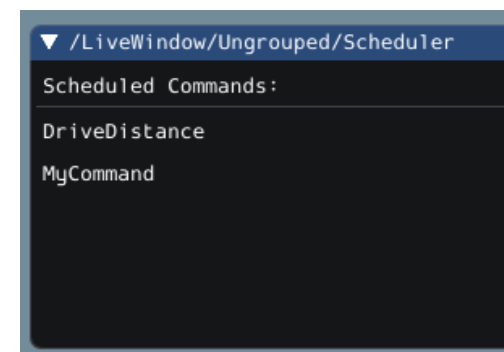
Widget Subsystem

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 11.4.5

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
    init subsystem or robot either in this Do //
        m_field); , "Field"(putData SmartDashboard.
    periodic subsystem or periodic robot either in this Do //
        ());getPoseMeters(m_odometry.setRobotPose m_field.
```

C++

```
frc/smartdashboard/Field2d.h<< include#
frc/smartdashboard/SmartDashboard.h<< include#

m_field; Field2d::frc
    init subsystem or robot either in this Do //
        m_field);& , "Field"PutData(::SmartDashboard :frc
    periodic subsystem or periodic robot either in this Do //
        m_field.SetRobotPose(m_odometry.GetPose());
```

PYTHON

```
Field2d SmartDashboard, import wpilib from
    Field2d() = field self
    init subsystem or robot either in this Do #
        field).self , "Field"putData( SmartDashboard
    periodic subsystem or periodic robot either in this Do #
        getPose()) odometry.self.setRobotPose(.field self
```

or API NetworkTables leveller- 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 ,Pose2d( new
                )),1- ,2Translation2d( new ),1 ,1Translation2d( new of List.
                ),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();

            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(
        }

```

PYTHON

```

        ):self(robotInit def
        period. autonomous the during follow to trajectory example An #
        generateTrajectory( TrajectoryGenerator trajectory wpimath = trajectory.self
    ),0fromDegrees(.Rotation2d geometry wpimath ,0 ,Pose2d( geometry wpimath
        [
            ),1 ,1Translation2d( geometry wpimath
            ),1- ,2Translation2d( geometry wpimath
        ],
    ),0fromDegrees(.Rotation2d geometry wpimath ,0 ,Pose2d( geometry wpimath
        TrajectoryConfig( trajectory wpimath
        )3.0feetToMeters( .units wpimath ),3.0feetToMeters( .units wpimath
        ),
    )

    visualizations. trajectory and robot for Field2d Create #
        Field2d() wpilib = field.self

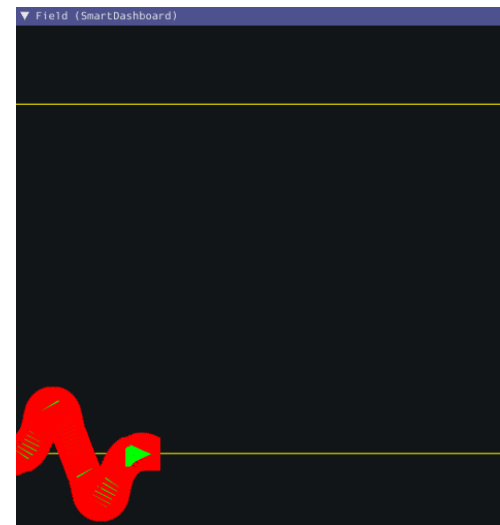
    SmartDashboard. to Field2d push and Create #
        field).selfputData( SmartDashboard wpilib

    Field2d. to trajectory the Push #
    trajectory).selfsetTrajectory( )"traj"getObject( .field.self

```

Glass with Trajectories Viewing

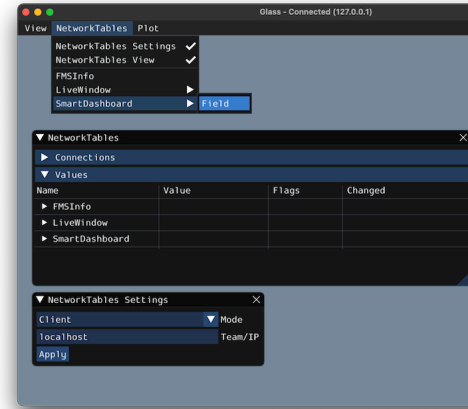
>- NetworkTables dropdown the through Glass with viewed be can trajectory sent The .Field2d >- SmartDashboard



not will) Python / C++ / Java(RamseteController the uses which example above The :□□□□ once. least at enabled is autonomous until trajectory sent the show

Glass in Pose Robot the Viewing

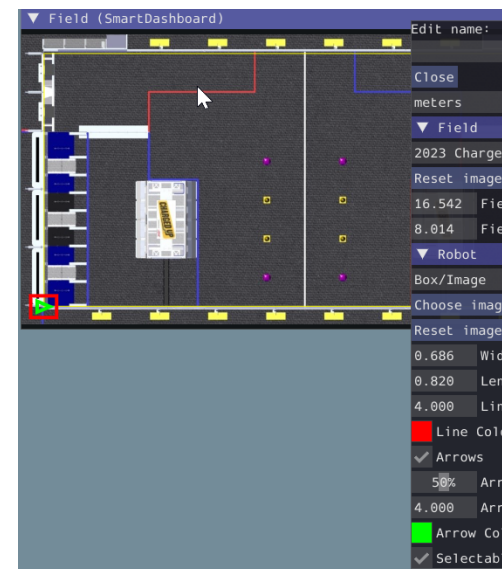
to added be can widget *Field2d* the NetworkTables, over instance *Field2d* the sending After instance the that name table the choosing bar, menu the in *NetworkTables* selecting by Glass button. *Field* the on clicking then and over, sent was



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 clicking Right- and field the of dimensions the choose and image, robot custom a select image, field custom a robot.

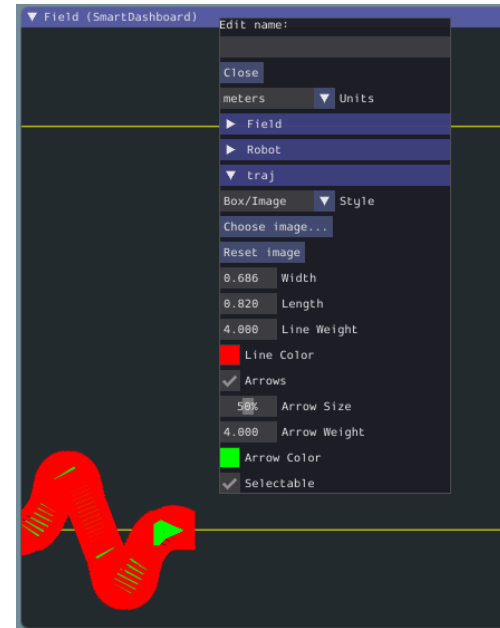
a select can you Or down.drop- *Image* the using layout field existing an from choose can You to choose can You *.image...* Choose selecting and Custom to *Image* the setting by file custom same the in is file image the as long as file JSON PathWeaver a or file image an select either in field the of location correct the import automatically will file JSON the Choosing directory. field. the of size correct the and image the

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

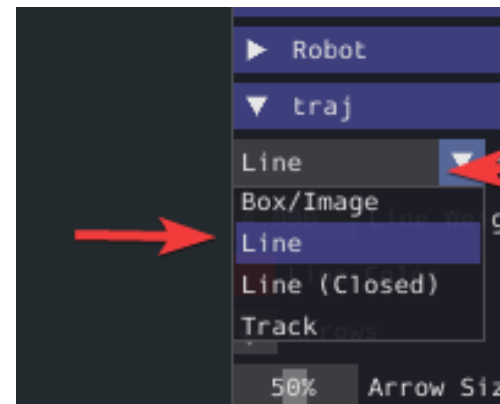


Style Pose Modifying

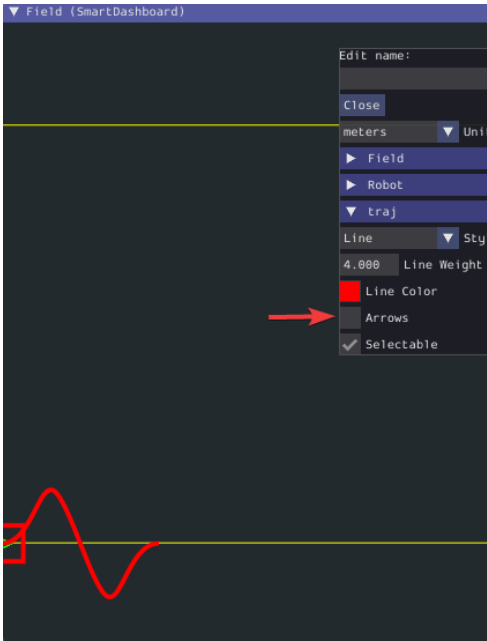
bar. menu Field2d the on clicking right by ways of plethora a in customized be can Poses weight, arrow width, arrow style, weight, line width, line are: customization of Examples etc. color,



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

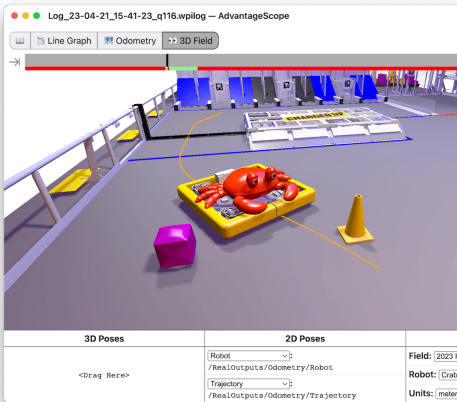


fluid and nice a like look to trajectory our cause will This checkbox. Arrows the uncheck Now, line!



AdvantageScope with Data Pose Viewing

object, Field2d a from data pose viewing for option alternative an is *AdvantageScope* visualizations 3D and 2D Both *.logs data WPILib* using file log a to recorded data including details. more for tabs *field 3D* and *odometry* the for documentation the See supported. are



Widget Mechanism2d The 11.4.6

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
```

43
44
45
46

C++

```
object mechanism main the //
};3 ,3m_mech{ Mechanism2d::frc
node root mechanism the //
);0 ,2 , "climber"m_mech.GetRoot( = m_root *MechanismRoot2d::frc
```

59
60
61
62

PYTHON

```
object mechanism main the #
)3 ,3Mechanism2d( wpilib = mech.self
node root mechanism the #
)0 ,2 , "climber"getRoot( mech self = root self
```

32
33
34
35

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"

```

PYTHON

```

the of section"/"stage"" each represent objects MechanismLigament2d #
                                     based are and mechanism, ↪
                                     object ligament another or node root the off #
                                     appendLigament(.root.self = elevator.self
90 kElevatorMinimumLength,.self , "elevator"
                                     )
                                     appendLigament(.elevator.self = wrist.self
kPurple).Color.Color8Bit(wpilib.wpilib ,6 ,90 ,0.5 , "wrist"
                                     )

```

NetworkTables: to object Mechanism2d the publish Then,

JAVA

```
dashboard the to mechanism the post //
mech); , "Mech2d" (putDataSmartDashboard.
```

55
56

C++

```
dashboard to publish //
m_mech); & , "Mech2d" PutData( : SmartDashboard::frc
```

36
37

PYTHON

```
dashboard the to mechanism the post #
mech).self , "Mech2d"putData(.SmartDashboard wpilib
```

46
47

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 //
());getDistance m_elevatorEncoder. + (kElevatorMinimumLengthsetLength m_elevator.
());get(m_wristPot.setAngle m_wrist.
}
```

59
60
61
62
63
64

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
}
```

40
41
42
43
44
45

PYTHON

```

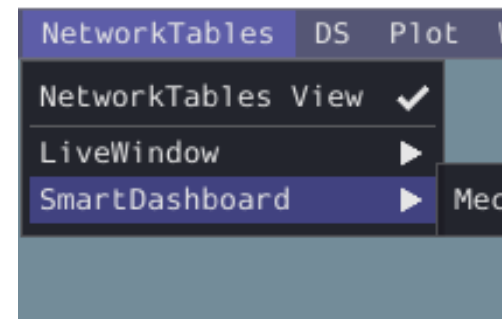
        ):self(robotPeriodic def
        state s'mechanism dashboard the update #
            setLength(.elevator self
getDistance().elevatorEncoder.self + kElevatorMinimumLength.self
        )
        get()).wristPot.selfsetAngle( wrist.self

```

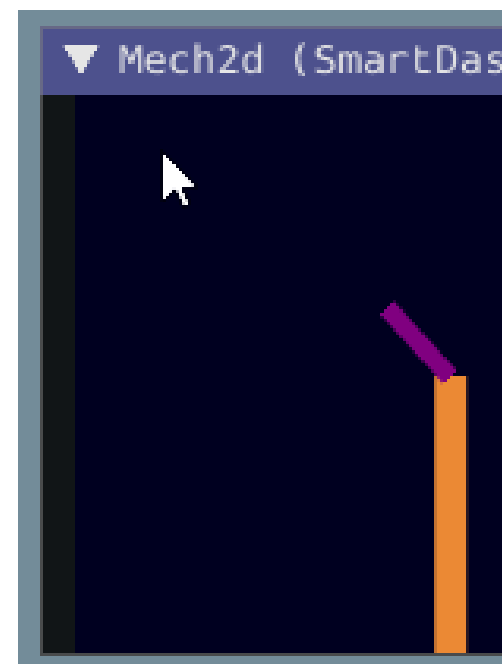
49
50
51
52
53
54

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

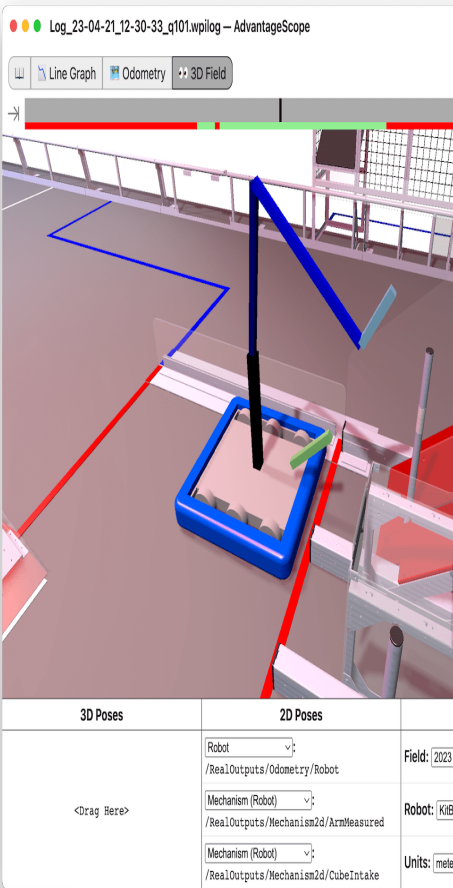


workspace Glass the on it place and resize can you below, shown as appears widget the Once of name the customize to you allow will widget the of top the clickingRight- desire. you as will mechanism the changes, encoder elevator and potentiometer wrist the As widget. the widget. the in update



AdvantageScope in Mechanism2d the Viewing

data including object, Mechanism2d a viewing for option alternative an is AdvantageScope supported. are visualizations 3D and 2D Both .logs data WPILib using file log a to recorded details. more for tabs field 3D and mechanism the for documentation the See



שליבים הבאים

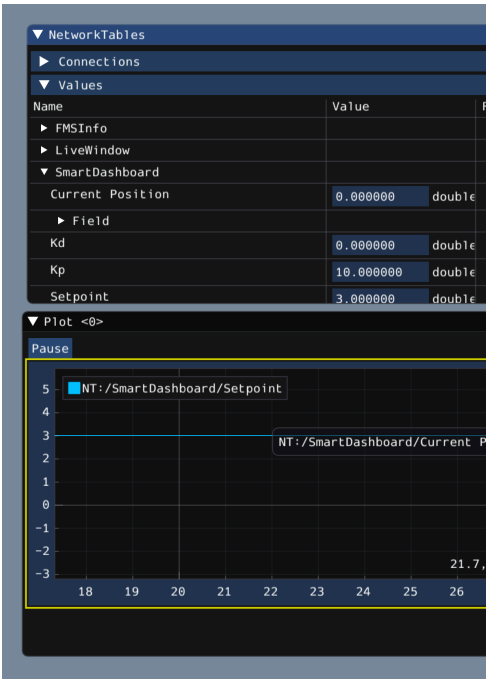
Simulation Physics with combined be can visualization Mechanism2d the above, mentioned As / C++ / Java(ArmSimulation The built. is robot your before mechanisms program you help to simulation physics combine examples)Python / C++ / Java(ElevatorSimulation and)Python arm jointed single a programming practice can you that so visualization Mechanism2d and robot. a without elevator and

Plots 11.4.7

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

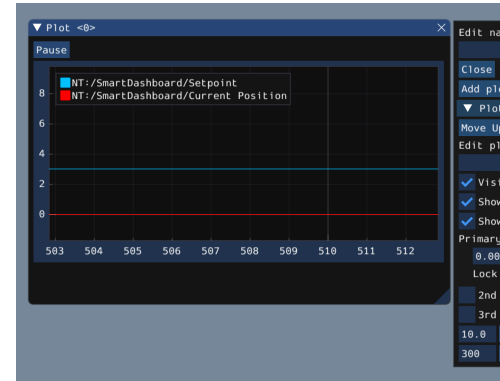
Plot a Creating

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

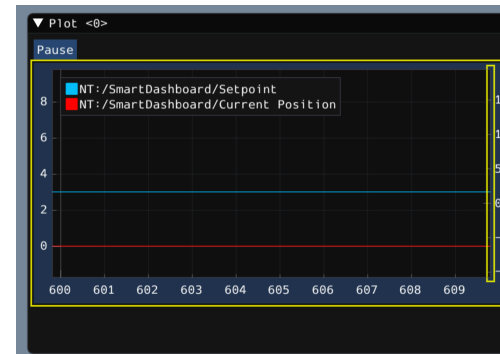


Plots Manipulating

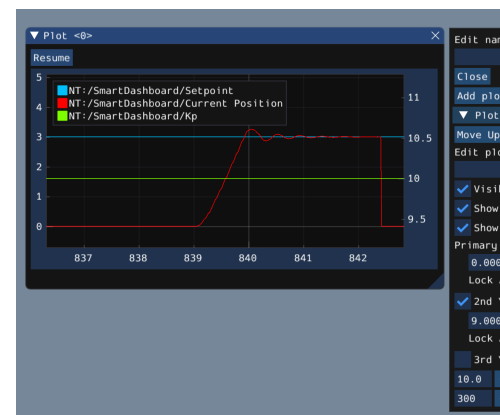
by the zoom to plot the of top on scroll and around move to plot the on drag and click can You limits axis and zoom the that so it autoscale will graph the on clicking Double out. and in axes with you present will plot the on clicking right- Furthermore, plotting. is it data the of all fit if axes, y 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



AdvantageScope with Plotting

a to recorded data from including plots, creating for option alternative an is *AdvantageScope* details. more for tab *graph line* the for documentation the See *.logs data WPILib* using file log

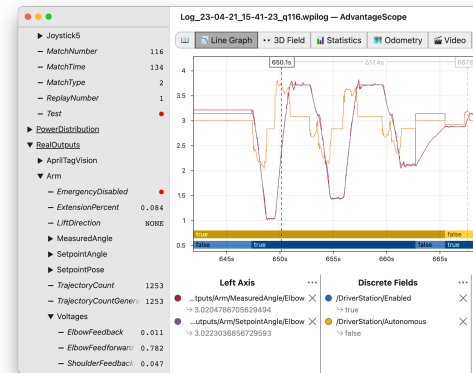


AdvantageScope 11.5

Driver and *.logs data WPILib* *.NetworkTables* for tool visualization data a is *AdvantageScope* used be can and dashboard) competition a than (rather tool programmer's a is It *.logs Station* network. the over live or file log a from code robot simulated or real debug to top the in logo WPILib the click or WPILib type and Ctrl+Shift+P press Code, Studio Visual In *.AdvantageScope* select then *.Tool Start* Select Palette. Command WPILib the launch to right browser. file standard a using *AdvantageScope* in file log supported any open also can You

available also is It *.here* found be can *AdvantageScope* for documentation Detailed :
bar. tab the in icon book the clicking by offline

- include: *AdvantageScope* of capabilities The
- tables and graphs in data boolean and textual, numeric, of Display
- robot 3D custom including 3D, and 2D in data mechanism and pose of Visualization
- models
- Zebra* and videos, match files, log including sources, data of synchronization Automatic
- tracking MotionWorks
- text console and states, module swerve joysticks, for displays Specialized
- measures statistical and histograms using fields numeric of Analysis
- logs data WPILib and CSV including options, export Multiple



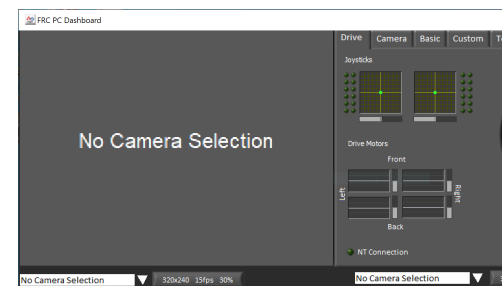
Dashboard LabVIEW 11.6

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++, Java, by *used be can* it While project. Dashboard new a creating by LabVIEW using be can which Shuffleboard or SmartDashboard prefer generally they teams, Python or language. respective their in customized

Dashboard LabVIEW FRC 11.6.1

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

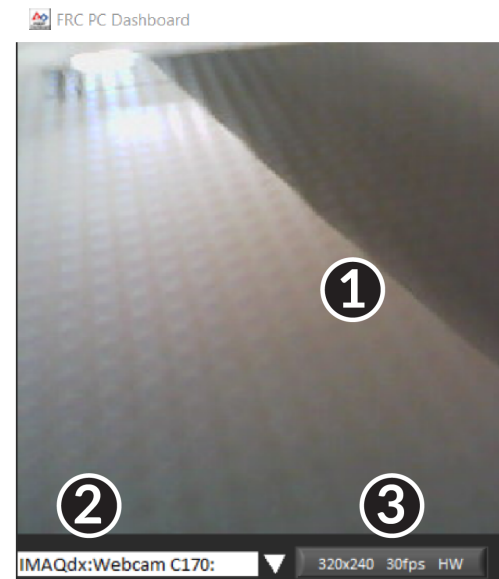
indicators and controls default some contains that tab Basic •

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 dropdown- 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

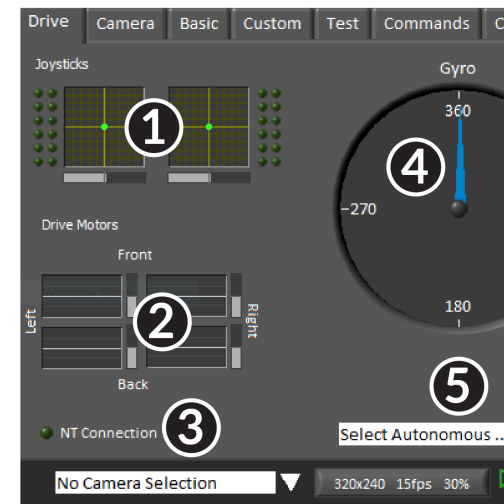
and framerate resolution, the change to you allows control This - Settings Camera 3.
the uppop- to control the click dashboard, the to stream image the of compression
configuration.

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.

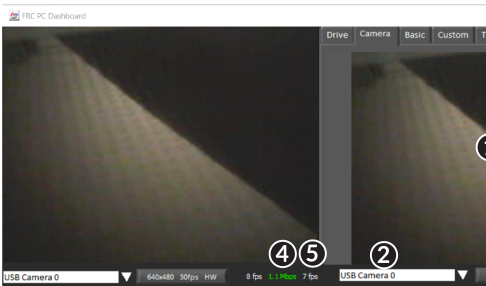
value Gyro a Displays 4.

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 Python or Java, C++, with Dashboard LabVIEW the*

Camera

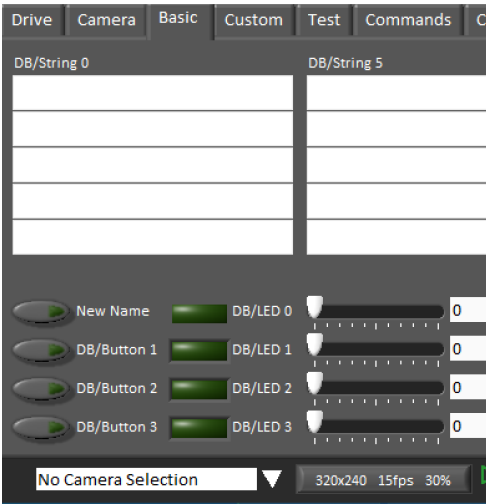
the on tab camera the use so output, camera single a display only can pane left The :□□□ needed. if output camera second a display to pane right



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

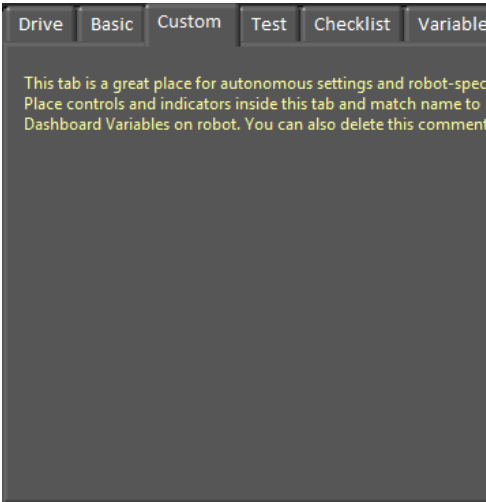
- Display Image Camera 1.
 - use. to display camera of type the select to you allows downdrop- This - Selector Mode 2.
HW Camera USB compression), (software SW Camera USB Off, Camera are choices The
setting Camera IP the that Note camera). (Axis Camera IP and compression) (hardware
USB. over roboRIO the to connected is PC your when work not will
 - and framerate resolution, the change to you allows control This - Settings Camera 3.
the uppup- 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.

Basic



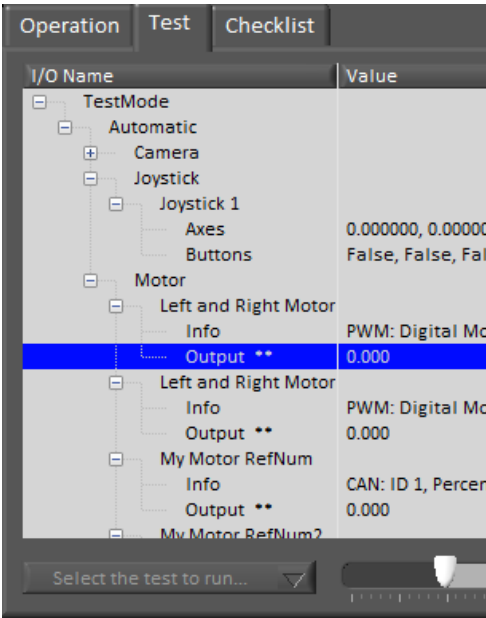
can which controls/indicators directionalbi- populatedpre- of variety a contains tab Basic The key SmartDashboard The robot. the from information display or robot the control to used be the of exception the with indicator the to next labeled are item each with associated names DB/String to 0 DB/String 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 Python or Java, C++, with Dashboard LabVIEW the Using

Custom



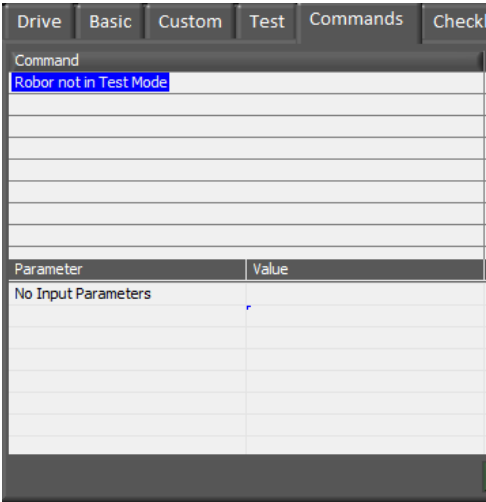
using dashboard the to controls/indicators additional add to you allows tab Custom The need will you tab this customize To functionality. existing any removing without LabVIEW LabVIEW. in project Dashboard a create to

Test



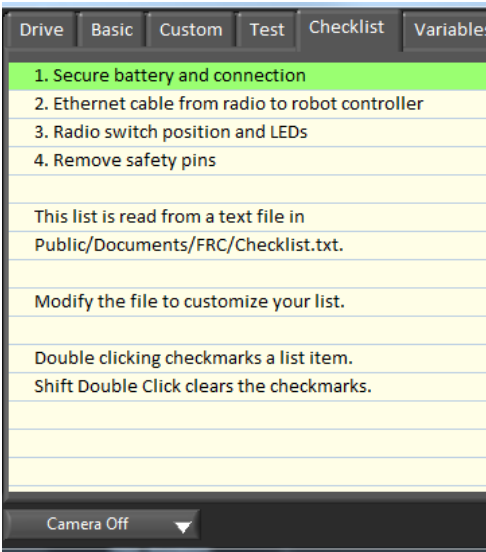
should teams C++ and (Java LabVIEW using teams for mode Test with use for is tab Test The libraries, the in items many For Mode). Test using when Shuffleboard or SmartDashboard use them to next ** have which items All automatically. here populated be will info Input/Output select to it on click output, 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



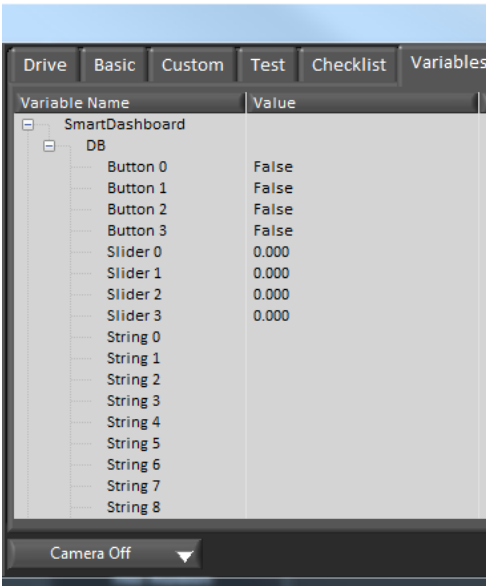
are commands which see to mode Test in Robot the with used be can tab Commands The purposes. test for commands run manually to and running

Checklist



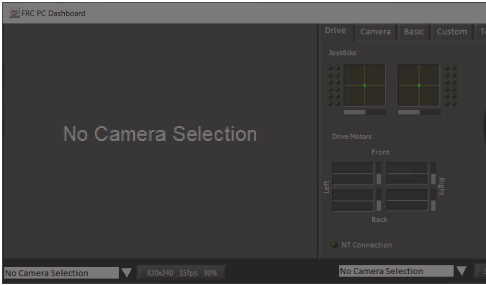
between or before perform to tasks of list a create to teams by used be can tab Checklist The checklist default the in populatedpre- are tab Checklist the using for Instructions matches. file.

Variables



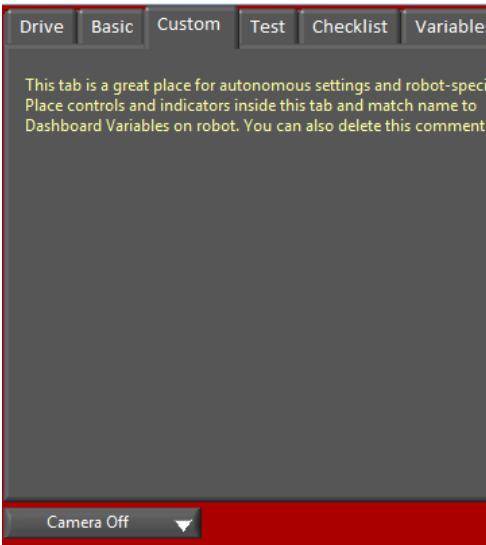
The display. tree a in variables NetworkTables all shows pane left the of tab Variables The about Information variable. each for shown are type data and Value (Key), Name Variable with shown be will Entries tab. this in displayed also is usage bandwidth NetworkTables the robot. the with synced currently not are they if diamonds black

Record/Playback



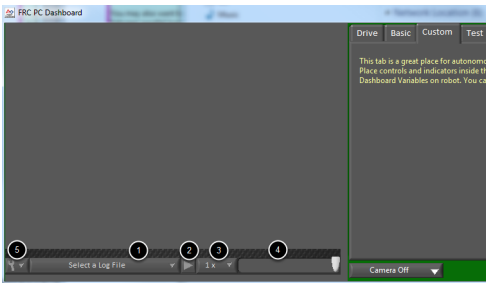
video record to you allows that feature Record/Playback a includes Dashboard LabVIEW The back it play and indicators) Dashboard your of state the as (such data NetworkTables and later.

Recording



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

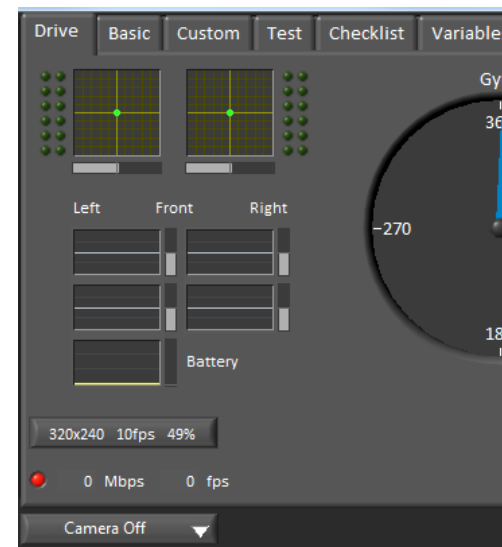
logfile the through rewind or forwardfast- to you allows slider This - Slider Control Time 4.
slider. the dragging or location desired the on clicking by

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 Python or Java, C++, with Dashboard LabVIEW the Using 11.6.2

therefore is and values pass to *NetworkTables* utilizes Dashboard LabVIEW default The
and keys the covers article This programs. robot Python and Java, C++, with compatible
Dashboard. the with work to use to ranges value

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" (putStringArray SmartDashboard.
                                                    ); } "Shoot" →

        auto of beginning the At //
        This // ) "Forwards Drive" , "Selector Auto" (getString SmartDashboard. = 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 //
        }
    
```

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 //
        }
    
```

PYTHON

```

SmartDashboard import wpilib from

        , "Backwards Drive" , "Forwards Drive" [ , "List Auto" putStringArray( SmartDashboard
                                                    ] ) "Shoot" →

        auto of beginning the At #
        would This # ) "Forwards Drive" , "Selector Auto" getString( SmartDashboard = autoName
        auto default the Forwards Drive" make →
        autoName: match
        : "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
```

PYTHON

```
SmartDashboard import wpilib from  
getHeading()) drivetrain.self ,"Gyro"putNumber( SmartDashboard
```

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. →
```

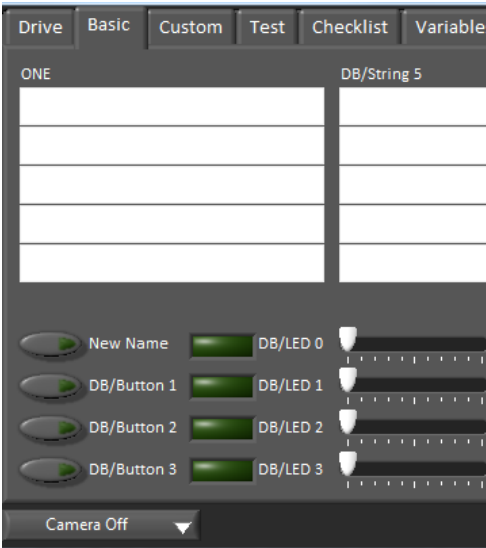
C++

```
drivetrain. drivetrain.GetLeftFront(),{ ,"Gyro"PutNumberArray(::SmartDashboard :frc  
drivetrain.GetRightBack()}); drivetrain.GetLeftBack(), GetRightFront(), →
```

PYTHON

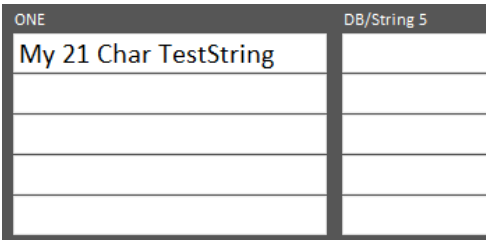
```
SmartDashboard import wpilib from  
.getLeftFront(),.drivetrain.self[ ,"Motors RobotDrive"putNumberArray(.SmartDashboard  
.drivetrain.self getLeftBack(),.drivetrain.self getRightFront(),.drivetrain.self →  
getRightBack())] →
```

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
```

PYTHON

```
SmartDashboard import wpilib from
)"TestString Char 21 My" ,"0 DB/String"putString( SmartDashboard
```

Dashboard: the on entered data string read To

JAVA

```
);"myDefaultData" ,"0 DB/String"(getStringSmartDashboard. = dashData String
```

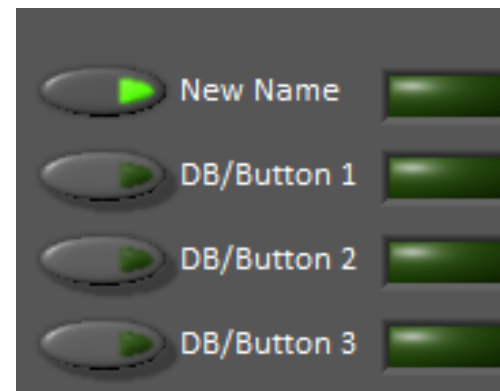
C++

```
);"myDefaultData" ,"0 DB/String"GetString(::SmartDashboard::frc = dashData string::std
```

PYTHON

```
SmartDashboard import wpilib from
)"myDefaultData" ,"0 DB/String"getString( SmartDashboard = dashData
```

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
```

PYTHON

```
SmartDashboard import wpilib from  
true) ,"0 DB/Button"putBoolean( SmartDashboard  
false) is value (default Buttons: the from read To
```

JAVA

```
);false ,"0 DB/Button"(getBooleanSmartDashboard. = buttonValue boolean
```

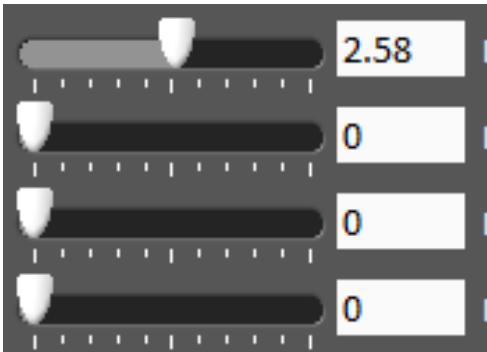
C++

```
);false ,"0 DB/Button"GetBoolean(::SmartDashboard :frc = buttonValue bool
```

PYTHON

```
SmartDashboard import wpilib from  
false) ,"0 DB/Button"getBoolean( SmartDashboard = buttonValue
```

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
```

PYTHON

```
SmartDashboard import wpilib from  
)2.58 ,"0 DB/Slider"putNumber( SmartDashboard
```

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
```

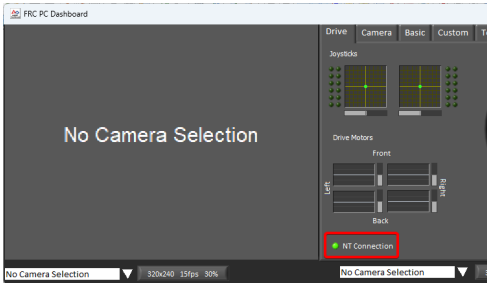
PYTHON

```
SmartDashboard import wpilib from
)0.0 , "0 DB/Slider"getNumber( SmartDashboard = dashData
```

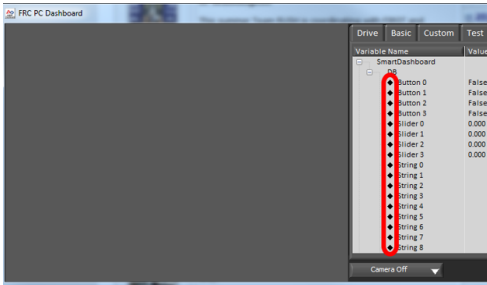
Connectivity Dashboard Troubleshooting 11.6.3

your to connected not is Dashboard the if recognize to how explain help will document This make. can you modification code a and condition this troubleshoot to steps robot,

Connectivity Dashboard LabVIEW Recognizing

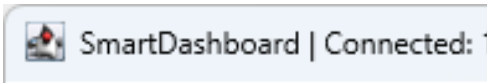


panel. front the on indicator Connection NetworkTables a has Dashboard LabVIEW The

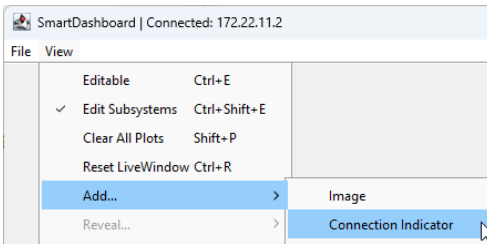


when diamond black a with shown are variables the Dashboard, the of tab Variables the On these and robot the to connects Dashboard the Once robot. the with synced not are they disappear. will diamond the synced, are variables

Connectivity SmartDashboard Recognizing



it address IP the shows It bar. title the in not or connected is it if indicates SmartDashboard connection. the configuring on more for *page this* See to. connected is



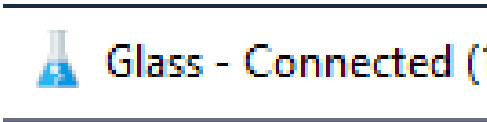
indicator connection The widget. Indicator Connection a add also can you visibility, more For checked. is checkbox Editable the if sizedre- or moved be can

Connectivity Shuffleboard Recognizing



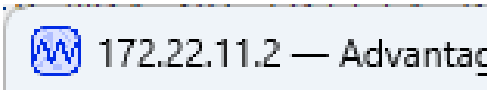
application the of corner right bottom the in not or connected is it if indicates Shuffleboard connection. the configuring on more for page See above. image the in shown as

Connectivity Glass Recognizing



connected is it address IP the shows It bar. title the in not or connected is it if indicates Glass connection. the configuring on more for page this See to.

Connectivity AdvantageScope Recognizing



is it address IP the shows It bar. title the in not or connected is it if indicates AdvantageScope AdvantageScope the See to. connect to attempting is it address IP the else or to, connected connection. the configuring on more for Documentation

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

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* 2024), 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

telemetry. robot facilitate to WPILib by provided interface an is)Python ,C++ ,Java(Sendable once - dashboard the to state their send declaratively can Sendable implement that Classes removes This loop. robot every values telemetry the send automatically will WPILib declared, values receiving and sending of logic iterationto-iteration- the handle to teams for need the robot their from code telemetry their separate to teams allows also and dashboard, the from logic.

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
```

PYTHON

```
SmartDashboard import wpilib from  
armPIDController) , "PID Arm"putData( SmartDashboard
```

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

Data WPILib the see format, file log data the of details the on information more For :[Log File Format Specification](#)

DataLogManager using Logging Data Standard 12.3.2

provides that log data centralized a provides)Python ,C++ ,Java(class DataLogManager The space disk when files old up cleans automatically It management. file log data automatic competition available) (if or date/time current on either based file the renames and low is one if logs called folder a in drive flash USB a to saved be will file data The number. match otherwise. home/lvuser/logs/ to or attached, is

or NTFS roboRIO. the with work to FAT32 as formatted be to need drives flash USB :[Log File Format Specification](#) work. not will drives formatted exFAT

DS the After connects. DS the until FRC_TBD_{random}.wpilog named initially are files Log is date/time the (where FRC_yyyyMMdd_HHmss.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_HHmss_{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 //
();start DataLogManager.
```

C++

```
frc/DataLogManager.h" include#
log data to recording Starts //
Start();::DataLogManager::frc
```

PYTHON

```
DataLogManager import wpilib from
start() DataLogManager
```

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 .System.out.println() for replacement a be can this so output, 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 //
();start DataLogManager.
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
```

PYTHON

```
DriverStation DataLogManager, import wpilib from

log data to recording Starts #
start() DataLogManager

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

(e.g. classes LogEntry associated its and)Python ,C++ ,Java(class DataLog The logs. data writing for access levellow- provides etc) ,DoubleLogEntry ,BooleanLogEntry

a to call **Every** performed. checking change no is there NetworkTables, Unlike :
Checking log. data the to written being record a in result will function LogEntry.append()
caller. the of responsibility the is necessary when log the to appending only and changes for

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
```

page) next on (continues

(0000 00000 0000)

```

        myStringLog; StringLogEntry

        { ()robotInit void public
        log data to recording Starts //
        ();start DataLogManager.

        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(myBooleanLog.
        );3.5(myDoubleLog.
        );"wow!"(myStringLog.
        }
    }

```

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 //
        );true(myBooleanLog.Append(
        );3.5myDoubleLog.Append(
        );"wow!"myStringLog.Append(
        }
    }

```

PYTHON

```

TimedRobot DataLogManager, import wpilib from
    ( import log.wpiutil from
        DataLog,
        BooleanLogEntry,
        DoubleLogEntry,
        StringLogEntry,
    )

    (TimedRobot):MyRobot class
        ):self(robotInit def
            log data to recording Starts #
            start().DataLogManager

            entries log custom up Set #
            getLog() DataLogManager = log
) "my/boolean/" BooleanLogEntry(log, = myBooleanLog self
) "my/double/" DoubleLogEntry(log, = myDoubleLog self
) "my/string/" StringLogEntry(log, = myStringLog self

        ):self(teleopPeriodic def
            : ... if
            necessary when log Only #
            ) True append( myBooleanLog self
            ) 3.5 append( myDoubleLog self
            ) "wow!" append( myStringLog self

```

Logs Data Processing & Downloading 12.4

or DataLogTool, the AdvantageScope, by offline viewed and processed be can logs Data memory flash integrated roboRIO the to stored being are files log data If utilities. custom delete and download periodically to important it's drive, flash USB removable a of instead up. filling from storage the avoid to logs data

AdvantageScope with Logs Data Managing 12.4.1

exporting and visualizing, downloading, supports that tool analysis an is *AdvantageScope* details: more for documentation the of sections relevant the See logs. data

files log Downloading •

formats new to Exporting •

DataLogTool the with Logs Data Managing 12.4.2

files log data downloading for client SFTP a integrates application desktop DataLogTool The computer. local the to coprocessor) or roboRIO (e.g. device network a from

steps: four of consists process This

coprocessor or roboRIO to Connect 1.

download to files what select and directory remote to Navigate 2.

folder download Select 3.

downloading after files remote delete optionally and files Download 4.

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

/ *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

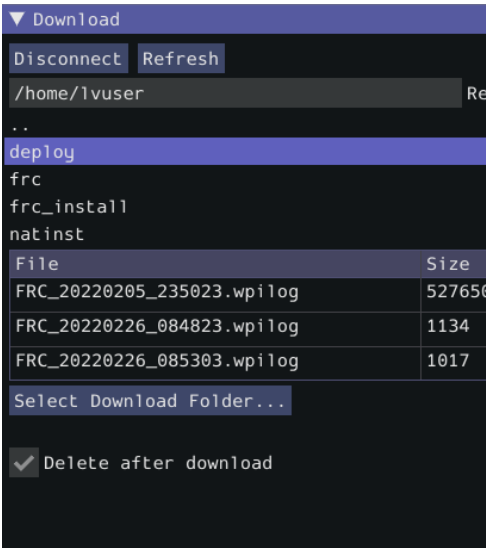
as such roboRIO, the than other devices network to connecting supports also tool The authentication. basedpassword- SFTP supports device the as long as coprocessors,

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* /

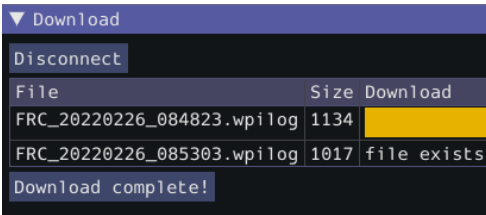
Files Downloading

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

u/logs/ or home/lvuser/logs/ either to saved typically are files log roboRIO, the On : location). stick (USB

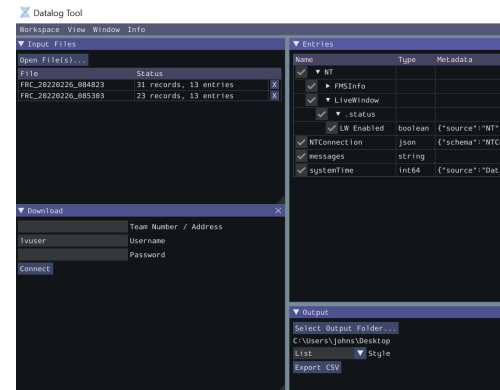


computer. local the for browser file a up bring to *Folder... Download Select Click*
the check downloaded, are they after device remote the from files the delete to want you If
checkbox. *download after Delete*
the button, this clicking After appear. will *Download* selected, is folder download a Once
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

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

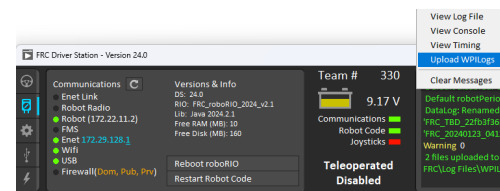


Files window. Files "Input the in files log data opening by started is process conversion The records of number (e.g. file each on status Summary .File(s)... Open clicking by opened are file. the closes row table the in X Clicking displayed. is entries) and

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 .

Station Driver the with Logs Data Managing 12.4.3



Upload select and icon gear the on Click WPILogs. download can software Station Driver The to automatically downloaded be will u/logs/ or home/lvuser/logs/ in logs The .WPILogs WPILogs\Files Log\FRC\Documents\Public\Users\C:

Logs Data of Processing Custom 12.4.4

be can't that values binary of processing for (e.g. logs data of processing advanced more For ,C++ ,Java in logs data reading for class DataLogReader a provides WPILib CSV), to converted the languages, other For).`dataLog.py`(reader `dataLog` python pure a also is There .Python or documented. also is `format log data`

data a over iterating supports it that in log, data a of view level-low- 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 like `NetworkTables`- a as such abstractions level higher usage. basic demonstrates)`dataLog.py` Python the (and C++ and Java in

Classes Sendable Own Your Writing 12.5

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) (SendableBuilder initSendable void public
            ); "BangBangController" (setSmartDashboardType builder.
            ::setTolerance); this ::getTolerance, this , "tolerance" (addDoubleProperty builder.
            ::setSetpoint); this ::getSetpoint, this , "setpoint" (addDoubleProperty builder.
            ); null ::getMeasurement, this , "measurement" (addDoubleProperty builder.
            ); null ::getError, this , "error" (addDoubleProperty builder.
            ); null ::atSetpoint, this , "atSetpoint" (addBooleanProperty builder.
        }

```

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(

```

page) next on (continues

(0000 00000 0000)

);nullptr ,} AtSetpoint()); return { }this[,"atSetpoint"

}

68

69

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 12.5.1

type of ,builder parameter, single a takes method initSendable the above, seen As of binding allow that methods exposes builder This).Python ,C++ ,java(SendableBuilder values that ensuring safely for methods as well as names, dashboard to setters and getters behavior. robot unsafe cause not do dashboard the *from* consumed

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::(wpiPWMMotorController::InitSendable void
);"Controller Motor"builder.SetSmartDashboardType(
);truebuilder.SetActuator(
);} Disable(); { }this ,=builder.SetSafeState([
builder.AddDoubleProperty(
,} Get(); return { }this ,=[ ,"Value"
);} Set(value); { value) double](this ,=[

```

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- 12.6

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

for hooks with framework logging basedeverything"- "Log only): (Java AdvantageKit • *simulation* in data logged replaying

on- and telemetry Extensive library. logging basedannotation- only): (Java Monologue • design and footprint code minimal with code robot your to added be can logging robot restrictions.

viewer. log station driver alternate An :DSLOG •

Programs Robot Creating 13.1

Tutorial Drive Tank 13.1.1

drive? tank using joysticks two with drive to robot my get I do How **Question:**

robot. your for drive tank up setting when consider to components four are There **Solution:** arcade the of instead used is drive.vi tank the sure make is do to want will you thing first The is consider to item second The previously. utilizing were you VI drive whichever or drive.vi the drive, tank In drive. to want you direction the to map to joysticks your want you how the control to used is joystick right the and motors left the control to used is joystick left the on up pushing by right turn robot your make to want you if example, For motors. right in accordingly joystick's your set to need will you joystick right the on down and joystick left lines *PWM* the confirm to want will you Next, below). detail more in shown is (this LabVIEW sure make Lastly, controlling. be will joysticks your ones same the are into, wired are you that will below steps The LabVIEW. in specified controllers motor the match controllers motor your detail: more in ideas these discuss

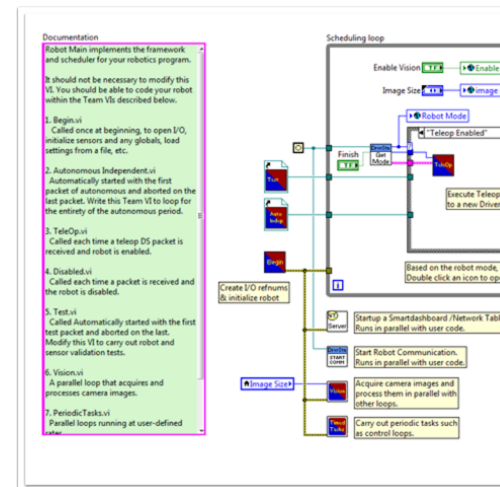
.Project roboRIO FRC click double and LabVIEW Open 1.



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.

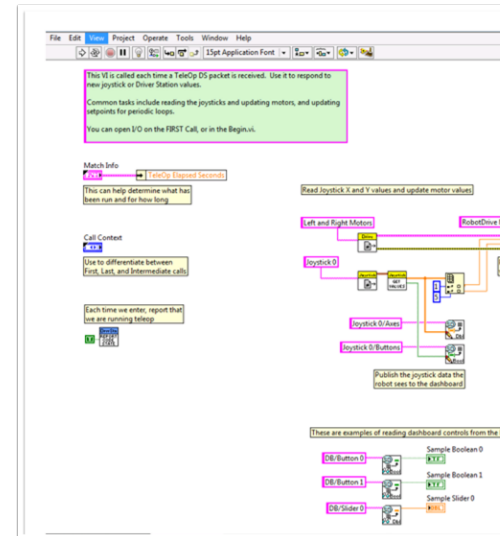


block its at Look structure. case Enabled Teleop the of inside vi "Teleop" the click Double 5.
 here: changes two make to want will You diagram.

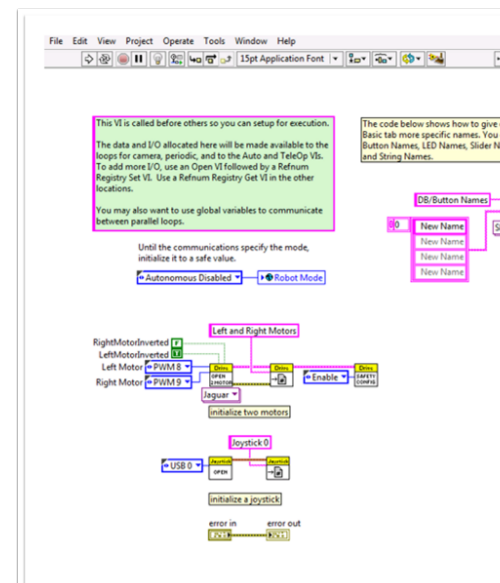
the on clicking right by found be can This drive.vi. tank the with Drive Arcade Replace •
 Drive Tank the clicking and >> Drive Robot >> Library Robotics WPI >> diagram block
 VI.

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. specific robot- 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 level high- 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

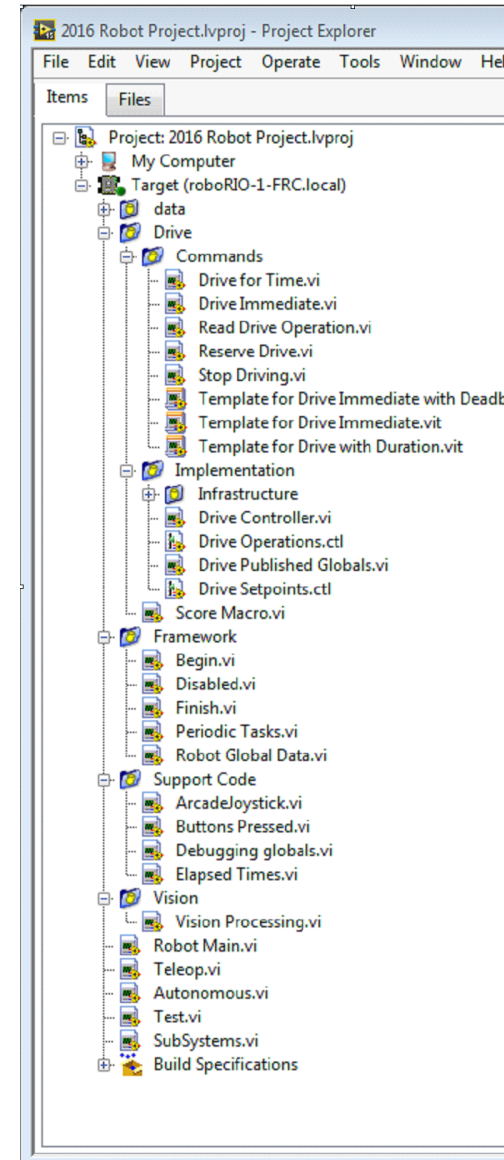
allowing templates, project LabVIEW existing the to functionality adds Control and Command used are Subsystems code. robot and robots sophisticated more with better scale to code of sequences from built is code game and implementation, the of details the abstract to points, set update can that VIs are 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



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

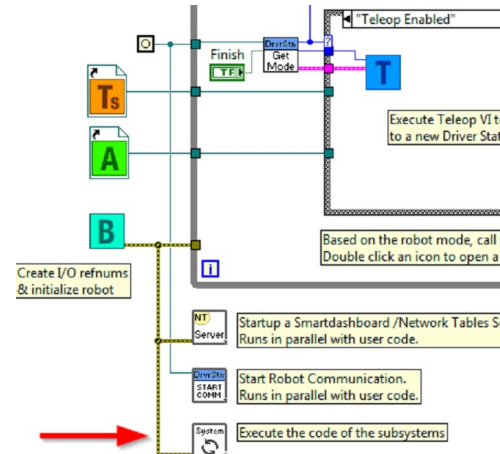
subsystems. all starts and contains that VI

Dependencies

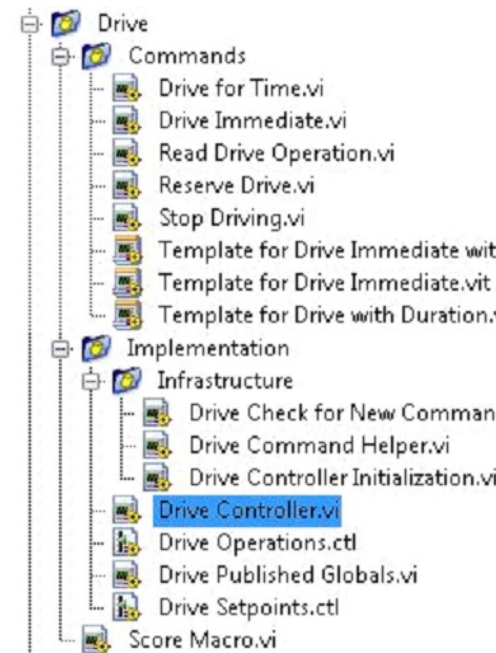
code. robot the by used files the Shows

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

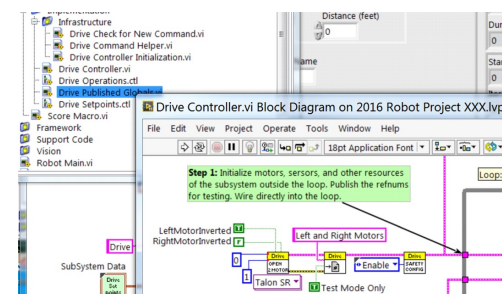
VIs Infrastructure

- 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.cti: Drive •
operation. an share can commands
- Drive the of modes operating all by used fields data the contains It Setpoint.cti: Drive •
subsystem.
- the about information global publishing for place useful A Globals.vi: Published Drive •
subsystem. drive

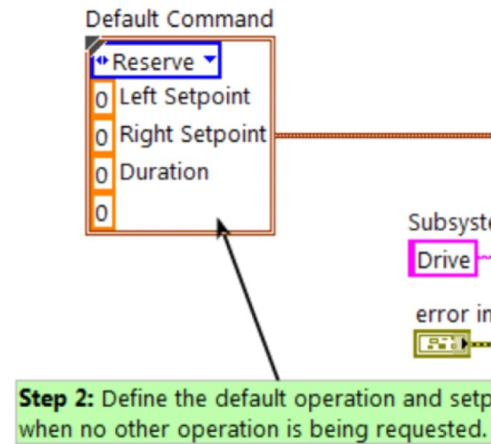
Subsystem Drive the Initializing :2 Part

that areas key out point that diagram block controller's the on comments green are There
edit. to how know to want will you

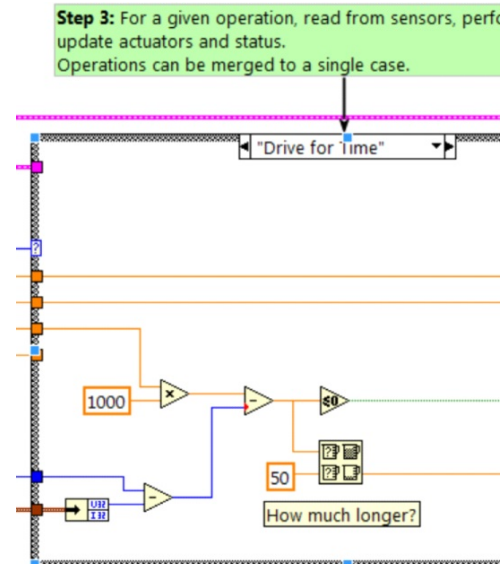
This up. starts subsystem the when once execute will loop control the of left the to area The
the publish may You data. state and I/O all initialize and allocate typically will you where is
other that so private them keep to Only Mode Test for them register may you or refnums, I/O
command. a using without motors update cannot code



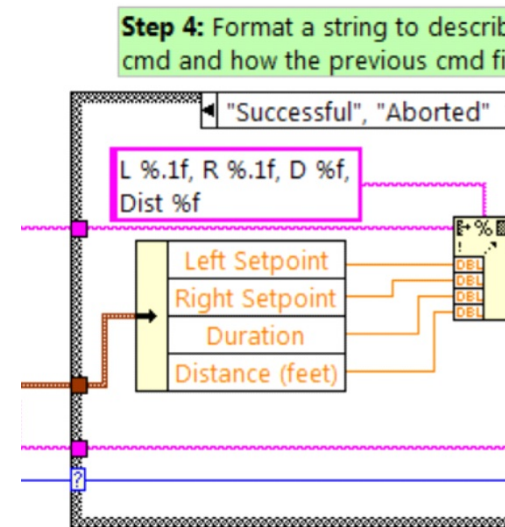
rather Controller.vi respective their in subsystem each for resources the Initializing :□□□□
and conflicts resource potential reducing encapsulation, I/O improves Begin.vi in than
debugging. simplifies



other no when values point set and operation default the select to is initialization the of Part processed. being is operation

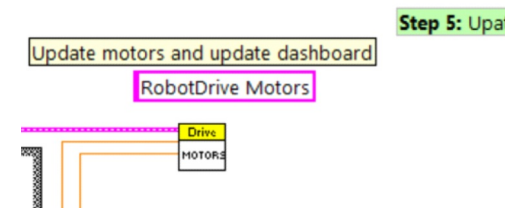


Set implemented. actually are operations where statement case a is loop control the Inside the how on influence have all can sensors and count, iteration delay, iteration values, point subsystem. the of state operation each for value a has structure case This operates. subsystem



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



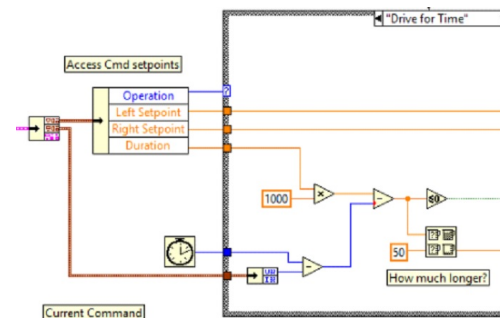
Commands Shipped Subsystem Drive :3 Part

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

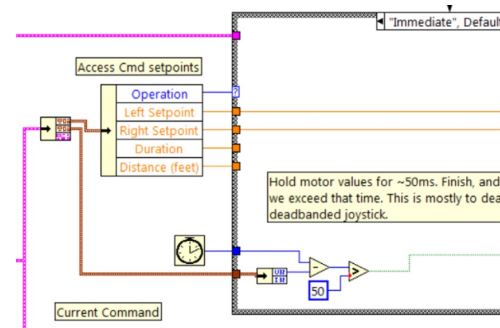


Immediate.vi Drive

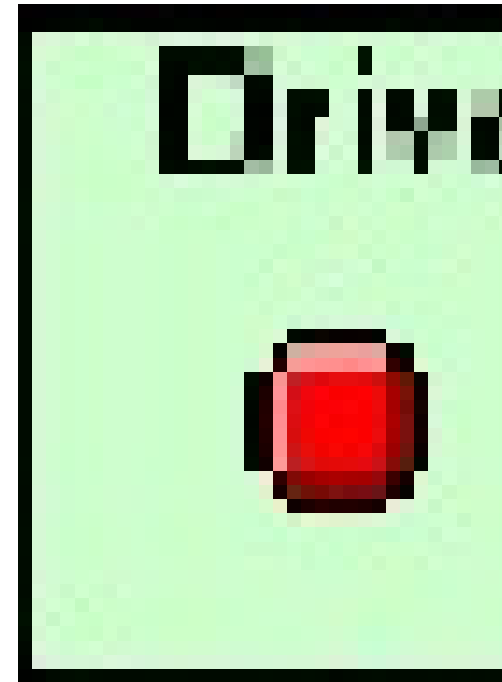


to immediately motors the set will and motors the for speeds right and left desired the Gets points. set those

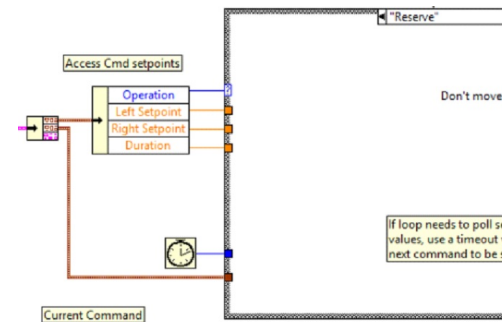
The command. the by defined point set the to motors the updates case Immediate The a until value this maintain to motors the want you since finished considered not is command command a anytime useful is timeout The value. timeout a until or in comes command new and band, dead the than smaller if requested 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



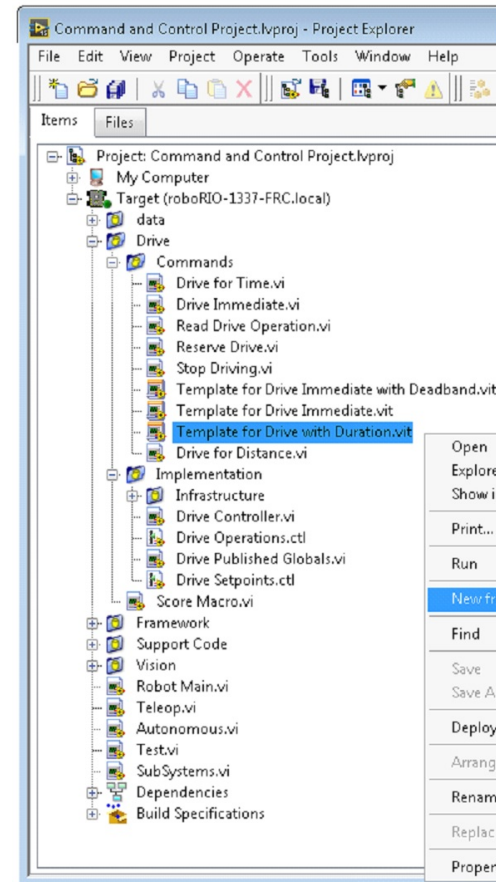
Commands New Creating :4 Part

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,

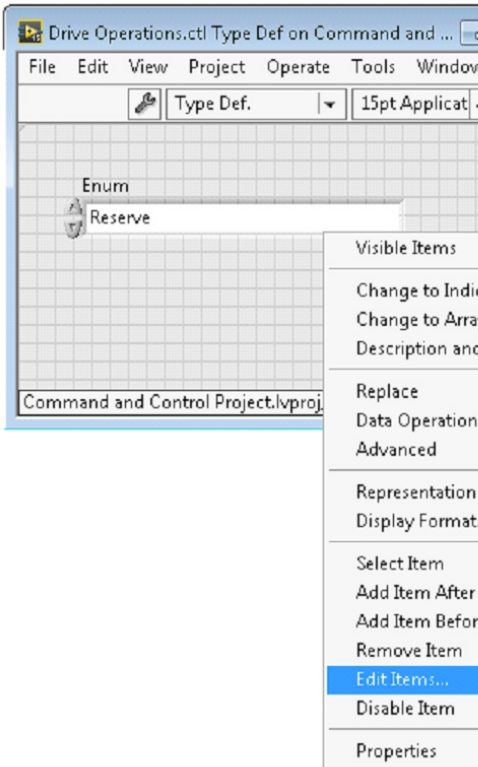
- setpoint. new the about subsystem the notifies VI This **:Immediate**
- and deadband the to value input the compares VI This **:deadband with Immediate**
- when useful very is This setpoint. new the about subsystem the notifies optionally
used. being are values continuous joystick

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.

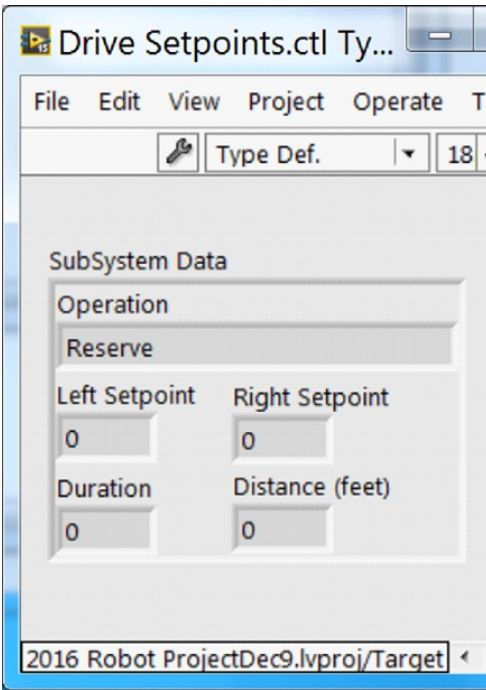
Distance“. for ”Drive command new the add will we example this In



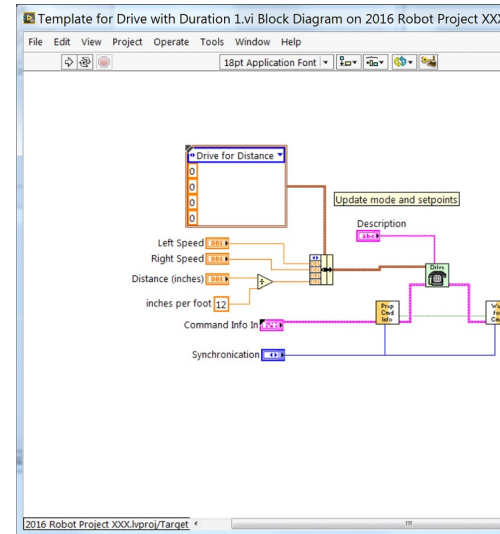
determine Next, Distance“. for ”Drive as such name descriptive a with VI new the save First, The typedef. enum Operations Drive the added value new a needs command new the whether image following the but Distance, for Drive of value enum an has already code project initial needed. if one add would you how shows



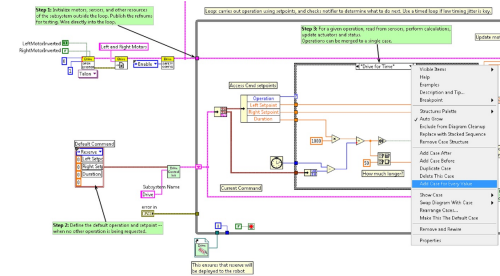
By control. setpoints the to it add execute, to information additional needs command a If Duration and Setpoint, Right Setpoint, Left the for fields has subsystem Drive the default, reuse could command Distance for Drive The executed. be to operation the with along Setpoints.ctl Drive the to control numeric a add and ahead go let's but distance, as Duration (feet). Distance called



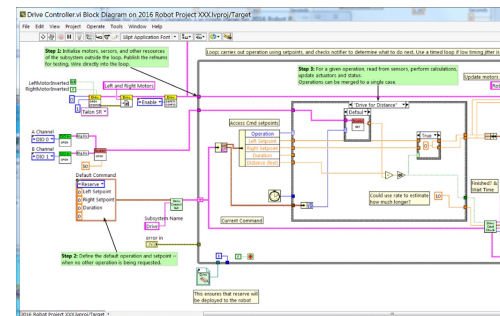
newly the modify can we command, our specify to needed fields the of all have we that Once enum's the from Distance for Drive select below, shown As Distance.vi. for Drive created not do units the If etc. speeds, distance, specify to parameters VI a add and menu down drop units. between map to place 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.

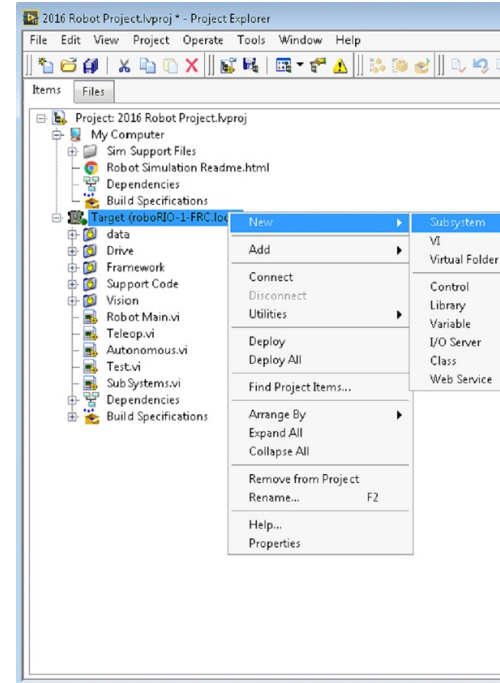


Open node. unbundle setpoints" Cmd "Access the grow fields, setpoint new access to order In structure, case the of diagram new the In loop. the of left the to outside, the on encoder(s) your There otherwise. it read and iteration loop first the on encoder the reset to call a added we new If power. motor 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

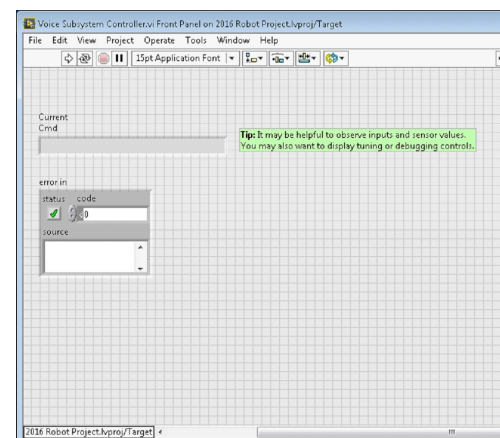


Subsystem a Creating :5 Part

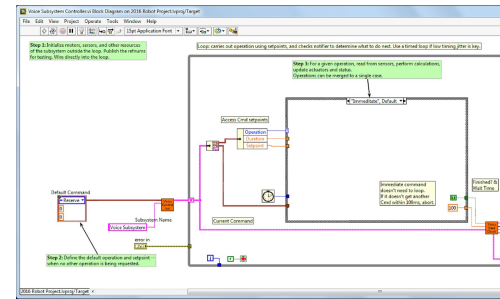
New» select and target roboRIO the on click right subsystem, new a create to order In operational the list subsystem, the of name the enter box, dialog up pop the In Subsystem. icon. the of color the specify and modes,



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

FRC® programming specifically and LabVIEW in programming about more learn To :□□□□ resources. following the out check LabVIEW, in robots

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

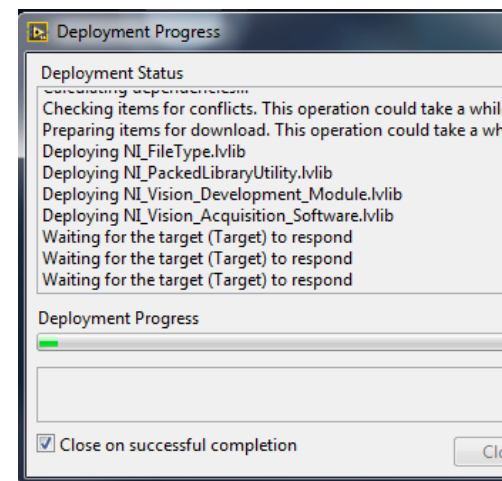
Resources Party Third

- 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

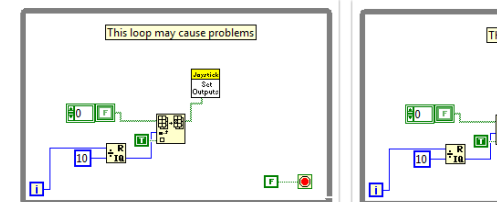
Symptom The



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

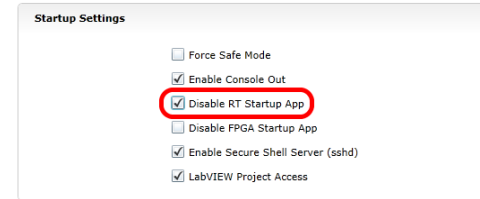
Problem The



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

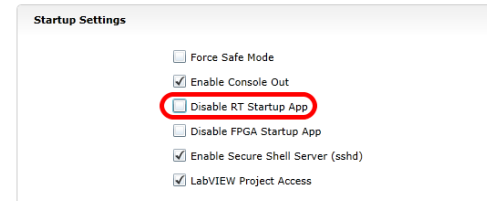


Settings Startup Dashboard Web roboRIO the on article the (see webserver roboRIO the Using App". Startup RT "Disable to box the **Check** details). more for

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

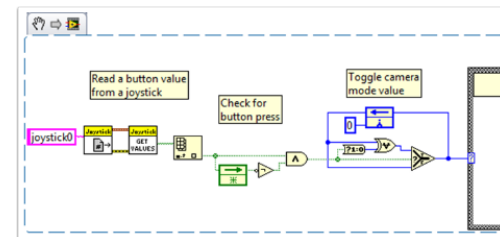
Modes Camera Two Between Toggle To How 13.2.3

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 •

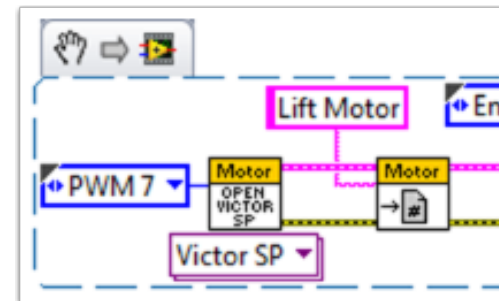
your post or documents more through Search discussions? and examples more for Looking posts your mark to forget Don't [here!](#) clicking by tutorial or code, example discussion, own tag! a with

Project a to Motor Independent an Add 13.2.5

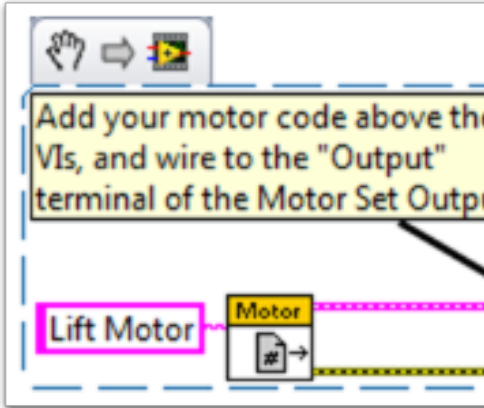
motor additional an add to need might you set, all is wheels the controls that drive your Once motor this Since arm. an as such wheels, the of independent completely something control to independent want definitely you'll drive, mecanum or arcade, tank, your of part be not will it. of control

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

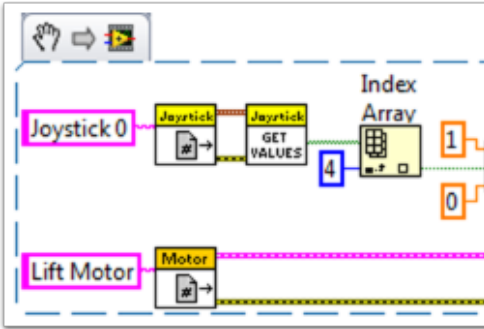
Open Control Motor the using **Begin.vi** the in reference motor a create FIRST, in clickingright- by found be can These **.VI Set Registry Refnum Control Motor** and **VI .Control Library>>RobotDrive>>Motor Robotics WPI** to going and diagram block the to it connected and Motor" "Lift mine named I motor. 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



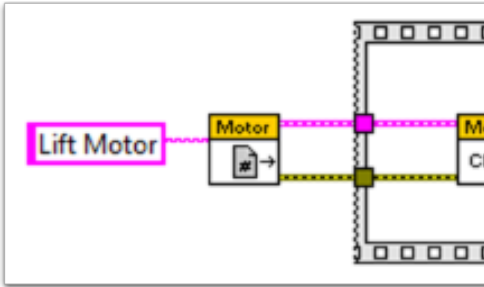
Motor the using **Teleop.vi** the in exact) be to has name (the motor your reference Now, **Output Set Control Motor** the with do to what it tell and **VI Get Registry Refnum Control** VIs. above the as place same the in are These **.VI**



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

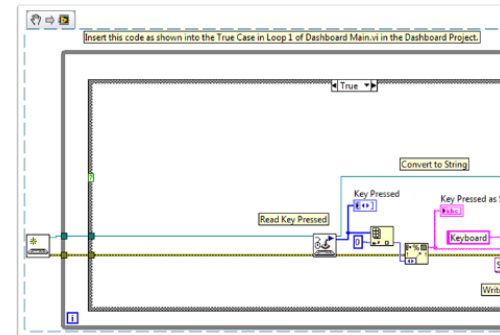


luck! Good ever! robot best the program you helps this hope I

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 configuration. drive tank a in motors drive two

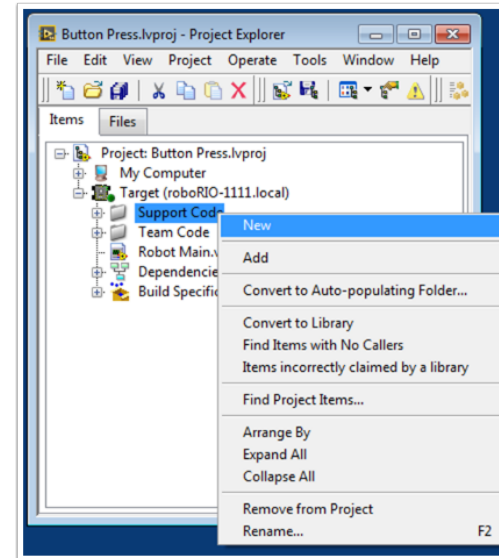
can You VI. Main Dashboard the in included be to need will that code the is Snippet VI first The keyboard the to connection a opens code The 1. Loop of case True the into code this insert is information This key. pressed the reads it iteration each on and begins, loop the before Loop When project. robot the in VI Teleop the to passed then is which string, a to converted closed. is keyboard the to connection the running, stops 1



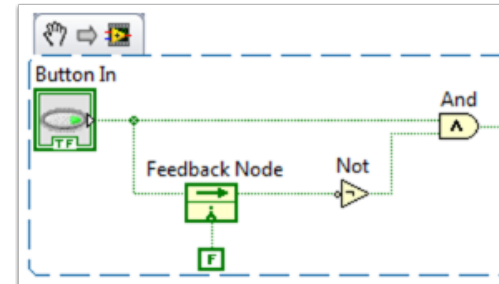
string the reads This VI. Teleop the in included be should that code is Snippet VI second The then Structure Case A pressed. was key which indicates that Dashboard the from value the on depending motors, right and left the to written be should values which determines this in case Each reverse. is S and 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,



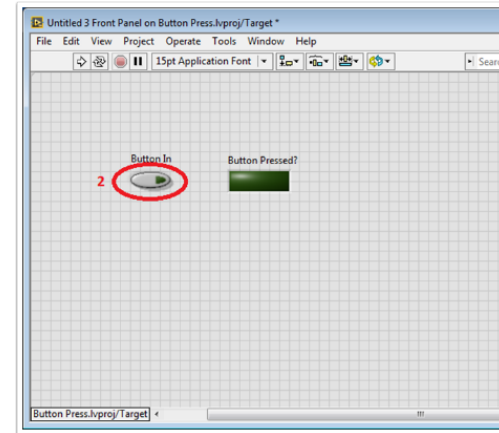
snippet. code following the in drop VI, new the of diagram block the on Now



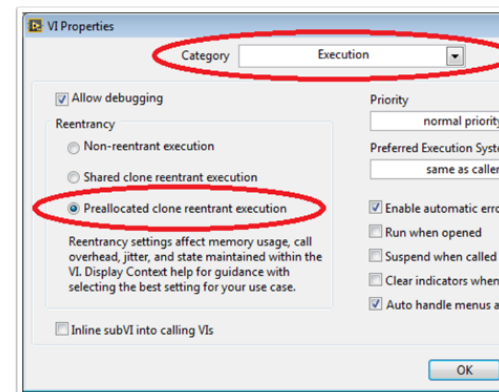
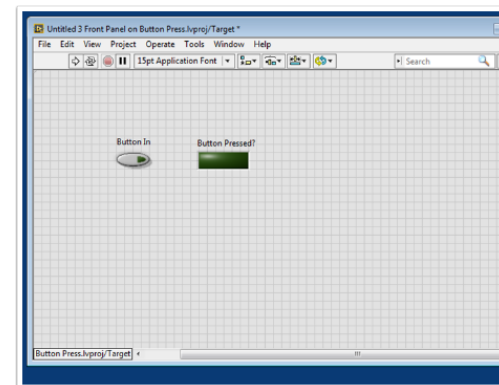
of value current the wired have We Node. Feedback the called function a uses code This the of arrow the of out coming wire The node. feedback the of side left the into button the feedback your on arrow the If button. the of value previous the represents node feedback reverse to option the find to click 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

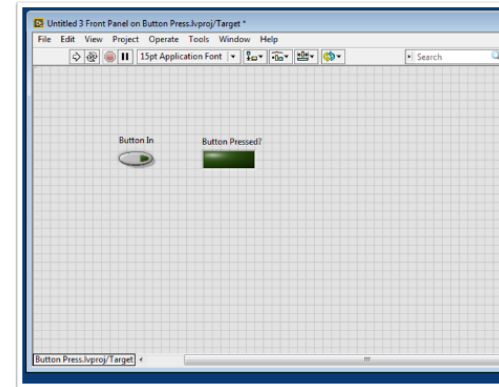
the of outputs and inputs the to indicator and control boolean the connect to need we Next the connect to button the click then pane, connector the on block the click first this, do To VI. indicator. the for this Repeat below). diagram the (see two



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"

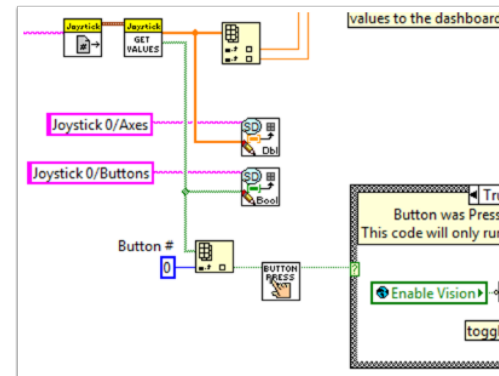


click Right function. VI's the of descriptive more be to Icon VI the change should we Lastly, Icon. new a Create Icon. Edit to go and Icon the



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

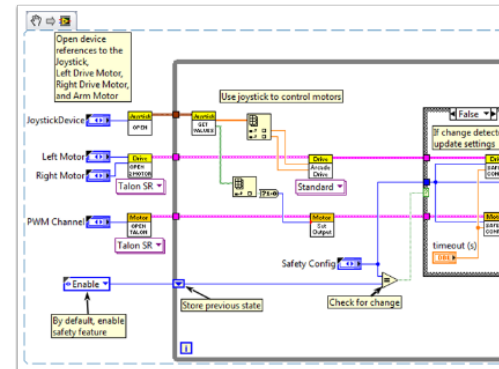
executing is code your of all that sure making is projects complex with problem common A execution long priority, high with tasks when arise can Problems to. it expect you when known is what to leads This roboRIO. the on power processing hog calls frequent or times, In busy. being processor the to due 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



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

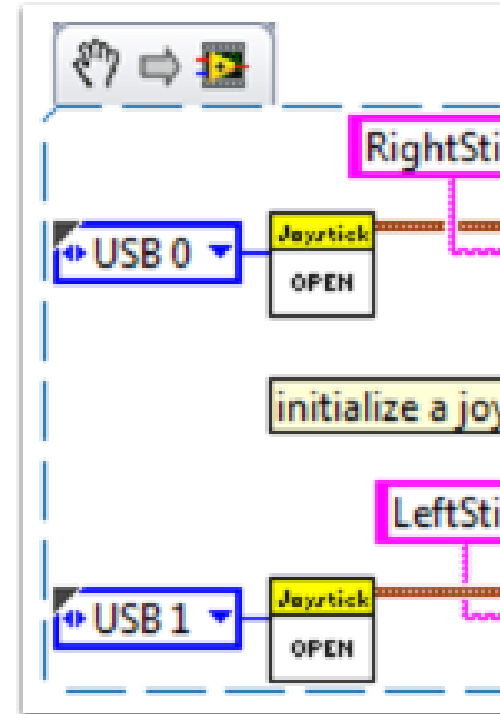
Solenoids or Motors Control to Buttons Joystick Use to How 13.2.9

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

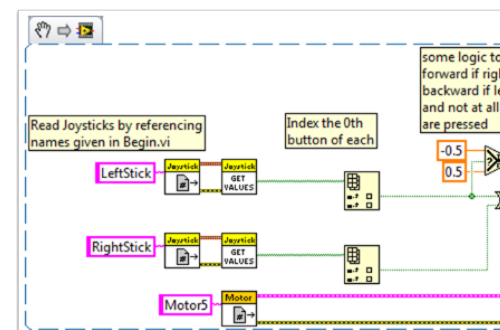


will we where is This "Teleop.VI" the in placed be will document this in code the of rest The solenoids. or motors our of aspects different control to buttons joystick our programming be

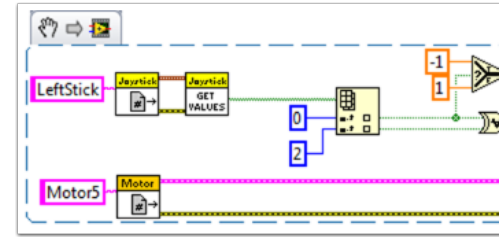
1 Scenario

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

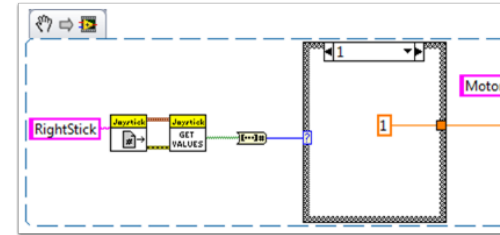
https://zone.ni.com/reference/en-XX/help/371361L-01/glang/case_structure/

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>

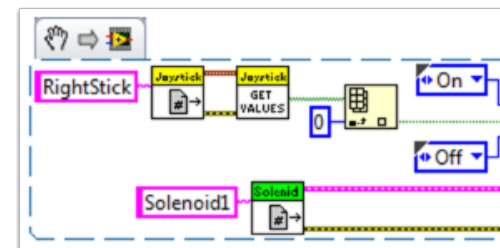


case For case. each in constant single a need only we simple, were requirements our Since constant any use can We etc. 0.5,- a use we back) (half 2 case for 1, a use we ahead) (full 1 (any pressed are buttons multiple if so default the as 0 case left I 1.- and 1 between value these customize to free 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

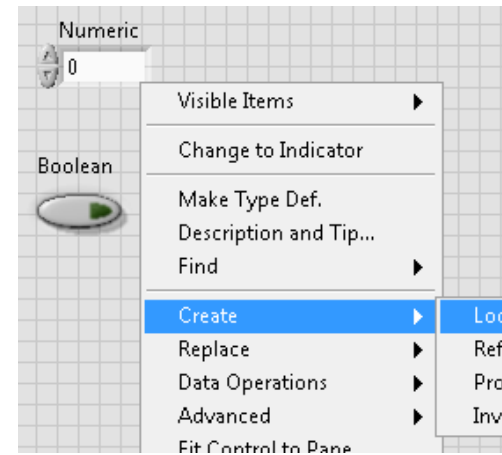
in used are they how variables, global and local to introduction an as serves example This your in them use to want might you how and Project, Robot FRC® for LabVIEW default the project.

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

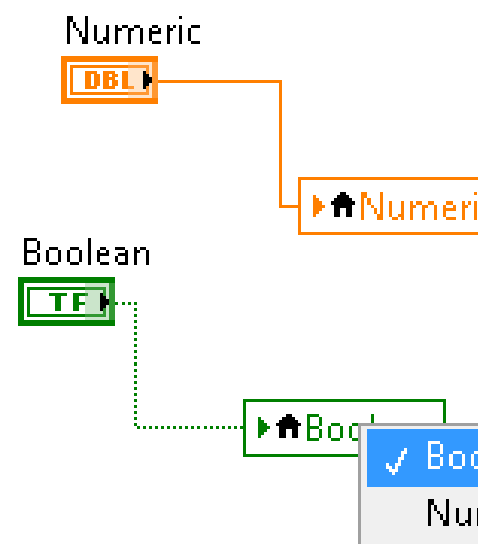
loop consecutive between data pass to need you that be may reason possible One Note: node feedback the that noted be also should It .post this in this covered Miro_T iterations; topic a be may that although register, shift the to equivalent an as used be may LabVIEW in day! another for

Variables Global and Local to Introduction

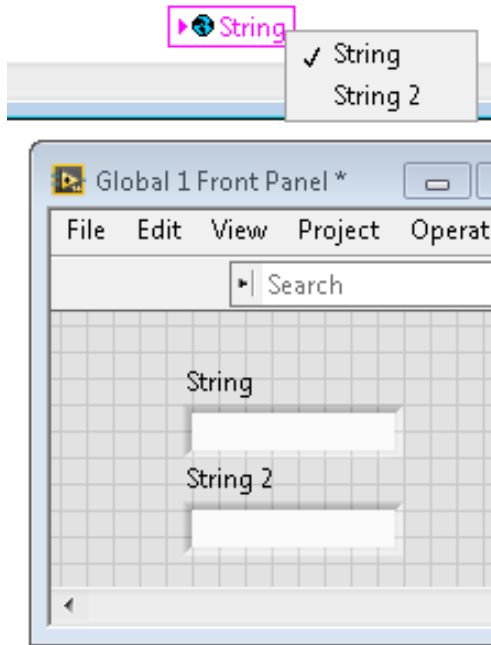
a clickingright- by variable local a Create VI. same the within used be may variables Local
Panel: Front your on indicator or control



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



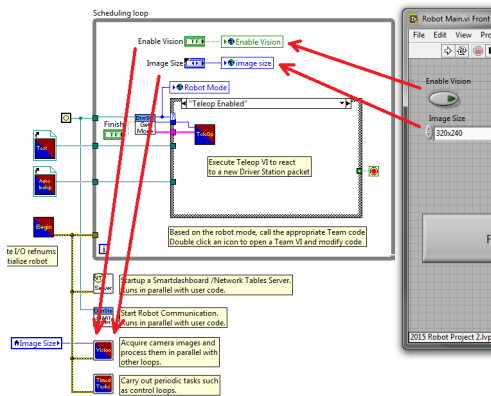
the from diagram block the to one Add differently. slightly created are variables Global
panel. front separate a opens it it, clickdouble- you when that notice and palette, Structures
front the to entities many as add you but diagram, block a have not does panel front This
file: *.vi a as it save and wish you as panel



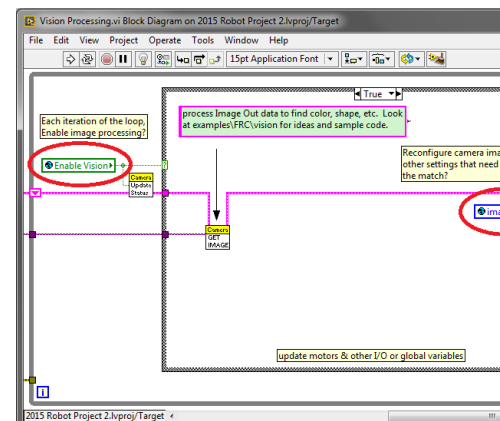
variables! global and local using when conditions race avoid to careful very Be :□□□□ multiple in variable same the to writing accidentally not are you that sure make Essentially, thorough more a For written. last was it location which to know to way a without locations [document help this see explanation,](#)

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



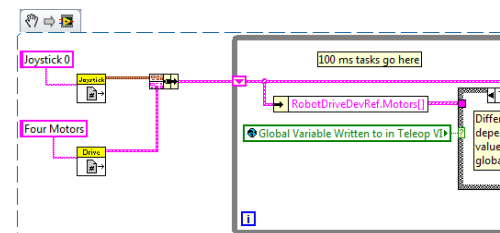
VI: Processing Vision the of iteration each in read then And ...



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

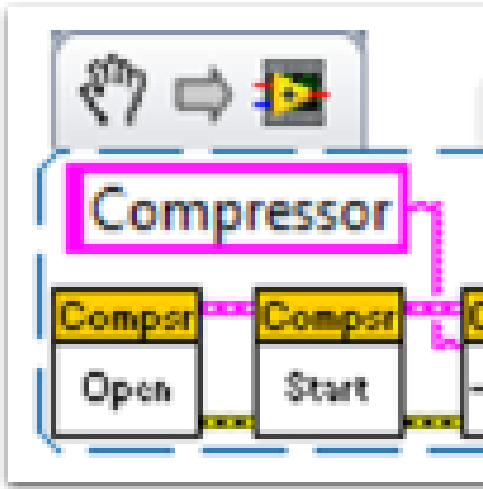
Manual Pneumatics FRC

Guide User's PCM

roboRIO the for Step by Step Pneumatics

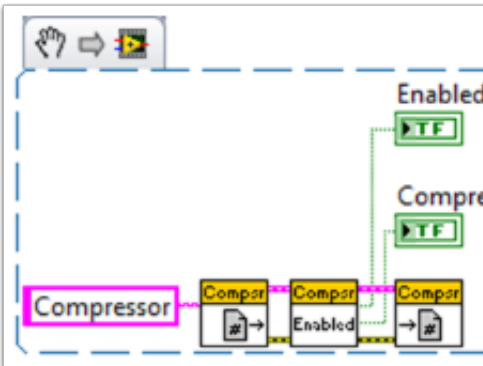
VI Begin

Begin.vi. the in snippet this Place



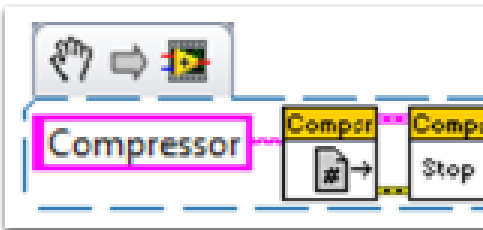
VI Teleop

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



usage pyproject.toml 14.1

run you when but ,pyproject.toml a have to required not are projects RobotPy :
you. for created be automatically will one sync robotpy

for configuration tooling and build store to way standard a become has pyproject.toml
store can tools where place a is file TOML the of section(s) [tool.XXX] The projects. Python
information. configuration their

the in ,pyproject.toml in information related deployment stores only RobotPy Currently
and want, they however sections other the customize can Users section. [tool.robotpy]
them. ignore will robotpy

this: like something looks file pyproject.toml The

```
#
# installed are packages RobotPy what control to file configuration this Use #
# RoboRIO your on #
#
#
# [tool.robotpy]
#
# on depends project this robotpy of Version #
# 2024.2.1.0" = robotpy_version
#
# installed be should components RobotPy extra Which #
# [...] robotpy[extra1, install pip` to equivalent >- #
# [ = robotpy_extras
#     all"" #
#     apriltag"" #
#     commands2"" #
#     cscore"" #
#     navx"" #
#     pathplannerlib"" #
#     phoenix5"" #
#     phoenix6"" #
```

page) next on (continues

(0000 0000 0000)

```
playingwithfusion"" #
    rev"" #
    romi"" #
    sim"" #
]
```

```
install to packages pip Other #
[] = requires
```

roboRIO: the to packages install to process deploy the instruct will following the of Each depends code robot this that package PyPI robotpy the of version the is robotpy_version on.

core the only as installed, be can that components RobotPy extra defines robotpy_extras default. by installed are libraries RobotPy

file. `requirements.txt` a of line a to equivalent is item each and strings, of list a is `requires` but work, likely will they and roboRIO the on packages python pure any install can You For roboRIO. the for compiledcross- be must dependencies binary have that packages any code: robot your in numpy use to needed you if example,

```
[tool.robotpy]
```

```
...
```

```
]numpy""[ = requires
```

that find you If `.server` Artifactory WPILib the on stored are installed be can that packages The repository. `wheelsroborio` the consult artifactory, on available isn't that package a need you

subcommands RobotPy 14.2

,cli - robotpy called package a installs it installation, Python your in RobotPy install you When robot your to related tasks perform to used be can that command robotpy a provides which code. related and

subcommands various the show will it line, command the from command the execute you If available: are that

Windows

```
robotpy m- 3- py
```

macOS

```
robotpy m- python3
```

Linux

```
robotpy m- python3
```

saying error an or logo RobotPy a see either but commands of list a see don't you If :
directly be cannot and package a is 'robotpy' robotpy.__main__; named module No
pip. via it reinstall then and module robotpy the uninstall should you ,executed
beta. 2024 the or 2024pre- from upgraded who users affects only This

For subcommand. the about information more see to argument help-- the pass can You
following: the do can you command sim the for help see to example,

Windows

```
help-- sim robotpy m- 3- py
```

macOS

```
help-- sim robotpy m- python3
```

Linux

```
help-- sim robotpy m- python3
```

subcommands: the of some for documentation detailed more has page This

roboRIO to program Python Deploy 14.2.1

your on RobotPy installing by start must you robot, your to code the deploying Before :
computer

roboRIO the of all download to sync robotpy ran have you that expected is it particular, In
dependencies. python

Windows

```
deploy robotpy m- 3- py
```

macOS

```
deploy robotpy m- python3
```

Linux

```
deploy robotpy m- python3
```

following: the do will it subcommand, `deploy robotpy` the execute you When
 fail) they if exit (will code your on tests `pytest` Run •
 present) already not (if roboRIO the on Python Install •
 not (if `pyproject.toml` your by specified as roboRIO the on packages python Install •
 present) already
 it execute and roboRIO the to directory project robot entire the Copy •

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

message. successful! was Deploy SUCCESS: a see will you successful, When
 the using by netconsole with problems) any see (and output code's robot your watch can You
 tools FRC normal the and netconsole use can You .*pynetconsole* or *Viewer Log Station Driver*
 code. robot running the with interact to
 :
Output Console Viewing

Netconsole via feedback Immediate

the adding by feedback immediate have can you roboRIO, the to code the deploying When
 by output, console program's your show to command deploy the cause will This `.-nc` option
 listener. netconsole a launching

Windows

```
nc-- deploy robotpy m- 3- py
```

macOS

```
nc-- deploy robotpy m- python3
```

Linux

```
nc-- deploy robotpy m- python3
```

your to connected be to software station driver the requires output netconsole Viewing :
robot

Tests Skipping

skip can you anyway, code the upload to want you but failing are tests the that event the In
.tests-skip- option the adding by them

Windows

```
skip-tests-- deploy robotpy m- 3- py
```

macOS

```
skip-tests-- deploy robotpy m- python3
```

Linux

```
skip-tests-- deploy robotpy m- python3
```


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 15.1

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 15.1.1

more send can controller CAN A .*PWM* and *CAN* flavors: main two in come controllers Motor
to set be only can controller PWM a whereas roboRIO, the to back information status detailed
Using see classes, drivetrain WPIlib the with motors these using on information For value. a
.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
a use To .*Depth in Controllers Motor PWM* see work, they *how* on background detailed more
WPIlib by provided class controller motor appropriate the use simply controller, motor PWM
approved All roboRIO. the on into plugged are controller(s) motor the port the it supply and
them. for provided classes WPIlib 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 // );@Spark( new = spark Spark
1 and 1- between motor, the of output % the // );0.75-(setspark.
to connected is this port PWM RIO the is 0 // );@VictorSP( 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 // };@spark{ 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 // };@victor{ 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 # )@Spark( 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 # )@VictorSP( 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 and ,[WPILib](#) [C++](#) [Python](#) ,*Devices CAN PartyThird- See Fusion. with Playing and Robotics, REV information. more for Projects Example Party Third*

Depth in Controllers Motor PWM 15.1.2

that classes of number a are There control. motor for support extensive has WPILib :[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 4096 in width pulse the vary can and 20ms or 10, 5, of periods with signals PWM special a being 0 with range 40960- this in are module this to sent values raw The . each 1us contains controller motor each for class The (disabled). low signal the holds which case deadband) the of side each and max (min, values bound typical the what about information value scaled the map to values these use then can WPILib midpoint. typical the as well as are seamlessly switch to code the for allows This controller. motor the for range proper the into signaling. specific the of details the out abstracts and controllers of types different between

Controllers Motor Calibrating

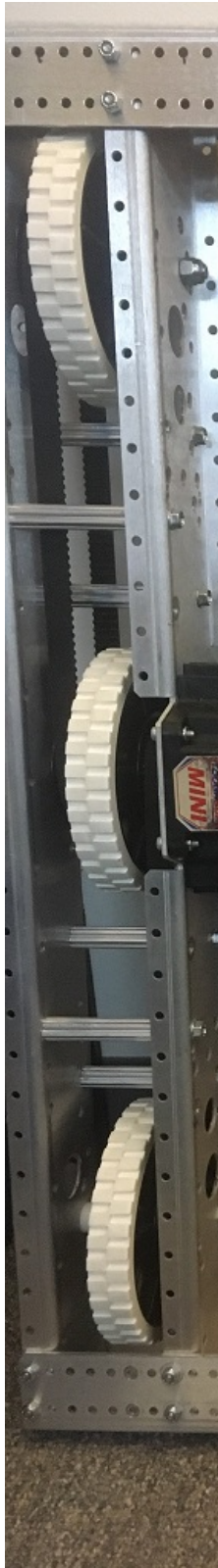
motor your calibrate to need ever you would why scaling, this all handles WPILib if So of measurement on based approximate are scaling for uses WPILib values The controller? an of timing the factors, of variety a to Due type. controller each of samples of number a "humming" eliminate definitively to 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 15.1.3

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 use the of responsibility
objects. motor their on SetInverted()/setInverted() calling by motors

JAVA

```
); PWMSparkMax( new = m_motorRight PWMSparkMax
    @Override
    { ()robotInit void public
    );true(setInvertedm_motorRight.
    }
```

C++

```
; }m_motorLeft{ PWMSparkMax::frc
    :public
    { override RobotInit() void
    );true m_motorRight.SetInverted(
    }
```

PYTHON

```
):self(robotInit def
) PWMSparkMax( wpilib = motorRight.self
)true setInverted( 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(setSafetyEnabledm_motorRight.
);false(setSafetyEnabledm_motorRight.
);1.(setExpirationm_motorRight.
()feedm_motorRight.
```

C++

```
);trueSetSafetyEnabled(>m_motorRight
);falseSetSafetyEnabled(>m_motorRight
);1 SetExpiration(>m_motorRight
Feed();>m_motorRight
```

PYTHON

```
)TruesetSafetyEnabled(.m_motorRight
)FalsesetSafetyEnabled(.m_motorRight
)1 setExpiration(.m_motorRight
feed().m_motorRight
```

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.

and conventions axis the about detail more for section [System Coordinate](#) the See :[□□□□](#) systems. coordinate

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

```

    { TimedRobot extends Robot class public
      m_robotDrive; DifferentialDrive private
    ); PWMSparkMax( new = m_leftMotor PWMSparkMax final private
    ); PWMSparkMax( new = m_rightMotor PWMSparkMax final private

    @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 //
      _side left the invert to have might you constructed, is gearbox //
      instead. ↵
    ); true(setInvertedm_rightMotor.

    m_ DifferentialDrive(m_leftMotor::set, new = m_robotDrive
      rightMotor::set); ↵
    }
  
```

(Header) C++

```

    }; m_leftMotor{ PWMSparkMax::frc
    }; m_rightMotor{ PWMSparkMax::frc
    m_robotDrive{ DifferentialDrive::frc
    ,} m_leftMotor.Set(output); { output) double}[0]
    ;}} m_rightMotor.Set(output); { output) double}[0]
  
```

(Source) C++

```

        { override ()RobotInit void
voltage positive that so drivetrain the of side one invert to need We //
s'robot your how on Depending forward. moving sides both in result //
    side left the invert to have might you constructed, is gearbox //
        instead. →
    );truem_rightMotor.SetInverted(
        }
    
```

Python

```

        ):self(robotInit def
function"" initialization Robot""

        )PwMSparkMax( wpilib = leftMotor
        )PwMSparkMax( wpilib = rightMotor
        DifferentialDrive(leftMotor,.drive.wpilib = robotDrive.self
        rightMotor) →
        positive that so drivetrain the of side one invert to need We #
        voltages →
s'robot your how on Depending forward. moving sides both in result #
        side left the invert to have might you constructed, is gearbox #
        instead. →
    )TruesetInverted(.rightMotor
    
```

DifferentialDrive MotorMulti-

from derived Classes side. each on motor 1 than more have drivetrains FRC® Many multiple that so method addFollower an have)Python / C++ / Java(PWMMotorController commanded. is controller motor leader the when updated be can controllers motor follower to how see to documentation vendor's the review features, similar have controllers motor CAN more to extend To drivetrain. side) per (2 motor 4 a show below examples The them. use calls. addFollower additional use and controllers additional the create simply motors,

Java

Subsystem); or Robot.java in (e.g. variables Class

```

drive. the of side left the on motors The //
PwMSparkMax(DriveConstants. new = m_leftLeader PwMSparkMax final private
    );kLeftMotor1Port →
PwMSparkMax(DriveConstants. new = m_leftFollower PwMSparkMax final private
    );kLeftMotor2Port →

drive. the of side right the on motors The //
PwMSparkMax(DriveConstants. new = m_rightLeader PwMSparkMax final private
    );kRightMotor1Port →
PwMSparkMax(DriveConstants. new = m_rightFollower PwMSparkMax final private
    );kRightMotor2Port →
    
```

constructor: Subsystem or robotInit In

```

        (m_leftFollower);addFollower(m_leftLeader.
        (m_rightFollower);addFollower(m_rightLeader.

voltage positive that so drivetrain the of side one invert to need We //
s'robot your how on Depending forward. moving sides both in result //
side left the invert to have might you constructed, is gearbox //
instead.
    );true(setInvertedm_rightLeader.

```

(Header) C++

```

private
    controllers motor The //
    m_left1; PWMSparkMax::frc
    m_left2; PWMSparkMax::frc
    m_right1; PWMSparkMax::frc
    m_right2; PWMSparkMax::frc

    drive s'robot The //
    ,} m_left1.Set(output); { output) double](m_drive{ DifferentialDrive::frc
    } m_right1.Set(output); { output) double](s[
    ;}

```

(Source) C++

constructor: Subsystem or robotInit In

```

        m_left1.AddFollower(m_left2);
        m_right1.AddFollower(m_right2);

voltage 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_right1.SetInverted(

```

Python

this update help you Can 2024. in *deprecated* is MotorControllerGroup :example?

```

    ):self(robotInit def
    )Spark(.wpilib = frontLeft
    )Spark(.wpilib = rearLeft
    rearLeft) MotorControllerGroup(frontLeft, wpilib = left
    can you side entire the invert to want you if # )True)setInverted(.left
    here so do
    )3Spark(.wpilib = frontRight
    )4Spark(.wpilib = rearRight

```

page) next on (continues

(0000 0000 0000)

```
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 :0000 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 //
    ());getYdriveStick.- (),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

```

;2 = kFrontLeftChannel int final static private
;3 = kRearLeftChannel int final static private
;1 = kFrontRightChannel int final static private
;0 = kRearRightChannel int final static private

@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.
    
```

page) next on (continues

(0000 0000 0000)

```

    );true(setInverted rearRight.

    frontRight::set, rearLeft::set, MecanumDrive(frontLeft::set, new = m_robotDrive
    rearRight::set);
    }

```

C++

```

                                :private
;0 = kFrontLeftChannel int constexpr static
;1 = kRearLeftChannel int constexpr static
;2 = kFrontRightChannel int constexpr static
;3 = kRearRightChannel int constexpr static

m_frontLeft{kFrontLeftChannel}; PWMSparkMax::frc
m_rearLeft{kRearLeftChannel}; PWMSparkMax::frc
m_frontRight{kFrontRightChannel}; PWMSparkMax::frc
m_rearRight{kRearRightChannel}; PWMSparkMax::frc
m_robotDrive{ MecanumDrive: frc
,} m_frontLeft.Set(output); { output double}(&[
,} m_rearLeft.Set(output); { output double}(&[
,} m_frontRight.Set(output); { output double}(&[
;}} m_rearRight.Set(output); { output double}(&[

{ override ()RobotInit void
to this remove or change to need may You motors. side right the Invert //
robot. your match //
);true m_frontRight.SetInverted(
);true m_rearRight.SetInverted(
}

```

PYTHON

```

to in plugged are controllers motor the that roboRIO the on Channels #
2 = kFrontLeftChannel
3 = kRearLeftChannel
1 = kFrontRightChannel
0 = kRearRightChannel

):self(robotInit def
kFrontLeftChannel).self PWMSparkMax(.wpilib = frontLeft.self
kRearLeftChannel).self PWMSparkMax(.wpilib = rearLeft.self
kFrontRightChannel).self PWMSparkMax(.wpilib = frontRight self
kRearRightChannel).self PWMSparkMax(.wpilib = rearRight self

motors side right the invert #
robot your match to this remove or change to need may you #
)True setInverted( frontRight.self
)True setInverted( rearRight self

MecanumDrive( drive wpilib = robotDrive self
rearRight self frontRight,.self rearLeft,.self frontLeft,.self
page) next on (continues

```

(0000 00000 0000)

```

)

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 clockwise counter- 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 **15.1.4** 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++

```
;} { 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 15.2

Cylinders Pneumatic Operating 15.2.1

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

```

        solenoid. single a to corresponds Solenoid //
        ID. CAN default the with PH a of 0 channel to connected s'it case, this In //
    );0 ,REVPHSolenoid(PneumaticsModuleType. new = m_solenoid Solenoid final private

        */
        whether on depending true/false is GetRawButton of output The *
        whether for boolean a takes Set pressed; is button the *
        (true). it extend or (false) solenoid the retract to *
        */
        (kSolenoidButton));getRawButton(m_stick.setm_solenoid.

```

(Header) C++

```

        solenoid. single a to corresponds Solenoid //
        CAN default the with PH a of 0 channel to connected s'it case, this In //
        ID. //
    };0 REVPH,::PneumaticsModuleType::m_solenoid{frc Solenoid::frc

```

(Source) C++

```

        */
        whether on depending true/false is GetRawButton of output The *
        whether for boolean a takes Set pressed; is button the *
        (true). it extend or (false) solenoid the retract to *
        */
        m_solenoid.Set(m_stick.GetRawButton(kSolenoidButton));

```

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 defaultnon- a have teams if DoubleSolenoid the to

Java

```

        solenoid, double a to corresponds DoubleSolenoid //
ID. CAN default the with PH a of 2 and 1 channels to connected s'it case, this In //
        = m_doubleSolenoid DoubleSolenoid final private
    );2 ,1 ,REVPH DoubleSolenoid(PneumaticsModuleType. new
    );kForward.Value(DoubleSolenoid.setm_doubleSolenoid.
    );kReverse.Value(DoubleSolenoid.setm_doubleSolenoid.

```

37
38
39
40

100
101

(Header) C++

```

        solenoid, double a to corresponds DoubleSolenoid //
default the with PH a of 2 and 1 channels to connected s'it case, this In //
        ID. CAN //
; }2 ,1 REVPH, ::PneumaticsModuleType :m_doubleSolenoid{frc DoubleSolenoid::frc

```

49
50
51
52

(Source) C++

```

kForward); ::DoubleSolenoid::m_doubleSolenoid.Set(frc
kReverse); ::DoubleSolenoid::m_doubleSolenoid.Set(frc

```

54
55

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 ,CTREPCM Solenoid(PneumaticsModuleType. new = exampleSingle Solenoid
);2 ,1 ,CTREPCM DoubleSolenoid(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++

```

    }; } 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();
}

```

Pressure Storing and Generating 15.2.2

The tanks. pneumatic in stored and compressor pneumatic a using created is Pressure The module. pneumatics robot's the by powered and robot the on be must compressor recommended *not* is it and default, by enabled is Compressor the on mode Loop" "Closed module pneumatic the enabled is control loop closed When setting. this change teams that (below closed is switch pressure digital the when on compressor the turn automatically will When (~120PSI). open is switch pressure the when off it turn and threshold) pressure the Compressor the Using on. turned be not will compressor the disabled is control loop closed or on (currently state The compressor. the of status the query can users class,)C++ / Java(Compressor the from queried be all can current compressor and state, switch pressure off),):C++ ,Java(project example Solenoid the from code following the by shown as object,

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

object: Compressor a Construct

(PH) Hub Pneumatic REV

Java

```

(1) ID CAN default a with PH a to connected Compressor //
);REVPHCompressor(PneumaticsModuleType. new = m_compressor Compressor final private

```

(Header) C++

```

ID CAN default a with PH a to connected Compressor //
REVPH}; ::PneumaticsModuleType::m_compressor{frc Compressor::frc

```

(PCM) Module Control Pneumatics CTRE

Java

```
(0) ID CAN default a with PCM a to connected Compressor //
Compressor(PneumaticsModuleType. new = m_compressor Compressor final private
);CTREPCM →
```

(Header) C++

```
ID CAN default a with PH a to connected Compressor //
```

state: and current compressor Querying

Java

```
draw. current compressor Get //
();getCurrentm_compressor. return
active. is compressor the whether Get //
();isEnabledm_compressor. return
PCM/PH. the to connected switch pressure digital the Get //
PSI. 120~ over is pressure the when open is switch The //
();getPressureSwitchValuem_compressor. return
```

(Source) C++

```
draw. current compressor Get //
m_compressor.GetCurrent(); = compressorCurrent ampere_t::units
compressorCurrent.value(); return
active. is compressor the whether Get //
m_compressor.IsEnabled(); return
PCM/PH. the to connected switch pressure digital the Get //
PSI. 120~ over is pressure the when open is switch The //
m_compressor.GetPressureSwitchValue(); return
```

default): by (enabled control compressor loopclosed- digital Enable/disable

Java

```
compressor. the on mode closed-loop Disable //
();disablem_compressor.
switch pressure digital the on based mode closed-loop Enable //
the to connected →
PCM/PH. //
PSI. 120~ over is pressure the when open is switch The //
();enableDigitalm_compressor.
```

(Source) C++

```
compressor. the on mode closed-loop Disable //
                                m_compressor.Disable();
switch pressure digital the on based mode closed-loop Enable //
over is pressure the when open is switch The PCM/PH. the to connected //
                                PSI. 120~ //
                                m_compressor.EnableDigital();
```

Analog REV the using control compressor enabling for methods has also Hub Pneumatic The
Sensor: Pressure

Java

```
to connected sensor pressure analog the on based mode closed-loop Enable //
in is sensor the by reported pressure the while run will compressor The //
                                PH. the →
                                the →
                                example). this in PSI] 120 PSI, ([70 range specified //
digital enables this PCM, the On PH! the on only exists mode Analog //
                                control. →
                                );120 ,70(enableAnalogm_compressor.
AND switch pressure digital the both on based mode closed-loop Enable //
                                analog the →
                                PH. the to connected sensor pressure //
sensor analog the by reported pressure the while run will compressor The //
                                the in is →
digital the AND example) this in PSI] 120 PSI, ([70 range specified //
                                reports switch →
                                full. not is system the that //
digital enables this PCM, the On PH! the on only exists mode Hybrid //
                                control. →
                                );120 ,70(enableHybridm_compressor.
```

(Source) C++

```
connected sensor pressure analog the on based mode closed-loop Enable //
the by reported pressure the while run will compressor The PH. the to //
example). this in PSI] 120 PSI, ([70 range specified the in is sensor //
digital enables this PCM, the On PH! the on only exists mode Analog //
                                control. //
                                psi);_120 psi,_70m_compressor.EnableAnalog(
the AND switch pressure digital the both on based mode closed-loop Enable //
                                analog →
                                PH. the to connected sensor pressure //
is sensor analog the by reported pressure the while run will compressor The //
                                the in →
switch digital the AND example) this in PSI] 120 PSI, ([70 range specified //
                                reports →
                                full. not is system the that //
control. digital enables this PCM, the On PH! the on only exists mode Hybrid //
                                psi);_120 psi,_70m_compressor.EnableHybrid(
```

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

```
(1) ID CAN default a with PH a to connected Compressor //
);REVPHCompressor(PneumaticsModuleType. new = m_compressor Compressor final private

PH. the to connected sensor analog the from PSI) (in pressure the Get //
PH! the on only supported is function This //
0. return will function this PCM, a On //
();getPressurem_compressor. return
```

(Header) C++

```
ID CAN default a with PH a to connected Compressor //
REVPH};: PneumaticsModuleType::m_compressor{frc Compressor::frc
```

(Source) C++

```
PH. the to connected sensor analog the from PSI) (in pressure the Get //
PH! the on only supported is function This //
0. return will function this PCM, a On //
m_compressor.GetPressure(); = pressure_pounds_per_square_inch_t::units
pressure.value(); return
```

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

```

        sensor pressure analog External //
        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 //
        ;250 = kScale double final static
        ;25- = kOffset double final static
        = m_pressureTransducer AnalogPotentiometer final private
        kOffset); kScale, ,2 port*/ AnalogIn the */AnalogPotentiometer( new

RIO. the to connected sensor pressure analog an from PSI) (in pressure the Get //
        ()); getm_pressureTransducer. return

```

(Header) C++

```

        sensor pressure analog External //
        manual product see conversion, voltage->pressure product-specific //
        250(V/5)-25 case, this in //
        from scaled is constructor AnalogPotentiometer the in parameter scale the //
        the output, AnalogPotentiometer raw the is r if so 5, of instead 1 //
        250r-25 is pressure //
        ;250 = kScale double constexpr static
        ;25- = kOffset double constexpr static
        ,2 port*/ AnalogIn the */m_pressureTransducer{ AnalogPotentiometer::frc
        kOffset}; kScale,

```

(Source) C++

```

        to connected sensor pressure analog an from PSI) (in pressure the Get //
        RIO. the //
        pounds_per_square_inch_t{m_pressureTransducer.Get()}; ::units return

```

Pneumatics Control to System Control FRC the Using 15.2.3

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 based CAN- a is (PCM) Module Control Pneumatics CTRE The module. per solenoids 8 to up and compressor the over



the over control provides that device based CAN- 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 channels.

switch pressure a using pressure robot's the regulating for responsible are modules These roboRIO the with communicate They off. and on solenoids switching and compressor a and . see information, more For CAN. over

Numbers Module 15.2.4

default The 0. is PCMs for ID CAN default The ID. CAN 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 CAN solenoids corresponding modules the where used be can modules Additional ID. CAN default DoubleSolenoid ,Solenoid the of constructors the in number module the by differentiated are classes. Compressor and

חיישנים 15.3

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

סקירת חיישנים - תוכנה 15.3.1

see hardware, sensor to guide a For software. in sensors using covers section This : see hardware, sensor to guide a For software. in sensors using covers section This .

a is processing vision "sensors", considered be definitely may cameras While : here. than rather , section own its in covered is it that subject complicated sufficiently-

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 15.3.2

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. dimensional multi- 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 //
}; // Accelerometer{ AnalogAccelerometer::fr

// G per volt 1 to accelerometer the of sensitivity the Sets //
}; // Accelerometer.SetSensitivity(

// volts 3 to accelerometer the of voltage zero the Sets //
}; // Accelerometer.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
a as well as z), and y, (x, direction cardinal each along acceleration the for getters are There
measure. will accelerometer the accelerations of range the for setter

JAVA

```

// s'G 8 and 8- between measure to accelerometer the Sets //
); // k8G.Range(BuiltInAccelerometer.setRangeAccelerometer.

```

C++

```

// s'G 8 and 8- between measure to accelerometer the Sets //
kRange_8G); // Range::Accelerometer.SetRange(BuiltInAccelerometer

```

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.RangeADXL345_I2C. , kMXP.PortADXL345_I2C(I2C. new = accelerometer ADXL345_I2C

```

C++

```
port I2C MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
kRange_8G};::Range: ADXL345_I2C::frc 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.RangeADXL345_SPI. ,kMXP.PortADXL345_SPI(SPI. new = accelerometer ADXL345_SPI
```

C++

```
port SPI MXP the on object accelerometer ADXL345 an Creates //
s'G 8 to 8- from range measurement a with //
kRange_8G};::Range: ADXL345_SPI::frc 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.RangeADXL362. ,kMXP.PortADXL362(SPI. new = accelerometer ADXL362
```

C++

```
port SPI MXP the on object accelerometer ADXL362 an Creates //
s'G 8 to 8- from range measurement a with //
kRange_8G};::Range: ADXL362::frc 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 BuiltInAccelerometer
```

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

```

;0.0 = prevXAccel double
;0.0 = prevYAccel double

BuiltInAccelerometer(); new = accelerometer BuiltInAccelerometer

@Override
{ ()robotPeriodic void public
directions Y and X the in accelerations current the Gets //
    ();getXaccelerometer. = xAccel double
    ();getYaccelerometer. = yAccel double

    directions Y and X the in jerk the Calculates //
    20ms is timing loop default because 02. by Divides //
    ;0.02 / prevXAccel) - (xAccel = xJerk double
    ;0.02 / prevYAccel) - (yAccel = yJerk double

    xAccel; = prevXAccel
    yAccel; = prevYAccel
}
```

C++

```

;0.0 = prevXAccel double
;0.0 = prevYAccel double

accelerometer; BuiltInAccelerometer::frc

{ ()Robot::RobotPeriodic void
directions Y and X the in accelerations current the Gets //
    accelerometer.GetX(); = xAccel double
    accelerometer.GetY(); = yAccel double

    directions Y and X the in jerk the Calculates //
    20ms is timing loop default because 02. by Divides //
    ;0.02 / prevXAccel) - (xAccel = xJerk double
    ;0.02 / prevYAccel) - (yAccel = yJerk double

    xAccel; = prevXAccel
    yAccel; = prevYAccel
}
```

combine to idea good a often is it and noisy, quite are use FRC for legal accelerometers Most noise: the reduce to)C++ ,Java(class `LinearFilter` the with them

JAVA

```

BuiltInAccelerometer(); new = accelerometer BuiltInAccelerometer
//X measured the of average moving a calculate will that LinearFilter a Create //
loop main the of iterations 10 past the over acceleration →
);10(movingAverageLinearFilter. = xAccelFilter LinearFilter

@Override
{ ()robotPeriodic void public
acceleration X filtered the Get //
();getX(accelerometer.calculatexAccelFilter. = filteredXAccel double
}

```

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 15.3.3

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 class. *AnalogGyro* the through gyros current the zeroing for functions and heading and rate angular current the getters are There gyro. the calibrating and heading

gyro. a calibrating while stationary remain robot the that crucial is It :□□□□

ADIS16448

Devices Analog the See).Python ,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
```

PYTHON

```
ADIS16448_IMU import wpilib from
port MXP the into plugged ADIS16448 #
ADIS16448_IMU() = gyro self
```

ADIS16470

Devices Analog the See).Python ,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 SPI the into plugged ADIS16470 //
ADIS16470_IMU(); new = gyro ADIS16470_IMU
```

C++

```
port SPI the into plugged ADIS16470 //
gyro; ADIS16470_IMU
```

PYTHON

```
port SPI the into plugged ADIS16470 #
ADIS16470_IMU() = gyro self
```

ADXRS450_Gyro

Devices Analog the for support provides)Python ,C++ ,java(class ADXRS450_Gyro The bus. SPI the over connects which parts, of kit the in available gyro ADXRS450

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
```

PYTHON

```
port SPI onboard the on object ADXRS450_Gyro an Creates #
ADXRS450_Gyro() = gyro self
```

AnalogGyro

an with gyro axissingle- any for support provides)Python ,C++ ,java(class AnalogGyro The output. analog

accordingly, FPGA; the in circuitry special through handled is accumulation Gyro : 1. and 0 ports analog on used be only may `sAnalogGyro

JAVA

```
// port on object AnalogGyro an Creates //
);AnalogGyro( new = gyro AnalogGyro
```

C++

```
// port on object AnalogGyro an Creates //
};gyro{ AnalogGyro::frc
```

PYTHON

```
// port on object AnalogGyro an Creates #
)AnalogGyro( = gyro self
```

navX

types. connection additional for documentation navX the See class. AHRS the uses navX The

JAVA

```
SPI using MXP navX //
);kMXP.PortAHRS(SPI. new = gyro AHRS
```

C++

```
SPI using MXP navX //
kMXP};::Port::gyro{SPI AHRS
```

PYTHON

```
navx import
SPI using MXP navX #
kMXP).Port AHRS(SPI navx = gyro self
```

Pigeon

with connected be either can Pigeon The class. `WPI_PigeonIMU` the use should Pigeon The on details full contains [Guide User's IMU Pigeon The TalonSRX](#). a to cable data by or CAN Pigeon. the using

JAVA

```

0 ID device with Bus CAN on is Pigeon // );@WPI_PigeonIMU( new = gyro WPI_PigeonIMU
connection) your on based other the or one (choose OR //
0 ID device with Bus CAN on is TalonSRX // );@TalonSRX( 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 // ;}@gyro{ WPI_PigeonIMU
connection) your on based other the or one (choose OR //
0 ID device with Bus CAN on is TalonSRX // ;}@talon{ TalonSRX
above created talon the uses Pigeon // gyro{talon}; WPI_PigeonIMU

```

PYTHON

```

phenix5 import
sensors.ctre import

0 ID device with Bus CAN on is Pigeon # );@WPI_PigeonIMU( ctre = gyro self
connection) your on based other the or one (choose OR #
0 ID device with Bus CAN on is TalonSRX # );@TalonSRX( ctre = talon
above created talon the uses Pigeon # WPI_PigeonIMU(talon) ctre = gyro self

```

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
}

```

PYTHON

```

Shuffleboard import shuffleboard.wpilib from
):self(robotInit def
here above from declaration gyro Use #
dashboard the on heading gyro the for indicator compass a Places #
gyro).self.add(). "tab Example"getTab( Shuffleboard

```

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 : unbalanced 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 = leftLeader Spark
        );1Spark( new = leftFollower Spark

        );2Spark( new = rightLeader Spark
        );3Spark( new = rightFollower Spark

rightLeader::set); DifferentialDrive(leftLeader::set, 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.

other the invert to have might You drivetrain. the of side right the Invert //
                                side →
                                );true(setInvertedrightLeader.

                                leaders the follow to followers the Configure //
                                (leftFollower);addFollowerleftLeader.
                                (rightFollower);addFollowerrightLeader.
                                }

                                @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 //
            ;}0leftLeader{ Spark::frc
            ;}leftFollower{ Spark::frc

            ;}2rightLeader{ Spark::frc
            ;}rightFollower{ Spark::frc

        ,} leftLeader.Set(output); { output) double](&drive{[ DifferentialDrive::frc
        ;}} rightLeader.Set(output); { output) double](&[

        { ()Robot::RobotInit void
other the invert to have might You drivetrain. the of side right the Invert //
            side →
            );trueRightLeader.SetInverted(

        leaders the follow to followers the Configure //
            leftLeader.AddFollower(leftFollower);
            rightLeader.AddFollower(rightFollower);
        }

        { ()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(
        }

```

PYTHON

```

        Spark import wpilib from
        MotorControllerGroup import wpilib from
        DifferentialDrive import drive.wpilib from

        ):self(robotInit def
        here above from declaration gyro Use #

        loop P simple a for gain The #
            1 = kP.self

        drive and controllers motor Initialize #
            )0Spark( = left1
            ) Spark( = left2
            )2Spark( = right1
            )3Spark( = right2

        left2) MotorControllerGroup(left1, = leftMotors

```

page) next on (continues

(0000 0000 0000)

```

right2) MotorControllerGroup(right1, = rightMotors
rightMotors) DifferentialDrive(leftMotors, = drive.self

setInverted(true) rightMotors

):self(autonomousPeriodic def
change to heading the want t'don we since 0, implicitly is Setpoint #
getRate().gyro.self- = error

the stabilize to gyro the using speed, half at continuously forward Drives #
error) * kP.self - 5. error, * kP.self + 5.tankDrive(.drive.self heading →

```

Python the update help you Can 2024. in *deprecated* is MotorControllerGroup :0000 example?

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 //
);Spark( new = left1 Spark
);Spark( new = left2 Spark

);Spark( new = right1 Spark
);Spark( 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

(0000 00000 0000)

```

    }

    @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 //
    ;}1left1{ 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
    );true;rightMotors.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(
    }

```

PYTHON

```

Spark import wpilib from
MotorControllerGroup import wpilib from
DifferentialDrive import drive.wpilib from

):self(robotInit def
here above from declaration gyro Use #

loop P simple a for gain The #
1 = kP.self

drive and controllers motor Initialize #
)0Spark( = left1
) Spark( = left2
)2Spark( = right1
)3Spark( = right2

left2) MotorControllerGroup(left1, = leftMotors
right2) MotorControllerGroup(right1, = rightMotors

rightMotors) DifferentialDrive(leftMotors, = drive.self

setInverted(true) rightMotors

):self(autonomousInit def
auto of start at heading current to setpoint Set #
getAngle() gyro self = heading.self

):self(autonomousPeriodic def
getAngle() gyro.self - heading.self = error

the stabilize to gyro the using speed, half at continuously forward Drives #
heading →
error) * kP.self - 5. error, * kP.self + 5.tankDrive(.drive.self

```

the closing When loop. control complicated more- a use can implementations advanced More- 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 useful highly- 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 //
            );Spark( new = left1 Spark
            );Spark( new = left2 Spark

            );Spark( new = right1 Spark
            );Spark( 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

        rightMotors}; drive{leftMotors, DifferentialDrive::frc

            { ()Robot::RobotInit void
            );true(rightMotors.SetInverted(
            }

```

page) next on (continues

(0000 0000 0000)

```

{ ()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
}

```

PYTHON

```

Spark import wpilib from
MotorControllerGroup import wpilib from
DifferentialDrive import drive.wpilib from

):self(robotInit def
here above from declaration gyro Use #

loop P simple a for gain The #
0.05 = kP.self

drive and controllers motor Initialize #
)0Spark( = left1
) Spark( = left2
)2Spark( = right1
)3Spark( = right2

left2) MotorControllerGroup(left1, = leftMotors
right2) MotorControllerGroup(right1, = rightMotors

rightMotors) DifferentialDrive(leftMotors, = drive.self

setInverted(true) rightMotors

):self(autonomousPeriodic def
90 is setpoint error; heading the Find #
getAngle() gyro.self - 90 = error

the stabilize to gyro the using speed, half at continuously forward Drives #
heading →
error) * kP.self- error, * kP.selftankDrive(.drive.self

```

loops. control complicatedmore- use can implementations advancedmore- before, As

the in friction static to due correctly tune to tricky be can loops angletoturn- :0000
 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 15.3.4

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 be
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 will) C++ ,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 //
    ;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

    ;0 = kLeftMotorPort int final static
    ;1 = kRightMotorPort int final static

    ;0 = kUltrasonicPingPort int final static
    ;1 = kUltrasonicEchoPort int final static

    // sudden to susceptible and noisy quite be to tend sensors Ultrasonic //
    outliers, →
    filter median 5-sample a with filtered are measurements so //
    );5MedianFilter( new = m_filter MedianFilter final private

```

page) next on (continues

```
(#####)
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_robotDrive DifferentialDrive final private
                                m_rightMotor::set); DifferentialDrive(m_leftMotor::set, new
                                kI, PIDController(kP, new = m_pidController PIDController final private
                                                                kD); ↵

                                { ()Robot public
    m_leftMotor); (m_robotDrive,addChildSendableRegistry.
    m_rightMotor); (m_robotDrive,addChildSendableRegistry.
                                }

                                @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
    Robot();
    ;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 //
    ;0.001 = kP double constexpr static
    constant speed integral //
    ;0.0 = kI double constexpr static
    constant speed derivative //
```

page) next on (continues

(0000 0000 0000)

```

;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, //
};m_filter{ :millimeter_t::units MedianFilter::frc

kUltrasonicEchoPort}; m_ultrasonic{kUltrasonicPingPort, Ultrasonic::frc
    m_left{kLeftMotorPort}; PWMSparkMax::frc
    m_right{kRightMotorPort}; PWMSparkMax::frc
    m_robotDrive{ DifferentialDrive::frc
        ,} m_left.Set(output); { output} double][0[
    ;}} m_right.Set(output); { output} double][0[
        kD}; kI, m_pidController{kP, PIDController::frc
    ;}

```

(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);adc)."Sensors"(getTabShuffleboard.

```

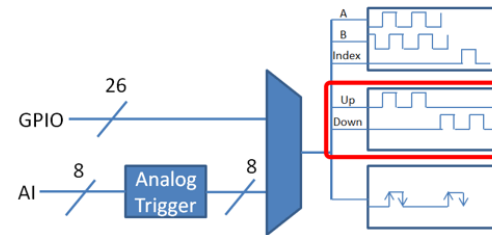
C++

```

dashboard the of tab Sensors"" the on ultrasonic the Add //
    automatically update will Data //
    ).Add(m_rangeFinder);"Sensors" GetTab(: Shuffleboard::frc

```

Counters 15.3.5



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 channels. different two of edges the on based down and up Counts :*mode pulseTwo-* 1. channel. single a on pulse a of duration the Measures :*mode periodSemi-* 2. the with channel, one of edges the on based down and up Counts :*mode lengthPulse-* 3. channel. that on pulse the of duration the by determined direction with channel, one of edges the on based down and up Counts :*mode direction External* 4. 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 //
);i(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 //
);icounter.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.GreenSetUpSource(

2X to type decoding the Set //
);true ,truecounter.GreenSetUpSourceEdge(

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 //

```

page) next on (continues

(0000 0000 0000)

```
);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 //
);counter.SetupSource(
);counter.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
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 :
 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 //
```

page) next on (continues

(0000 0000 0000)

```
samples 127 and 1 between be Can //
);5(counter.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 15.3.6

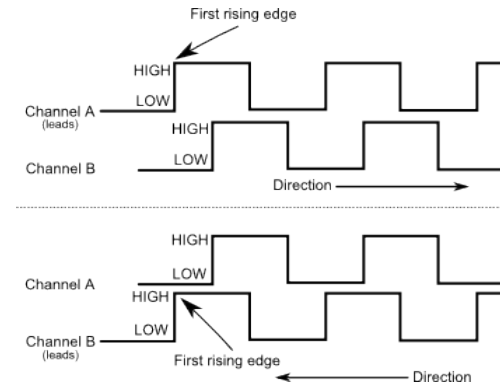
see encoders, to guide hardware a For software. in encoders covers section This :□□□□
□□□□□ - □□□□□□□□

shaft). a of rotation the (usually, motion measure to used devices are Encoders

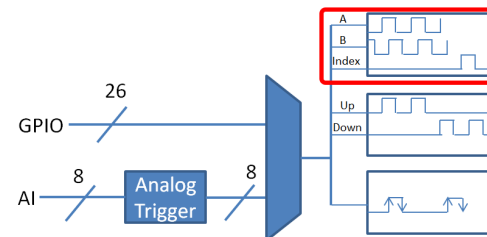
into directly plugged are that encoders for used only are document this in classes The :
encoders using for documentation vendors« appropriate the reference Please roboRIO! the
controllers. motor into plugged

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- •

CIMcoder •

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 :
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 //
);DutyCycleEncoder( new = encoder DutyCycleEncoder
```

C++

```
0 pins DIO on encoder cycle duty a Initializes //
; }encoder{ 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 //
;};encoder{ 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 = leftLeader Spark
);1Spark( new = leftFollower Spark

);2Spark( new = rightLeader Spark
);3Spark( new = rightFollower Spark

rightLeader::set); DifferentialDrive(leftLeader::set, 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.

other the invert to have might You drivetrain. the of side right the Invert //
side →
);true(setInvertedrightLeader.

leaders the follow to followers the Configure //
(leftFollower);addFollowerleftLeader.
(rightFollower);addFollowerrightLeader.
}

@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 //
};0leftLeader{ Sparks:frc
};1leftFollower{ Sparks:frc

};2rightLeader{ Sparks:frc
};3rightFollower{ Sparks:frc

,} leftLeader.Set(output); { output) double](&drive{[ DifferentialDrive::frc
;}} rightLeader.Set(output); { output) double](&[

```

page) next on (continues

(0000 0000 0000)

```

{ ()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(

other the invert to have might You drivetrain. the of side right the Invert //
side →
    );trueRightLeader.SetInverted(

leaders the follow to followers the Configure //
    leftLeader.AddFollower(leftFollower);
    rightLeader.AddFollower(rightFollower);
}

{ ()Robot::AutonomousPeriodic 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 :0000 encoders.

JAVA

```

);1 ,0Encoder( new = encoder Encoder
    );Spark( new = spark Spark

    2 DIO on switch Limit //
);DigitalInput( 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 //
    { ()getLimit.!(if
    );0.5-(setSpark.
        { else }
    );0(setSpark.

```

page) next on (continues

(0000 00000 0000)

```
());resetencoder.
}
}
```

C++

```
;};Encoder{ Encoder::frc
    };Spark{ Spark::frc
    2 DIO on switch Limit //
};Limit{ 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 15.3.7

inputs, analog to guide hardware a For software. in inputs analog covers section This :0000
 .00000 - 000000 000 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 :0000
 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

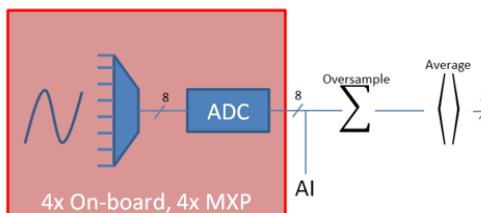
JAVA

```
0 port on AnalogInput an Initializes //
); AnalogInput( new = analog AnalogInput
```

C++

```
0 port on AnalogInput an Initializes //
; } analog{ 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 $bits$ of number the specify may Users value. accumulated the return $:2^n$ is together added samples of number the oversampling, of bits

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 //
); (setOversampleBits analog.
```

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, //
amount. similar a by decrease will rate //
); analog.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 : 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

```
() ; getValue analog. |
```

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

```
() ; getVoltage analog. |
```

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

```
() ; getAverageValue analog. |
```

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 //
); analog.SetAccumulatorInitialValue(

// from subtracted is value This 0. to accumulator the of center"" the Sets //
// accumulation. to prior values measured all //
); analog.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); getAccumulatorOutput analog.

// 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 leveller- 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 15.3.8

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 //
// ); AnalogInput( new = input AnalogInput
// );2(setAverageBits:input.

// 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 //
// };input{ 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

```

AnalogPotentiometer the from values Reading

method: get the calling simply by read be can value scaled The

JAVA

```
() ; get pot .
```

C++

```
pot . Get ( ) ;
```

code in AnalogPotentiometers Using

same the measure that sensors other way the in much code in used be can sensors Analog be can it angle, arm an measuring potentiometer a is sensor analog the If be. can thing other to similarly used be can it sensor, ultrasonic an is it If .*encoder* an to similarly used .*ultrasonics*

have generally potentiometers physical actual, that mind in keep to important very is It mechanism physical the both in present be should Safeguards motion. of range limited a its past traveling by sensor the break not does mechanism the that ensure to code the and throw. maximum

Software - Inputs Digital 15.3.9

inputs, digital to guide hardware a For software. in inputs digital covers section This :
.*Hardware - Inputs Digital* see

through available made are these of 10 inputs. digital 26 to up supports FPGA roboRIO's The *MXP* the through available are 16 other the while itself, RIO the on ports DIO inbuilt- the port. breakout

RIO the on ports inbuilt- the default, By "low." or "high" - states two of one read inputs Digital - *Inputs Digital* see information, more (for resistors uppull- internal to due "high" read will sort. some of switches with used commonlymost- are inputs digital Accordingly,).*Hardware*).C++ ,java(class DigitalInput the through provided is usage this for Support

class DigitalInput The

follows: as initialized be can DigitalInput A

JAVA

```
0 DIO on DigitalInput a Initializes //
);DigitalInput( new = input DigitalInput
```

C++

```
0 DIO on DigitalInput a Initializes //
};input{ DigitalInput::frc
```

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 //
); AnalogTrigger( new = trigger0 AnalogTrigger

oversampling 2-bit enables and 1 port on AnalogInput an Initializes //
); AnalogInput( new = input AnalogInput
); 2(setAverageBits input.

input above the using AnalogTrigger an Initializes //
AnalogTrigger(input); new = trigger1 AnalogTrigger

```

C++

```

0 port on AnalogTrigger an Initializes //
}; trigger0{ AnalogTrigger::frc

oversampling 2-bit enables and 1 port on AnalogInput an Initializes //
}; input{ 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(setLimitsRaw trigger.

1.5 of value a at disable and volts, 4 of voltage a at enable to trigger the Sets //
volts →
); 4 ,1.5(setLimitsVoltage trigger.

```

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

```

);Spark( new = spark Spark

2 DIO on switch Limit //
);DigitalInput( 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++

```

mechanism the for Motor //
};spark{ Spark::frc

2 DIO on switch Limit //
};limit{ DigitalInput::frc

{ ()AutonomousPeriodic void
pressed is limit the unless speed, half at forwards motor the Runs //
{ limit.Get()!(if
);5.spark.Set(
{ else }

```

page) next on (continues

(0000 00000 0000)

```
);spark.Set(
    }
}
```

mechanism a Homing

encoder. an with mechanism a "home" to able being for important very are switches Limit
.Mechanism a Homing see this, of example an For

Switches Limit Programming 15.3.10

are switches limit While robots. on mechanisms control to used often are switches Limit
 ideal them makes This part. moving a of position single a sense can only they use, to simple
 the controlling at good so not but limit some exceed doesn't movement that ensuring for
 on joint shoulder rotational a example, For limit. the approaches it as movement the of speed
 limit A encoder. absolute an or potentiometer a using controlled be best would arm robot a
 the stop would switch limit the failed, ever potentiometer the if that sure make could switch
 damage. causing and far too going from robot

a if control will This outputs. closed" "normally or open" "normally have can switches Limit
 hardware switch limit about more learn To closed. or opened is switch the means signal high
.article this see

Switches Limit Two with Motor a Controlling

JAVA

```
);DigitalInput( new = toplimitSwitch DigitalInput
);DigitalInput( new = bottomlimitSwitch DigitalInput
);PWMVictorSPX( new = motor PWMVictorSPX
);Joystick( new = joystick Joystick

@Override
{ ()teleopPeriodic void public
));2(getRawAxis;setMotorSpeed(joystick.
}

{ speed) double(setMotorSpeed void public
{ })0 > (speed if
{ ()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.
```

page) next on (continues

(0000 0000 0000)

```

                                { else }
    ⌵commanded at go so tripped not is limit bottom but down going are We //
                                speed →
                                (speed);setmotor.
                                }
                                }
                                }

```

C++

```

    };{ toplimitSwitch DigitalInput:frc
    };{ bottomlimitSwitch DigitalInput:frc
    };{ motor PWMVictorSPX:frc
    };{ joystick Joystick:frc

    { ()TeleopPeriodic void
    ));SetMotorSpeed(joystick.GetRawAxis(
    }

    { speed) double(SetMotorSpeed void
    { ) > (speed if
    { (toplimitSwitch.Get()) if
    stop so tripped is limit top and up going are We //
    );motor.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 //
    );motor.Set(
    { else }
    ⌵commanded at go so tripped not is limit bottom but down going are We //
    speed →
    motor.Set(speed);
    }
    }
    }

```

APIs Hardware Miscellaneous 15.4

standalone. are that APIs hardware miscellaneous highlights section This

LEDs Addressable 15.4.1

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 which strip,

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 task`

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++ :`Array`

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 //
        );66AddressableLEDBuffer( new = m_ledBuffer
        ());getLength(m_ledBuffer.setLengthm_led.

            data the Set //
        (m_ledBuffer);setData m_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 //
    ;}m_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();
    }

```

LEDs WS2812B As object. AddressableLED 1 only supports only roboRIO The : from from series in connected strips several drive can you series, in connected are object. AddressableLED

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);setData m_led.

```

C++

```

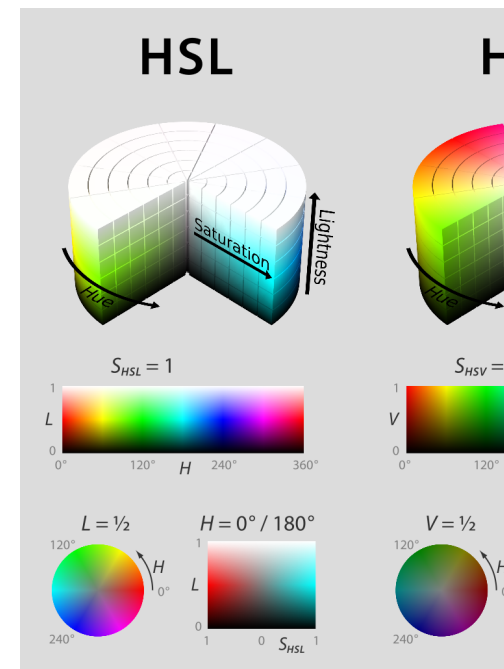
    { } ++i kLength; < i ; 0 = i int( for
    ); 0 , 0 , 255 m_ledBuffer[i].SetRGB(
    }

    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 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);setData m_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 22
    pixel every For // 23
    { }++i kLength; < i ;0 = i int( for 24
    color the because rainbows for easier is hue - hue the Calculate // 25
    precess to needs value one only so circle a is shape // 26
    ;180 % kLength)) / 180 * (i + (firstPixelHue = pixelHue auto const 27
    value the Set // 28
    );128 ,255 m_ledBuffer[i].SetHSV(pixelHue, 29
    } 30
    move" rainbow the make to by Increase // 31
    ;3 += firstPixelHue 32
    bounds Check // 33
    ;180 =% firstPixelHue 34
    } 35

```

set and method the call actually to have we created, method rainbow our have we that Now
LED. the of data the

Java

```

@Override 34
{ ()robotPeriodic void public 35
    rainbow a with buffer the Fill // 36
    rainbow(); 37
    LEDs the Set // 38
    (m_ledBuffer);setData m_led. 39
    } 40

```

C++

```

{ ()Robot::RobotPeriodic void 15
    rainbow a with buffer the Fill // 16
    Rainbow(); 17
    LEDs the Set // 18
    m_led.SetData(m_ledBuffer); 19
    } 20

```

Controllers Motor 15.5

DC brushed For move. motors making for robot your on responsible is controller motor A
motor the that voltage the regulates controller motor the 775, or *CIM* the as such motors
the 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

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 15.5.1

FRC® of list full the is This sets. feature and sizes shapes, of lots in come controllers Motor 2024: 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,
- 5276)am- 2159,11-REV- (P/N Controller Motor Flex Spark •
- 4260)am- 1200,11-REV- (P/N: Controller Motor Spark •
- 4261)am- 2158,11-REV- (P/N: Controller Motor MAX Spark •
- WCP- 6515_Short,am- 6515,am- 708850,19- 6515,217- (P/N Controller Motor FX Talon •
only, X60 Kraken or 500 Falcon integral controlling for 0940)
- 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 15.6

using another or state one in that's something make to way easy and quick a are Pneumatics
. *APIs Pneumatics* see pneumatics, operating on information For air. compressed

controllers Pneumatics Legal FRC 15.6.1

4243)217- 2858,am- (P/N: Module Control Pneumatics •

1852)11-REV- (P/N Hub Pneumatic •

Relays 15.7

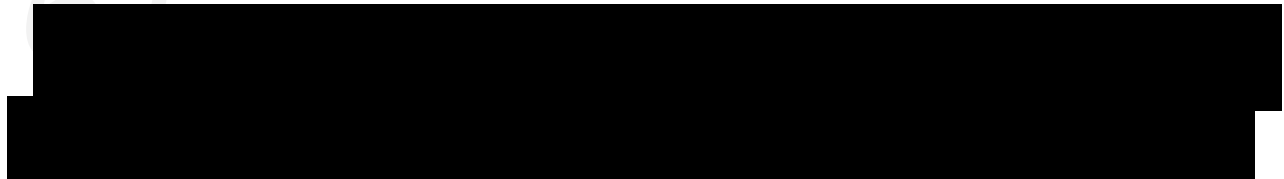
fashion. On/Off an in electronics custom or motor a to power controls relay A

Modules Relay Legal FRC 15.7.1

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 •



Devices CAN Using 16.1

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 16.2



control complete provides that device based-*CAN* 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 ,C++ ,Java(Solenoid the by handled are Solenoids the and),Python ,C++ ,Java(class classes.)Python ,C++ ,Java(DoubleSolenoid and)Python

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 16.3



the over control complete provides that device based-CAN 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 ,C++ ,Java(Solenoid the by handled are Solenoids the and),Python ,C++ ,Java(class classes.)Python ,C++ ,Java(DoubleSolenoid and)Python

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 16.4

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 16.4.1

PowerDistribution the of instance an create module, Distribution Power either the use To detected, be will object Distribution Power the arguments, no With). Python , C++ , Java(class additional default, non- is ID CAN the If REV. for 1 or CTRE for 0 of ID CAN use must and type. and ID CAN the specify to available are constructors

JAVA

```
PowerDistribution(); new = examplePD PowerDistribution
); kCTRE ModuleType. , 0 PowerDistribution( new = examplePD PowerDistribution
); kRev ModuleType. , 1 PowerDistribution( new = examplePD PowerDistribution
```

C++

```
examplePD{}; PowerDistribution
kCTRE}; ModuleType : PowerDistribution : frc , 0 examplePD{ PowerDistribution
kRev}; ModuleType : PowerDistribution : frc , 1 examplePD{ PowerDistribution
```

PYTHON

```
PowerDistribution import wpilib from
PowerDistribution() = examplePD
kCTRE) .ModuleType .PowerDistribution , 0 PowerDistribution( = examplePD
kRev) .ModuleType .PowerDistribution , 1 PowerDistribution( = examplePD
```

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 16.4.2

JAVA

```

Volts. in PDP, the into going voltage the Get //
Volts. 0.05 of increments in voltage the returns PDP The //
    ();getVoltage m_pdp. = voltage double
voltage); , "Voltage"(putNumber SmartDashboard.

```

32
33
34
35

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

```

28
29
30
31

PYTHON

```

Volts. in PDP, the into going voltage the Get #
Volts. 0.05 of increments in voltage the returns PDP The #
    getVoltage() pdp.self = voltage
voltage) , "Voltage" putNumber( SmartDashboard wpilib

```

34
35
36
37

robot the when detecting things) other (among for useful be can voltage bus the Monitoring
See manner. controlled a in brownout avoid to taken be can action that so brownout, a near is
information. more for *document Brownouts roboRIO* the

Temperature the Reading 16.4.3

JAVA

```

Celsius. degrees in PDP, the of temperature the Retrieves //
    ();getTemperature m_pdp. = temperatureCelsius double
temperatureCelsius); , "Temperature"(putNumber SmartDashboard.

```

37
38
39

C++

```

Celsius. degrees in PDP, the of temperature the Retrieves //
    m_pdp.GetTemperature(); = temperatureCelsius double
temperatureCelsius); , "Temperature" PutNumber( SmartDashboard::frc

```

33
34
35

PYTHON

```

Celsius. degrees in PDP, the of temperature the Retrieves #
    getTemperature() pdp self = temperatureCelsius
temperatureCelsius) , "Temperature" putNumber( SmartDashboard wpilib

```

39
40
41

too drawing been has robot the if detecting for useful be can temperature the Monitoring
wiring other or short a is there if or while, a for down shut be to needs and power much
problem.

Energy and Power, Current, Total the Reading 16.4.4

JAVA

```

channels. all of current total the Get //
    ();getTotalCurrentm_pdp. = totalCurrent double
totalCurrent); , "Current Total"(putNumber SmartDashboard.

channels. all of power total the Get //
Watts. units the with current the by multiplied voltage bus the is Power //
    ();getTotalPowerm_pdp. = totalPower double
totalPower); , "Power Total"(putNumber SmartDashboard.

channels. all of energy total the Get //
Joules. units with time over summed power the is Energy //
    ();getTotalEnergym_pdp. = totalEnergy double
totalEnergy); , "Energy Total"(putNumber SmartDashboard.

```

41
42
43
44
45
46
47
48
49
50
51
52
53

C++

```

channels. all of current total the Get //
    m_pdp.GetTotalCurrent(); = totalCurrent double
totalCurrent); , "Current Total" PutNumber( : SmartDashboard::frc

channels. all of power total the Get //
Watts. units the with current the by multiplied voltage bus the is Power //
    m_pdp.GetTotalPower(); = totalPower double
totalPower); , "Power Total" PutNumber( : SmartDashboard::frc

channels. all of energy total the Get //
Joules. units with time over summed power the is Energy //
    m_pdp.GetTotalEnergy(); = totalEnergy double
totalEnergy); , "Energy Total" PutNumber( : SmartDashboard::frc

```

37
38
39
40
41
42
43
44
45
46
47
48
49

PYTHON

```
channels. all of current total the Get #
getTotalCurrent().pdp.self = totalCurrent
totalCurrent) , "Current Total"putNumber(.SmartDashboard wpilib

channels. all of power total the Get #
Watts. units the with current the by multiplied voltage bus the is Power #
getTotalPower().pdp.self = totalPower
totalPower) , "Power Total"putNumber(.SmartDashboard wpilib

channels. all of energy total the Get #
Joules. units with time over summed power the is Energy #
getTotalEnergy().pdp.self = totalEnergy
totalEnergy) , "Energy Total"putNumber(.SmartDashboard wpilib
```

43
44
45
46
47
48
49
50
51
52
53
54
55

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 16.4.5

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.
```

26
27
28
29
30

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
```

22
23
24
25
26

PYTHON

```

        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 #
        )7getCurrent( pdp self = current7
        current7) , "7 Channel Current"putNumber(.SmartDashboard wpilib
    
```

28
29
30
31
32

stalled or shorts detecting for useful be can draws current device individual Monitoring
motors.

(PDH) Channel Switchable the Using 16.4.6

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(
    
```

PYTHON

```

        )True(setSwitchableChannel( examplePD
        )False(setSwitchableChannel( examplePD
    
```

Devices CAN PartyThird- 16.5

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 16.5.1

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 -

Devices CAN Other CTRE

Controller LED CANdle

)C++ ,Java(Documentation API -

Robotics REV 16.5.2

can which controllers motor Flex SPARK and MAX SPARK the offers currently Robotics REV motors. Vortex) NEO and 550, NEO (NEO, brushless REV and brushed for used be

Controllers Motor REV

MAX SPARK •

)C++ ,Java(Documentation API -

Flex SPARK •

)C++ ,Java(Documentation API -

Fusion With Playing 16.5.3

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 =

Sensors PWF

Sensor Flight of Time

)C++ ,Java(Documentation API -

Robotics Redux 16.5.4

the and encoder magnetic *PWM* + *CAN* Canandcoder the offers currently Robotics Redux
sensor. color enabled-*CAN* Canandcolor

Sensors Redux

Canandcoder •

)C++ ,Java(Documentation API -

Canandcolor •

)C++ ,Java(Documentation API -

16.6 ספציפיקציות מכשירי CAN ב-FRC

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

Addressing 16.6.1

: 5- ID- ID FRC- CAN

סוג המכשיר

00 .0000 00000000 00000000 0000 00 0000 0000 .000000 000 00 000000 000000 5 00000 000 0000
FIRST-0 0000 000 000 ,``0000``00000000 000 00000 000 0000000 0000000

סוגי מכשירים	
(Broadcast) 000000 000000	0
Controller Robot	1
Controller Motor	2
Controller Relay	3
00000'0 000000	4
Accelerometer	5
Sensor Ultrasonic	6
Sensor Tooth Gear	7
Module Distribution Power	8
Controller Pneumatics	9
Miscellaneous	10
Breakout IO	11
00000 3012-	
000000 000000	31

יצרן

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

יצרן	
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
AndyMark	15
Hosting Vivid	16
00000 25517-	

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	
Control Enable	0
Control Disable	1
Setpoint Set	2
Constant P	3
Constant I	4
Constant D	5
Reference Set	6
Enable Trusted	7
Ack No Set Trusted	8
Ack No Setpoint Set Trusted	10
Ack No Setpoint Set	11

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

Example
Speed Control Mode Disable from Luminary Micro Jaguar

Field Value	Device Type 2	Manufacturer Code 2	API Class 1
Bits Bit Position	0 0 0 1 0 28 27 26 25 24	0 0 0 0 0 1 0 23 22 21 20 19 18 17	0 0 0 0 16 15 14 13

Frames Protected 16.6.2

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

(Broadcast) שידור 16.6.3

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 16.6.4

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 16.6.5

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 ms. 20 every sent is heartbeat This to. react
is It).0x061 ID API and 0 ID Device type, RobotController ID, Manufacturer NI the is (which
layout. bitfield following the with packet CAN byte 8 an

Description	Byte	(bits) Width
(seconds) time Match	8	8
000000 0000	76-	10
number Replay	6	6
alliance Red	5	1
Enabled	5	1
mode Autonomous	5	1
mode Test	5	1
watchdog System	5	1
type Tournament	5	3
(year) day of Time	4	6
(month) day of Time	43-	4
(day) day of Time	3	5
(seconds) day of Time	32-	6
(minutes) day of Time	21-	6
(hours) day of Time	1	5

```
{ RobotState packed}:[[gnu struct
;8 : matchTimeSeconds uint64_t
;10 : matchNumber uint64_t
;6 : replayNumber uint64_t
;1 : redAlliance uint64_t
;1 : enabled uint64_t
```

page) next on (continues

(0000 00000 0000)

```

;1 : autonomous uint64_t
;1 : testMode uint64_t
;1 : systemWatchdog uint64_t
;3 : tournamentType uint64_t
;6 : timeOfDay_yr uint64_t
;4 : timeOfDay_month uint64_t
;5 : timeOfDay_day uint64_t
;6 : timeOfDay_sec uint64_t
;6 : timeOfDay_min uint64_t
;5 : timeOfDay_hr uint64_t
;}
```

since passed has ms 100 If enabled. are controllers motor set, is flag watchdog System the If
act should devices and hung, considered be can program robot the received, was packet this
disabled. been has robot the if as
will watchdog System and ,mode Test ,mode Autonomous ,Enabled except fields all that Note
connects. Station Driver the after time arbitrary an until values invalid contain

17.1 מבוא ל-Git

□□□□ : more A depthin- guide on Git is available on the Git website.

Git is a Distributed Version Control System (VCS) created by Linus Torvalds, also known for Linux kernel. Git is maintaining and creating changes tracking for system a is Control Version kernel. Linux the maintaining and creating are: Control Version Git of advantages The developers. for code of

- 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](#)

17.1.1 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

Git מונחי 17.1.2

commands: and structures data core several around revolves Git
אשר יתבצעו באמצעות git. אלה הן הפעולות הבסיסיות של **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 17.1.3

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 •

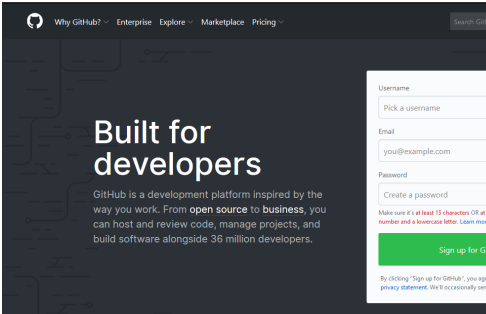
repository the Creating

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 :אפשר
Github. to alternatives

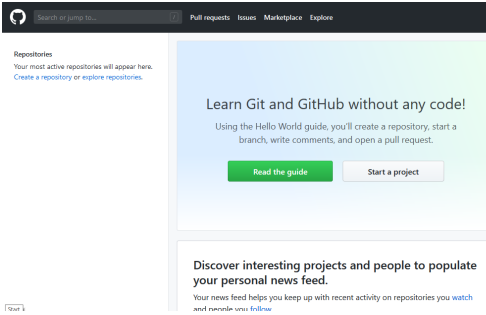
Account GitHub a Creating

screenon- the following and [website](#) the visiting by account GitHub a create and ahead Go
prompts.

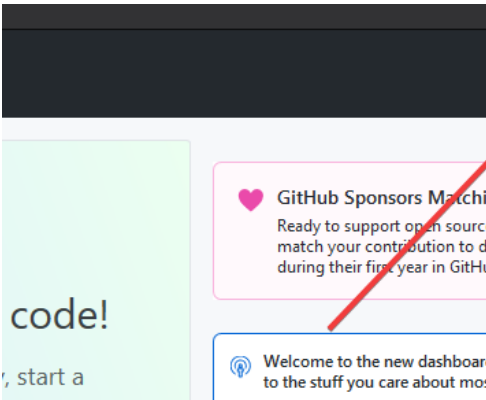


Creation Local

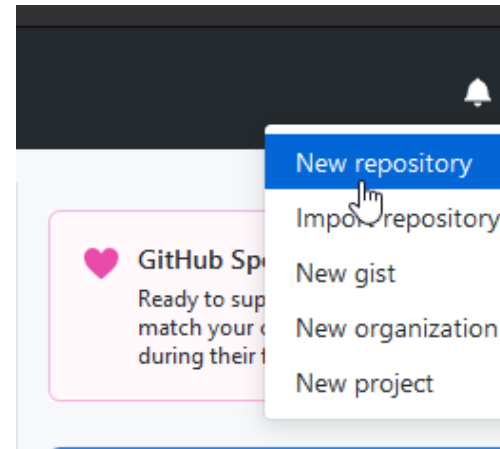
similar look It'll homepage. the visit to want you'll account, your verifying and creating After image. shown the to



right. top the in icon plus the Click



Repository" "New click Then



repository" "Create click then and information, appropriate the out Fill

Create a new repository

A repository contains all project files, including the revision history. Already have a project? [Import a repository.](#)

Owner: / Repository name:

Great repository names are short and memorable. Need inspiration? How about reinventing the wheel?

Description (optional):

☒ Public
Anyone can see this repository. You choose who can commit.

☐ Private
You choose who can see and commit to this repository.

☐ Initialize this repository with a README
This will let you immediately clone the repository to your computer. Skip this step if you're importing an existing repository.

Add .gitignore: Add a license:

Create repository

this to similar screen a see should You

Quick setup — if you've done this kind of thing before

Set up in Desktop or [HTTPS](#) [SSH](#) <https://github.com/ExampleUser9007/ExampleRepo.git>

Get started by [creating a new file](#) or [uploading an existing file](#). We recommend every repository include a README file.

...or create a new repository on the command line

```
echo "# ExampleRepo" >> README.md
git init
git add README.md
git commit -m "first commit"
git remote add origin https://github.com/ExampleUser9007/ExampleRepo.git
git push -u origin master
```

...or push an existing repository from the command line

```
git remote add origin https://github.com/ExampleUser9007/ExampleRepo.git
git push -u origin master
```

...or import code from another repository

You can initialize this repository with code from a Subversion, Mercurial, or TFS project.

[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

Windows PowerShell
PS C:\Users\daltz\Documents\Example Folder>

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

with Folder" Example\Documents\ExampleUser9007\Users\"C: filepath the Replace :
https://github.com/ URL remote the replace and in, repo the create to want you one the previous the in created you repo the for URL the with ExampleUser9007/ExampleRepo.git steps.

Directory Empty

```
Folder" C:\Users\ExampleUser9007\Documents\Example" cd >
init git >
Folder/ C:/Users/ExampleUser9007/Documents/Example in repository Git empty Initialized
git/. <
README.md >> ExampleRepo" #" echo >
README.md add git >
commit" First" m- commit git >
commit First fafafa] (root-commit) [main
deletions(-) 0 insertions(+), 1 changed, file 1
README.md 100644 mode create
https://github.com/ExampleUser9007/ExampleRepo.git origin add remote git >
main origin u- push git >
```

פרויקט קיים

```
Folder" C:\Users\ExampleUser9007\Documents\Example" cd >
init git >
Folder/ C:/Users/ExampleUser9007/Documents/Example in repository Git empty Initialized
git/. ↵
. add git >
commit" First" m- commit git >
commit First fafafa] (root-commit) [main
deletions(-) 0 insertions(+), 1 changed, file 1
README.md 100644 mode create
https://github.com/ExampleUser9007/ExampleRepo.git origin add remote git >
main origin u- push git >
```

Commits 17.1.4

of *versions* or states saved are Commits commits. of composed primarily are Repositories code.

favorite your in file that Open README.md. called file a created we example, previous the In close. and save simply bit, a for file the with tinkering After lines. few a edit and editor text commands. following the type and PowerShell to Navigate

```
README.md add git >
repository" the to description a Adds" m- commit git >
repository the to description a Adds bcbcbc] [main
deletions(-) 0 insertions(+), 2 changed, file 1
push git >
```

on guide A project. maintainable a of part key a is messages commit good Writing :□□□□
 .here found be can messages commit writing

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 :□□□□

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 17.1.5

can they then and same, the off start They worlds. parallel to similar are Git in Branches this. to similar look to flow control Git the Consider paths. varying different into out "branch"

Branch a Creating

The create. to branch the of name the is namebranch- where name-branch branch git Run:
branch. active current the from created be will history branch new

Branch a Entering

branch. the enter then to have you created, is branch a Once
previously was that branch the is namebranch- where name-branch checkout git Run:
created.

Merging 17.1.6

them. merge can you another, into history branches one copy to want you where scenarios In
the of name the being namebranch- with name-branch merge git calling by done is merge A
branch. active current the into merged automatically is It from. merge to branch

Whenever have. not do you that (history) work contain to repository remote a for common It's
copy. local your into commits those merge automatically to attempt will it ,pull git run you
below. the like look may merge That

Resets 17.1.7

done be can This undone. be to needs commit a or reset, be to needs history Sometimes ways. multiple

Commit the Reverting

should it origin or branch which know not does git as merge, a revert cannot You :□□□□ choose.

be can IDs commit The .id-commit revert git run commit a to up leading history revert To command. log git the using shown

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 17.1.8

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 17.1.9

included is that file `gitignore`. the modify **not do** teams that important extremely is It :`git` 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 17.1.10

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 17.2

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 17.2.1

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#
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;_5 = 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 `auto` 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 17.2.2

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

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

Library Units Java The 17.3

of units to related mistakes avoid programmers helps that tool a is library units The ensuring by and measurement, of units the of track keeping by this does It measurement. that errors prevent to help can This units. correct the with performed are operations all that meters. in distance a to inches in distance a adding as such results, incorrect to lead can

the making By bugs. reduces also which maintainability, and readability is benefit added An what understand and read to easier becomes it code, your in explicit measurement of units to easier is it as maintainable, more code your make to help also can This doing. is code your measurement. of units to related errors fix and identify

features: of number a has library units The

seconds. and degrees, meters, as such units, predefined of set A •

- units. different between convert to ability The
- units. with quantities on comparisons and arithmetic performing for Support
- format. readablehuman- a in units with quantities displaying for Support

Terminology 17.3.1

Dimension

mass. or time, length, as such quantity, physical a of nature the represent Dimensions
meters of dimension the example, For system. unit specific any of independent are They
inches. or millimeters, meters, in expressed is length the whether of regardless length, is

Unit

physical expressing of way the are They dimensions. of realizations specific are Units
for second the length, for meter the as such unit, base a has dimension Each quantities.
as such units, base combining by formed are units Derived mass. for kilogram the time,
velocity. for second per meters

Measure

particular a in expressed quantities, physical of magnitude specific the are Measures
distance. of measure a is meters 5 example, For unit.

has *seconds 10* **measure** the example, For Library. Units the within used are concepts These
seconds. is **unit** the and time, is **dimension** the 10, of magnitude a

Library Units the Using 17.3.2

relevant most The `package. edu.wpi.first.units` the in available is library units Java The
are: classes

- Time and Distance** as such dimensions, predefined for classes various The
- browse to `javadoc Units` the a look a Take units. predefined of set a contains which , **Units**
- types. their and units available the
- unit. a with value a tag to used is which , **Measure**

access full get to `edu.wpi.first.units.Units.*` import static to recommended is It :
units. predefined the all to

Generics Java

as such dimension, various involving expressions complex be can measurement of Units
units of definition the for allow **parameters type generic** Nested velocity. and time, distance,
concise, library the keep to used are Generics expressions. complex such represent can that
generics. Java for syntax the to due verbose be to tends it but extensible, and reusable,

a represents type This `.>><Distance<VelocityMeasure` type the consider instance, For
unit per distance of unit a as expressed is itself velocity the where velocity, for measurement
second per meters like units of representation the for allows structure nested This time. of
`>>><DistanceVelocity <Voltage,<PerMeasure` type the Similarly, minute. per feet or

representing for useful is type This velocity. to voltage of ratio a for measurement a represents gains. *feedforward* some for measure of unit the second, per meter per volts like quantities

For types. nested complex such require measurements all not that note to important It's meters like units simple representing for sufficient is ><DistanceMeasure type the example, is parameters type generic nested of use the units, complex more for However, feet. or essential.

full the including of instead keyword *var* Java's use to choose may you variables, local For equivalent: are these example, For name. type

```
);8(ofVoltsPerMeterPerSecond. = v >>>Distance<Velocity Voltage,<Per Measure
);8(ofVoltsPerMeterPerSecond. = v var
```

Measures Creating

its with quantity) (physical magnitude a represents that type generic a is class *Measure* The dimensions different handle to way safetype- and consistent a provides It unit. corresponding particular the away abstracts but velocity, and angle, distance, as such measurements, of the on method *Unit.of* the call you object, *Measure* a create To inch). vs. meter (e.g. unit a representing object ><DistanceMeasure a create to example, For object. unit appropriate write: would you inches, 6 of distance

```
);8(ofInches. = wheelDiameter >Distance Measure
```

method: *Unit.of* their using created be also can measures Other

```
);1.423(ofKilograms. = kArmMass >Mass Measure
);32.25(ofInches. = kArmLength >Distance Measure
);5(ofDegrees. = kMinArmAngle >Angle Measure
);0.45(ofRotations. = kArmMaxTravel >Angle Measure
);2.5(ofMetersPerSecond. = kMaxSpeed >>Distance Velocity Measure
```

Calculations Performing

subtraction, addition, as such operations, arithmetic supports also class *Measure* The These objects. the on methods calling by done are These division. and multiplication, calculation, the performing before compatible are units the that ensure always operations ><DistanceMeasure two add can you example, For object. *Measure* new a return they and units: different have they if even together, objects

```
);10(ofInches. = distance1 >Distance Measure
);0.254(ofMeters. = distance2 >Distance Measure
(distance2);plusdistance1. = totalDistance >Distance Measure
```

unit same the to measures the convert automatically will library units the code, this In new a be will object *totalDistance* resulting The distances. two the adding before inches. 20 or meters, 0.508 of value a has that object ><DistanceMeasure

per distance the calculatate to ratio gear and diameter wheel the combines example This wheel: the of rotation

```
); (of Inches. = wheelDiameter > Distance Measure
; 10.48 = gearRatio double
).Pi(Math.times wheelDiameter. = distancePerRotation > Distance Measure
(gearRatio); divide →
```

results. their for instances Measure new create operations arithmetic default, By :
 livedshort- of number large a creating on discussion for *Collection Garbage Java* See
 possible a for below section *Creation Object and Mutability* the also, See objects.
 workaround.

Units Converting

will system type Java The .Measure.in(Unit) calling by done be can conversions Unit
 angles. to distances as such types, incompatible between converted being from units prevent
 you, to up is it - information unit without values double bare be will values returned The
 unit use only to recommended strongly is It correctly! them interpret to programmer, the
 library. units the support not do that APIs with interacting when conversions

```
); 12.5(of FeetPerSecond. = kMaxVelocity >> Distance Velocity Measure
(Second).per FeetPerSecond. = kMaxAcceleration >>> Distance Velocity Velocity Measure
); 22.9(of →

3.81 Returns OK! => // (MetersPerSecond); inkMaxVelocity.
be cannot Velocity<Angle> error! Compile => // (RadiansPerSecond); inkMaxVelocity.
Unit<Velocity<Distance>> to converted →

meters: to convert to have we so units, metric SI use libraries math WPILib The //
(ConstraintsTrapezoidProfile. new = kDriveConstraints ConstraintsTrapezoidProfile.
(MetersPerSecond), in maxVelocity.
(MetersPerSecondPerSecond) in maxAcceleration.
);
```

Example Usage

effector end the calculates that example an create can we together, concepts the of all Pulling
 mechanism: arm an of position

```
)); 4.25(of (Inches.plus).3(of Feet. = armLength > Distance Measure
(Radians))); in(getArmAngle().cos(Math.times armLength. = endEffectorX > Distance Measure
(Radians))); in(getArmAngle().sin(Math.times armLength. = endEffectorY > Distance Measure
```

Formatting readableHuman-

of representation readablehuman- a get to used be can that methods has class Measure The logs. in or dashboard a on measure a display to useful is feature This measure. the a in measure the of representation string a return toShortString() and toString() and name, full the than rather used, is unit backing the of symbol The form. shorthand V/m 1.234e+04 example, For notation. scientific in represented is magnitude the form. longhand a in measure the of representation string a returns toLongString() is magnitude the and symbol, its than rather used, is unit backing the of name The Meter per Volt 1234 example, For notation. scientific not string, full a in represented

Creation Object and Mutability 17.3.3

special a usage, memory reduce and create, you instances object of number the reduce To you if objects mutable using consider to want may You available. is class MutableMeasure *Garbage Java* See loop. periodic robot's the in as such repeatedly, library units the using are objects. livedshort- of number large a creating on discussion more for *Collection*

results the with as such updated, be to object the of state internal the allows MutableMeasure when taken be to needs care Special objects. new allocating avoid to operations, arithmetic of referenced. is instance that place every value the change will it because measure a mutating regular a return method that have method, public a of part as exposed be will object the If state. internal your modifying from caller the prevent to signature its in Measure

that Note value. internal the updating for MutableMeasure on available are methods Extra methods these that obvious it make to is this - prefix mut_ the with begin all methods these API and methods of list full the For unsafe! potentially are and object the mutating be will documentation API MutableMeasure the see documentation,

mut_plus(double, Unit)	The unit. another in amount an by value internal the Increments same the stay will unit internal
mut_plus(Measure)	The measurement. another by value internal the Increments same the stay will unit internal
mut_minus(double, Unit)	The unit. another in amount an by value internal the Decrements same the stay will unit internal
mut_minus(Measure)	The measurement. another by value internal the Decrements same the stay will unit internal
mut_times(double)	scalar a by value internal the Multiplies
mut_divide(double)	scalar a by value internal the Divides
mut_replace(double, Unit)	and value given the equal to it sets and state internal the Overrides unit
mut_replace(Measure)	given the to identical it make to state internal the Overrides measurement
mut_setMagnitude(double)	careful Be unit. internal the keeping value, internal the Overrides this! using when

```
(Feet); zeroMutableMeasure. = measure >Distance MutableMeasure
    feet 0.8333 // Inches); ,10(mut_plusmeasure.
    feet 1.6667 // ));10(of(Inches.mut_plusmeasure.
    feet 1.25 // Inches); ,5(mut_minusmeasure.
    feet 0.8333 // ));5(of(Inches.mut_minusmeasure.
```

page) next on (continues

(0000 00000 0000)

```

        feet 5 = 6 * 0.8333 //          );6(mut_timesmeasure.
        foot 1 = 5 / 5 //          );5(mut_dividemeasure.
        changed! unit the note - meters 6.2 // Meters) ,6.2(mut_replacemeasure.
        again! changed unit the - 14.2mm // ))14.2(of(Millimeters.mutablemeasure.
                                   72mm //          )72(mut_setMagnitudemeasure.

```

mut_times optionally, and, - mut_replace use can we above, from example arm the Revisiting position effector end the calculate to -

```

        ;edu.wpi.first.units.Measure import
        ;edu.wpi.first.units.MutableMeasure import
        ;edu.wpi.first.units.Units.* static import

        { Arm class public
        calls. Inches.of and Feet.of the for allocations object ephemeral two the Note //
        garbage be easily will they once, just computed value constant a is this Because //
        without collected →
        jitter. timing loop or use memory with problems any //
        4.(of(Inches.plus).3(ofFeet. = kArmLength >Distance<Measure final static private
        ));25 →

        s'let loop, robot main the in called be likely will locations X/Y and Angle //
        MutableMeasure a in them store →
        objects short-lived of lots allocating avoid to //
        (Degrees);zeroMutableMeasure. = m_angle >Angle<MutableMeasure final private
        (Feet);zeroMutableMeasure. = m_endEffectorX >Distance<MutableMeasure final private
        (Feet);zeroMutableMeasure. = m_endEffectorY >Distance<MutableMeasure final private

        Encoder(...); new = m_encoder Encoder final private

        { ()getEndEffectorX >Distance<Measure public
          (mut_replacem_endEffectorX.
        to magnitude new the // (Feet),inkArmLength. * (Radians))in(getAngle().cosMath.
        store →
          magnitude new the of units the // Feet
          );
          m_endEffectorX; return
        }

        { ()getEndEffectorY >Distance<Measure public
          units the repack and unpack to have t'don we so approach alternative An //
          (kArmLength);mut_replacem_endEffectorY.
          (Radians));in(getAngle().sin(Math.mutablem_endEffectorY.
          m_endEffectorY; return
        }

        { ()getAngle >Angle<Measure public
          ();getPositionm_encoder. = rawAngle double
        configured be must encoder the NOTE: // Degrees); (rawAngle,mutable_angle.
          degrees! of terms in distancePerPulse with →
          m_angle; return
        }
    }
}

```

is It time! any at values their change - definition by - can objects MutableMeasure :[] [] [] [] Measure. the using value a extract to prefer - them to reference stateful a keep to unsafe same the For stored. safely be can that Measure.copy with copy a create or method, in .Measure accepting methods about careful be also must authors library reason,

code? this in bug the spot you Can

```
m_lastDistance; >Distance Measure private
{ currentDistance) >Distance<(Measure calculateDelta >Distance Measure public
    { )null == (m_lastDistance if
        currentDistance; = m_lastDistance
        currentDistance; return
        { else }
        (m_lastDistance); minus currentDistance. = delta >Distance Measure
        currentDistance; = m_lastDistance
        delta; return
    }
}
```

pattern: a see can we times, few a method calculateDelta the run we If

```
(Inches); zero MutableMeasure. = distance >Distance MutableMeasure
    Inches); ,10(mut_plus distance.
    good! - 10 get and inches 10 expect // calculateDelta(distance);

    Inches); ,2(mut_plus distance.
    instead! 0 get but inches, 2 expect // calculateDelta(distance);

    Inches); ,8(mut_plus distance.
    instead! 0 get but inches, 8 expect // calculateDelta(distance);
```

object MutableMeasure same the to reference a is field m_lastDistance the because is This on currentDistance) - (currentDistance as calculated is delta the Effectively, input! the as track to be would solution One zero. returns always naturally which first, the after call every approach this however, snapshot; a take to measure input the of copy a as m_lastDistance object about careful be to need you If copy. the for allocation object extra one incur does .MutableMeasure a as stored be also could m_lastDistance allocations,

Copies Immutable

```
m_lastDistance; >Distance Measure private
{ currentDistance) >Distance<(Measure calculateDelta >Distance Measure public
    { )null == (m_lastDistance if
        ( ); copy currentDistance. = m_lastDistance
        currentDistance; return
        { else }
        (m_lastDistance); minus currentDistance. = delta var
        ( ); copy currentDistance. = m_lastDistance
        delta; return
    }
}
```


Mutable allocationZero-

```
(Meters); zeroMutableMeasure. = m_lastDistance >Distance<MutableMeasure final private
(Meters); zeroMutableMeasure. = m_delta >Distance<MutableMeasure final private

{ currentDistance) >Distance<(Measure calculateDelta >Distance Measure public
    m_lastDistance - currentDistance = m_delta //
    (currentDistance); mut_replace m_delta.
    (m_lastDistance); mut_minus m_delta.
    (currentDistance); mut_replace m_lastDistance.
    m_delta; return
}
```

Units New Defining 17.3.4

library: the in present already isn't that unit new a define to ways four are There
 units; other two of composite a create to methods Unit.mult or Unit.per the Using •
 methods; helper Kilo and ,Micro ,Milli the Using •
 and unit; base the to relates unit new the how customizing and method derive the Using •
 dimension. new a define to Unit Subclassing •
 Unit.per and Unit.mult the using units existing of combinations as defined be can units New
 methods.

```
(Inch); perVolts. = VoltsPerInch >Distance Voltage,<Per
(Second); perKilograms. = KgPerSecond >Mass<Velocity
Kilograms. = Newtons >Distance Velocity<Velocity Mass,<Mult
(MetersPerSecondSquared); mult →
```

to object same the return will call Every unit. resulting the store will per and mult Using
 pressure. collector garbage and allocations unnecessary avoid

```
@Override
{ ()robotPeriodic void public
    loop, first the on unit new a creates Feet.per(Millisecond) //
    loop successive every on reused be will which //
(Millisecond)); per(Feet.in().getSpeed m_drivebase. , "Speed"(putNumber SmartDashboard.
}
```

and from different is which unit, Velocity a return will Unit.per(Time) Calling :□□□□
 unit! Per a with incompatible

two the implementing and Unit subclassing by created be also can dimensions New
 type generic the where type, generic parameterized a also is Unit that Note constructors.
 have to us allows what is This .><DistanceUnit a is Distance referential;self- is argument
 dimensions. unrelated between conversions prevent to system type the in guarantees stronger

```
{ >ElectricCharge<Unit extends ElectricCharge class public
{ symbol) String name, String baseUnitEquivalent, double(ElectricCharge public
symbol); name, baseUnitEquivalent, ,class(ElectricCharge.super
page) next on (continues
```

(0000 0000 0000)

```

    }

    etc. Kilo, Milli, with derivation for required //
    UnaryFunction toBaseConverter, (UnaryFunctionElectricCharge public
    { symbol) String name, String fromBaseConverter, →
    symbol); name, fromBaseConverter, toBaseConverter, ,class(ElectricCharge.super
    }
    }

    ); "C" , "Coulomb" , 1ElectricCharge( new = Coulomb ElectricCharge final static public
    , 1.60217646e-19ElectricCharge( new = ElectronCharge ElectricCharge final static public
    ); "e" , "Charge Electron" →
    Ah" , "Hour Amp" , 3600ElectricCharge( new = AmpHour ElectricCharge final static public
    ); " →
    Milli(AmpHour); = MilliampHour ElectricCharge final static public

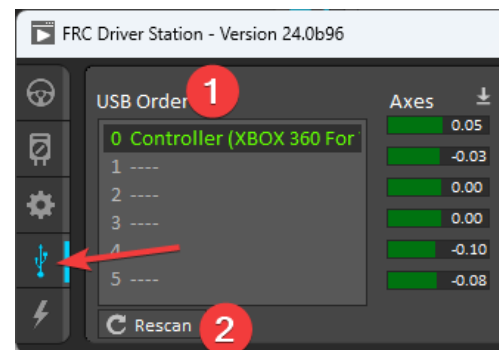
```

Joysticks 17.4

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 17.4.1



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

Class Joystick 17.4.2



JAVA

```
as used be to Port USB the is 0 // );0Joystick( new = exampleJoystick Joystick
Station Driver the on indicated →
```

C++

```
the on indicated as used be to Port USB the is 0 // ;}0exampleJoystick{ Joystick
Station Driver →
```

PYTHON

```
on indicated as used be to Port USB the is 0 # )0Joystick(.wpilib = exampleJoystick
Station Driver the →
```

significantly robot the operate to joystick flight a using make to designed is class Joystick The and Z, Y, X, specific the set to need may user the joystick, flight the on Depending easier. accessing for methods special offers class This uses. joystick flight your that channels Throttle joystick. flight the of magnitude and angle the

when values the negate usually teams systems, coordinate in differences to Due : more for section *system coordinate controller and Joystick* the See axes. joystick reading detail.

Class XboxController 17.4.3



JAVA

```
used be to Port USB the is 0 // );XboxController( new = exampleXbox XboxController  
Station Driver the on indicated as →
```

C++

```
the on indicated as used be to Port USB the is 0 // ;}exampleXbox{ XboxController  
Station Driver →
```

PYTHON

```
on indicated as used be to Port USB the is 0 # )XboxController(.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

when values the negate usually teams systems, coordinate in differences to Due :□□□□ more for section *system coordinate controller and Joystick* the See axes. joystick reading detail.

Class PS4Controller 17.4.4



JAVA

```
as used be to Port USB the is 0 // );PS4Controller( new = examplePS4 PS4Controller
Station Driver the on indicated →
```

C++

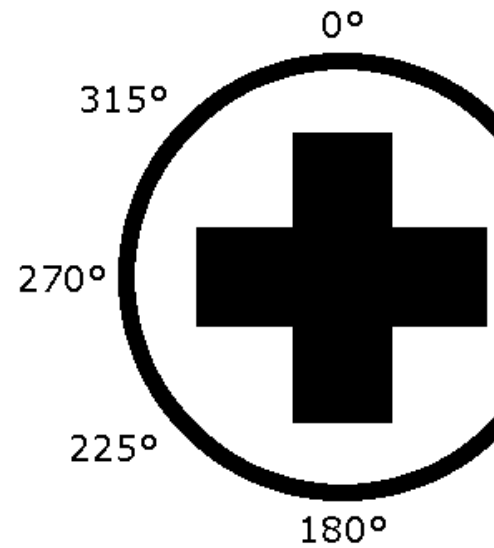
```
the on indicated as used be to Port USB the is 0 // );examplePS4{ PS4Controller
Station Driver →
```

PYTHON

```
on indicated as used be to Port USB the is 0 # )PS4Controller(.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,

when values the negate usually teams systems, coordinate in differences to Due :
more for section *system coordinate controller and Joystick* the See axes. joystick reading detail.

POV 17.4.5

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 17.4.6

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
DifferentialDrive(m_leftMotor::set, new = m_robotDrive DifferentialDrive final private
                                m_rightMotor::set); ↵
);kJoystickPortGenericHID(Constants. new = m_stick GenericHID final private
                                );1(getRawAxism_stick. ),0(getRawAxism_stick.-(arcadeDrive m_robotDrive.
```

C++

```

        kLeftMotorPort};: m_leftMotor{Constants PWMVectorSPX:frc
        kRightMotorPort};: m_rightMotor{Constants PWMVectorSPX:frc
    }, m_leftMotor.Set(output); { output) double]}(&m_robotDrive{[ DifferentialDrive:frc
;}} m_rightMotor.Set(output); { output) double]}(&[
        kJoystickPort};:m_stick{Constants GenericHID:frc

)); m_stick.GetRawAxis( ),&m_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
)) getRawAxis( stick.self ),0getRawAxis( stick.self arcadeDrive( robotDrive.self

```

Usage Button 17.4.7

For framework, basedcommand- the using not code for is following the as such Usage :
.Triggers- Commands see framework, basedcommand- the in usage button

respond to methods released and pressed the use to want usually will you axis, an Unlike
check. last the since activated been has button the if true return will These input. button to
continuously to having not but occurs event the when once action an taking for helpful is This
down. held is button the while it do

JAVA

```

        { })0(getRawButtonPressed(joystick. if
on turns intake the pressed When // turnIntakeOn();
        }
        { })0(getRawButtonReleased(joystick. if
off turns intake the released When // turnIntakeOff();
        }

OR

        { })0(getRawButton(joystick. if
turnIntakeOn();
        { else }
turnIntakeOff();
        }

```


C++

```

{ })0(joystick.GetRawButtonPressed( if
on turns intake the pressed When // turnIntakeOn();
}
{ })0(joystick.GetRawButtonReleased( if
off turns intake the released When // turnIntakeOff();
}

OR

{ })0(joystick.GetRawButton( if
turnIntakeOn();
{ else }
turnIntakeOff();
}

```

PYTHON

```

):0getRawButtonPressed(.joystick if
on turns intake the pressed When # turnIntakeOn()

):0getRawButtonReleased(.joystick if
off turns intake the released When # turnIntakeOff()

OR #

):0getRawButton(.joystick if
turnIntakeOn()
: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++

```

        ;}false toggle{ bool
    { })@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
    ):@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

```

System Coordinate 17.5

common the of few A places. several in programming FRC in used are systems Coordinate planning. path and AprilTags, estimation, *pose* input, joystick movement, robot are: places WPILib throughout used system coordinate the of basics the understand to important is It teams Many PathPlanner. as such robot, FRC an programming for tools common other and this and WPILib, in used is what from different is that system coordinate a of think intuitively to worthwhile is It season. the throughout down tracked be to need that problems to leads reference a as here back come and system, coordinate the understand to minutes few a take working joystick a with movement robot get to difficult very not It's programming. when on build to difficult more much be will it but right, system coordinate the getting without path and *AprilTags* with *estimation pose* add to system coordinate different a using code autonomous. for planning

system coordinate WPILib 17.5.1

reference external as UpWest-(North- convention axes NWU the uses WPILib cases, most In the ahead, points axis X positive the where convention, axes NWU the In frame.) world the in When floor. the from referenced up points axis Z positive the and left, points axis Y positive positive a is (CCW) clockwisecounter- you, toward pointing axis positive each with viewed value. negative a is (CW) clockwise and value

choose can you where settings configuration have sensors Some 179°.- not 181°, read they Careful code. your in handled be to need others while range, and behavior wrapping their loop control your and consistent are readings sensor sure make to paid be should attention sensor. your as way same the in wrapping handles

system coordinate controller and Joystick 17.5.3

system. coordinate NWU same the use don't controllers, on sticks the including Joysticks, ahead, points axis X positive the where convention, Down)East-(North- NED the use They each with viewed When down. points axis Z positive the and right, points axis Y positive the clockwise and value positive a is (CCW) clockwisecounter- you, toward pointing axis positive value. negative a is (CW)

translations. not axis, an around rotations are values input joystick that note to important It's means: this terms, practical In

the around rotation CW a is axis) X positive the (toward joystick the on forward pushing value. Y negative a get you so axis, Y

so axis, X the around rotation CCW a is axis) Y positive the (toward right the to pushing value. X positive a get you

axis, Z the around rotation CCW a is axis) Y positive the (toward CW joystick the twisting value. Z positive a get you so

robot a drive to input controller and Joystick Using 17.5.4

as same the not is robot the for WPILib by used system coordinate the noticed, have may You understand to taken be to needs Care controllers. and joysticks for used system coordinate the subsystem. drive the to input driver pass properly and difference, the

example drivetrain Differential

move cannot drivetrain robot the means which holonomic,non- are drivetrains Differential X the along backward and forward move can drivetrain of type This (strafe). sideto-side-single a using scheme drive arcade common a Consider axis. Z the around rotate and axis, robot forward/backward for forward/backward joystick the pushes driver the where joystick left/right. robot the rotate to left/right joystick the push and movement,

robot the drive to classes Joystick and DifferentialDrive the uses below snippet code The coordinate robot the uses DifferentialDrive above. described scheme arcade the with system. coordinate joystick the uses Joystick and above, defined system

example drivetrain Mecanum

side-to-side- move to ability the have they meaning holonomic, are drivetrains Mecanum like axis Z the around rotate and forward/backward move can drivetrain of type This Consider axis. Y robot's the along side-to-side- move also can it but drivetrains, differential joystick the pushes driver the where joystick single a using scheme drive arcade common a to left/right joystick the pushes movement, robot forward/backward for forward/backward robot. the rotate to joystick the twists and side-to-side- move

JAVA

```

{ ()teleopPeriodic void public
joystick. the of axes Z and Y, X, the using Drive //
();getZ_m_stick.- (),getY_m_stick.- (),getY_m_stick.- (driveCartesian m_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(
}

```

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 →

```

method, zRotation) ySpeed, MecanumDrive.driveCartesian(xSpeed, the calls code The class: Joystick the from gets it values with

xSpeed is argument first The •

forward/backward. is which axis, X robot's the along speed the is xSpeed Robot: -
its along joystick the rotating by speed forward/backward sets driver The Joystick: -
forward/backward. joystick the pushing is which axis, Y
forward robot whereas rotation, Y negative is forward joystick the Moving Code: -
by inverted be to needs value joystick the means This axis. X positive the along is
value. the of front in sign) (minus - a placing

ySpeed is argument second The •

left/right. is which axis, Y robot's the along speed the is ySpeed Robot: -
axis, X its along joystick the rotating by speed left/right sets driver The Joystick: -
left/right. joystick the pushing is which
right robot whereas rotation, X positive is right the to joystick the Moving Code: -
by inverted be to needs value joystick the means This axis. Y negative the along is
value. the of front in sign) (minus - a placing

zRotation is argument third The •

rotating is which axis, Z robot's the along rotation of speed the is zRotation Robot: -
left/right.

axis, Z its along joystick the twisting by speed rotation sets driver The Joystick: -
left/right. joystick the twisting is which

rotation robot whereas rotation, Z positive is right the to joystick the Twisting Code: -
- a placing by inverted be to needs value joystick the means This positive. CCW is
value. the of front in sign) (minus

example drivetrain Swerve

move to ability the have and holonomic are drivetrains swerve drivetrains, mecanum Like
drivetrains, holonomic all for way same the handled be can control Joystick side-to-side-
described is coding Swerve swerve. for class drive robot inbuilt- a have doesn't WPILib but
set to input joystick using of example an but documentation, this of sections other in
scheme drive arcade common same the Consider below. included is values ChassisSpeeds
driver the where joystick single a uses scheme The above. section mecanum the in described
the pushes movement, robot forward/backward for forward/backward joystick the pushes
robot. the rotate to joystick the twists and side,to-side- move to left/right joystick

JAVA

```
joystick. the of axes Z and Y, X, the using Drive //
());getZm_stick.- (),getYm_stick.- (),getYm_stick.-ChassisSpeeds( new = speeds var
```

C++

```
joystick. the of axes Z and Y, X, the using Drive //
m_stick.GetZ());- m_stick.GetX(),- m_stick.GetY(), speeds{ ChassisSpeeds::frc
```

PYTHON

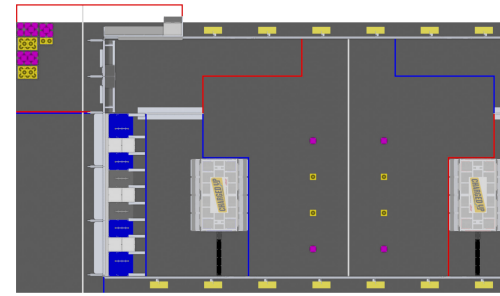
```
joystick. the of axes Z and Y, X, the using Drive #
getZ()) stick.self- getX(), stick.self- getY(), stick.self-ChassisSpeeds( = speeds
```

driveCartesian as same the are constructor ChassisSpeeds the to arguments three The
the of description the See .zRotation and ,ySpeed ,xSpeed above; section mecanum the in
above. section the in input joystick their and arguments,

kinematics drive Robot 17.5.5

here discussing worth it's but ,*section different a in covered is that topic a is Kinematics* configured is kinematics that important critically is It system. coordinate the to relation in for point starting common a is Kinematics above. described system coordinate the using driving, oriented field control, drivetrain basic to cascade then that errors system coordinate planning. path and estimation, pose

you object, MecanumDriveKinematics or SwerveDriveKinematics a construct you When use translations These wheel. each to robot your of center the from translation a specify robot. your of center the in origin the with above, system coordinate the



2023 in UP CHARGED from field Mirrored 7: Fig.

alliance blue or red with Dealing

both In system. coordinate field the define to choose teams many ways primary two are There direction. (CCW) clockwise counter- the in is (theta) rotation positive methods,

the after change) to appear (or change may alliance your where cases are There :□□□□□ can you competition, a at *FMS* the to connected not are you When initialized. is code you when Even time. any at application Station Driver the in station alliance your change you so FMS the to connecting before initialize usually will robot your competition, a at are information. alliance have not will

and Station Team your report automatically will FMS the events, competition At :□□□□ Station Team your choose can you FMS, an to connected not are you When color. alliance .*Tab Operation* Station Driver the on color alliance and

origin blue Always

regardless there it keep and side, blue the on field the of origin the define to choose may You alliance blue the from away points axisx- positive solution, this With color. alliance your of wall.

are: approach this to advantages Some

unique. are field the throughout AprilTags simplified. is AprilTags with estimation Pose • for need no is there alliance, of regardless same the system coordinate the keep you If alliance. your to relative field the on AprilTags of location the with deal to logic special tools the of Some convention. this follow FRC in used libraries and tools the of Many • widget. Field2d Glass and ShuffleBoard the and Choreo, PathPlanner, include:

the consider to needs input driver driving, oriented field for approach this use to order In alliance red the behind standing is driver the and red is alliance your When color. alliance when However, wall. alliance blue the toward downfield move to robot the want will they wall, alliance red the toward downfield go to robot the want will driver the blue, is alliance your wall.

the by reported color alliance the check to is driving oriented field with deal to way simple A above, noted As alliance. the on based controls driver's the invert and class, *DriverStation* iteration. robot every on checked be to needs it so change can color alliance your



(0000 0000 0000)

```
imu. zRotation, invert, * ySpeed invert, * m_robotDrive.driveCartesian(xSpeed
GetRotation2d()); ↵
```

PYTHON

```
inverted be to need Y and X red, is alliance our When blue. always is origin The #
1 = invert
kRed: Alliance DriverStation wpilib == getAlliance() DriverStation wpilib if
1- = invert

Swerve controlling for ChassisSpeeds relative field Create #
FromFieldRelativeSpeeds( ChassisSpeeds wpilib = chassis_speeds
GetAngle() imu self zRotation, invert, * ySpeed invert, * xSpeed
)

drivetrain mecanum a Control #
.imu.self zRotation, invert, * ySpeed invert, * driveCartesian(xSpeed.robotDrive.self
GetAngle()) ↵
```

alliance your follows Origin

this With one. are you alliance the on based field the of origin the define to choose may You
 wall. alliance your from away points always axisx- positive the approach,
 this: like looks origin your alliance, blue the on are you When



Preferences Initializing 17.6.1

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 //
        ; kDefaultArmKp Constants. = m_armKp double private
; kDefaultArmSetpointDegrees Constants. = m_armSetpointDegrees double private
        { ()Arm public
        ); kArmEncoderDistPerPulse( Constants.setDistancePerPulse m_encoder.
    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 inline
; "ArmP" = kArmPKey string_view::std constexpr inline

        ; 50.0 = kDefaultArmKp double constexpr inline
deg; _75.0 = kDefaultArmSetpoint degree_t::units constexpr inline

        { 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
        }

```

Python

```

        "ArmPosition" = kArmPositionKey
        "ArmP" = kArmPKey

    arm. this drives that controller PID the for gain P The #
        50.0 = kDefaultArmKp
        75.0 = kDefaultArmSetpointDegrees

    arm. this drives that controller PID the for gain P The #
        kDefaultArmKp Constants = armKp.self
        kDefaultArmSetpointDegrees Constants = armSetpointDegrees self

    don keys the if Preferences to constant P and setpoint position Arm the Set #
page) next on (continues

```

(0000 00000 0000)

```

                                exist already t' →
                                initDouble(.Preferences.wpilib
armSetpointDegrees.self kArmPositionKey,.Constants
                                )
armKp).self kArmPKey,.initDouble(Constants.Preferences.wpilib

```

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 17.6.2

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);
                                }
                                }

```

Python

```

        ):self(loadPreferences def
        Teleop entering on kP and setpoint Arm for Preferences Read #
        getDouble(.Preferences.wpilib = armSetpointDegrees self
        armSetpointDegrees self kArmPositionKey, Constants
    )
armKp):.self kArmPKey, getDouble(Constants Preferences.wpilib != armKp.self if
armKp).self kArmPKey, getDouble(Constants Preferences.wpilib = armKp.self
armKp).self setP( controller.self

```

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. (),getDistanceencoder.
        (pidOutput);setVoltageencoder.
    }

```

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
}

```

Python

```

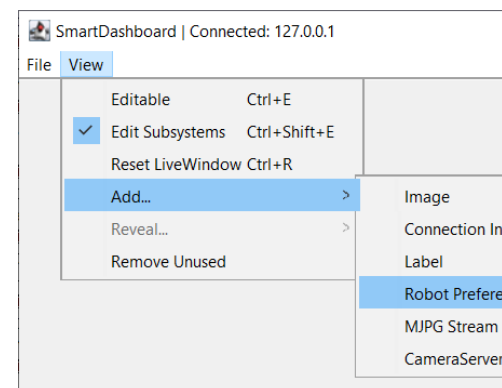
):self.teleopPeriodic def
getTrigger(): joystick.self if
normal, like control PID run we Here, #
reachSetpoint().arm.self
:else
motor. the disable we Otherwise, #
stop().arm.self

):self(reachSetpoint def
calculate( controller.self = pidOutput
getDistance(), encoder.self
armSetpointDegrees),.self.degreesToRadians( units
)
setVoltage(pidOutput) motor.self

```

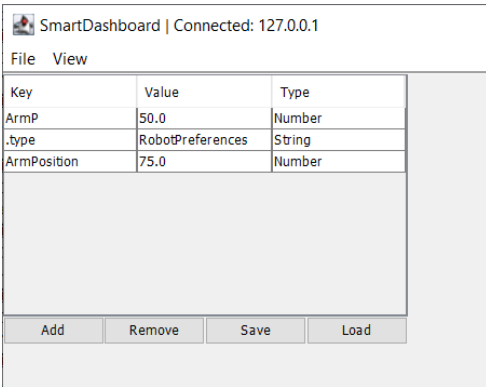
SmartDashboard in Preferences Using 17.6.3

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

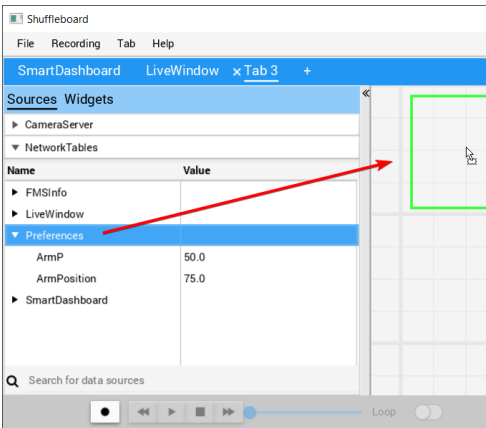
SmartDashboard in Preferences Editing



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

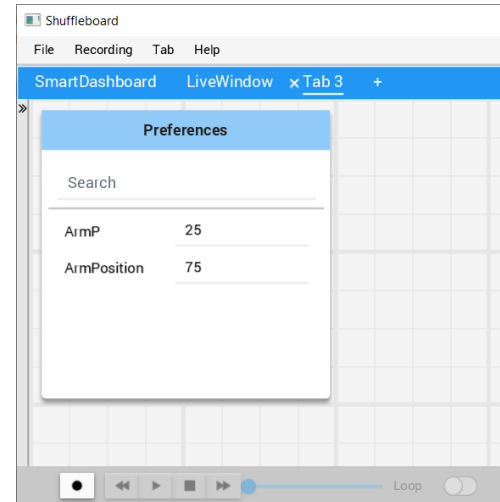
Shuffleboard in Preferences Using 17.6.4

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

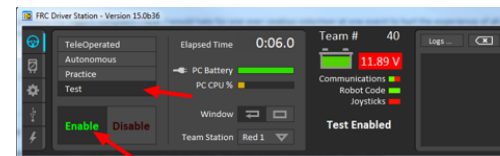


be to need values the If code. the from values default the with here shown are values The
here. edited be can they adjusted

Mode Test Using 17.7

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 17.7.1



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

code robot your to code mode Test Adding 17.7.2

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

Mode Test in LiveWindow 17.7.3

LiveWindow Enabling See default! by disabled is Mode Test in LiveWindow 2024, Since :□□□□ it. enable to *Mode Test* in

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

Stacktraces Reading 17.8

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 17.8.1

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 17.8.2

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 17.8.3

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

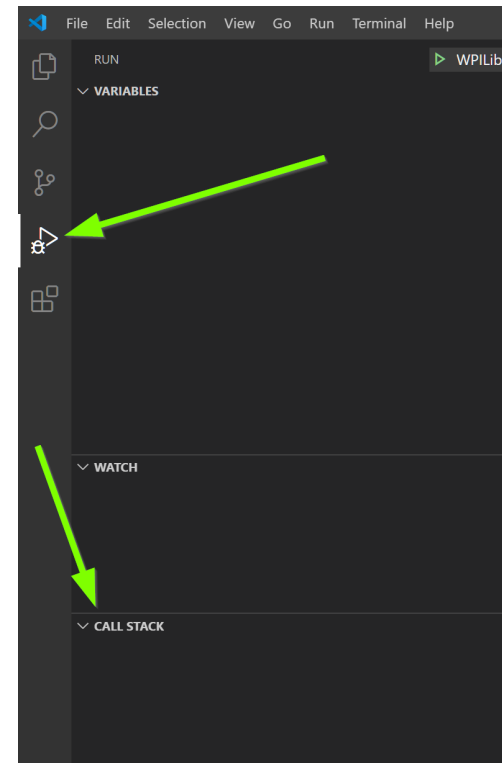
```
exception: Unhandled frc.robot.Robot.buggyMethod(TooManyBugs.java:1138): at Error
                                     java.lang.NullPointerException ↪
                                     frc.robot.Robot.buggyMethod(TooManyBugs.java:1138) at
                                     frc.robot.Robot.barInit(Bar.java:21) 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.

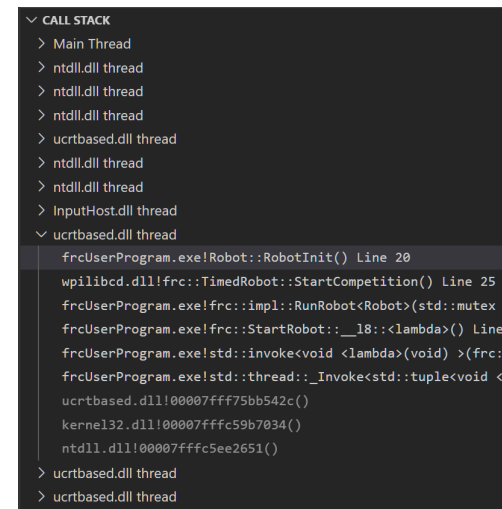
C++

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 17.8.4

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
};m_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 →
```

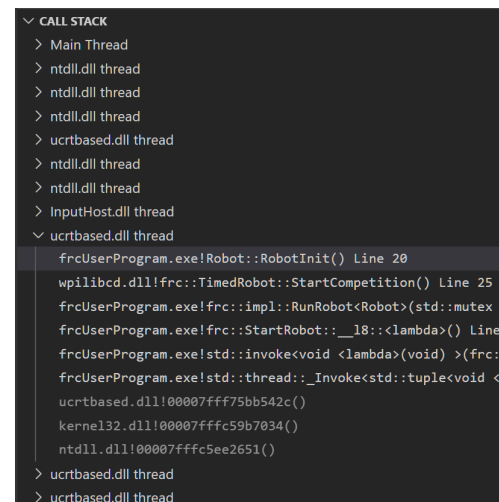
robotInit() the of inside happened issue the that see can you trace, stack the Reading
 Pointer". "Null involved exception the and 23, line on function,
 .armMotorCtrl - null be could which thing one only is there see can you 23, line to going By
 never but declared, is object armMotorCtrl the that see 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
); PWMSparkMax( new = armMotorCtrl
); true(setInverted armMotorCtrl.
}
```

C++

```
{ TimedRobot::frc public : Robot class
:public
{ override RobotInit() void
m_armMotor;& = motorRef
); false SetInverted(> motorRef
}
:private
}; m_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
        }
        :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

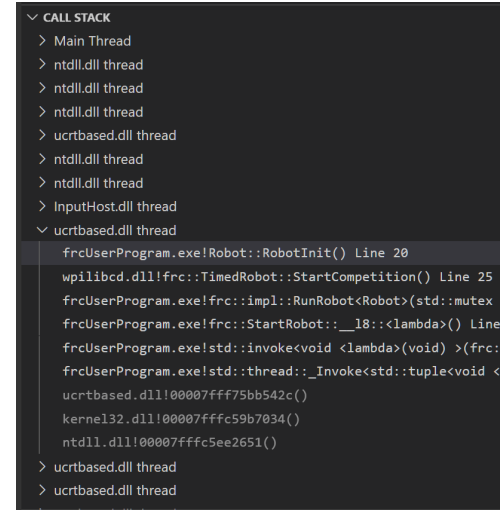
inspect could you 24, line on stopping and debugger stepsingle- the running by Alternatively,
 .0 of value a has shoulderToElbow_in discover to variables all of value the

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



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
        ;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
}; PWMSparkMax( new = leftFrontMotor
); PWMSparkMax( new = leftRearMotor
}

```

C++

```

{ TimedRobot::frc public : Robot class
:public
{ override RobotInit() void
};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

```

page) next on (continues

(0000 0000 0000)

```
(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] →
```

page) next on (continues

(0000 0000 0000)

```

[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

); PWMSparkMax( new = leftFrontMotor
); PWMSparkMax( new = leftRearMotor
}

```

C++

```
17 :start lineno:

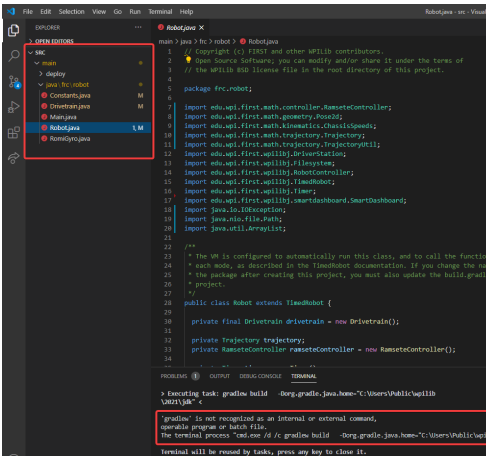
{ TimedRobot::frc public : Robot class
    :public
    { override RobotInit() void
    };0.5m_frontLeftMotor.Set(
    );0.25m_rearLeftMotor.Set(
    }

: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 17.9

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 17.9.1

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 specific team- 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 based Command*- 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. shaped appropriately- 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 17.9.2

"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 Command 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 existing already- 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:

```

└─,} );0.0 ,0.5(arcadeDrive└drivetrain. { >- 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 confusingly less- 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(arcadeDrive drivetrain. >- 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 17.9.3

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.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 `RunOnce`
here. discussed be not will

```
(RunOnce CommandPtr  
action, >()void<function::std  
requirements); Requirements
```

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
parameters no with function a it give to need we, `runOnce` call we When value). return no
that way a in methods class existing to refer to way clean a lacks C++ value. return no and
define to is this do to way typical the so, `std::function` a to converted be automatically can
expression". "lambda a with inline function new a

C++ in Expressions Lambda

using expression function inline short a write to need we, `runOnce` to function a pass To
few a in varies but declarations, function C++ ordinary resembles that syntax special a
ways: important

```
speed half at forward drive the runs that InstantCommand an Create //  
, } ); 0.0 , 0.5 drivetrain.ArcadeDrive( { } thisRunOnce([ :cmd = driveHalfSpeed CommandPtr  
drivetrain}); { →
```

a parts: three has It expression". "lambda a } body; { (params) [captures] calls C++
body function a and (parentheses), *list parameter* optional an brackets), (square *list capture*
lambda a between difference real only the but strange, little a look may It brackets). (curly
addition the is name) function a of lack the from (apart function ordinary an and expression
list. capture the of

lambda our value, return no and parameters no with function a wants `RunOnce` Since
here expression" "lambda The statement. return no and list parameter no has expression
- parameters of set specific a with `drivetrain.ArcadeDrive` calls that function a represents
it passes and it defines merely but function, the *call* not does code above the that again note
scheduled. is Command the when later run be to Command the to

Expressions Lambda C++ 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

generally we that is this of cost One Java. than semantics powerfulmore- somewhat has C++ capture to it want we *exactly how* out figure to help some compiler C++ the give to need of purposes the For *list capture* the of purpose the is This scope. enclosing the from state list capture a use to sufficient usually is it framework, basedCommand- WPILibC the using enclosing the capturing by class enclosing the of members to access gives which, [this] of value. by pointer this class's

explicitly captured be must and pointer, this the with captured be cannot locals Method instead by implicitly by (or list capture the in them including by value by or reference by either since value,by- locals capture to safer typically is It semantics). capture default a specifying details, more For reference. by captures it object an of lifespan the outlive can lambda a [.semantics capture on documentation library standard C++ the consult](#)

Color Alliance Get 17.10

from data getting for features useful many has)Python ,C++ ,Java(class DriverStation The & (Java get Alliance is features important most the of One computer. Station Driver the (C++). Get Alliance / Python)

handles code that important is It yet. color no and blue, red, cases: three are there that Note Station Driver the until available be not will color alliance the because correctly case third the during available be will color alliance the that assume not should code particular, In connects. *teleopInit* or *autoInit* time the by available be should it but ,*robotInit* or methods constructor the FMS, to connected not when automatically; color alliance the set will FMS called. is).*Tab Operation the on Station* "Team" (see Station Driver the from set be can color alliance

Action an Doing and Color Alliance your Getting 17.10.1

JAVA

```
() ;get Alliance Driver Station. = ally :Alliance Optional
{ () is Present(ally. if
{ )Red Alliance. = ()get(ally. if
>ACTION RED<
}
{ )Blue Alliance. = ()get(ally. if
>ACTION BLUE<
}
}
{ else
>ACTION YET COLOR NO<
}
```

C++

```

Alliance; DriverStation::frc using
{ GetAlliance()::DriverStation::frc = ally auto( if
    { kRed)::Alliance == (ally.value() if
        >ACTION RED<
    }
    { kBlue)::Alliance == (ally.value() if
        >ACTION BLUE<
    }
    { else
        >ACTION YET COLOR NO<
    }
}

```

PYTHON

```

DriverStation import wpilib from
getAlliance() DriverStation = ally
:None not is ally if
kRed: Alliance DriverStation = ally if
    >ACTION RED<
kBlue: Alliance DriverStation = ally elif
    >ACTION BLUE<
:else
    >ACTION YET COLOR NO<

```

Collection Garbage Java 17.11

objects. Java for memory managing automatically of process the is collection garbage Java the and objects, destroying and creating for responsible is (JVM) Machine Virtual Java The objects. unused reclaiming and identifying for responsible is collector garbage

not does programmer the that means which process, automatic an is collection garbage Java are objects which of track keeps collector garbage The memory. deallocate explicitly to need objects. unused reclaims periodically it and not, are which and use in

Creation Object 17.11.1

issues. performance and memory to lead can Java in objects of number large a Creating efficiently, management memory handle to designed is (GC) Collector Garbage Java the While degradation. performance cause and GC the overwhelm can objects many too creating

Concerns Memory

of footprint memory overall the increases it created, are objects of number large a When become can it insignificant, be may object single a for overhead the While application. the objects. of number large a by multiplied when substantial

allocated. is memory where see to used be can *VisualVM* :□□□□

Concerns Performance

garbage While memory. in objects unused reclaim and identify periodically to is job GC's The paused. is program robot the of execution Java, in coded robot FRC an on running is collection run to application the pause to has it objects, of number large a collect to has GC the When more perform to has GC the because is This time. of periods longer for or frequently more object. each process and collect to work

pauses, occasional as manifest can programs robot in degradation performance relatedGC-memory. reclaim to works GC the as overruns loop or freezes,

Considerations Design

important is it objects, livedshort- of number large a creating application your anticipate you If Here issues. performance and memory potential the mitigate to strategies design consider to consider: to strategies some are

If creation. object each for need the evaluate Carefully creation: object Minimize • or arrays as such structures, data alternative use or objects existing reuse possible, objects. new creating avoid to primitives,

data of type the for suitedwell- are that structures data Use structures: data Efficient • primitive of number large a with dealing are you if example, For with. working are you primitives. for designed specifically collections or arrays using consider values,

Dumps Heap with Errors Memory of Out Diagnosing 17.11.2

typically objects As *.heap* the called memory of section a in retained are Java in objects All snapshot a take to useful often is it program, Java a in memory of amount greatest the consume capture only dumps Heap issues. memory analyze dump—to heap heap—a the of state the of not if useful be to unlikely are they so time, in point single a at heap program's a of state the issues. memory experiencing is program the time the at exactly captured

a want to reason common a are and program the crash both `sOutOfMemoryError` Since an moment the dump heap a take automatically to configured be can JVM the dump, heap code `frcJava` the locate options, these configure To JVM. the by caught is `OutOfMemoryError` :`build.gradle` project's your in block

```

    { deploy
      { targets
        { })'RoboRIO'(getTargetTypeClass'roborio
wpilib/wpilib_preferences.json. the from either loaded is number Team //
    thrown. be will exception an found not If line. command from or //
page) next on (continues

```

(0000 00000 0000)

```

you if getTeamNumber of instead getTeamOrDefault(team) use can You //
file. this in number team a store to want //
)(getTeamNumber.frc project = team
>false(getDebugOrDefault.frc project = debug

```

```

{ artifacts
type artifact is 2nd name, artifact is part First //
a using type class the get to shortcut a is getTargetTypeClass //

```

string ↩

```

artifact files Static //
{ })'FileTreeArtifact'(getArtifactTypeClass(frcStaticFileDeploy
)'src/main/deploy'(fileTree.project = files
'home/lvuser/deploy/' = directory
}
}
}
}
}
}

```

below: shown as commands, jvmArgs two contains it that so block code the to Add

```

{ })'FRCJavaArtifact'(getArtifactTypeClass(frcJava
it. remove to need not do you here, configuration other have you If //
OutOfMemoryError on dumps heap automatic Enable //
below see drive, flash USB a on path a is here path dump heap the Note: //
)XX:+HeapDumpOnOutOfMemoryError"-"(add.jvmArgs
)XX:HeapDumpPath=/u/frc-usercode.hprof"-"(add.jvmArgs
}

```

the at usercode.hprof-frc named file a to dumps heap write to JVM the cause will This is It memory. of out runs code the when roboRIO the to attached drive flash USB a of root intrinsically dumps heap because drive flash USB a to dumps heap these save to recommended the when memory in did heap program the as disk on space of amount same the consume capacity has storage internal roboRIO's the than larger be to likely are and crashed, program these without code your redeploy ,OutOfMemoryError the reproduced have you Once for. for computer a to dump heap the transfer to drive flash USB the use and enabled, options .VisualVM as such profiler memory a in analysis

to connected remain drive flash the that requires way this JVM the Configuring :000000 running. is code your while roboRIO the

on options these of use the allow to storage onboard enough provide may cards SD Larger to option XX:HeapDumpPath- the set this, do To drive. flash USB a without 2 roboRIO the computer a to dump heap the transfer to FTP/SFTP use and card, SD the on path a reference card. SD the from it deleting before

specified filename and path exact the with dumps heap overwrite **not** will JVM the that Note with file a to heap process the dump it will nor exist, already they if XX:HeapDumpPath- by will JVM the file, a to path a of instead supplied is directory a to path a If name. different a the with directory, specified the within filenames unique with dumps heap out write instead

memory. of out ran that JVM the of ID process the is NNNN where ,java_pidNNNN.hprof name you if so out, cleaned not are they if disk on up build to files large cause can this that Note delete and computer a to dumps heap copy frequently to sure be way, this JVM the configure afterward. card drive/SD flash the from them

storage underlying the on space available of amount the about vigilant be Always :
feature. this use you while medium
play. competitive during recommended not is feature this of Use

Tuning Memory System 17.11.3

system embedded an As terminated. be will program the memory, allocate cannot JVM the If the on MB 512 1, roboRIO the on MB (256 available memory of amount small a only with memory. of out running to susceptible particularly is roboRIO the 2), roboRIO

control-of-out- by caused errors memory of out fix can tuning system of amount No allocations.

and/or dumps heap with allocations investigate always memory, of out running are you If first. *VisualVM*

steps taking and VisualVM with investigating after even memory of out run to continue you If make to available are options different few a objects, allocated of number the minimize to program. robot the to available memory additional

- server web system the Disabling
- options) kernel (Linux sysctls Setting
- collector garbage the calling Periodically
- drive flash USB a on swap up Setting

running and roboRIO the to *SSH with connecting* require options these of most Implementing when careful be so recover, to reimage a require may it incorrectly, run If commands. instructions. the following

Server Web System the Disabling

seen)*Dashboard Web roboRIO* (the webpage the provides server web system NI inbuilt- The It settings. address IP change to e.g. roboRIO, the to connect to browser web a using when consumes it However, functionality. download log data Station's Driver the by used is also use. to program robot the for memory that up free will it disabling so RAM, of MB several server: web the disable to ways several are There

and 2024.2.1 Versions tool. *Setter Number Team RoboRIO* the use to is easiest and first The teams few a However, server. web the enable or disable to button a have tool the of later two are There reboots. between persist not does or work not does this that reported have SSH with roboRIO the to connecting require both server; web the disable to ways alternate user. admin the as in logging and

```
systemWebServer f- rc.d-update stop; etc/init.d/systemWebServer/ Run 1.  
sync remove;
```

```
sync usr/local/natinst/etc/init.d/systemWebServer;/ x-a chmod Run 2.
step: corresponding the take server, web the enablere- and ways alternate the revert To
etc/init.d/systemWebServer/ defaults; systemWebServer f- rc.d-update Run 1.
sync start;
sync usr/local/natinst/etc/init.d/systemWebServer;/ a+x chmod Run 2.
```

sysctls Setting

allocates kernel the how tweak to set be can sysctls) (called options kernel Linux Several errors: memoryof-out- reduce to found been have options Several memory.

to kernel the causes This 2). is value default (the 1 to vm.overcommit_memory Setting • time the at allocation memory requested a for memory enough is there pretend always memory enough actually there's if see to checks always setting default the allocation; of used. actually is memory the when not allocation, of time the at allocation an back to

this Increasing 100). is value default (the 1000 to vm.vfs_cache_pressure Setting • may it caches; object system file reclaim aggressively more much to kernel the causes performance. degrade slightly

more to kernel the causes This 60). is value default (the 100 to vm.swappiness Setting • effect no has option this Changing file. swap the to memory process swap aggressively file. swap a add you unless

.vm.overcommit_memory is one important most the options; these of all or some set can You the as in logging and SSH with roboRIO the to connecting requires options these Setting commands: following the running then user, admin

```
etc/sysctl.conf/ >> vm.overcommit_memory=1"" echo
etc/sysctl.conf/ >> vm.vfs_cache_pressure=1000"" echo
etc/sysctl.conf/ >> vm.swappiness=100"" echo
sync
```

check, (to done when end the at lines following the contain should file etc/sysctl.conf/ The):etc/sysctl.conf/ cat command the run can you

```
vm.overcommit_memory=1
vm.vfs_cache_pressure=1000
vm.swappiness=100
```

and editor) vi the of use the require will (this etc/sysctl.conf/ edit change, the revert To lines. 3 these remove

Collector Garbage the Calling Periodically

quantity the with up keep to enough frequently run won't collector garbage the Sometimes on it running occur, to collection garbage a trigger to way a provides Java As allocations. of a and Timer a adding by done be can This usage. memory peak reduce may basis periodic a check: periodic

```
Timer(); new = m_gcTimer Timer
{ ()robotInit void public
```

page) next on (continues

(0000 0000 0000)

```

        ());startm_gcTimer.
    }

    { ()periodic void public
seconds 5 every collector garbage the run //
    { })5(advanceIfElapsed(m_gcTimer. if
        ());gcSystem.
    }
}

```

Drive Flash USB a on Swap Up Setting

system the by used be can that space backeddisk- provides system Linux a on file swap A aren't they when programs and data used infrequently put to memory virtual additional as strongly is It program. robot the as such use active for RAM physical up freeing used, being a for 1 roboRIO the on storage flash replaceablenon- inbuilt- the use not to recommended a however, Instead, quickly. out wear may and cycles write limited very has it as file, swap USB the require does This purpose. this for used be may drive flash USB formattedFAT32- boot. before roboRIO the into plugged be always to drive flash

connected stay stick USB the critical it's means stick USB a on file swap a Having :000000 powered. is it times all at roboRIO the to

Generally help. above steps other the of none if resort last a as used be should This optimize to first VisualVM use so issue, allocation other some of indicative is swap needing allocations.

port, USB roboRIO the into drive flash USB the plugging by up set be can file swap A the running and user, admin the as in logging and SSH with roboRIO the to connecting file a save and edit to how of knowledge requires step vi the Note commands. following vi. in

```

u/swapfile/ 100M l- fallocate
u/swapfile/ mkswap
u/swapfile/ swapon
etc/init.d/addswap.sh/ vi
etc/init.d/addswap.sh/ a+x chmod
defaults addswap.sh v- update-rc.d
sync

```

this: like look should contents file etc/init.d/addswap.sh/ The

```

bin/sh/!#
u/swapfile/ e- swapon && ] sbin/swapon/ x- [
0 exit :

```

etc/init.d/addswap./ rm remove; addswap.sh f- rc.d-update run change, the revert To .reboot sync; sh;

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הם מודעים לבעיות, אך הם לא מודעים לבעיות. FRC® מודע לבעיות, אך הם לא מודעים לבעיות. הם מודעים לבעיות, אך הם לא מודעים לבעיות.

18.1 תיעוד נוסף

הם מודעים לבעיות, אך הם לא מודעים לבעיות. הם מודעים לבעיות, אך הם לא מודעים לבעיות.

- FRC NI-
FIRST
CTRE
Documentation Robotics REV

18.2 פורומים

הם מודעים לבעיות, אך הם לא מודעים לבעיות. הם מודעים לבעיות, אך הם לא מודעים לבעיות.

- as questions, software Station Driver and LabVIEW (roboRIO, Forum Support FRC NI repairs) roboRIO as well
- Station) Driver-
LabVIEW) Java C++,-

18.3 תמיכת CTRE

Electronics Road The Cross (SRX Talon PDP,) VRM
support@crosstheroadelectronics.com

18.4 תמיכת Robotics REV

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

18.5 ספקים נוספים

הנה מספר ספקים המספקים KoP-ים:

- Copperforge •
- (NavX) Labs Kauai •
- Limelight •
- (Discord) PhotonVision •
- Fusion with Playing •

18.6 תמיכה לא רשמית

הנה מספר ספקים המספקים FIRST®-ים:

- Delphi Chief •
- Discord FRC •

18.7 דיווח על באגים

אם אתם מוצאים באג, אנא דווחו עליו ב- WPILibSuite-: <https://github.com/wpilibsuite/Issue>

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AM

while service outstanding and products innovative develop to strives - Inc AndyMark, community. our in impact positive a making and customers our inspiring

AprilTags

useful are AprilTags localization. accuracy high overhead, low provide that tags Visual goal some to itself align can it so field, the on at is it where know robot your helping for position.

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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 organized specially- 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](#)

CAD

object. an of model accurate an design to used software - Design Aided Computer-aid and measurements accurate get to robot the design to used often is this FRC For construction.

CAM

the in tools machine control to software of use the - Manufacturing Aided Computer-pieces. work of manufacturing

CAN

microcontrollers allow to designed protocol based message- - Network Area Controller computer. host a without applications other's each with communicate to devices and

CD

serves today that [forum](#) driven community popular a inspired 47 team FRC - Delphi Chief FRC. things all for hub discussion unofficial an as

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

CIM

made that company the is [Limited Components Chiaphua](#) - Limited Motor, Industrial CCL motor. brushed powerful, relatively used, commonly the

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 [□□□□□](#)

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](#)

C RTP

derives X` class a which in idiom software A - Pattern Template Recurring Continuously on [C RTP](#) See [argument](#). [template a as itself X`](#) using [instantiation template class a from](#) [info](#). more for Wikipedia

CSA

Control Robot with teams assists that position volunteer FRC - Advisor Systems Control issues. relatedSystem-

CTRE

and development software design, engineering an is - [LLC Electronics Road the Cross](#) focus primarily They MI. Macomb, in Detroit of outside based manufacturer electronics control and control, motor communication, electronics qualityhigh- performing,high- on in founded was Electronics CTR industry. EV the and teams FIRST for products system Omar and Copioli Mike team: robotics their through met who mentors FRC two by 2006 mentors. & volunteers active and alumni, FRC by largely staffed is and Zrien

C++

languages. programming supported officially four the of One

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 chosen intentionally- particular, A into developers constrain to language programming a of features certain using excludes on [pattern design](#) See [space.problem-](#) particular a to suited well- 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. defined pre- of set a to refer to used typically set, a of elements all of list A

EPA

to ratings transforms but system, rating Elo the upon builds - [Added Points Expected modifications](#). several makes and units point

programming driven event-

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 [based event-](#) See [events](#). these "handle"

FIRST

nonprofit global a - Technology and Science of Recognition and Inspiration For changing life- of suite a through future the for people young prepares that organization resilience. and confidence, skills, build that programs robotics youth

FLL

to (STEM) math and engineering, technology, science, Introduces - League Lego FIRST learning. on hands- exciting fun, through 164- ages children

point floating

fixed a using arithmetic, based computer- 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

controlling and sensing for responsible core electronics the - System Management Field field. Competition Robotics FIRST the

FPGA

many of consisting circuit integrated specialized a - array gate programmable Field- 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

FRC

of rigors the with sport of excitement the Combining - Competition Robotics FIRST students. schoolHigh- inspiring Mind the for Sport ultimate The technology. and science

FTA

ensuring for responsible is that position volunteer FRC - Advisor Technical FIRST FIRST with accordance in and safely, smoothly, run events Competition Robotics FIRST and participants event all for experience qualityhigh- a ensuring and requirements, teams.

FTC

and program, build, design, to challenged are 127- Grades - Challenge Tech FIRST format. alliance an in challenge headto-head- a in compete to robots operate

GDC

and rules the develops and year each for game the designs - Committee Design Game competition. each for setup field

GP

that things doing of way a It's FIRST. of ethos the of part - Professionalism Gracious individuals respects and others, of value the emphasizes work, qualityhigh- encourages community. the and

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*

I2C

(controller/target), slavemaster/multi-multi- synchronous, a - Circuit IntegratedInter-bus. communication serial ended,single-

Java

languages. programming supported officially four the of One

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, 2024 the For .KOP the of part as

LabVIEW

languages. programming supported officially four the of One

LED

flows current when light emits that device semiconductor a - Diode EmittingLight-device. the of status the convey to parts robot multiple on Used it. through

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

MXP

the expand to designed roboRIO the of center the in Port - Port Expansion myRIO connector. one through types IO different multiple offering by count IO traditional

NetworkTables

programs. between data communicate to system messaging subscribepublish- A

opno-

computer the When operation. no means which instruction computer a is opNo-sequential next the to moves simply it instruction, opno- a encounters processor . [Wikipedia on opno- about more Read instruction.](#)

odometry

field. the on robot the of pose the of estimate an create to robot the on sensors Using

OPR

contribution point average the deduce to attempt to system a - [Rating Power Offensive alliance an to team a of](#)

PCM

pneumatic for interface onein-all- easy an provides - Module Control Pneumatic components.

PDH

20 With FRC. for distribution power in evolution latest - Hub Distribution Power REV currentlow- switchable 1 and max), (15A currentlow- 3 channels, max) (40A currenthigh- delivery. power overall for flexibility more teams gives PDH the channel,

PDP

(40A currenthigh- 8 with module distribution power - Panel Distribution Power CTRE 1 and),[VRM](#) and [PCM](#) (for channel protected 20A 1 30A), / (20A current lower 8 max), roboRIO). the (for channel protected 10A

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](#)

PH

24V and 12V both switching of capable is that module standalone a is - Hub Pneumatic which channels solenoid 16 features Hub Pneumatic The valves. solenoid pneumatic of combination a or solenoids, actingdouble- 8 solenoids, actingsingle- 16 to up for allow types. two the

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

estimation pose

.[AprilTags](#) and/or [odometry](#) with commonly pose, robot's the estimating of process The .[Localization fieldon-](#) as known Also

PWM

amplitude or power average the controlling of method a - modulation widthPulse- using not motors of output the control to FRC in Used signal. electrical an by delivered bus. [CAN the](#)

Python

languages. programming supported officially four the of One

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.

REV

robotics educational the within creativity and innovation inspires - [Robotics REV](#)

resources, educational extensive lines, product comprehensive offering by community global a With programs. sponsorship specialized and service, customer classworld-STEM of generation next the empower we countries, 190 over spanning presence success. for tools essential and solutions edgcutting- providing by professionals Robotics REV Yanoshak, David and Needel Greg enthusiasts robotics by 2014 in Founded world exciting the explore they as students support and inspire to mission the by driven is are employees our of majority A potential. design robotic full their unlock and robotics of the for mentors and volunteers as serving involved, actively remain who Alumni FIRST supporting to commitment our reflects engagement deep This Community. FIRST local enthusiasts. STEM of generation next the inspiring and

RPM

the components, system critical most the of one keep to designed is - Module Power Radio competition. the of moments toughest the in powered radio, WiFi ACOM5P- OpenMesh motors. describing when used often speed rotational of unit a - Minute Per Revolutions

RSL

operational its indicate to used robot FRC every on light safety - Light Signal Robot status.

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

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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.

SPI

used communication, serial synchronous for protocol - Interface Peripheral Serial between communication wired distanceshort- for systems embedded in primarily circuits. integrated

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

TBA

information. event and statistics team *FRC* up looking for Website - Alliance Blue The 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

VRM

custom for voltages constant different to access provides - Module Regulator Voltage
from power fed Directly Input DC 12V applications. unique other or cameras, sensors,
system. control FRC roboRIO the with work to Designed Panel Distribution Power the

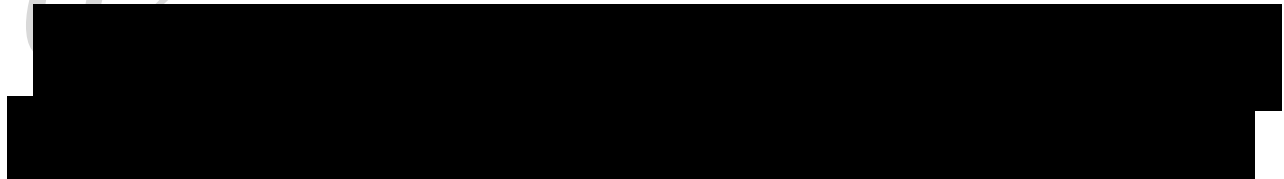
WCP

(R.C.) Chahal Ranjit by 2011 of Fall in founded was - [LLC Design & Products WestCoast](#)
[notch top educators and Hobbyists, Teams, FIRST](#) provide to aims WCP Rico. Harvey and
projects. their for designs and products quality

WFA

an done has who individual an recognizes award This - Award Flowers Woodie
the challenging also while communication through motivation of job outstanding
communications. their in succinct and clear be to students

02

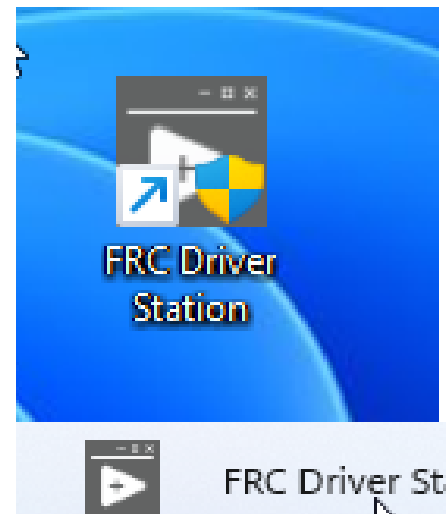


LabVIEW NI by Powered Station Driver FRC 20.1

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 20.1.1



by or Desktop the on icon the clickingdouble- by launched be can Station Driver FRC The Station. Driver >FRCApps- >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

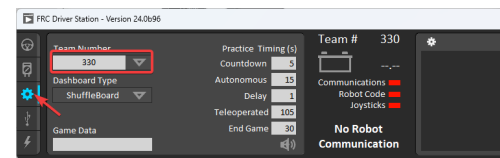
Shortcuts Key Station Driver 20.1.2

- 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

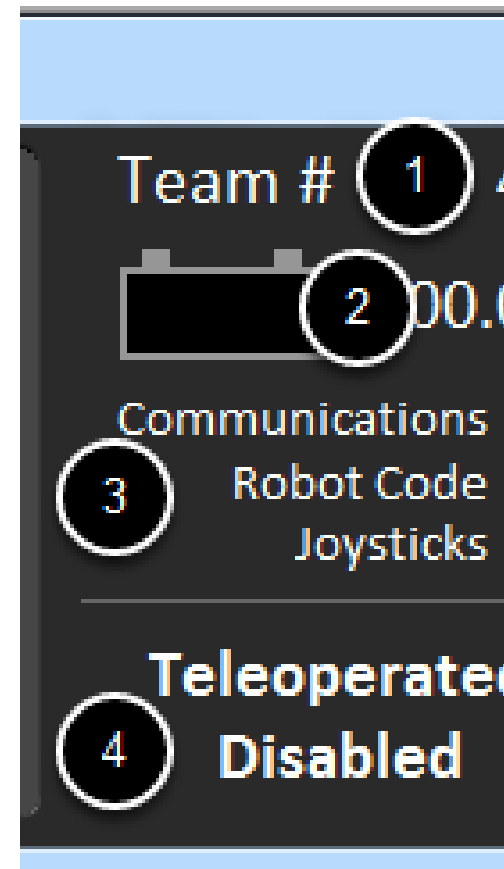
Station Driver the Up Setting 20.1.3



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 20.1.4



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

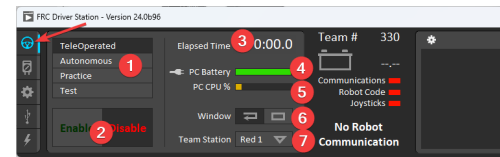
your match should This for. configured currently is DS the number Team The - # Team 1. Tab. Setup the see number team the change To number. team FRC

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 20.1.5



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.

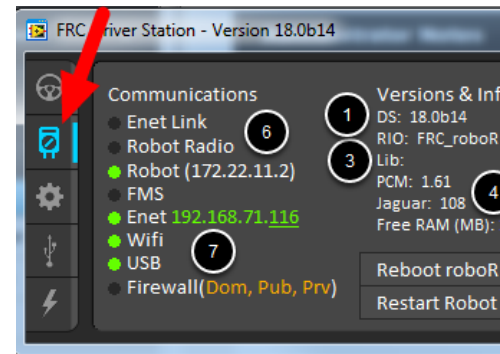
PC. DS the of Utilization CPU the Indicates - CPU% PC 5.

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

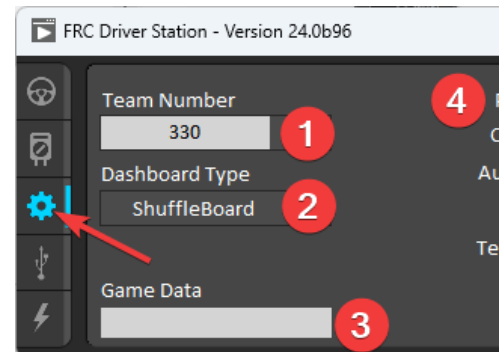
Tab Diagnostics 20.1.6



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 4.
- not has Framework Phoenix CTRE the if present be not may items These bus. CAN the loaded. been
- memory. roboRIO the about stats shows section This - Stats Memory 5.
- various to status connection show indicators these of half top The - Indicators Connection 6.
- components.
- 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 7.
- communication purposes; informational for provided are These firewalls. and adapters
- section. this in indicators unlit more or one with even established be may
- 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* 8.
- dialog). confirmation a through clicking
- (but robot the on running code the restart to attempts button This - *Code Robot Restart* 9.
- OS). the restart not

Tab Setup 20.1.7



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

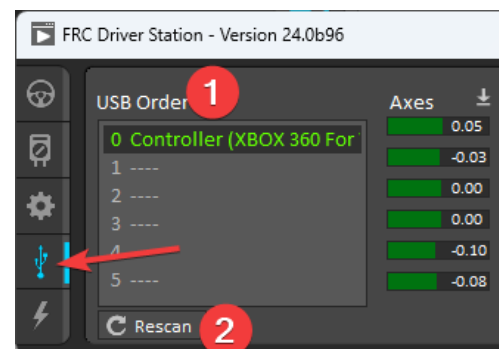
Default Station. Driver the by launched is Dashboard what Controls - *Type Dashboard* 2.
information more (for Storage.ini" Data DS "FRC the by to pointed file the launches
Program the in Dashboard.exe is this default By).*dashboard custom* a setting about
the at dashboard a launch to attempts *LabVIEW* 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

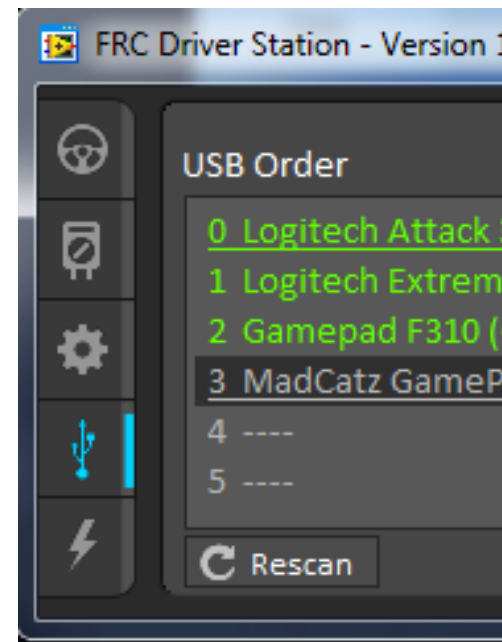
Practice the when sounded are tones audio whether controls button This - *Control Audio* 5.
used. is Mode

Tab Devices USB 20.1.8



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

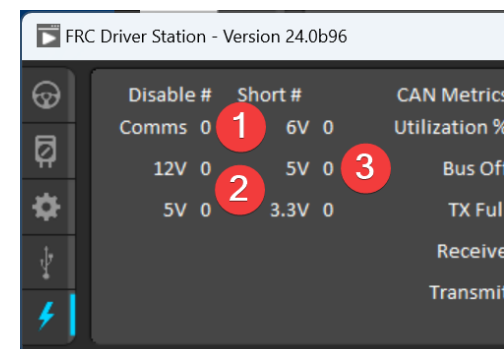
the of more or one unplug you If slots). swap may devices (the determinate not is behavior locked proper the to return should they move; may others the of positions the devices, of set reconnected. are devices all when slots

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 20.1.9



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

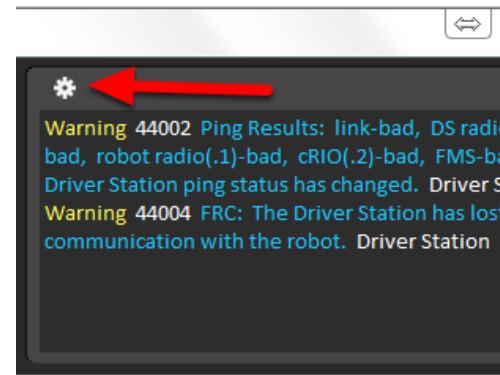
circuits) short by caused (typically faults of number the Indicates - Faults 6V/5V/3.3V 3.
connected been has DS the since Rails Voltage User the on occurred have that

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.

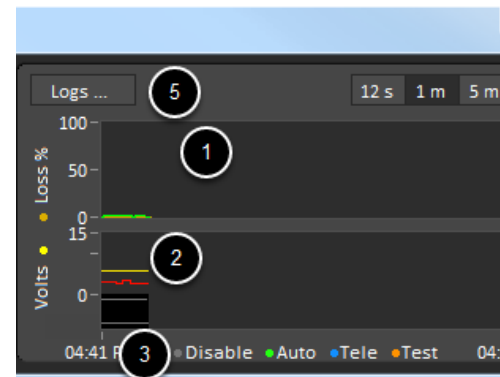
Tab Messages 20.1.10



the and/or Code, User WPILib, DS, the from messages diagnostic displays tab Messages The roboRIO.

that menu a display will This icon. Gear the click tab, Messages the for settings access To launch messages, viewing for window Console larger a launch box, the clear to you allow will robot. the from files log download or timing, program for viewer a launch Viewer, Log DS the

Tab Charts 20.1.11



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 20.1.12

side. by side Charts and Messages displays which tab Both the is side right the on tab last The

Practices Best Station Driver 20.2

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 20.2.1

dedicated A do. teams Many station. driver a as solely used be to laptop a Dedicate 1.
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

durable more much They're Why? station. driver your for laptop classbusiness- a Use 2.
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

dashboard and Station Driver FRC® The new. than rather laptops used Consider 3.
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

example, For .11 Windows with compatible is it ensure laptop used a buying Before :□□□□
compatible. are later and processors core generation 8th Intel only

features recommended Laptop 4.

greater or RAM of 8GB - RAM .□

1440x1050. of resolution minimum with greater, or 13" of size display A .□

Ports .□

The port. sizedfull- a it's that Ensure preferred. highly is port Ethernet inbuilt- A i.
use. repeated to up hold don't ports Ethernet hinged

extends This connection. Ethernet your make to saver port Ethernet an Use ii.
a have you if important particularly is This laptop. the on port the of life the
port. Ethernet hinged a with laptop gradeconsumer-

laptop the replace either dodgy, is laptop your on port Ethernet the If iii.
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.

spend disk, rotating a has laptop the If larger. or GB 256 (SSD), disk statesolid- A .
SSD. a with it replace and \$50

11. or 10 Windows of release current the to Updated .

6E FiWi- the with use for recommended is GHz) (6 6E FiWi- supports that laptop A .
later. and 2025 for radio

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 20.2.2

- .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

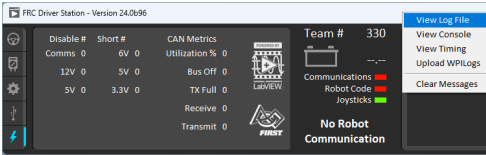
Match Each Before 20.2.3

- 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

to connects station driver your after robot the to connected is Dashboard your Ensure 6. robot. the

Viewer File Log Station Driver 20.3

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 in menu, Start the Station. Driver



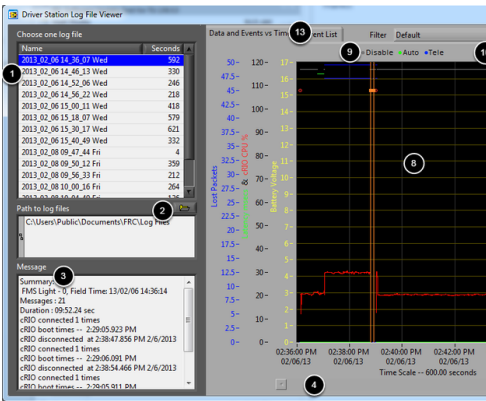
Driver FRC the to functionality similar provide that exist tools alternative Several : is Reader DSLOG and WPILib, in included option an is AdvantageScope Viewer. Log Station projects. partythird- for support no offers WPILib that Note option. partythird- a

Logs Event 20.3.1

(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 are files Log Station Driver and Log Event the Viewer, File Log Station Driver the with Files display. single a in overlaid

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

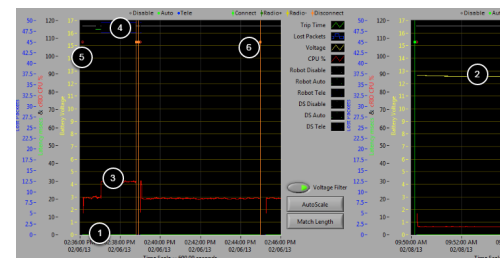
UI Viewer Log 20.3.2



Driver the of analysis the in aid to displays and controls of number a contains Viewer Log The files: log Station

- selected currently the in files log available all displays window This - Box Selection File 1.
it. select to list the in file log a on Click folder.
- log for in looking is viewer the folder current the displays box This - Files Log to Path 2.
folder the Click in. files log stores Station Driver the that folder the to defaults This files.
location. different a to browse to icon
- When Log. Event the from messages all of summary a displays box This - Box Message 3.
that for information the display to changes box this graph the on event an over hovering
event.
- scrolling horizontal for allows bar scroll this in, zoomed is graph the When - Bar Scroll 4.
graph. the of
- The on). to (defaults off and on Filter Voltage the turns control This - Filter Voltage 5.
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
log. the in data all show to out graph the zooms button This - AutoScale 6.
- FRC an of length the approximately to graph the scales button This - Length Match 7.
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
- roboRIO time, trip (voltage, file Log DS the from data graph shows display This - Graph 8.
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 20.3.3



- 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 20.3.4

DS Time	Event Message Text
2:36:07.288 PM	WARNING <Code> 44007 occurred at FRC_NetworkCommunications <second> 1 Warning <Code> 44001 occurred at No Change to Network Configuration: "1" FRC: Time since robot boot. Driver Station <time> 2/6/2013 2:36:07 PM<unique#> 3 ERROR <Code> 44009 occurred at Driver Station <time> 2/6/2013 2:36:06 PM<unique#> 2 FRC: A joystick was disconnected while the robot was enabled. Warning <Code> 44006 occurred at Driver Station <time> 2/6/2013 2:36:06 PM<unique#> 1 FRC: Custom I/O is not enabled or is not connected to the driver station.
2:36:07.328 PM	FMS Connected: FMS Light - 0, Field Time: 13/02/06 14:36:14
2:36:10.441 PM	WARNING <Code> 44008 occurred at FRC_NetworkCommunications <radio(4)-G FRC: Robot radio detection times.
2:37:01.461 PM	Watchdog Expiration: System 1, User 0
2:38:47.856 PM	Warning <Code> 44004 occurred at Driver Station <time> 2/6/2013 2:38:47 PM<unique#> 4 FRC: The Driver Station has lost communication with the robot.
2:38:49.356 PM	Warning <Code> 44002 occurred at Ping Results: link-GOOD, DS radio(4)-G <time> 2/6/2013 2:38:49 PM<unique#> 5 FRC: Driver Station ping status has changed.
2:38:53.460 PM	WARNING <Code> 44007 occurred at FRC_NetworkCommunications <second> 1 FRC: Time since robot boot.
2:38:54.466 PM	Warning <Code> 44004 occurred at Driver Station <time> 2/6/2013 2:38:53 PM<unique#> 6 FRC: The Driver Station has lost communication with the robot.
2:38:55.468 PM	Warning <Code> 44002 occurred at Ping Results: link-GOOD, DS radio(4)-G <time> 2/6/2013 2:38:55 PM<unique#> 7 FRC: Driver Station ping status has changed.
2:38:59.278 PM	WARNING <Code> 44008 occurred at FRC_NetworkCommunications <radio(4)-G FRC: Robot radio detection times. WARNING <Code> 44007 occurred at FRC_NetworkCommunications <second> 1

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 20.3.5

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

Matches from Logs Identifying 20.3.6

3:19:30.893 PM FMS Connected: Practice - 1, Field Tim

came logs which identify to is Logs Station Driver the with working when task common A identified be now can match a during taken were which Logs matches. competition from Qualification (Practice, type match the display will which event Connected *FMS* the using this In server. FMS the to according time current the and number, match Elimination), or computer Station Driver the of time the and time server FMS the that see can you example, apart. seconds 7 approximately close, fairly are

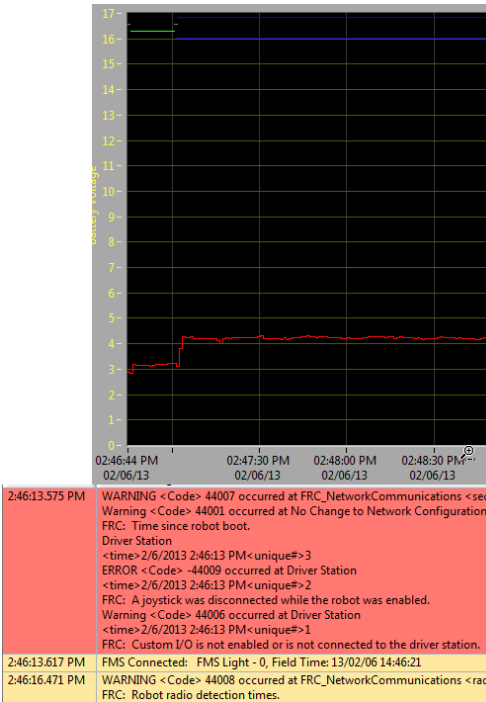
Viewer Log the with Failures Connection Common Identifying 20.3.7

system the of knowledge thorough for substitute no is there issues, robot diagnosing When connection a diagnosing assistance need you If approach. debugging methodical a and and/or *FTA* your from assistance seek to recommended strongly is it events your at problem can failures common some how with teams familiarize to is section this of goal The *.CSA* conditions of variety a on depending that note Please files. Log DS the in themselves manifest file. log a in differently slightly show failure particular a

using length match to scaled been have section this in shown files log all that Note :□□□□ Also, mode. autonomous the of beginning the to scrolling then and button Length Match the capture log for used platform the information, voltage battery contain not do logs the of many voltage. battery the reporting for wired properly not was

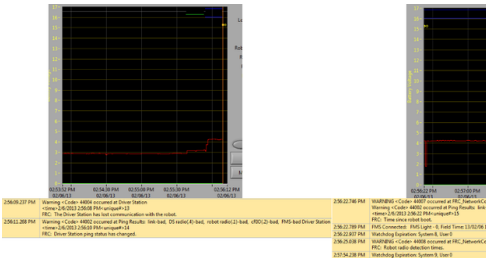
are more and below show are Viewer Log the in found are that messages error Some :□□□ article. *Errors/Warnings Station Driver* the in detailed

Log "Normal"



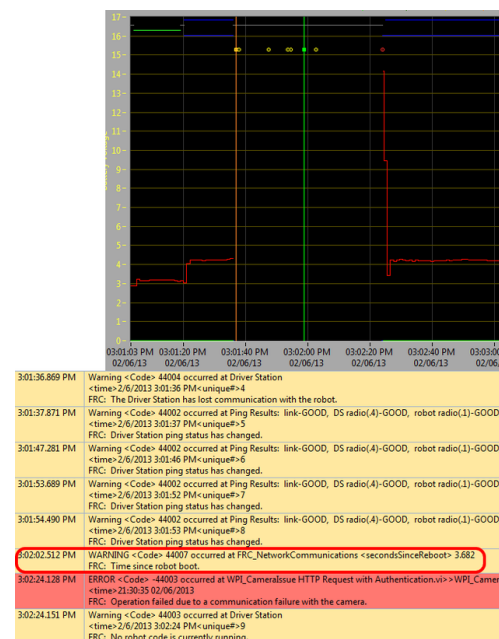
first the in contained warnings and errors The log. match normal a of example an is This observing by confirmed is This ignored. be can and started first DS the when from are box can shown event last The event. Connected:" "FMS the to prior occurred events these that after seconds 3 occurs (it DS the to connecting first robot the from also is it ignored, be also started. match the before seconds 30 roughly occurs and FMS) to connecting

FMS from Disconnected



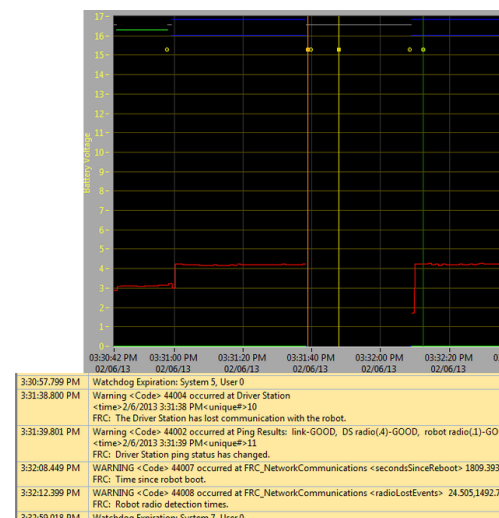
segment may it match the during robot, the therefore and FMS, from disconnects DS the When log, first the of event last the are failure this to indicators key The pieces. into log the log 2nd the from event second the and "bad" now is FMS to connection the that indicating into transitioning immediately 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



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

3:21:57 PM 02/06/13 3:22:20 PM 02/06/13 3:22:43 PM 02/06/13 3:23:00 PM 02/06/13 3:23:20 PM 02/06/13 3:23:40 PM 02/06/13

3:22:11.489 PM Watchdog Expirations: System 2, User 0

3:22:44.030 PM Warning <Code> 44004 occurred at Driver Station
 <time> 2/6/2013 3:22:43 PM<unique>=6
 FRC: The Driver Station has lost communication with the robot.

3:22:45.531 PM Warning <Code> 44002 occurred at Ping Results: link-GOOD, D5 radio(4)-GOOD, robot radio(1)-ba
 <time> 2/6/2013 3:22:45 PM<unique>=7
 FRC: Driver Station ping status has changed.

3:23:11.620 PM WARNING -<Code> 44007 occurred at FRC_NetworkCommunications <secondsSinceReboot> 1272.77
 FRC: Time since robot boot.

3:23:11.690 PM Watchdog Expirations: System 3, User 0

Errors/Warnings Station Driver 20.4

601

Unplugged Joystick 20.4.1

```
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 20.4.2

```
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 20.4.3

```
_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 20.4.4

```
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 20.4.5

```
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 20.4.6

```
Station Driver at occurred 44003>Code<Warning
8>#unique AM 13:50:9 2013/8/2>time<
running currently is code robot No FRC:
```

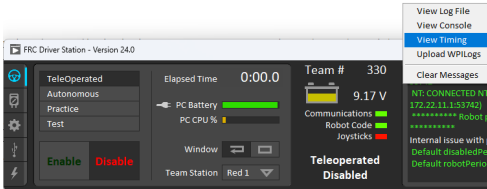
no detects but roboRIO, the with communicating begins DS the when printed is message This is Station Driver the if printed be will message this of instance single A running. code robot the with communication begin will DS the as booting is roboRIO the while running and open loading. finishes code robot the before roboRIO

Viewer Timing Station Driver 20.5

issues. control robot diagnose help to window new a a has Station Driver 2024 The

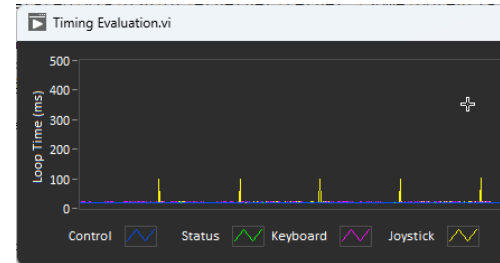
Viewer Timing the Opening 20.5.1

.Timing View select then and icon gear the select Viewer, Timing Station Driver the start To

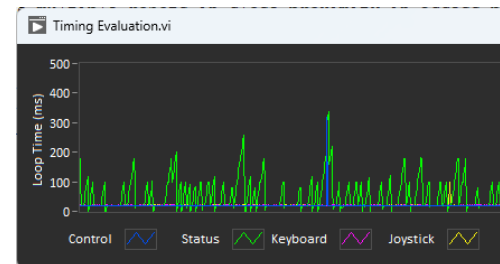


Timing Viewing 20.5.2

joystick, the measuring loops station driver the of timing the shows viewer Timing The be should values all good, is timing When packets. network status and control and keyboard, issues. control robot causing is what diagnose help can This ms. 0 to close



packets network causes congestion network when like looks it what shows image next The robot the that bad so was communication the example, this In combined. and delayed be to second. a then more for connected or enabled stay wouldn't



Offseason FMS for Radios Programming 20.6

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- 20.6.1

Programming in instructions the per software Utility Configuration Radio FRC® the Install *radio your*

:□□□□□□ □□□□□□ □□□□

utility configuration the prevent may it as computer, your on connections WiFi Disable 1. bridge the with communicating properly from

the to closest port ethernet bridge wireless the into computer your from directly Plug 2. 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. •

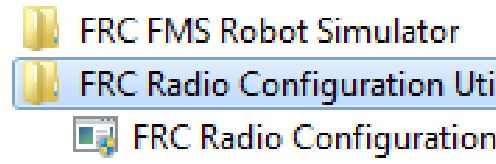
lights status radio the of behavior the on details for *Reference Light Status* the See :☐☐☐☐ configured. when

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 :☐☐☐☐

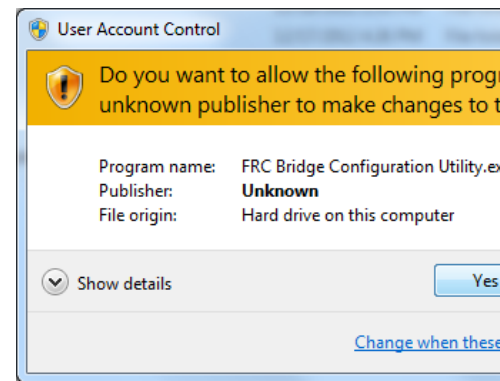
software the Launch 20.6.2



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

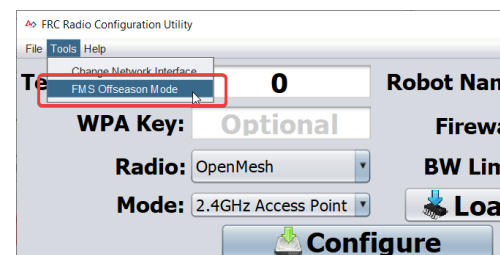
FRC\(\x86) Files Program\C: to installed is it program, the locate to need you If :
 FRC\Files Program\C: is path the machines bit32- For .Utility Configuration Radio
 Utility Configuration Radio

prompted if changes, make to program the Allow 20.6.3



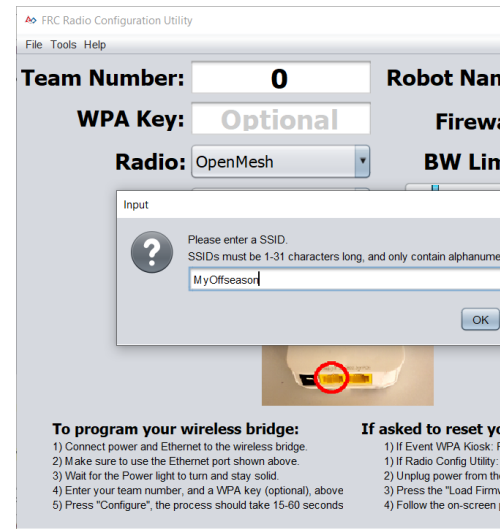
the to changes make to utility configuration the allowing about appear may prompt A
 appears. prompt the if Yes Click computer.

Mode Offseason FMS Enter 20.6.4



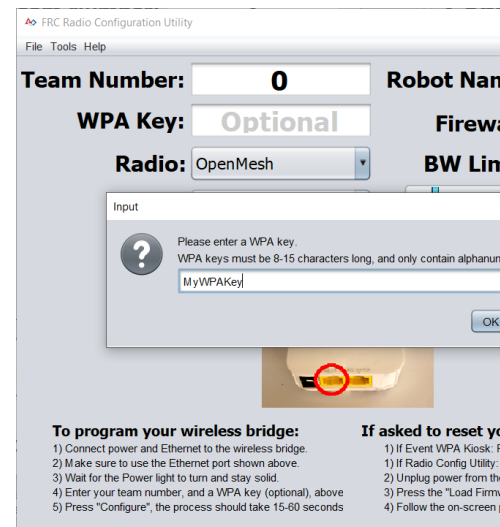
Mode. LiteFMS- enter to Mode Lite-FMS >- Tools Click

SSID Enter 20.6.5



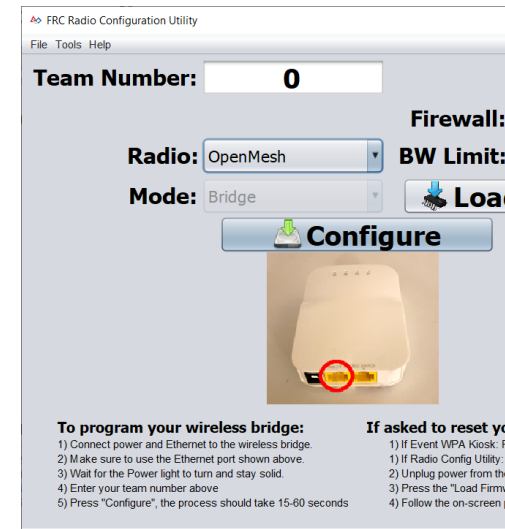
OK. click and box the in network wireless your of (name) SSID the Enter

Key WPA Enter 20.6.6



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 20.6.7



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 20.6.8

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 20.6.9

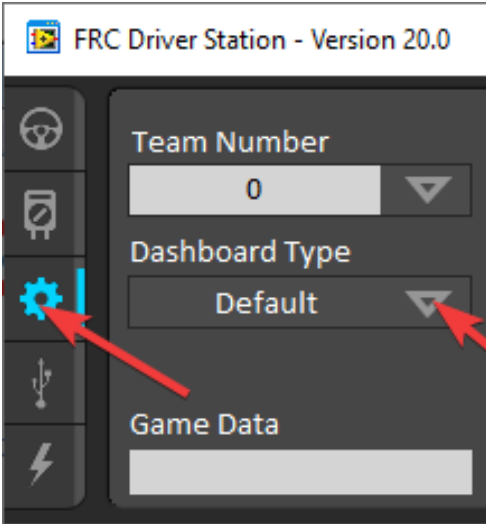
radio your Programming in steps troubleshooting the See

Custom Start to Station Driver the Setting Manually 20.7 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.

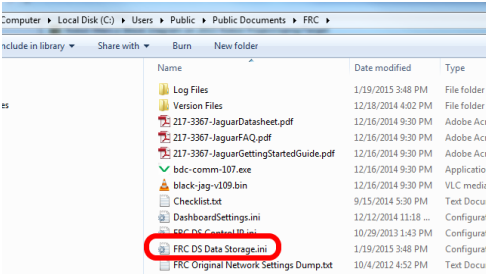
Dashboard appropriate the using try installations, most for needed not is This :□□□□□ first. language your for *setting Type*

Default to Station Driver Set 20.7.1



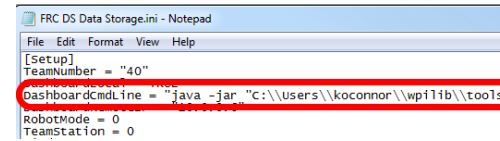
to setting Dashboard the set and tab Setup the on click software, Station Driver the Open
Station! Driver the close Then Default.

file Storage Data DS Open 20.7.2



to Storage Data DS FRC on click double and FRC\Documents\Public\Users\C: to Browse
it. open

DashboardCmdLine 20.7.3



to dashboard the to point to it Modify .DashboardCmdLine with beginning line the Locate starts station driver the when launch

Dashboard Custom LabVIEW

is specified path the where DASHBOARD.exe"\\T0\\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"\\T0\\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 20.7.4

opened. is it time each dashboard the launch now should Station Driver The

Introduction - RobotBuilder 21.1

Overview RobotBuilder 21.1.1

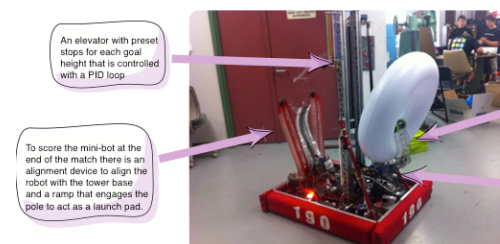
RobotBuilder process. development robot the aid to designed application an is RobotBuilder
you: help can

- 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

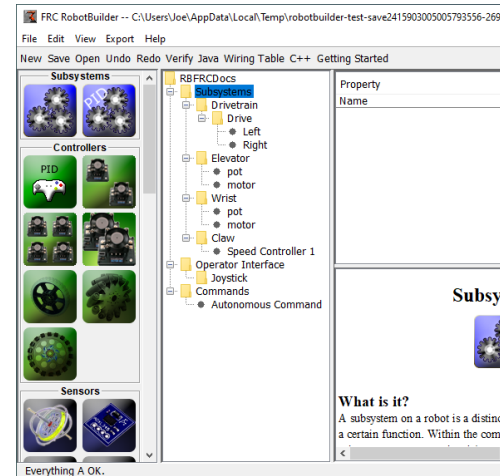
Subsystems into Robot the Divide



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

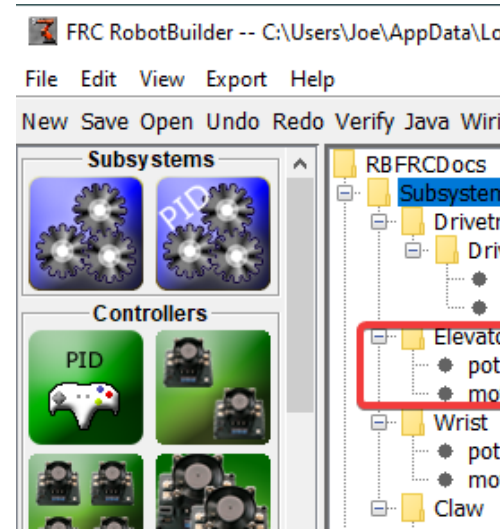
PID a with operation subsystems a control to desirable is it often - PIDSubsystems 1. example for element, subsystem the makes that program your in code is This controller. PIDSubsystems it. reaching when stop then position desired a to quickly more angle, arm it adding then convenient more often are 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

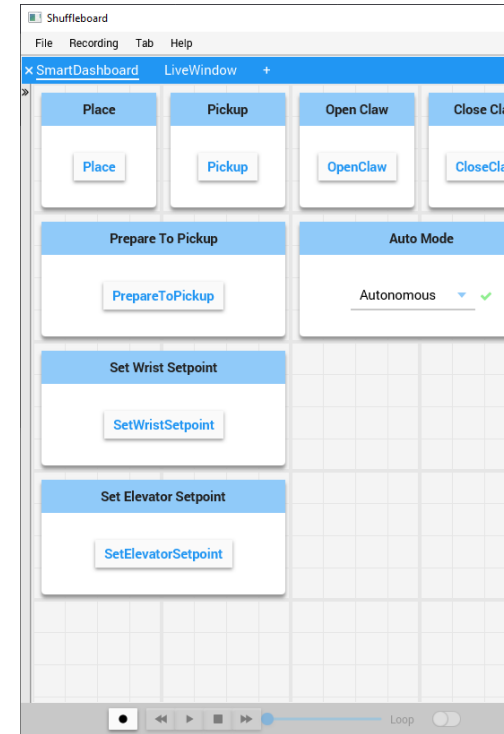
Goals Subsystem Describe That Commands Adding

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

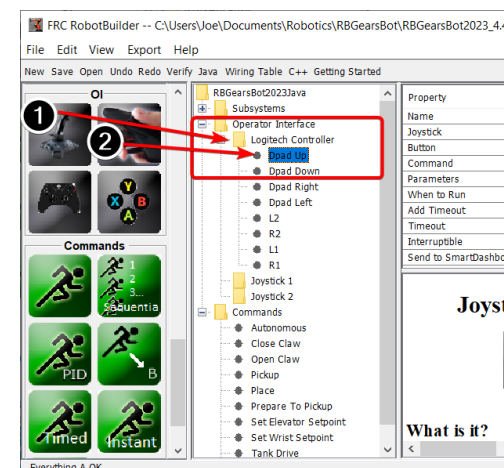
Command each Testing



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

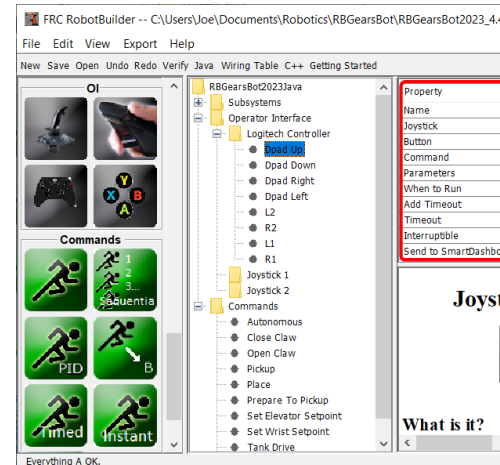
Components Interface Operator Adding



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

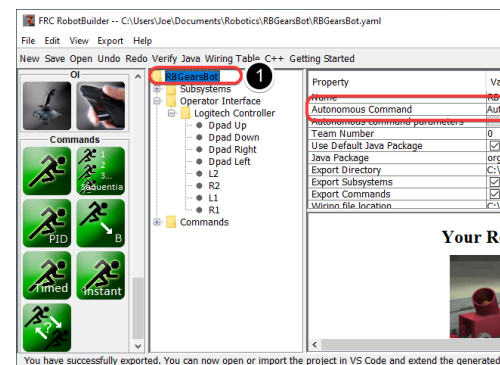


is command the pressed is button a when that so buttons with associated be can Commands robot your of part operatedtele- the of most handle part, most the for should, This scheduled. program.

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

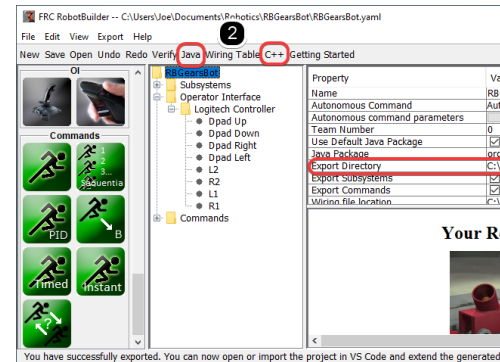
Commands Autonomous Developing



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



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

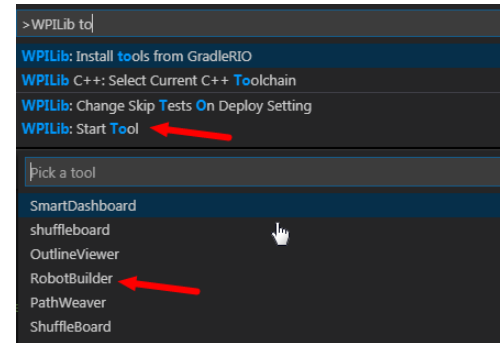
RobotBuilder Starting 21.1.2

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

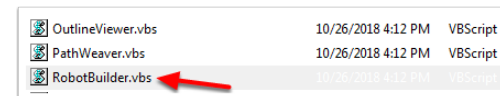


the launch to right top the in logo WPIlib the click or "WPIlib" type and Ctrl+Shift+P Press .Builder Robot select then ,Tool Start Select Palette. Command WPIlib

Shortcuts - 2 Option

the on folder Tools WPIlib 2024 the and Menu Start Windows the to installed are Shortcuts desktop.

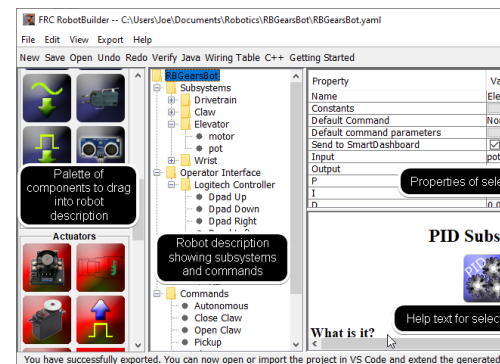
Script the from Running - 3 Option



~ and year the is YYYY (where ~/wpilib/YYYY/tools to tools the installs process install The Windows). on Public\Users\C: is

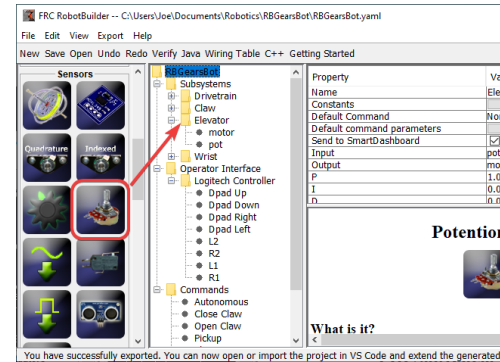
use can you that files (macOS/Linux) py. and (Windows) vbs. find will you folder this Inside what are and JDK correct the using tools the launch help scripts These tool. each launch to tools. the launch to use should you

Interface User RobotBuilder 21.1.3



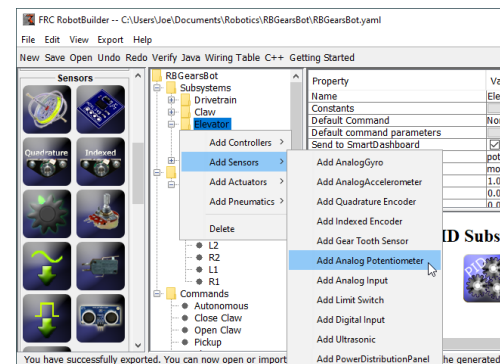
Almost programs. robot of development rapid for designed interface user a has RobotBuilder lists. dropdown- from options selecting or dropand-drag- by performed are operations all

Description Robot the to Palette the from Items Dragging



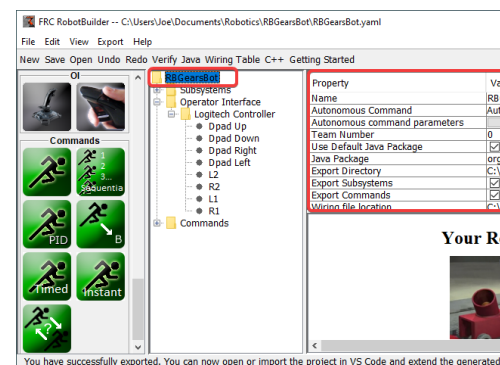
palette the on drag the starting by description robot the to palette the from items drag can You example, this In located. be to item the like would you where container the on ending and item subsystem. Elevator the to potentiometer a dropping

Menu Context ClickRight- the using Components Adding



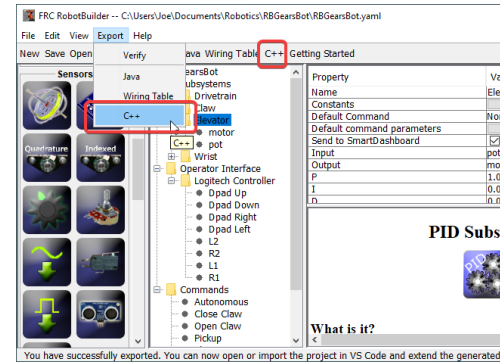
container the on clickright- to is description robot the to items adding of method shortcut A identical is This (Potentiometer). added be should that item the select and (Elevator) object people. some for easier be might but drop and drag using to

Items Description Robot of Properties Editing



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



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 21.1.4

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

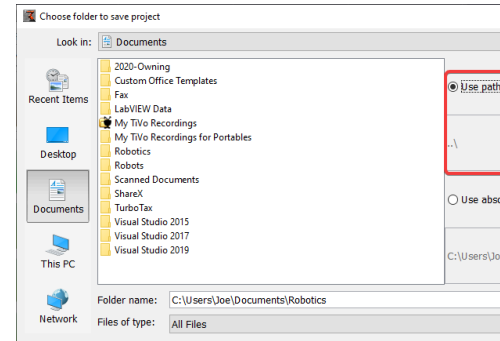
Properties Project Robot

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

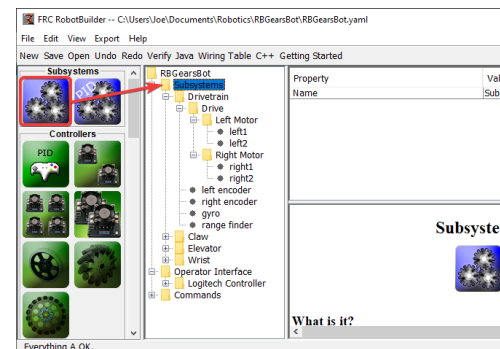


and computers of number a on used be typically will project the control source using When
If another. to computer users one from different be might directory project the to path the
user the contain typically will it path, absolute an using stored is file project RobotBuilder the
"relative select work, 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 21.1.5

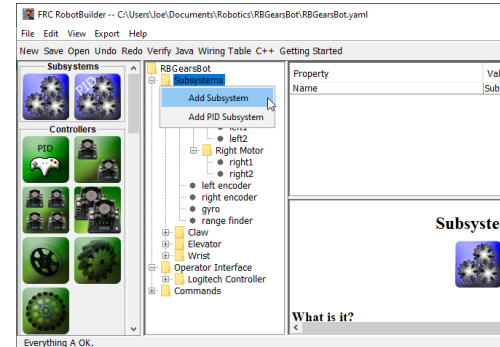
a make that code and data the all contain) (or encapsulate that classes are Subsystems
the with program robot a creating in step first The operate. robot your on subsystem
of Examples robot. the on subsystems the all create and identify to is RobotBuilder
subsystem Each etc. arms, elevators, base, drive 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



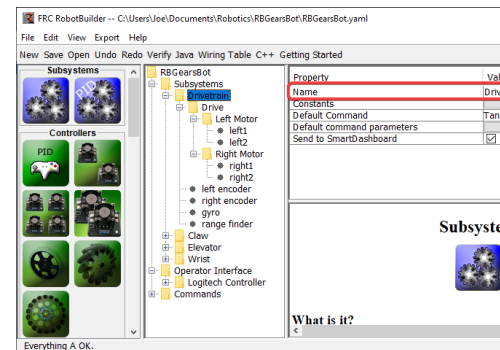
description robot the in folder Subsystems the to palette the from icon subsystem the Drag
class. subsystem a create to

Menu Context the using Subsystem a Creating



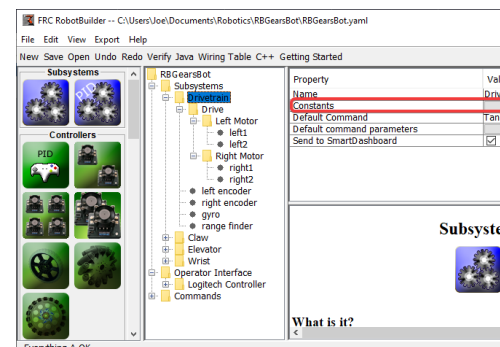
folder. that to subsystem a add to description robot the in folder Subsystem the on clickRight-

Subsystem the Name



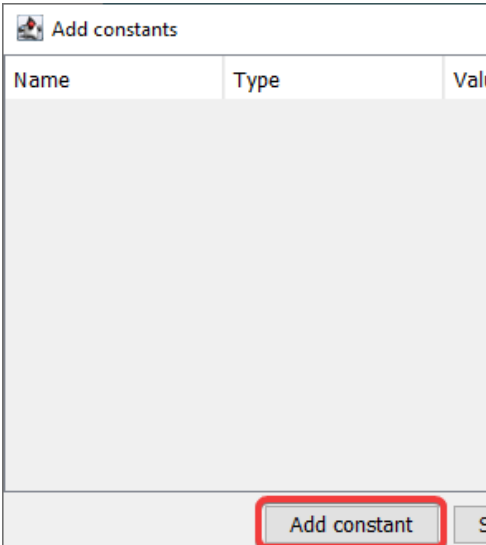
described as menu context the using or dragging either by subsystem the creating After
multiple be can name The subsystem. the give to like would you name the type simply above,
Java proper a make to words the concatenate will RobotBuilder spaces, by separated words
you. for name class C++ or

Constants Adding



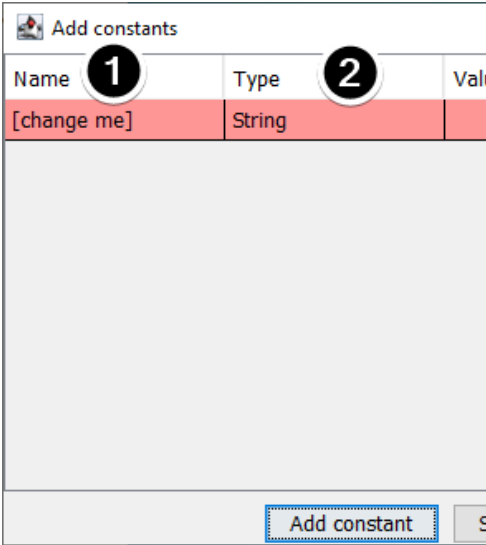
In code, your in numbers magic of amount the reduce to useful very are Constants specific for values sensor as such values, certain of track keep to used be can they subsystems, robot. the drive to which at speed the or elevator, an of heights "Constants" to next button the Press subsystem. a in constants 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

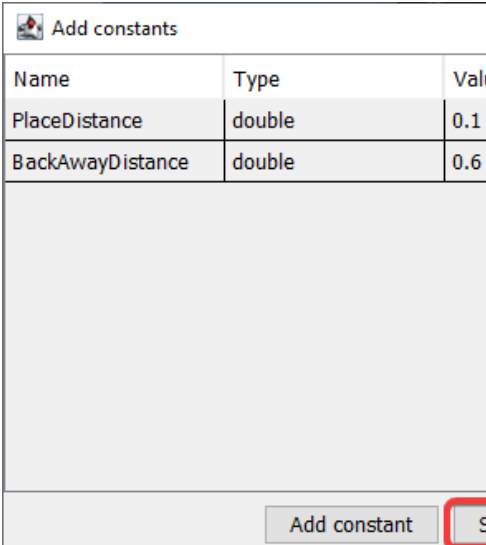
Constants Add



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

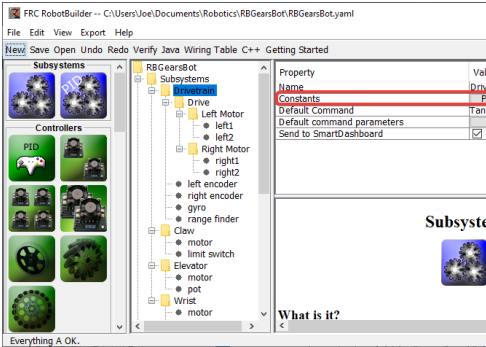
one from choose can you but double, a be likely most will This constant. the of type The 2.
byte. or boolean, long, int, double, String, of:
constant. the of value The 3.

Constants Saving



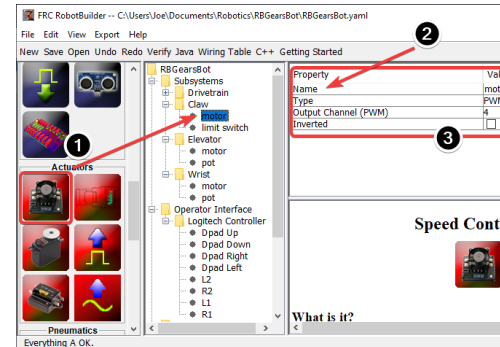
the save to close“ and “Save press just values, their setting and constants adding After
top the on button exit the press save, to want don’t you If dialog. the close and constants
window. the of

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.

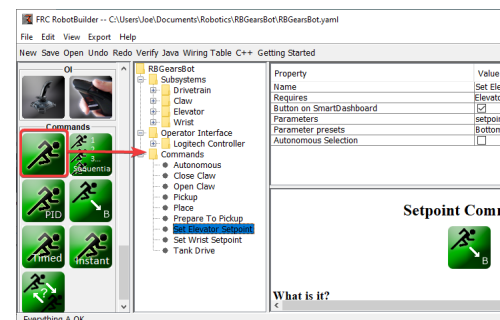
the on module each for numbers channel incrementing use automatically will RobotBuilder channel unique assign RobotBuilder let just can you robot the wired yet haven't you If robot. wiring generating the to according robot the wire and actuator or sensor each for numbers table.

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 21.1.6

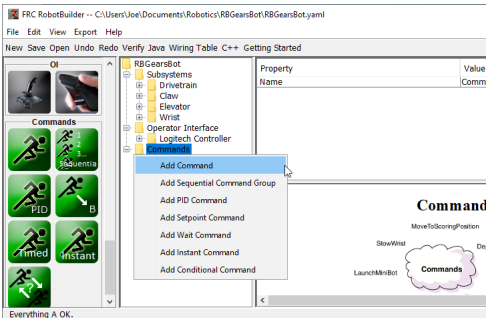
The subsystems. your for actions or behaviors provide that create you classes are Commands the start to MoveElevator like subsystem, the of operation the set should class subsystem commands The setpoint. PID elevator's the set to ElevatorToSetPoint or moving, elevator finished. is it when of track keep 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



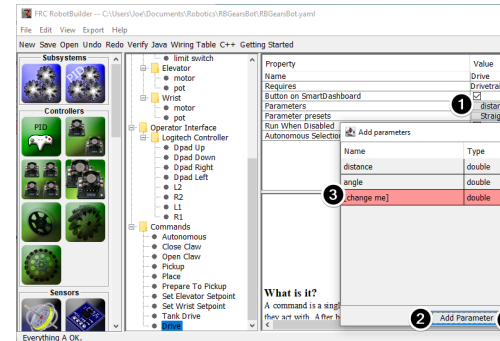
in folder Command the on menu context clickright- the using commands create also can You description. robot the

Command the Configuring

Property	Value
Name	Set Elevator Setpoint
Requires	Elevator
Button on SmartDashboard	<input checked="" type="checkbox"/>
Parameters	setpoint
Parameter presets	Bottom, Platform, Top
Autonomous Selection	<input type="checkbox"/>

- 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.

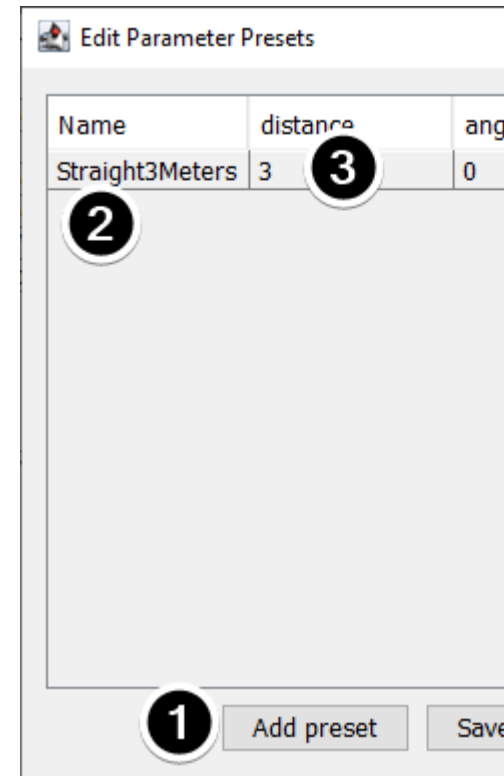
parameter a add to button *Parameter Add* the Press 2.

type the and *me*] [*change* to defaults name The added. been just has that parameter A 3.
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*

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

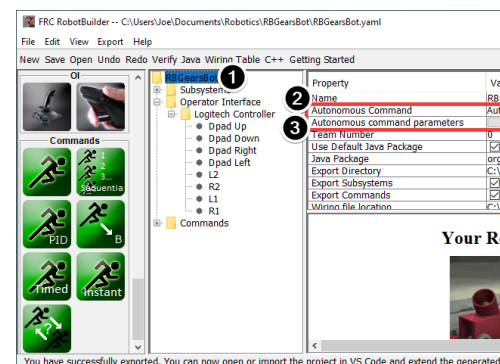
Presets Parameter Editing and Adding



preset. new a add to *set parameter Add* Click 1.
 example this in presets The descriptive. something to preset the of name the Change 2.
 subsystem. gripper the closing and opening for are
 (e.g. in value a type either can You preset. the for parameter(s) the of value the Change 3.
 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
 press saving, without exit to dialog; the exit and changes save to *close and Save* Click 4.
 window. the of bar top the in button exit the

Commands Autonomous the Setting 21.1.7

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



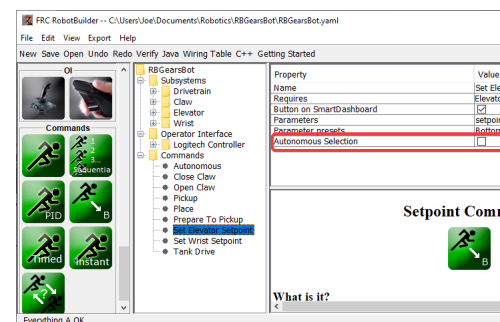
selected not is command another if runs that command autonomous default the designate To dashboard: the on

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 dropdown- a is This mode. autonomous in placed is defined. been has that command any select

any. if takes, command the parameters the Set •



Autonomous the select Chooser, Sendable the to options as add to commands select To box. check Selection

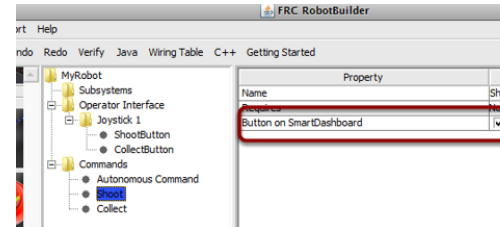
be will command Autonomous chosen the mode, autonomous into put is robot the When scheduled.

Command a Test to Shuffleboard Using 21.1.8

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

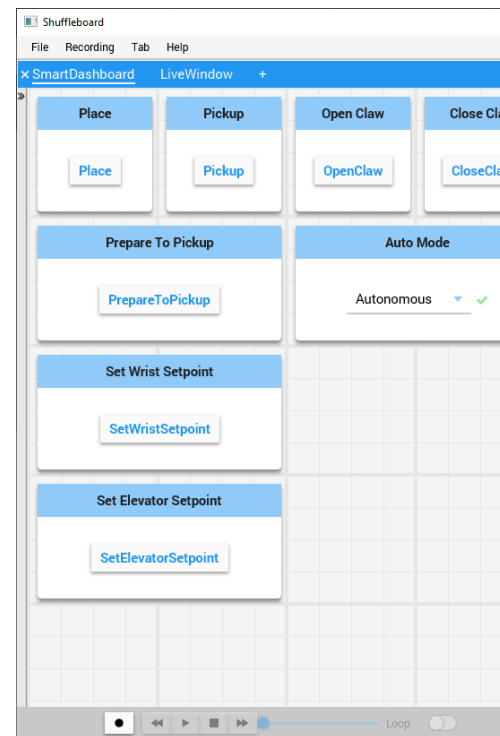
commands. writing each programmers, multiple accommodating of benefit added the has This tested. individually be can commands the project, robot main the into checked is code the As

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"(putData SmartDashboard.  
    OpenClaw(m_claw); new , "Claw Open"(putData SmartDashboard.  
    CloseClaw(m_claw)); new , "Claw Close"(putData SmartDashboard.
```

C++

```
AutonomousCommand()); new , "Command Autonomous" PutData( : SmartDashboard  
    m_claw));&OpenClaw( new , "Claw Open" PutData( : SmartDashboard  
    m_claw));&CloseClaw( new , "Claw Close" PutData( : SmartDashboard
```

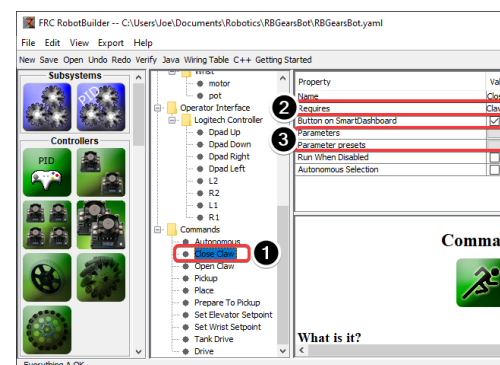
is This yourself. code the writing by manually Shuffleboard the to added be can Commands that name the with along method PutData the to command the of instances passing by done scheduled are instances These Shuffleboard. the on button the with associated be should generated RobotBuilder as same the exactly 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 21.1.9

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

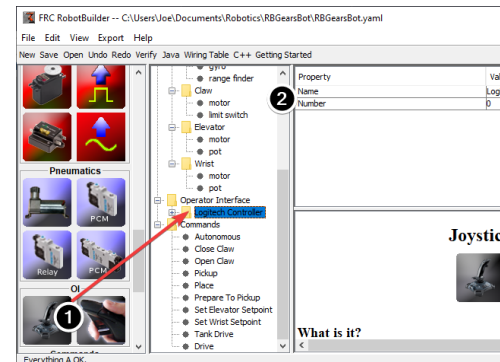
Press Button a with Command a Run



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 1. robot

this that ensure will This subsystem. Claw the requires command the that Notice 2.
 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
 you let presets things; multiple do to command one for possible it make Parameters 3.
 them reuse and command the to pass you values define

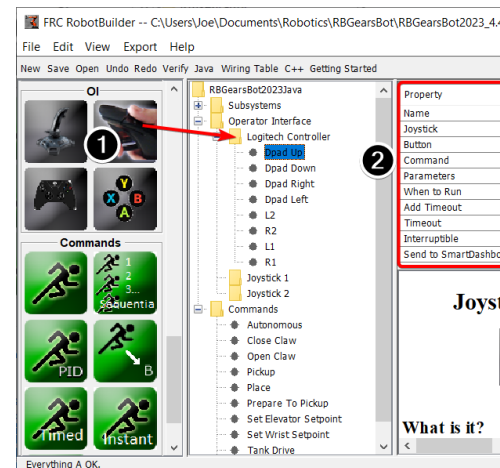
Program Robot the to Joystick the Adding



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

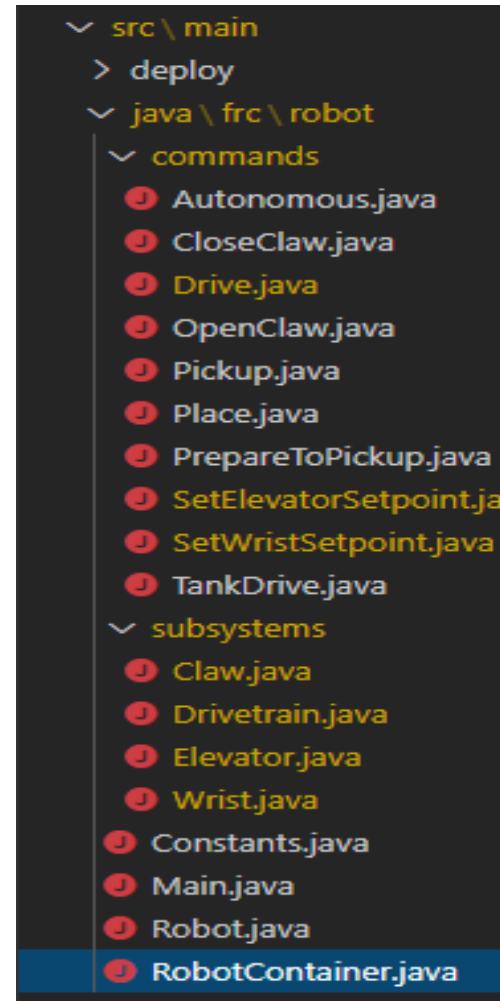
the under it's that so Controller) (Logitech Joystick the to button joystick the Drag 1.
 joystick

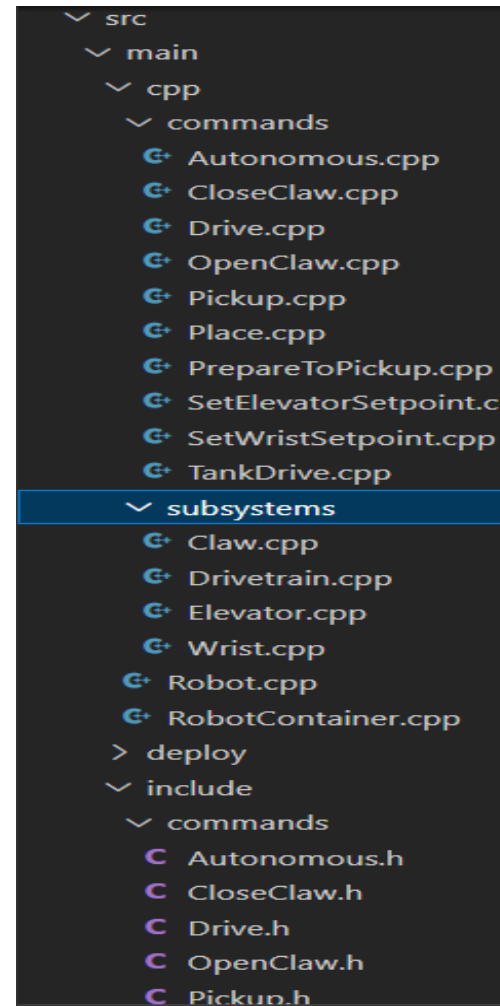
the when run to command the number, button the button: the for properties the Set 2.
 to property *run to When* the and takes, command the parameters pressed, is button
 pressed. is button joystick the whenever run should command the that indicate to *onTrue*

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 21.1.10

Project Generated RobotBuilder a of Layout The





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(
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

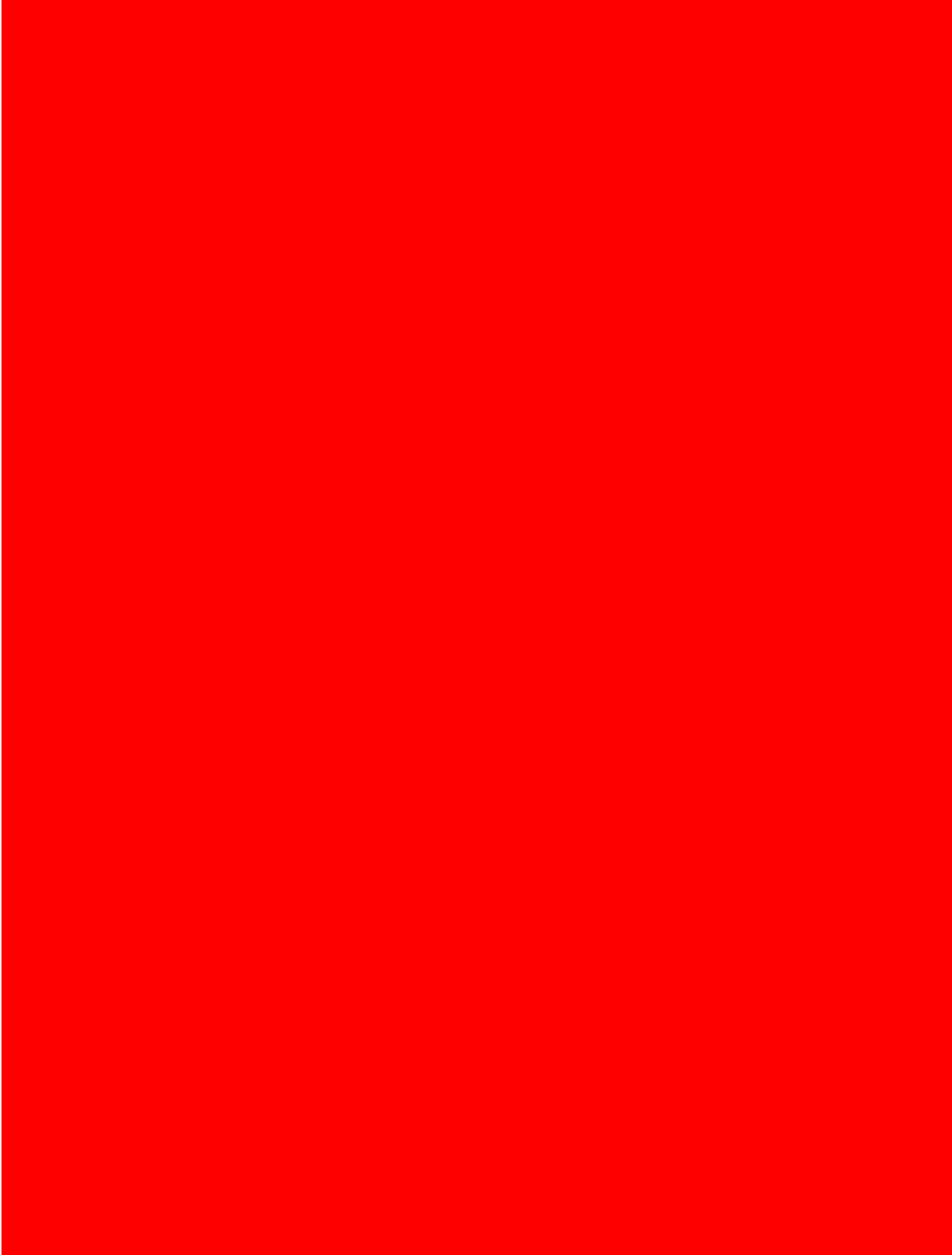
Program Robot Main

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 *
```

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page) next on (continues

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```

    */
    @link{ your by selected command autonomous the runs autonomous This *
    class. RobotContainer} ↪
    */
    @Override
    { ()autonomousInit void public
    
    */
    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 // 11
                                once pragma# 12
13
frc/TimedRobot.h>< include# 14
frc2/command/Command.h>< include# 15
16
RobotContainer.h" include# 17
18

:public 20
;override RobotInit() void 21
;override ()RobotPeriodic void 22
;override ()DisabledInit void 23
;override ()DisabledPeriodic void 24
;override ()AutonomousInit void 25
;override ()AutonomousPeriodic void 26
;override ()TeleopInit void 27
;override ()TeleopPeriodic void 28
;override ()TestPeriodic void 29
30
:private 31
it teleop testing if that so default by null it Have // 32
crash. potentially and behavior undefined have t'doesn // 33
;nullptr = m_autonomousCommand *Command: frc2 34
35
GetInstance();: RobotContainer = m_container *RobotContainer 36
; 37

```

(Source) C++

```

Robot. TYPE: ROBOTBUILDER // 11
12
Robot.h" include# 13
14
frc/smartdashboard/SmartDashboard.h>< include# 15
frc2/command/CommandScheduler.h>< include# 16
17
}{ ()Robot::RobotInit void 18
19
*/ 20
Use mode. the matter no packet, robot every called is function This * 21
disabled, during run to want you that diagnostics like items for this * 22
test. and teleoperated autonomous, * 23
* 24
before but functions, periodic specific mode the after runs This p>< * 25
updating. integrated SmartDashboard and LiveWindow * 26
*/ 27
28
*/ 30
You mode. Disabled enters robot the time each once called is function This * 31
the when clear to want you information subsystem any reset to it use can * 32
disabled. is robot * 33

```

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```

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75
76
*/
}{} ( )Robot::DisabledInit void
}{} ( )Robot::DisabledPeriodic void
*/
@link{ your by selected command autonomous the runs autonomous This *
class. RobotContainer} *
*/
{ ( )Robot::AutonomousInit void
}
}{} ( )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

and autonomousPeriodic() your call will TimedRobot TimedRobot. extends class This 1.
20ms. every methods teleopPeriodic()

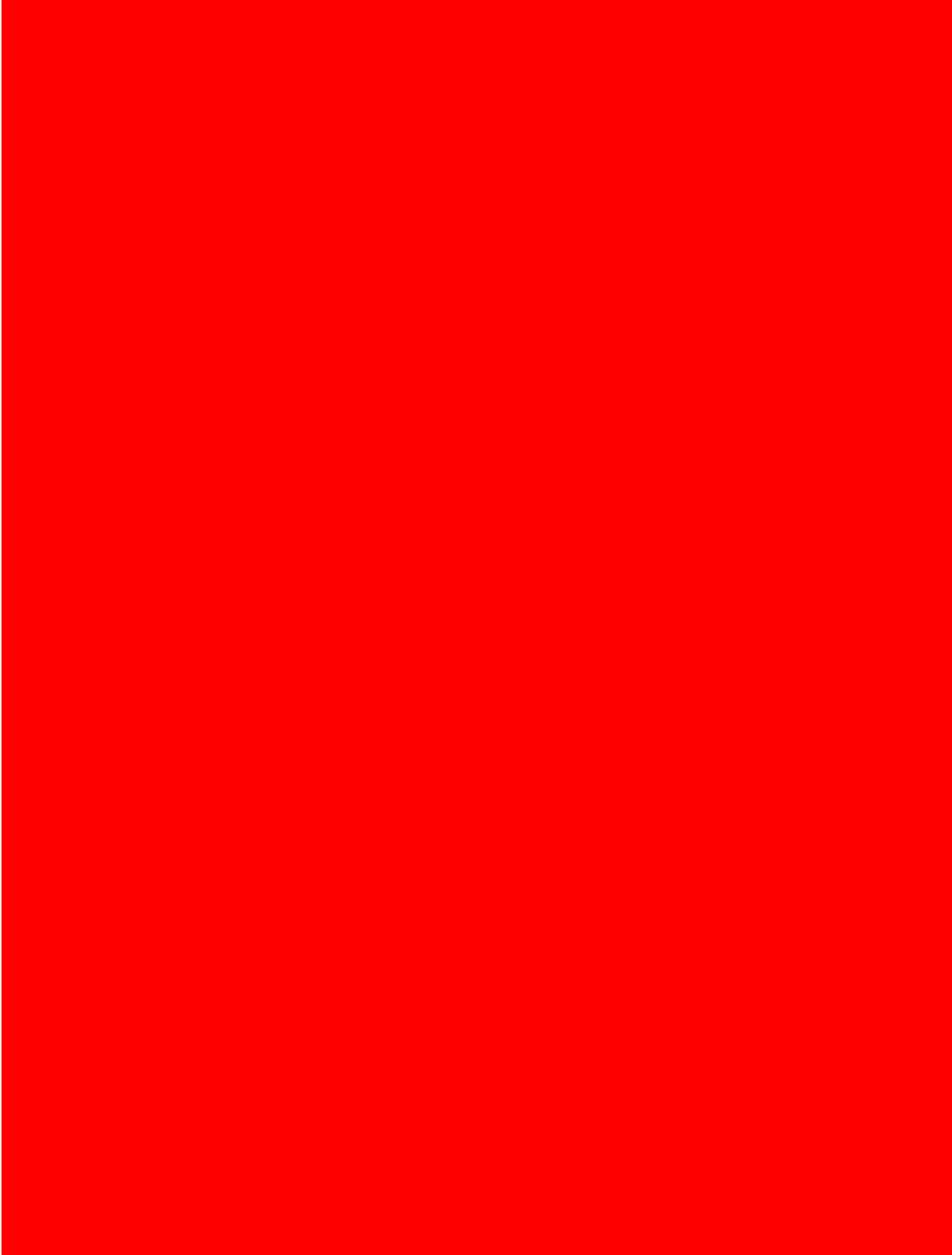
pass. scheduling one make 20ms, every called is which method robotPeriodic the In 2.
the in autonomous of start the at scheduled is provided command autonomous The 3.
in period autonomous the of end the at canceled and method autonomousInit()
.teleopInit()

RobotContainer

Java

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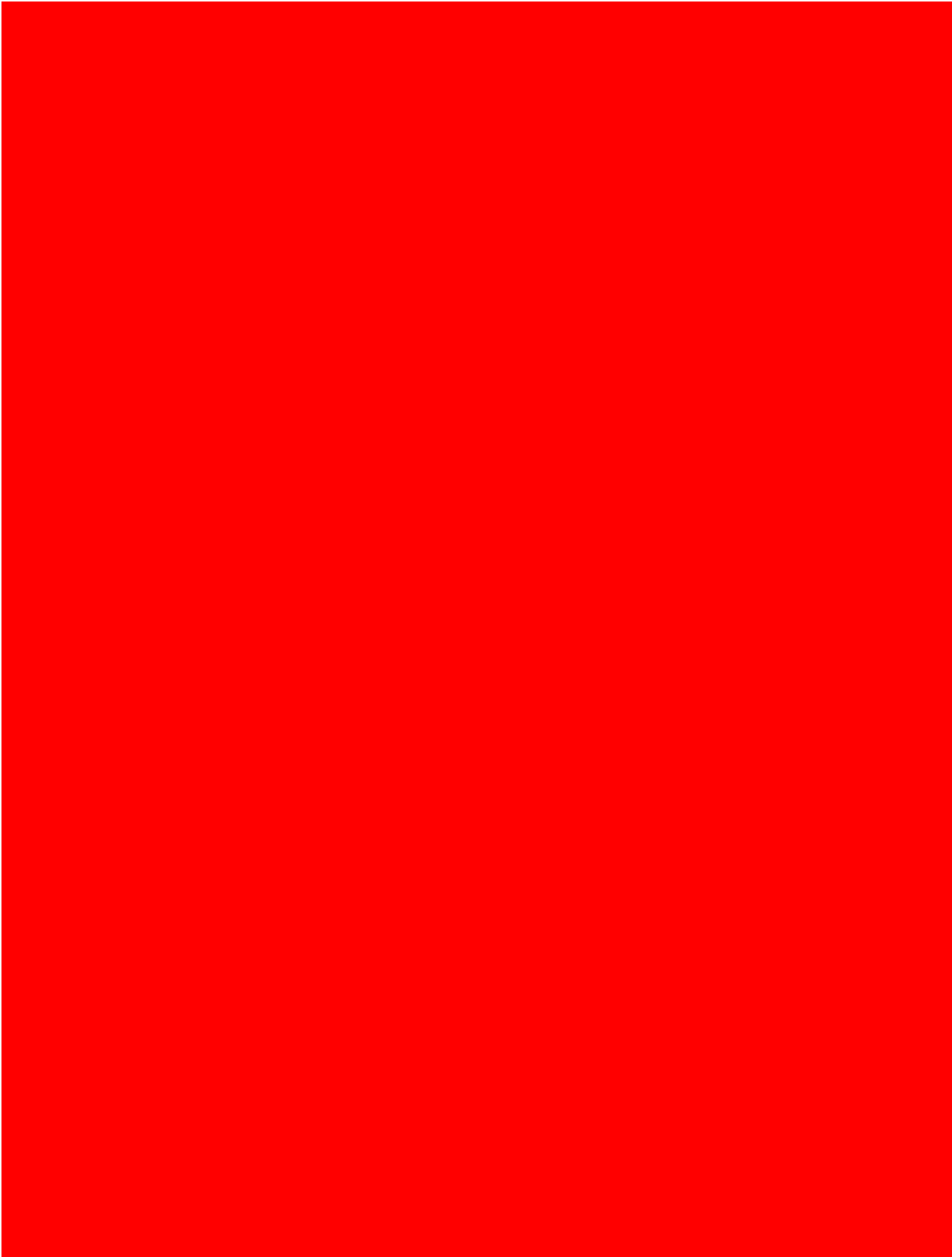
() () ()



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```

    }
    158
    { ()getJoystick2 Joystick public
    joystick2; return
    159
    }
    160
    161
    162
    163
    164
    ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
    165
    166
    167
    class. Robot} @link{ main the to command autonomous the pass to this Use *
    168
    *
    169
    autonomous in run to command the @return *
    170
    */
    171
    { ()getAutonomousCommand Command public
    172
    autonomous in run be will command selected The //
    173
    ();getSelectedm_chooser. return
    174
    }
    175
    176
    177
    }
    178

```

(Header) C++

```

    RobotContainer. TYPE: ROBOTBUILDER //
    11
    once pragma#
    12
    13
    ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
    14
    frc/smartdashboard/SendableChooser.h"> include#
    15
    frc2/command/Command.h"> include#
    16
    17
    18
    subsystems/Claw.h"" include#
    19
    subsystems/Drivetrain.h"" include#
    20
    subsystems/Elevator.h"" include#
    21
    subsystems/Wrist.h"" include#
    22
    23
    commands/Autonomous.h"" include#
    24
    commands/CloseClaw.h"" include#
    25
    commands/Drive.h"" include#
    26
    commands/OpenClaw.h"" include#
    27
    commands/Pickup.h"" include#
    28
    commands/Place.h"" include#
    29
    commands/PrepareToPickup.h"" include#
    30
    commands/SetElevatorSetpoint.h"" include#
    31
    commands/SetWristSetpoint.h"" include#
    32
    commands/TankDrive.h"" include#
    33
    frc/Joystick.h"> include#
    34
    frc2/command/button/JoystickButton.h"> include#
    35
    36
    ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
    37
    38
    { RobotContainer class
    39
    40

```

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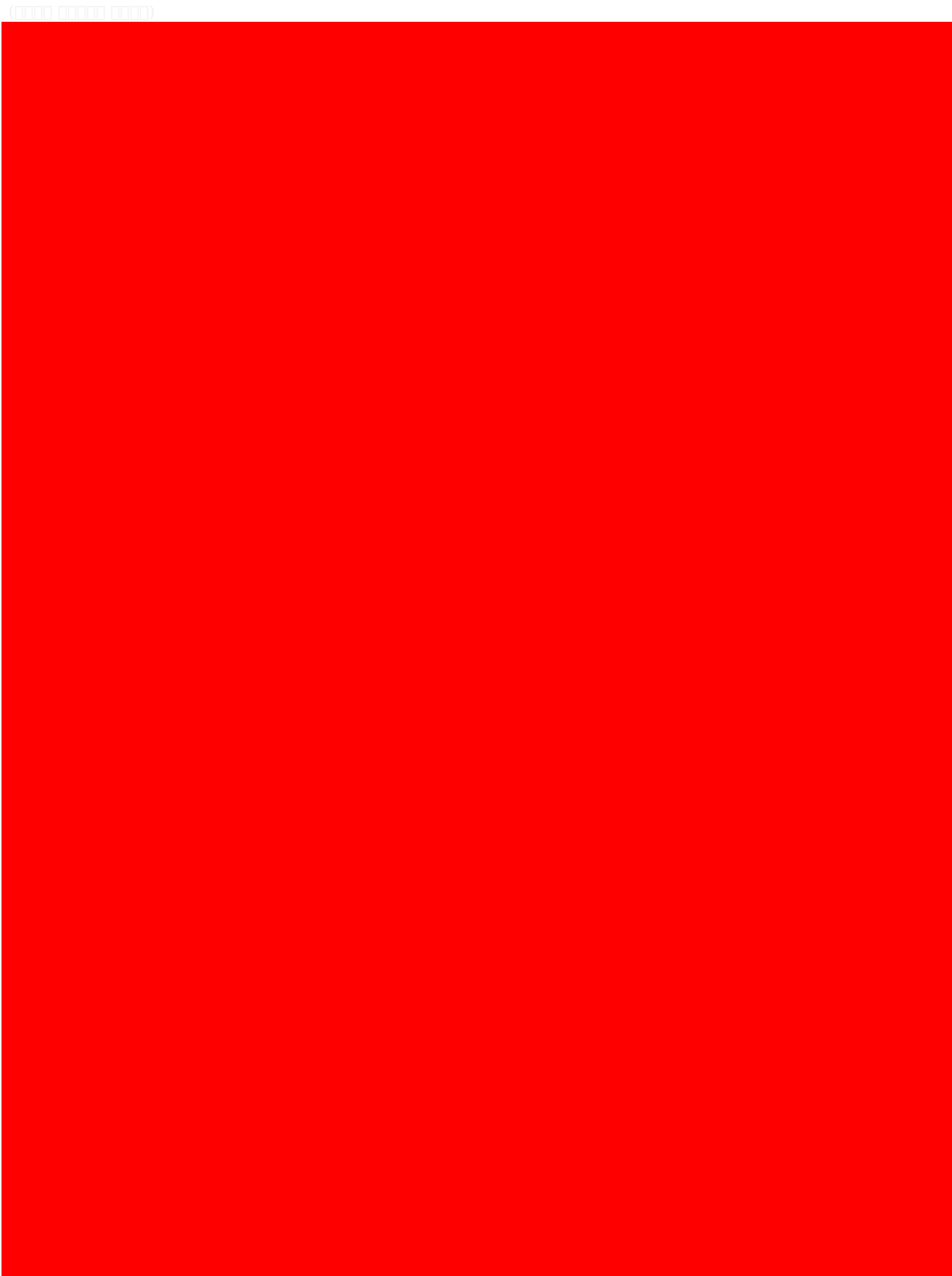
:public 41
42
GetAutonomousCommand(); *Command::frc2 43
();GetInstance *RobotContainer static 44
45
ID=PROTOTYPES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 46
subsystems s'robot The // 47
48
m_claw; Claw 49
m_elevator; Elevator 50
m_wrist; Wrist 51
52
53
();getJoystick2 *Joystick::frc 54
();getJoystick1 *Joystick::frc 55
();getLogitechController *Joystick::frc 56
57
ID=PROTOTYPES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 58
59
:private 60
61
RobotContainer(); 62
63
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 64
Joysticks // 65
66
;}m_joystick1{ Joystick::frc 67
;}m_joystick2{ Joystick::frc 68
69
m_chooser; >*Command::frc2<SendableChooser::frc 70
71
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 72
73
m_autonomousCommand; Autonomous 74
m_robotContainer; *RobotContainer static 75
76
();ConfigureButtonBindings void 77
;} 78
```

(Source) C++

```

RobotContainer. TYPE: ROBOTBUILDER // 11
12
RobotContainer.h" include# 13
frc2/command/ParallelRaceGroup.h>< include# 14
frc/smartdashboard/SmartDashboard.h>< include# 15
16
17
18
;NULL = m_robotContainer::RobotContainer *RobotContainer 19
20
m_autonomousCommand( : RobotContainer():RobotContainer 21
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 22
){ 23
```

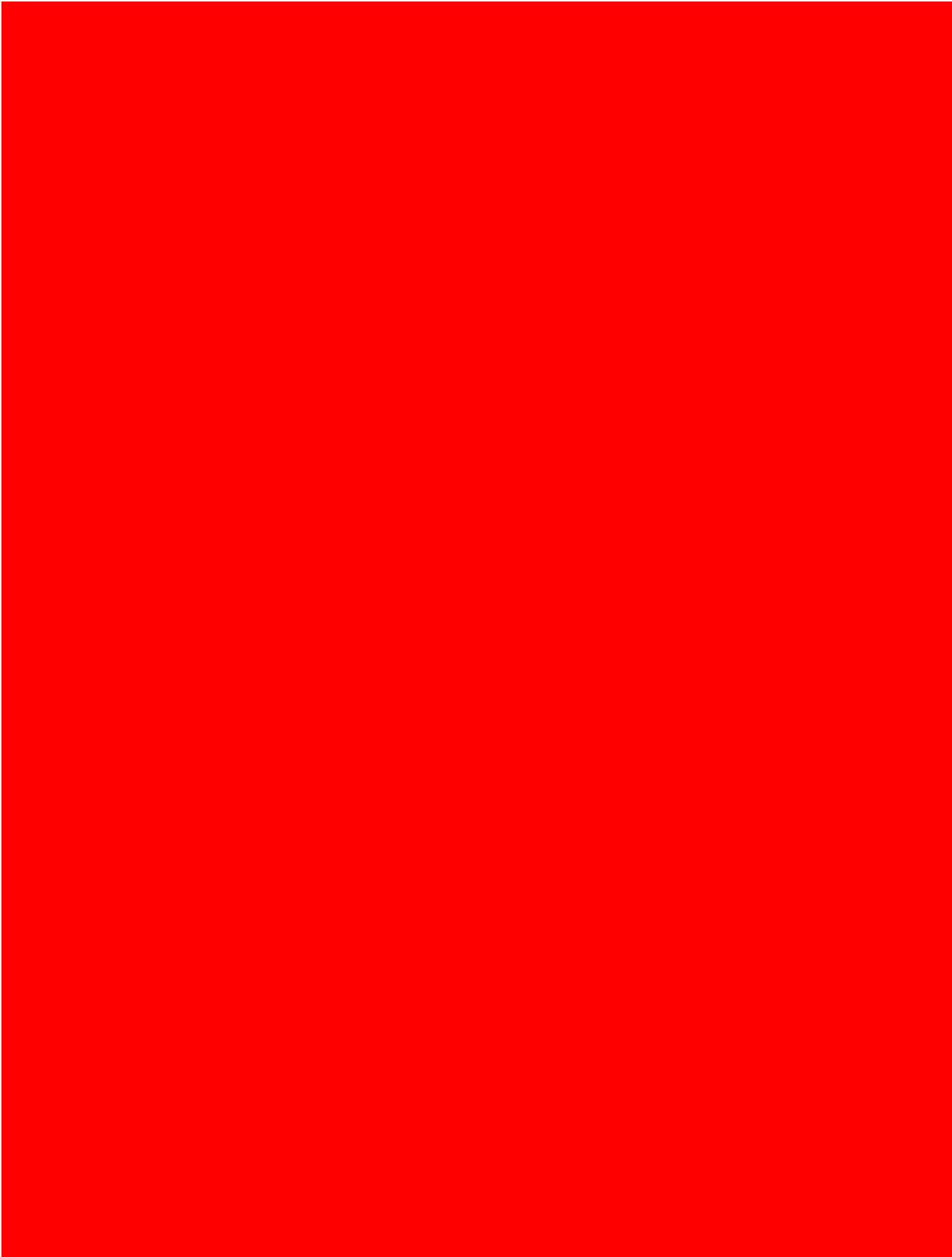
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```

m_joystick1;& return 119
} 120
{ getJoystick2():RobotContainer *Joystick::frc 121
m_joystick2;& return 122
} 123
124
ID=FUNCTIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 125
126
127
{ GetAutonomousCommand():RobotContainer *Command::frc2 128
autonomous in run be will command selected The // 129
m_chooser.GetSelected(); return 130
} 131

```

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):

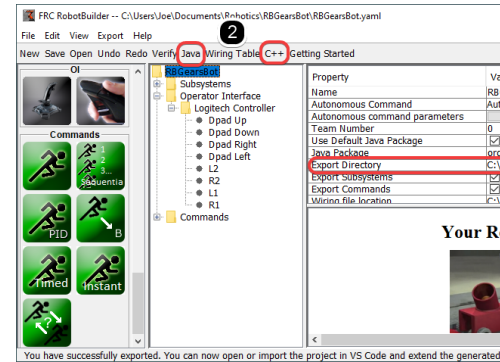
any to parameters as passed be can They here. declared is subsystems the of Each 1.
 them. require that commands
 is it properties, robot RobotBuilder in provided command autonomous an is there If 2.
 dashboard. the on selected be to Chooser Sendable the to added
 here. generated is components interface operator the all for code The 3.
 generated also is run should that commands to buttons OI the link to code the addition In 4.
 here.
 defined are running are commands other no when subsystem a on run be to Commands 5.
 here.
 here. defined are dashboard a via run be to Commands 6.

Code the Writing - RobotBuilder 21.2

Project a for Code Generating 21.2.1

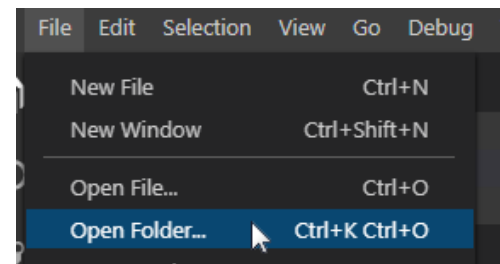
and code the export to need you'll RobotBuilder, in framework robot your up set you've After so. doing for process the describes article This Code. Studio Visual into it load

Project the for Code the Generate



(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

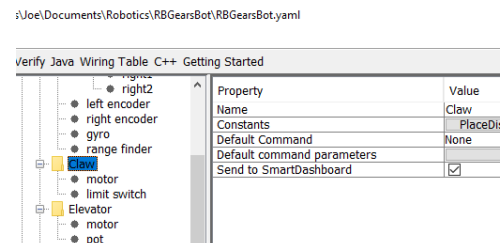


click and location Export your to Navigate **.Folder Open >- File** select and Code VS Open **.Folder Select**

Subsystem a for Code the Writing 21.2.2

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
object. an gripping is claw

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 //
*/
*
*/
{ SubsystemBase extends Claw 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 //
motor; PWMVictorSPX private
limitswitch; DigitalInput private
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
*/
*
*/
{ ()Claw public
ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
);PWMVictorSPX( new = motor
motor);,"motor"addChild(
);false(setInvertedmotor.
);4DigitalInput( new = limitswitch
limitswitch); ,"switch limit"addChild(
ID=CONSTRUCTORS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

```

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```

    }
    @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 //
    }
}
```

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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 //
```

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```

}
31
32
33 { Periodic()::Claw void
34     loop every run be to here code Put //
35
36 }
37
38 { SimulationPeriodic()::Claw void
39     simulation in when run scheduler per once called be will method This //
40
41 }
42
43 ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
44
45 ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
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```

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 :0000
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 // 11
    once pragma# 12
13
ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 14
    frc2/command/SubsystemBase.h>< include# 15
    frc/DigitalInput.h>< include# 16
    frc/motorcontrol/PWMVictorSPX.h>< include# 17
18
ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 19
20
    /** 21
    * 22
    * 23
    ExampleAuthor @author * 24
    */ 25
    { SubsystemBase::frc2 public :Claw class 26
        :private 27
        except private is possible everything that desirable s'It // 28
        capabilities subsystem implement that methods for // 29
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 30
        ;}4m_limitswitch{ DigitalInput::frc 31
        ;}m_motor{ PWMVictorSPX::frc 32
33
ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 34
        :public 35
        Claw(); 36
37
        ;override ()Periodic void 38
        ;override ()SimulationPeriodic void 39
40
41
42
43
ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 44
45
ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 46
ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 47
    ;0.1 = PlaceDistance double const constexpr static 48
    ;0.6 = BackAwayDistance double const constexpr static 49
50
ID=CONSTANTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 51
52
53
    ;} 54

```

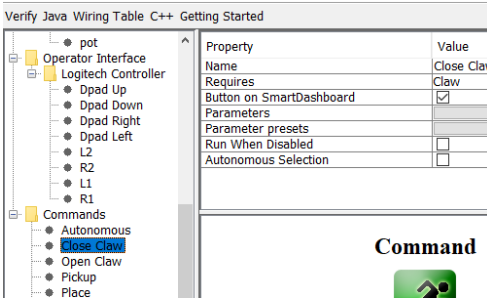
declarations the ,Claw.cpp file, implementation class the to methods the adding to addition In be must that declarations Those .Claw.h file, header the to added be to need methods the for here. shown are added

define to need you closing and opening handle to subsystem claw the to behavior the add To .commands

Command a for Code the Writing 21.2.3

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 //
```

page) next on (continues

(RobotBuilder Code)

```

        { 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

        }

        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 //
        }
    }

```

```

Command. TYPE: ROBOTBUILDER // 11
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 12
commands/CloseClaw.h" include# 13
m_claw) *CloseClaw(Claw::CloseClaw 14
m_claw(m_claw){: 15
dependencies subsystem declare to here AddRequirements() Use // 16
AddRequirements(m_Subsystem); eg. // 17
);"CloseClaw"SetName( 18
AddRequirements({m_claw}); 19
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 20
} 21
time first the runs Command this before just Called // 22
{ Initialize():CloseClaw void 23
} 24
run to scheduled is Command this when repeatedly Called // 25
{ Execute():CloseClaw void 26
} 27
execute() run to needs longer no Command this when true return this Make // 28
{ IsFinished():CloseClaw bool 29
} 30
true returns isFinished after once Called // 31
{ interrupted) boolEnd():CloseClaw void 32
} 33
{ const RunsWhenDisabled():CloseClaw bool 34
ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 35
;false return 36
ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 37
} 38
} 39
} 40
} 41
} 42
} 43
} 44
} 45
} 46
} 47
} 48
} 49
} 50
} 51
} 52
} 53
} 54

```

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

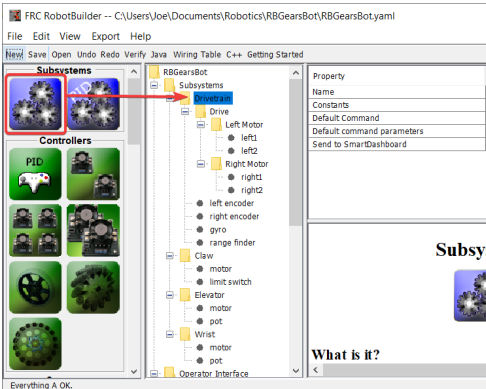
that method *Close()* the calling by direction closing the in moving motor claw the Start 1. method. Initialize *CloseClaw* the in subsystem *Claw* the to added was tripped. is subsystem *Claw* the in switch limit the when finished is command This 2.

In up. clean to place a is and finished is command the when called is method End() The 3.
out. run has time the since stopped is motor the case, this

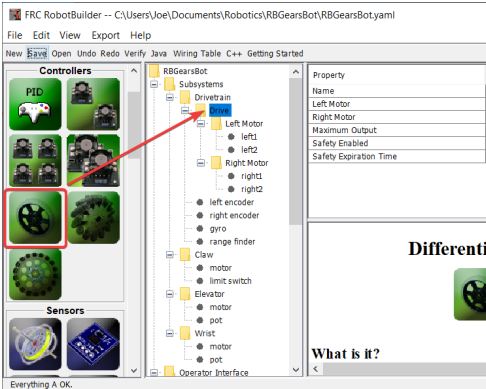
Joysticks and Drive Tank with Robot the Driving 21.2.4

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.

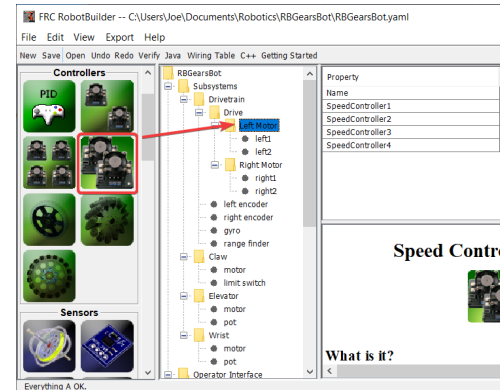
Subsystem Train Drive a Create



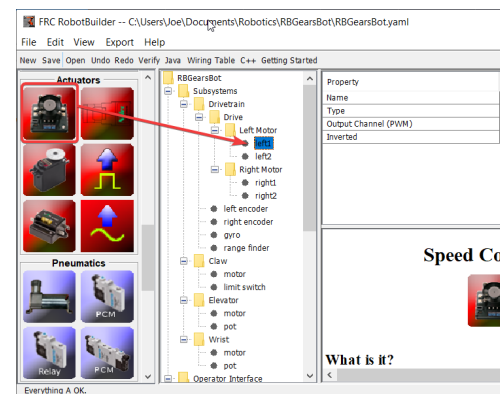
the for driving the handle to be will responsibility Its Train. Drive called subsystem a Create
base. robot



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

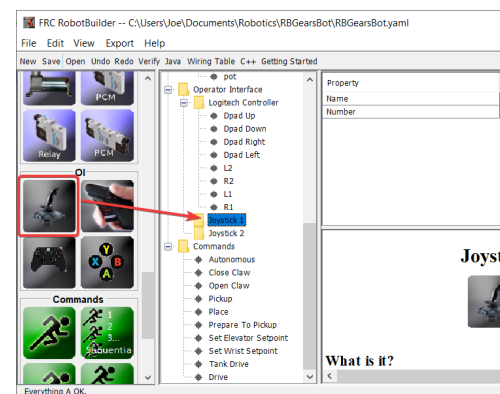


Drive, Differential the inside robot, the drive to motors two then more use to want we Since can they so controllers motor multiple group will These Groups. Controller Motor two create Drive. Differential with used be



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
;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 //
); PWMVictorSPX( new = left1

```

page) next on (continues

(0000 00000 0000)

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119

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page) next on (continues

(RobotBuilder Code)

```

{ ()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. //

```

(Header) C++

```

Subsystem. TYPE: ROBOTBUILDER //
once pragma#

ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
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 //
};m_rangefinder{ AnalogInput:frc
};m_gyro{ AnalogGyro:frc
k4X};;Encoder::frc ,false ,3 ,2m_rightencoder{ Encoder:frc
k4X};;Encoder::frc ,false ,1 ,1m_leftencoder{ Encoder:frc
m_rightMotor}; m_drive{m_leftMotor, DifferentialDrive:frc
}; m_right2 m_rightMotor{m_right1, MotorControllerGroup:frc
};m_right2{ PWMVictorSPX:frc
};m_right1{ PWMVictorSPX:frc
}; m_left2 m_leftMotor{m_left1, MotorControllerGroup:frc
};m_left2{ PWMVictorSPX:frc
};m_left1{ PWMVictorSPX:frc

ID=DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
public
Drivetrain();

```

page) next on (continues

(RobotBuilder Code)

```

;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 //
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(
);true m_drive.SetSafetyEnabled(
s);_0.1m_drive.SetExpiration(
);1.0m_drive.SetMaxOutput(
m_rightMotor);& , "Motor Right"AddChild(
m_right2);& , "right2"AddChild(
);false m_right2.SetInverted(
```

page) next on (continues

(0000 00000 0000)

```

        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 //

    }

ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //

ID=CMDPIDGETTERS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //

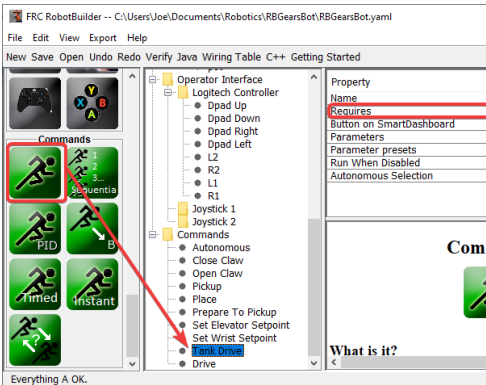
    subsystem this controlling for methods Put //
    Commands. from these Call here. //

```

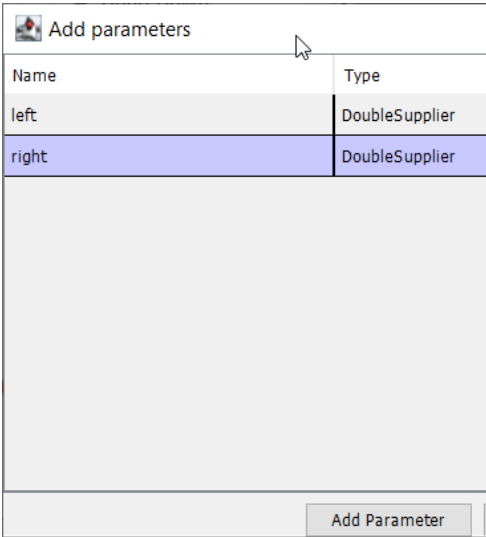
joystick. driver right and left the case this in inputs, joystick the takes that method a Create using steering tank does turn in that object DifferentialDrive the to passed are values The this driving, from robot the stops that stop() called method a create Also values. joystick the later. handy in come might

clarity for example this for removed been has output RobotBuilder Some :0000

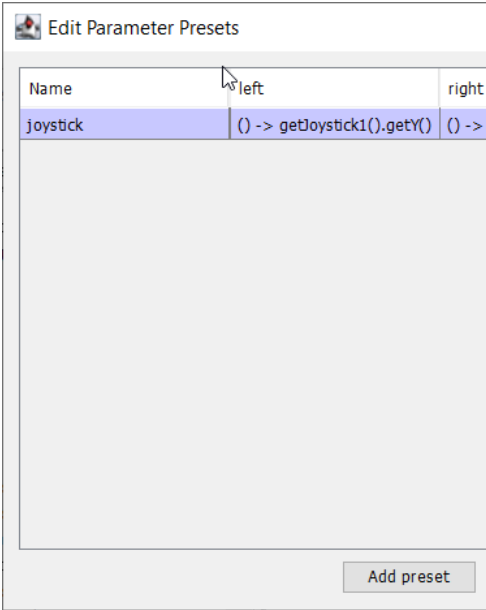
Methods Subsystem the Call and Values Joystick Read



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



for C++) for ><double()std::function or Java for DoubleSupplier(parameters two Create speeds. right and left the



() 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 // 11
12
13 ;frc.robot.commands package
14 ;edu.wpi.first.wpilibj.Joystick import
15 ;edu.wpi.first.wpilibj2.command.CommandBase import
16 ;frc.robot.RobotContainer import
17 ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
18 ;frc.robot.subsystems.Drivetrain import
19
20 ID=IMPORTS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
21
22 */
23 *
24 */
25 { CommandBase extends TankDrive class public
26
27 ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
28 m_drivetrain; Drivetrain final private
29
30 ID=VARIABLE_DECLARATIONS SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
31
```

page) next on (continues

(0000 0000 0000)

```

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
}
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
{ ()runWhenDisabled boolean public
ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
;false return
ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}
}

```

(Header) C++

```

Command. TYPE: ROBOTBUILDER // 11
12
once pragma# 13
14
ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 15
16
frc2/command/CommandHelper.h>< include# 17
frc2/command/CommandBase.h>< include# 18
19
subsystems/Drivetrain.h" include# 20
21
ID=INCLUDES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 22
RobotContainer.h" include# 23
frc/Joystick.h>< include# 24
25
**/ 26
* 27
* 28
ExampleAuthor @author * 29
*/ 30
{ >TankDrive CommandBase,::frc2 CommandHelper::frc2 public :TankDrive class 31
:public 32
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 33
m_drivetrain); *TankDrive(Drivetrain explicit 34
35
ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 36
37
;override ()Initialize void 38
;override ()Execute void 39
;override ()IsFinished bool 40
;override interrupted) bool(End void 41
;override const ()RunsWhenDisabled bool 42
43
44
:private 45
ID=VARIABLES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN // 46
47
48
m_drivetrain; *Drivetrain 49
50
51
ID=VARIABLES SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END // 52
53
;}; 54

```

(Source) C++

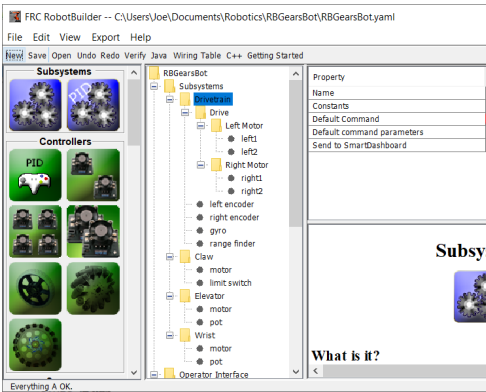
```

11 Command. TYPE: ROBOTBUILDER //
12
13 ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
14
15 commands/TankDrive.h" include#
16
17 m_drivetrain) *TankDrive(Drivetrain::TankDrive
18 m_drivetrain(m_drivetrain){:
19
20 dependencies subsystem declare to here AddRequirements() Use //
21 AddRequirements(m_Subsystem); eg. //
22 ); "TankDrive"SetName(
23 AddRequirements({m_drivetrain});
24
25 ID=CONSTRUCTOR SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
26 }
27
28 time first the runs Command this before just Called //
29 { Initialize()::TankDrive void
30
31 }
32
33 run to scheduled is Command this when repeatedly Called //
34 { Execute()::TankDrive void
35
36 }
37
38 execute() run to needs longer no Command this when true return this Make //
39 { IsFinished()::TankDrive bool
40 ;false return
41 }
42
43 true returns isFinished after once Called //
44 { interrupted) boolEnd()::TankDrive void
45
46 }
47
48 { const RunsWhenDisabled()::TankDrive bool
49 ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
50 ;false return
51
52 ID=DISABLED SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
53 }

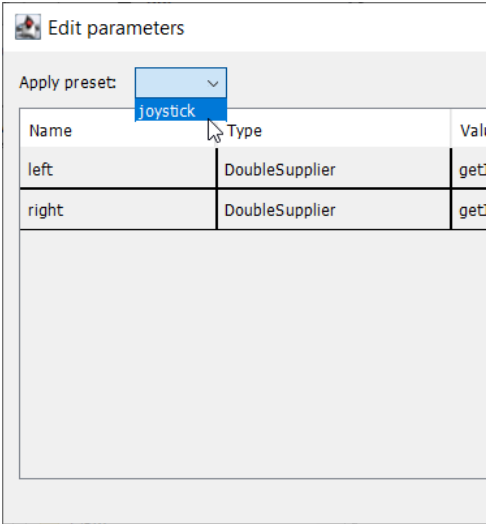
```

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

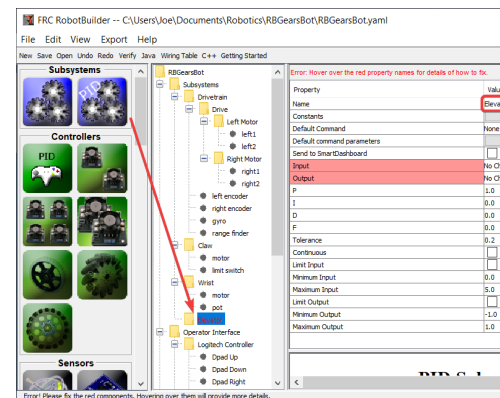
continuing. before Java or C++ to program your export to sure Be :□□□□

Advanced - RobotBuilder 21.3

Actuators Control to PIDSubsystem Using 21.3.1

for results guaranteed get to feedback for sensors use will subsystems advanced More to feedback use PIDSubsystem 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

PIDSubsystem a Create

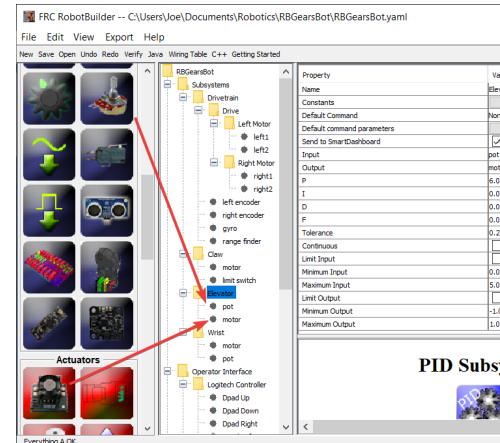


is mechanism a of speed or position the control to feedback uses that subsystem a Creating easy, very

description robot the in folder Subsystems the to palette the from PIDSubsystem a Drag 1.
case this in subsystem, the for name meaningful more a to Subsystem PID the Rename 2.
Elevator

that indicates This red, turned have description robot the of parts the of some that Notice
The in, filled be to need and completed been haven't PIDSubsystem) (the components these
red, in shown are incorrect or missing either are that properties

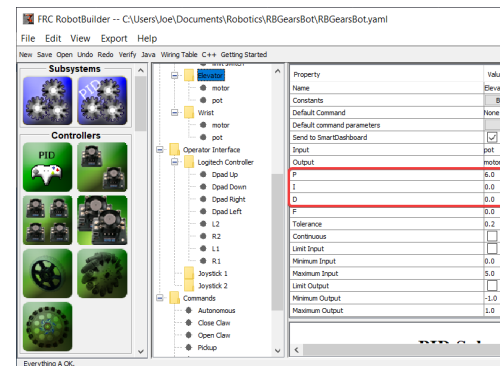
PIDSubsystem the to Actuators and Sensors Adding



PIDSubsystem the for components missing the Add

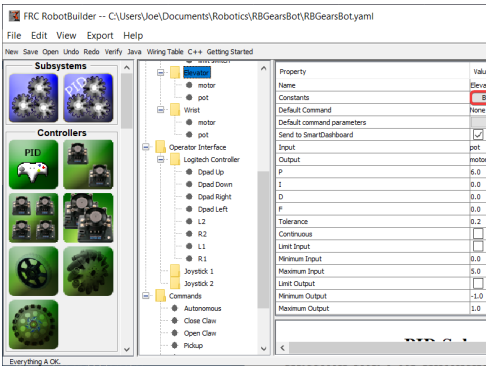
1. Elevator
2. sensor the case this in subsystem, the to feedback for used be will that sensor the Drag feedback. height elevator give might that potentiometer a is

Parameters PID the in Fill

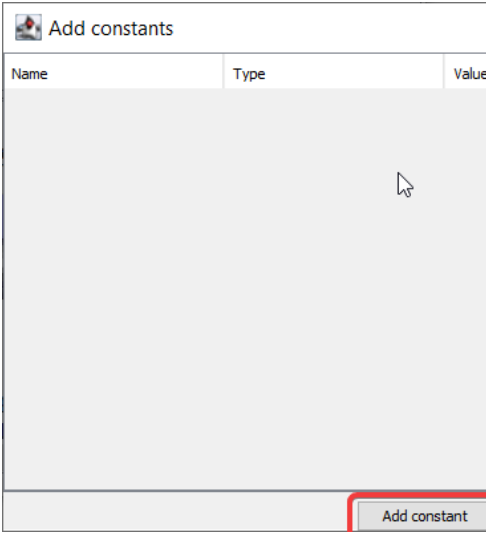


the of stability and sensitivity desired the get to in filled be to need values D and I, P, The I the for 0 and 6.0 of constant proportional a use we elevator our of case the In component. terms. D and

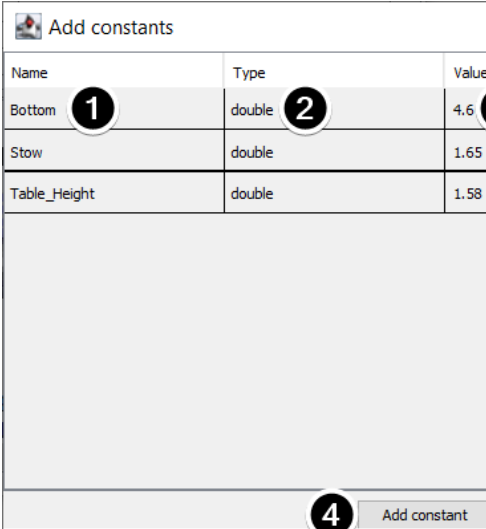
Constants Setpoint Create



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, dropdown- 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 21.3.2

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 private pot; 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++

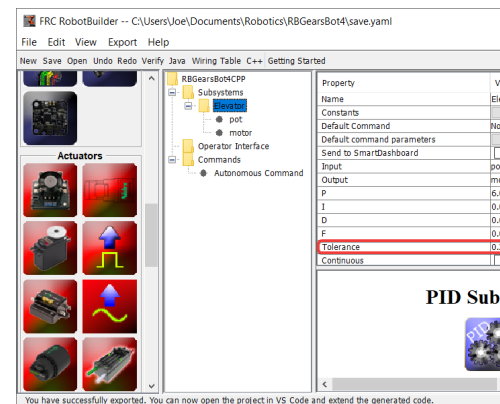
```
{ setpoint) double output, double(Elevator::UseOutput void
kF;*setpoint += output
ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED BEGIN //
m_motor.Set(output);
ID=OUTPUT SOURCE=ROBOTBUILDER CODE, AUTOGENERATED END //
}
```

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 21.3.3

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

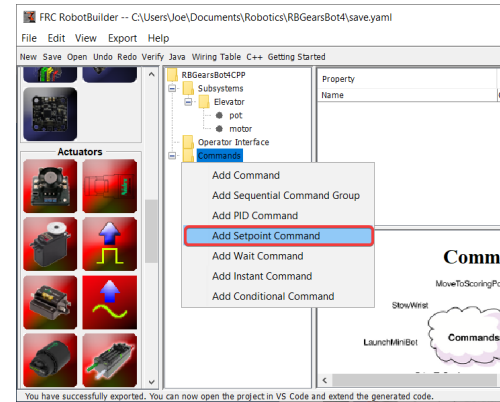
PIDSubsystem a with Start



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

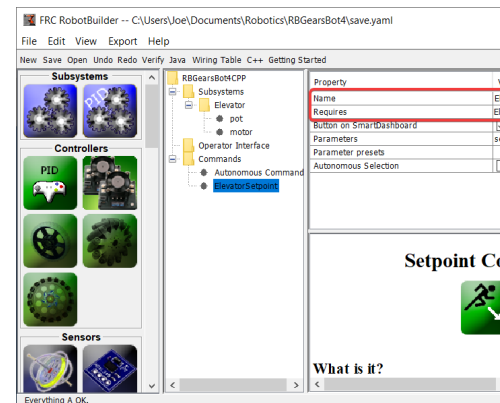
current the off far how controls This parameter. **Tolerance** the set to important is It
the that criteria the is This target. on considered be and setpoint the from be can value
command. next the onto move to uses SetpointCommand

Command Setpoint the Creating

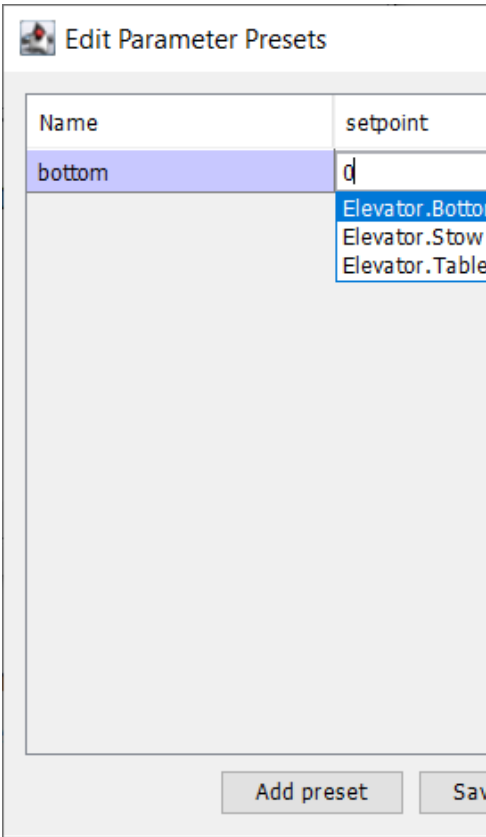


command". Setpoint "Add select and palette the in folder Commands the on clickRight-

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



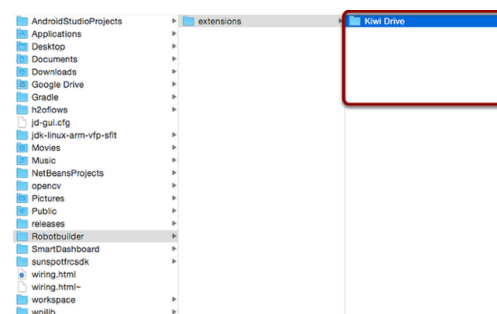
- setpoints. the up set to Presets Parameter the on Click 1.
- Preset Add Select* 2.
- »bottom« case this (in name preset a Enter 3.
- box entry setpoint the to next dropdown the Click 4.
- subsystem Elevator the in created was that constant, Elevator.Bottom the Select 5.
- previously
- setpoints. other 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 21.3.4

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

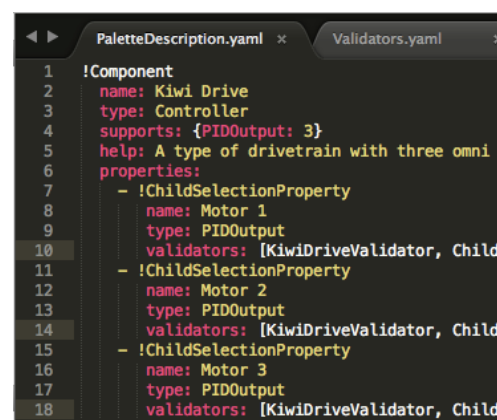
Structure Component Custom



\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 use 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 is one of:
- !StringProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
- !BooleanProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
- !DoubleProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
- !FileProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
  extension: The extension at the end of this file with
  folder: Whether or not to select folders instead of files
- !ChoicesProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
  choices: List of choices to present to the user.
- !ChildSelectionProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
  type: Type of the child to select.
- !TypeSelectionProperty
  name: The name of this property, should be unique with
  validator: Optional. The validator that should be used to
    validate this property.
  default: The default value when no other is presented
  type: Type of component to select.
```

Validators.yaml

```
Validators.yaml
1 !DistinctValidator
2   name: KiwiDriveValidator
3   fields: ["Motor 1", "Motor 2", "Motor 3"]
```

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

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:

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

Export.yaml Java



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, |
. 000 00000 0000 00 0000 C++,-0 00000000 000 00
```

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`

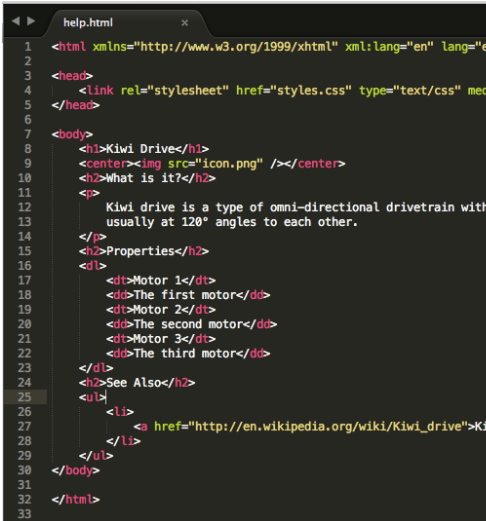
name the is "Name" (i.e. somewhere defined variable a the usually string, a takes #variable of name the into it turns and Motor"), "Arm as such RobotBuilder, in component the to given in results Motor") #variable("Arm example, For code. generated the in defined variable a ArmMotor string the

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:
be will this subsystem, a in is component the If component. the of name full the Name:
 subsystem the of name the to appended name short the
be should This any. if in, created be should component this file the of name The Export:
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:
 used.
this of variable a declare to how for Construction, to similar instruction, an Declaration:
 "None" default the by of care taken is This type. component
component this of instance new a create to how for instruction an Construction:
LiveWindow the to component this add to how for instruction an LiveWindow:
behave to component this for calls method or functions extra any for instructions Extra:
 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
 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



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



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](#)

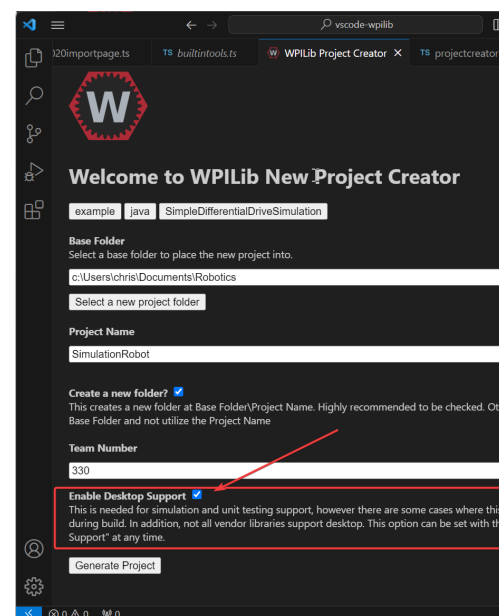


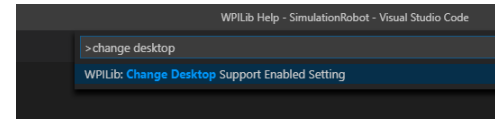
Simulation Robot to Introduction 22.1

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.

Java/C++

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



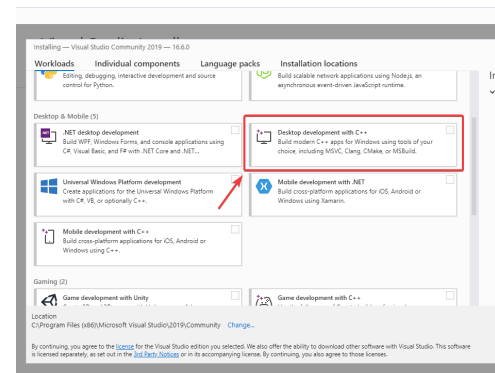


located file `build.gradle` your editing manually by enabled be also can support Desktop to `false = includeDesktopSupport` change Simply project. robot your of root the at `true = includeDesktopSupport`

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

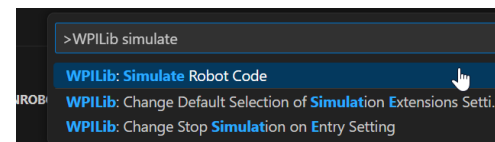
the runre- simply Support, Desktop disable to want you time in point any at If change or palette command the from Setting“ Enabled Support Desktop Change “WPILib: `build.gradle`. in `false` to `includeDesktopSupport`

Windows, For installed. be to compiler native a that requires simulation robot C++ :
Xcode requires macOS Code), VS **not** (later or 17.9 version 2022 Studio Visual be would this package. essential-build the requires (Ubuntu) Linux and ,later or 14 installer Studio Visual the in checked is option *C++ with Development Desktop* the Ensure support. simulation for



Simulation Robot Running

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

in hardware the using and PC your to hardware attaching support vendors Some :
about information more for *documentation vendor* See CANivore). (e.g. simulation desktop
.Code Robot Sim Hardware WPILib: command the

Python

RobotPy. install you when default by installed is support simulation GUI
simulation: in code your run to execute can you that subcommand robotpy a is There

Windows

```
sim robotpy m- 3- py
```

macOS

```
sim robotpy m- python3
```

Linux

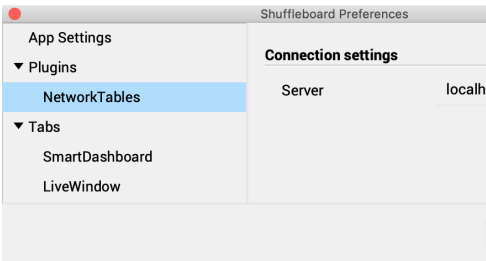
```
sim robotpy m- python3
```

Dashboards Robot Running 22.1.1

WPILib with used be can AdvantageScope and Glass, SmartDashboard, Shuffleboard,
)localhost (i.e. computer local the to connect to configured are they when simulation

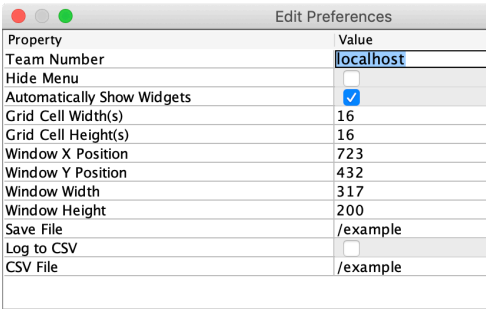
Shuffleboard

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



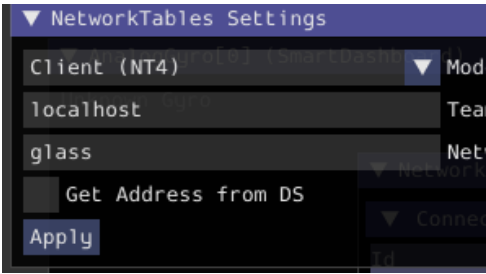
SmartDashboard

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



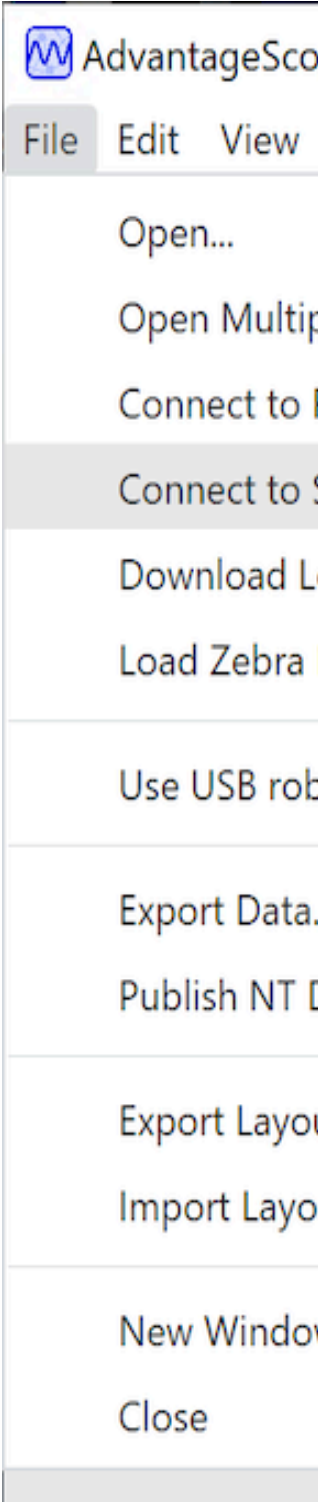
Glass

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



AdvantageScope

local the on running instance NetworkTables a to connect to required is configuration No
or menu *File* the under *Simulator to Connect* click simulation, a to connect To computer.
.Ctrl+Shift+K press

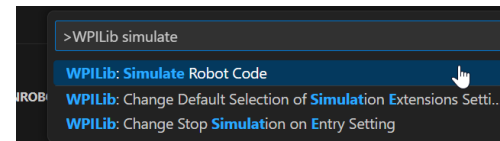


Elements Interface User Specific Simulation 22.2

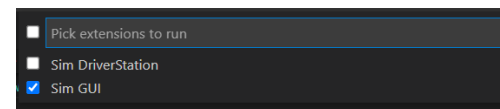
(GUI) interface user graphical a introduce to simulation robot extended has WPILib outputs. and inputs robot's their visualize easily to teams allows This component.

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

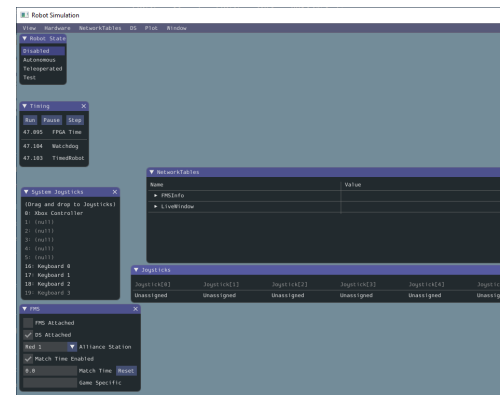
GUI the Running 22.2.1



option. palette command **Simulation Run** the via GUI the launch simply can You

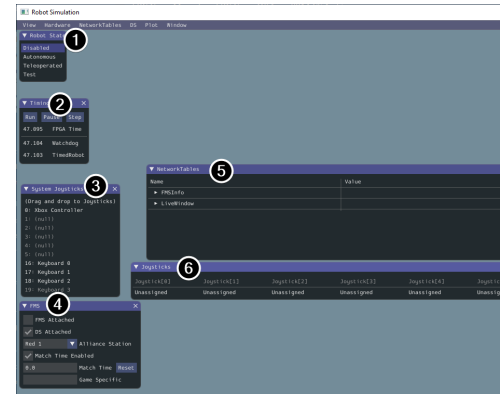


Press default. by selected be will and dialog new a in popup should option GUI Sim the And GUI! Simulation the launch now will This .Ok



GUI the Using 22.2.2

Layout the Learning



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

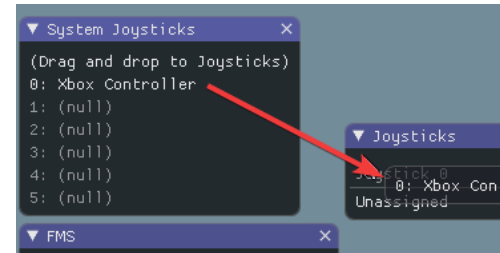
relays. Spike VEX includes This devices. relay any includes This - **Relays** 7.

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

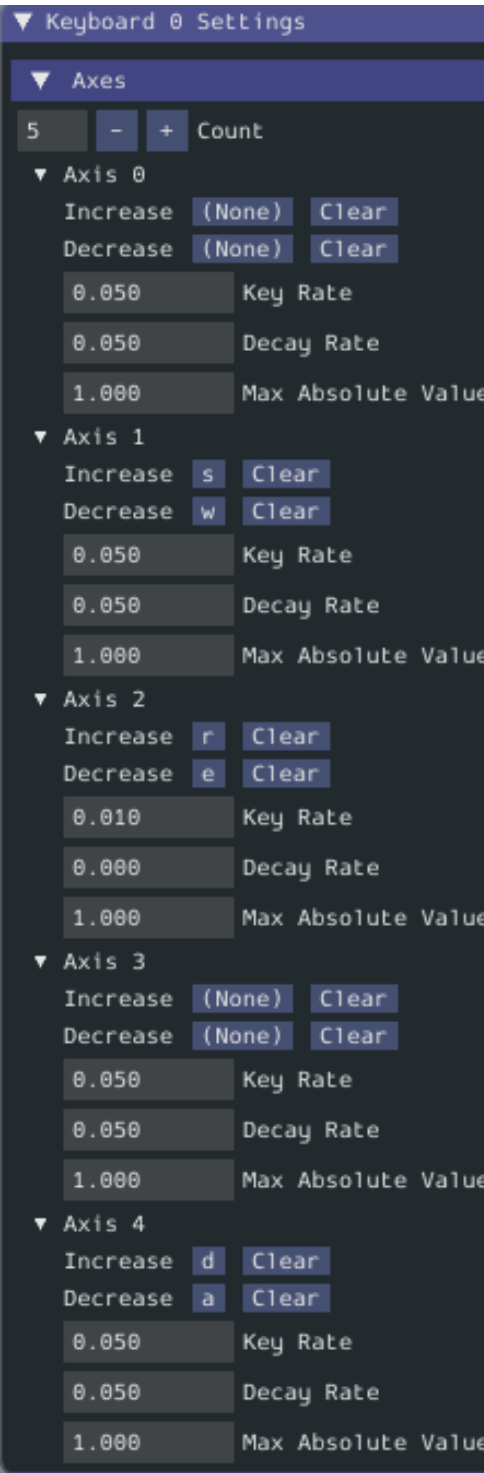
joystick shown a drag and click simply joysticks, system of list the from joystick a add To menu". "Joysticks" the to menu Joysticks" "System the under



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

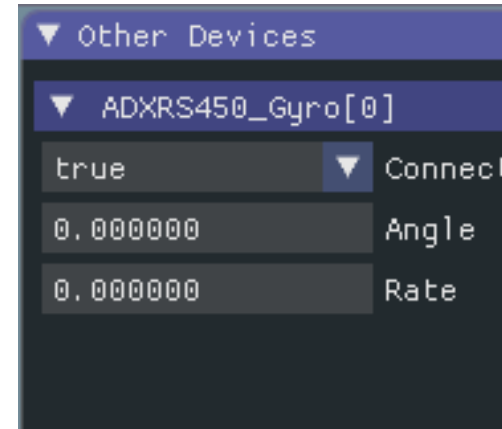
Joystick a as Keyboard the Using

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



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



Code Robot from Simulation Determining 22.2.3

can you simulation, robot the running when compile not do libraries vendor where cases In .boolean a returns which RobotBase.isReal() with content their wrap

JAVA

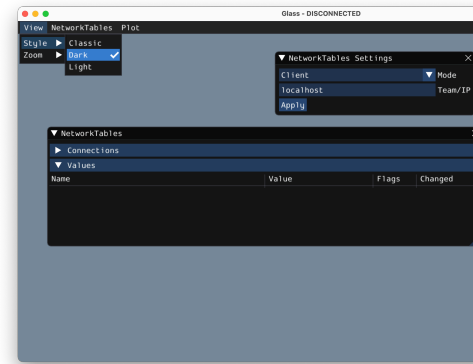
```
motorLeft; TalonSRX
motorRight; TalonSRX

{ ()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 22.2.4

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 22.2.5

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 22.3

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 22.3.1

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 $\mathbf{Ax}_k + \mathbf{Bu}_k$ 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 22.3.2

.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 some and elevator, the of height starting the meters), (in elevator the of height maximum and estimate. position our to add to noise random

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.
            ,kElevatorDrumRadiusConstants.
            ,kMinElevatorHeightMetersConstants.
            ,kMaxElevatorHeightMetersConstants.
```

47
48
49
50
51
52
53
54
55

page) next on (continues

(0000 00000 0000)

```

, true
, 0
));0.01(fillVecBuilder.
EncoderSim(m_encoder); new = m_encoderSim EncoderSim final private

```

56
57
58
59

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
m, _0
;}}0.01{
m_encoderSim{m_encoder}; EncoderSim::sim::frc

```

51
52
53
54
55
56
57
58
59
60
61

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); + (pidOutputsetVtagem_motor.
}

```

31
32
33
34
35
36
37
38
39
40

99
100
101
102
103
104
105
106

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);_0.6m_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 : simulationPeriodic() 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 //
    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 22.4

API. SimDevice the of form the in data device simulation manage to way a provides WPILib

Classes Device WPILib Core Simulating 22.4.1

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)GetXx()/getXx()(getter has class simulation Each will functions getter The .Xxx field each for functions)SetXx(value)/setXx(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 22.4.2

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 22.5

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.

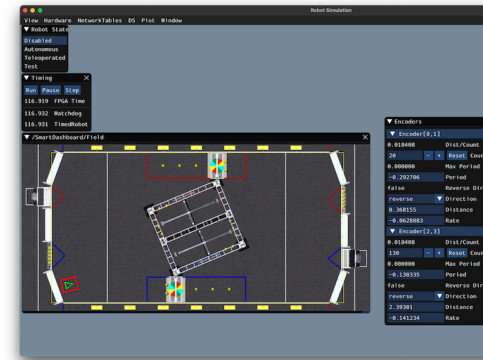
to approach traditional more a uses)C++ ,Java(SimpleDifferentialDriveSimulation •
flow. data

window. *Project New Code* VS the in available also are examples these of Both

Overview Simulation Drivetrain 22.5.1

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- framework. simulation WPILib the behind concepts underlying basic the Understand 1. parameters. physical robot's your using model simulation drivetrain a Create 2. voltage specific given move will robot real your how predict to model simulation the Use 3. inputs. having before inversion) motor (e.g. bugs common squash and constants feedback Tune 4. hardware. physical to access field. virtual a on movement robot visualize to GUI Simulation the Use 5.



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 22.5.2

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 ,@Encoder( new = m_leftEncoder Encoder private
);3 ,@Encoder( 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 ,m_leftEncoder{ Encoder::frc
};3 ,m_rightEncoder{ Encoder::frc

```

page) next on (continues

(0000 00000 0000)

```
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 :0000
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 //
    ); AnalogGyro( 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 //
    ;} m_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 22.5.3

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 •
) .kgm² 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: //
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: //

```

page) next on (continues

(0.005 0.005 0.001)

```

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(fill VecBuilder.

```

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: //
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 22.5.4

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

    { ()Drivetrain public
        ...
        kEncoderResolution); / kWheelRadius * PI*Math. * 2(setDistancePerPulse m_leftEncoder.
        kEncoderResolution); / kWheelRadius * PI*Math. * 2(setDistancePerPulse m_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.
page) next on (continues

```

(0000 00000 0000)

```
(());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.setDistance_m_leftEncoderSim.
    (());getLeftVelocityMetersPerSecond(m_driveSim.setRate_m_leftEncoderSim.
    (());getRightPositionMeters(m_driveSim.setDistance_m_rightEncoderSim.
    (());getRightVelocityMetersPerSecond(m_driveSim.setRate_m_rightEncoderSim.
    (());getDegrees().getHeadingm_driveSim.-(setAngle_m_gyroSim.

```

```
}
```

C++

```

    ;}m_leftMotor{ PWMSparkMax::frc
    ;}m_rightMotor{ PWMSparkMax::frc

```

```
{ Drivetrain()
```

```

    // kWheelRadius * pi::numbers::std * 2m_leftEncoder.SetDistancePerPulse(
    // kWheelRadius * pi::numbers::std * 2m_rightEncoder.SetDistancePerPulse(
    // kWheelRadius * pi::numbers::std * 2m_rightEncoder.SetDistancePerPulse(
    // kWheelRadius * pi::numbers::std * 2m_rightEncoder.SetDistancePerPulse(

```

```
{ 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());
    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 :0000 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 22.5.5

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"(putData SmartDashboard.
        }

```

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.update m_odometry.
            ());getDistance m_leftEncoder.
            ());getDistance m_rightEncoder.
            ());getPoseMeters(m_odometry.setRobotPose m_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 22.6

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 22.6.1

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
                    DoubleSolenoid( new
                        ,CTREPCM.PneumaticsModuleType.
                        ,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
            { ()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 // );m_motor.Set(
}

{ speed) double(Intake::Activate void
{ (IsDeployed()) if
m_motor.Set(speed);
nothing do open, t'isn piston if // { else }
);m_motor.Set(
}
}

{ const ()Intake::IsDeployed bool
kForward;::Value::DoubleSolenoid::frc == m_piston.Get() return
}
```

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

```

page) next on (continues

(0000 00000 0000)

```

        { ()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
        ,CTREPCM PneumaticsModuleType.
        ,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
        { ()doesn'tWorkWhenClosed 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
        ();retractm_intake.
        ());getm_simPiston. ,kReverse.ValueassertEquals(DoubleSolenoid.
        }

        @Test
        { ()deployTest void
        ();deploym_intake.
        ());getm_simPiston. ,kForward.ValueassertEquals(DoubleSolenoid.
        }
    }
}

```

C++

```

        frc/DoubleSolenoid.h>< include#
frc/simulation/DoubleSolenoidSim.h>< include#
        frc/simulation/PWMSim.h>< include#
        gtest/gtest.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 22.6.3

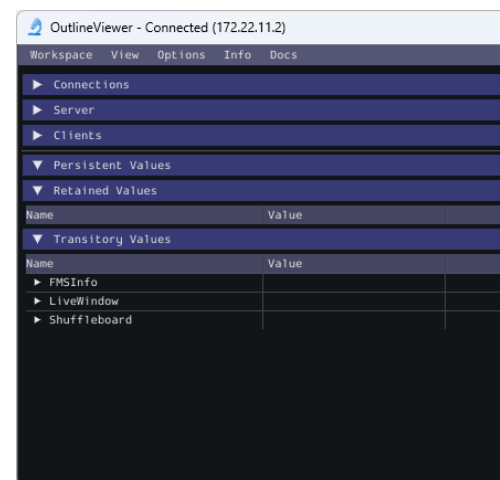
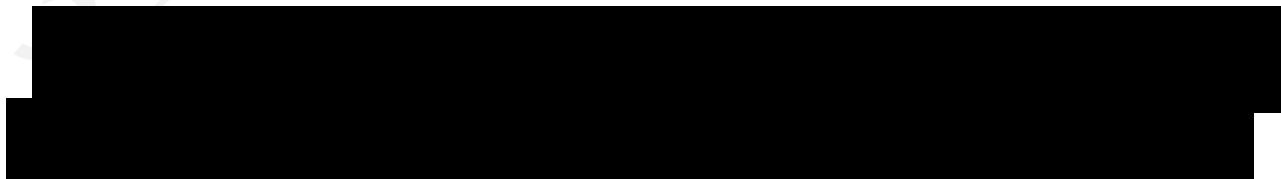
more and prerequisites For desktop. your on simulation in run be always will Tests :
[introduction simulation the see info,](#)

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 a tests failed any 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 link

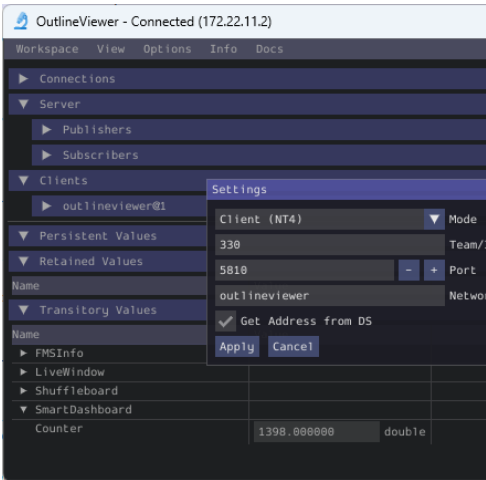
will This deploys. including built, is code robot whenever tests the runs Gradle default, By this prevent To fail. to deploy and build the cause will tests failing and time, deploy increase Palette Command the from *Setting Deploy On Tests Skip Change* use can you happening, from deploying. when tests run to whether configure to



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 the set and settings then options slect and OutlineViewer open robot, your to connect To you If connect. will OutlineViewer ,Apply click you After number. team your be to Team/IP .Steps Troubleshooting Dashboard the see please OutlineViewer to connecting trouble have

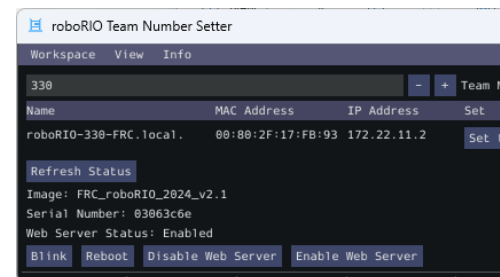
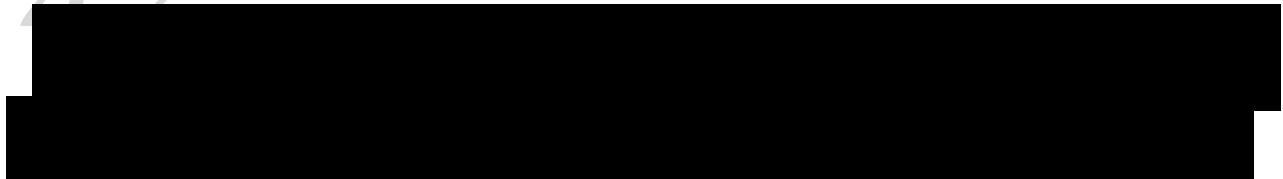
simulated a at OutlineViewer point to number team a of instead localhost use can You :□□□□ XRP. or Romi robot,



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

42



team the set to used be can that utility platformcross- a is Setter Number Team roboRIO The
 team the setting for tool imaging roboRIO the to alternative an is It roboRIO. the on number
 number.

logo WPILib the click or WPILib type and Ctrl+Shift+P press Code, Studio Visual In
 select then ,Tool Start Select Palette. Command WPILib the launch to right top the in
 .roboRIOTeamNumberSetter

the when method simplest the is this as tool, the use to USB over roboRIO the to Connect
 set. been hasn't number team

Number Team Setting 24.1

take will This .xxxx to team Set select and field Number Team the in number team your Enter
 number team new the so roboRIO the reboot to button Reboot the press then second, a about
 effect. takes

Webserver Enabling/Disabling 24.2

However, configuration. some enables and debugging some provides *webserver roboRIO's* The the on clicking by it disable can You program. robot the from away memory takes also it .*Server Web Enable* click can you again, it enable to like you'd If button. *Server Web Disable*

Identification roboRIO 24.3

help to times few a blink to LED Radio roboRIO's the cause will button *Blink* the Clicking roboRIO. the identify

Introduction Vision 25.1

Vision? is What 25.1.1

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 OpenCV. using Pi Raspberry the as such

Pi Raspberry with Processing Vision •

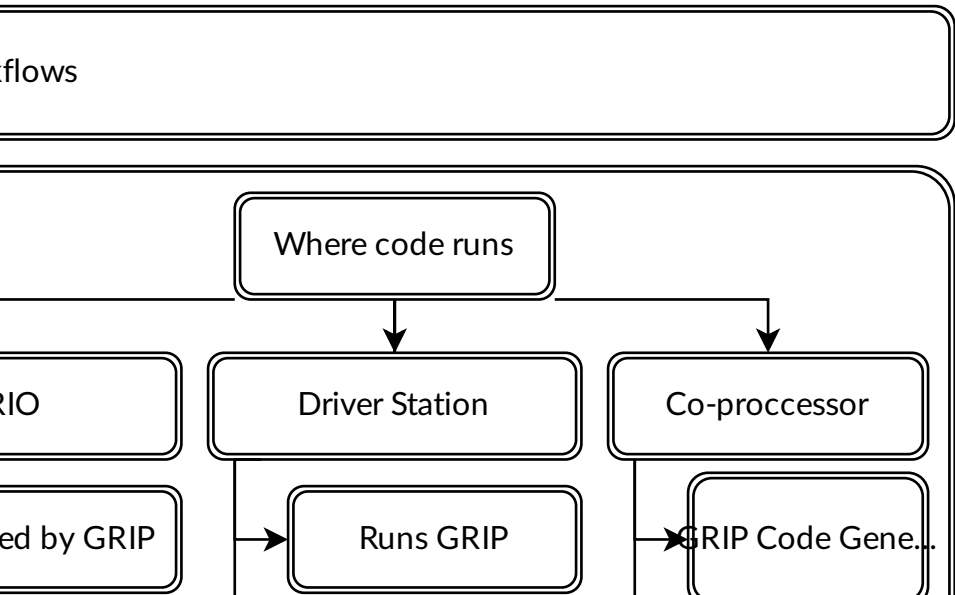
roboRIO the with Processing Vision •

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 25.1.2

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

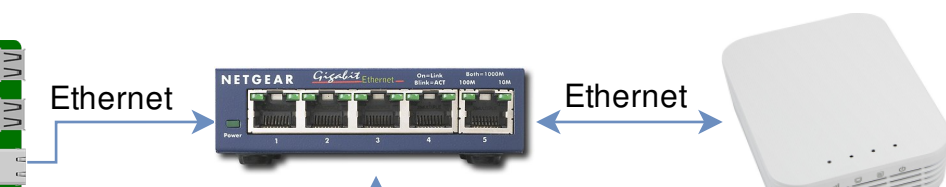
the where and processing vision for components the choosing for options many are There
and options of number a support tools associated and WPILib run. should program vision
some you give to attempt will article This do. to what decide to flexibility of lot a teams give
available. are that tradeoffs and choices the of many into insight



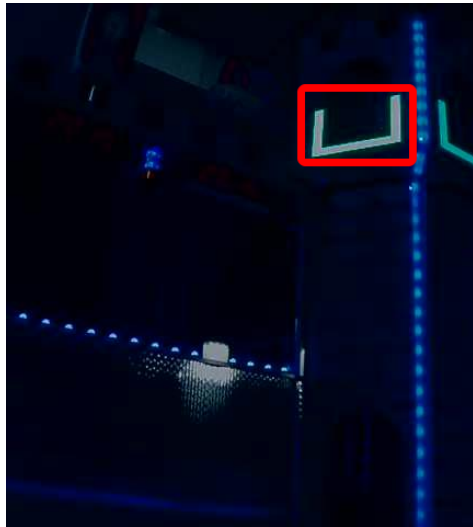
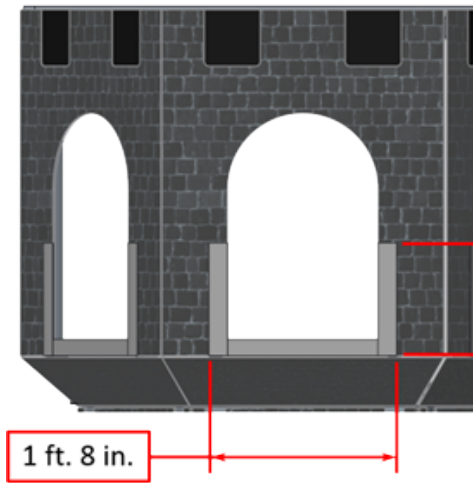
roboRIO on Code Vision



Coprocessor on Code Vision



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

a at off" "bounces light that so mirrored generally are materials reflective Highly degrees. 180 to sum angles red and blue the left,above- shown As angle. supplementary line green the normal surface the about reflects light the that is explanation equivalent An to return will surface the at pointed light a that Notice surface. the to perpendicular drawn degrees. ~ 90 is angle blue the if only source light the

across facets shiny either have typically will it but mirrored, not are materials reflectiveRetro- materials likepearl- or faceted all Not appearance. likepearl- a have will it or surface, the 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

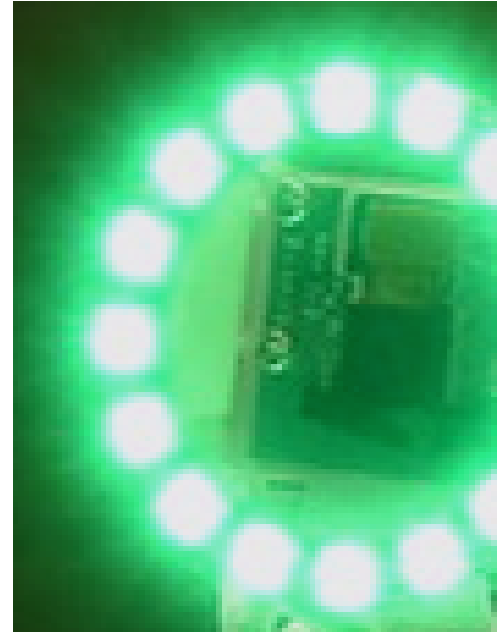
Demonstration

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 25.1.4

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

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 examples. code vision the with provided are images sample Additional size. different a of light



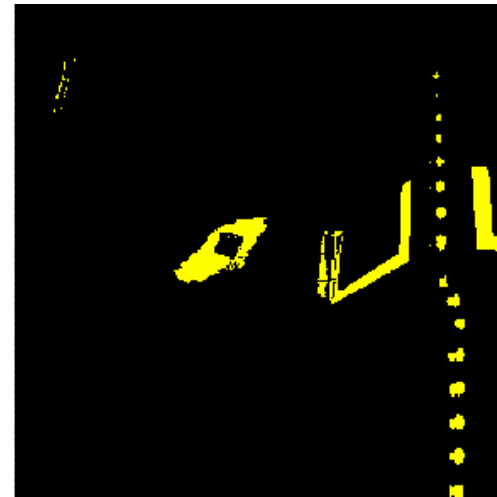
HSL/HSV? is What

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

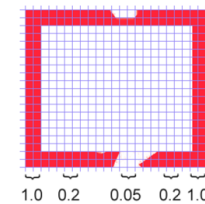
height and width The Height). Particle / Width (Particle on based is score ratio aspect The The rectangle". "equivalent the called something using determined are particle the of particle the equals $2x + 2y$ where y and x lengths side with rectangle the is rectangle equivalent aspect the for used is 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 above. or below varies ratio the as linearly drops and ratio target the matches ratio 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



Column averages for a particle rectangle.



White line is the limit, and green is the actual data.

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

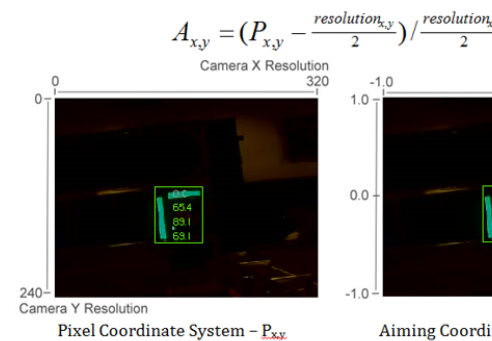
some calculate to sense makes it target, a considered be to enough well scores particle a If these includes code example The distance. and position as such measurements worldreal- it. understand better to involved math the at look let's so measurements, basic

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

$$A_{x,y} = \left(P_{x,y} - \frac{\text{resolution}_{x,y}}{2} \right) / \frac{\text{resolution}_{x,y}}{2}$$



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 25.1.5

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

JAVA

```

;edu.wpi.first.cameraserver.CameraServer import
;edu.wpi.cscore.CvSink import
;edu.wpi.cscore.CvSource import

them connects and [1] MjpegServer and UsbCamera Creates //
();startAutomaticCaptureCameraServer.

UsbCamera the to it connects and CvSink the Creates //
();getVideoCameraServer. = cvSink CvSink

them connects and [2] MjpegServer and CvSource the Creates //
);480 ,640 , "Blur"(putVideoCameraServer. = outputStream CvSource

```

C++

```

cameraserver/CameraServer.h" include#

them connects and [1] MjpegServer and UsbCamera Creates //
StartAutomaticCapture();: CameraServer::frc

UsbCamera the to it connects and CvSink the Creates //
GetVideo();: CameraServer::frc = cvSink CvSink::cs

them connects and [2] MjpegServer and CvSource the Creates //
);480 ,640 , "Blur"PutVideo(): CameraServer::frc = outputStream CvSource::cs

```

(for level cscore the at following the does effectively implementation CameraServer The creating as such details the of many of care takes CameraServer purposes). explanation CameraServer numbers. port selecting automatically and objects cscore all for names unique 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 ,kMJPECPixelFormat. , "Blur CvSource( new = outputStream CvSource
page) next on (continues

```

(0000 0000 0000)

```
);1182 , "serve_Blur" MjpegServer( new = mjpegServer2 MjpegServer
(outputStream);setSourcemjpegServer2.
```

C++

```
cscore_00.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 25.1.6

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

WPILibPi with Vision 25.2

Pi Raspberry the with WPILibPi using of Walkthrough Video A 25.2.1

WPILibPi. of name old the is which FRCVision mentions video The :0000

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 25.2.2

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

dashboard the to data camera Streaming

network. robot the over dashboard the to data camera the stream simply to desirable often is It a on viewed and network the to sent be can connections camera more or one case this In advantage the has Shuffleboard Using browser. web a or Shuffleboard as such dashboard the integrating as well as rate bit and resolution camera the set to controls easy having of robot. the from sent data other with streams camera lines target as such image, the to annotation add and images process to possible also is It the to forward it send then detected has code processing image the what showing boxes or robot. the around what's of picture clear a see to operators for easier it make to dashboard

FRC for Pi Raspberry the Using 25.2.3

because: Pi Raspberry the is choices coprocessor popular most the of One

\$35 around - cost Low •

including suppliers, of number a from Pis Raspberry find to easy it's - availability High •
Amazon

specifications: following the has 3b+ Pi Raspberry current the - performance good Very •

64bit A53 Core QUAD ARMv8 bit 64 BCM2837BO Broadcom - Specifications: Technical •
WiFi BCM43143 - RAM 1GB - 1.4GHz at run Computer Board Single powered Processor
ports USB2 x 4 - GPIO extended pin 40 - board on (BLE) Energy Low Bluetooth - board on
for port camera CSI - HDMI size Full - port video Composite and output Stereo pole 4 -
Raspberry the connecting for port display DSI - camera Pi - Raspberry the connecting
storing and system operating your loading for port MicroSD - display screen touch Pi -
Amps. 2.5 to up supports (now source power USB Micro switched Upgraded - data

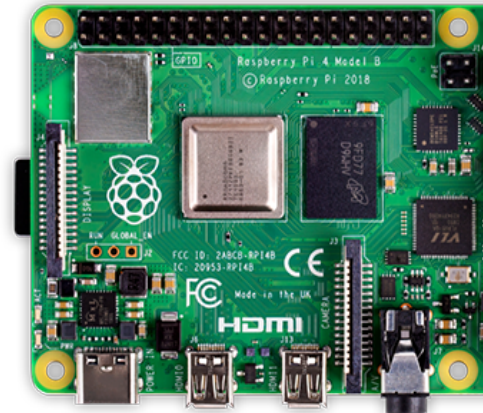


image Pi Raspberry builtPre-

Raspberry provided a is there teams, for possible as easy as Pi Raspberry the using make To By booted. and Pi, the into inserted card, SD micro a to copied be can image The image. Pi supports: it default

functions common most the for it configuring for interface web A •
on published are that one) to (defaults streams camera number arbitrary an Supports •
interface network the
and Java, C++, for libraries language and Server, Camera ,[NetworkTables](#) [OpenCV](#), •
programs custom Python

dashboard) (and network the to cameras more or one stream to is requirement only the If interface. web the through up set completely be can and required is programming no then

Pi. the boot and card flash a onto image the install to how discusses section next The

running image Pi the get to need you What 25.2.4

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

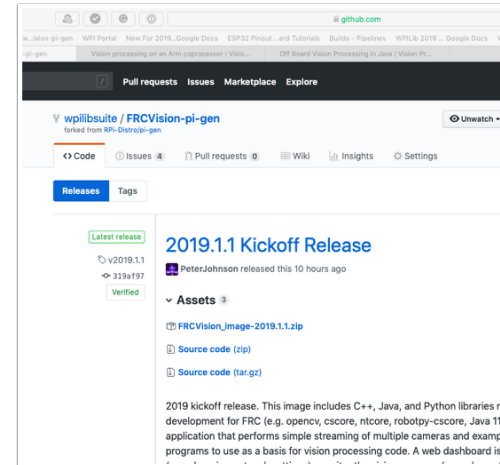


card. MicroSD the to image FRC® the write will that dongle USB inexpensive an is Shown

card MicroSD your to image the Installing 25.2.5

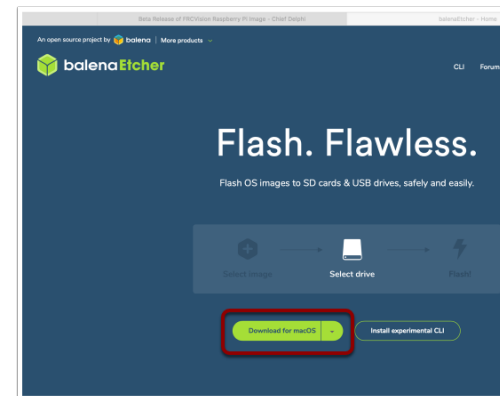
image PI Raspberry FRC the Getting

.repository WPILibPi the for page release GitHub the on stored is image The page web GitHub the on documentation the see page, this on instructions the to addition In (below). use Always it. downloading when connection internet fast a have so large fairly is image The releases. of list the of top the from release recent most the

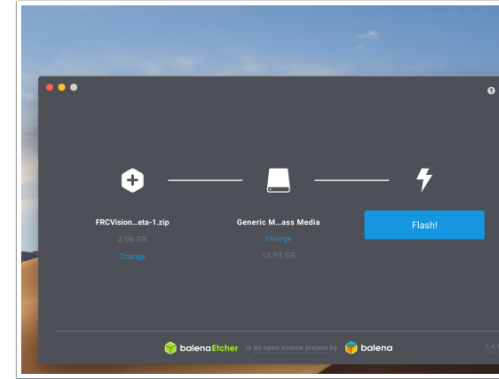


card MicroSD your to image the Copy

at be to needs card SD micro The card. SD micro the image to Etcher install and Download cards. SD micro to writing for well works dongle USB to SD micro A GB. 8 least



source, the as file zip the selecting by Etcher using image the with card MicroSD the Flash minutes 3 about take to process the Expect "Flash". click and destination the as card SD your laptop. fast fairly a on



PI Raspberry the Testing

power. apply and 3 rPi a in card SD micro the Put 1.
 http:/ to connect and browser web a Open PC. or LAN a to ethernet 3 rPi the Connect 2.
 will filesystem the bootup first the On dashboard. web the open to wpilibpi.local//
 the click to necessary it's so only, read to default will bootups later but writable, be
 changes. make to button "writable"

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 25.2.6

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

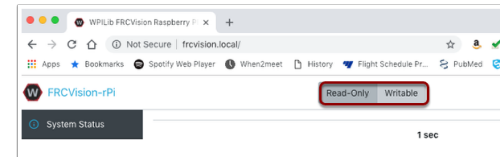
- status PI Raspberry the at Look •
- camera the running process background the of status the View •
- settings network change or View •
- cameras additional add and rPi the into plugged camera each at Look •
- rPi the onto program vision new a Load •

Writable vs. OnlyRead- be to rPi the Setting

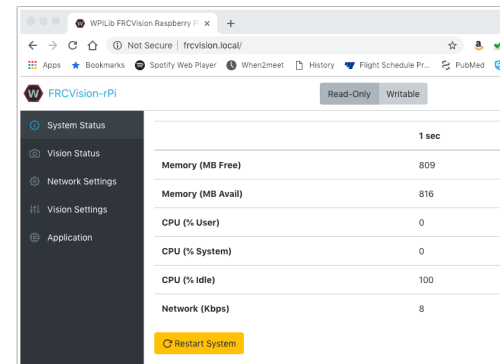
changed. be cannot system file the that means which OnlyRead- to set normally is rPi The isn't system file the rPi the down shutting first without removed is power if that ensures This saved be cannot settings new the sections), (following changed are settings When corrupted. system file the allow that provided are Buttons OnlyRead- 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



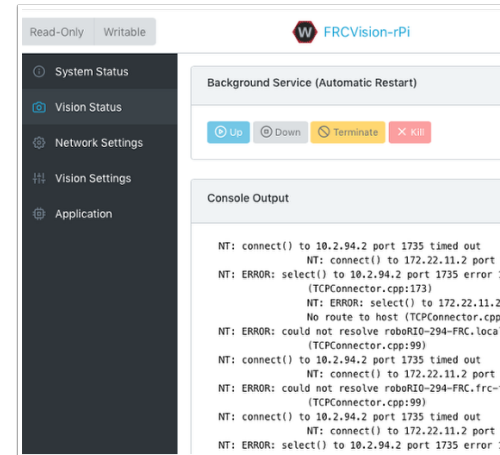
status System



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
- is bandwidth camera used the if determine to one allows which - bandwidth Network
- year any for rules robot the in allowed bandwidth maximum the exceeding

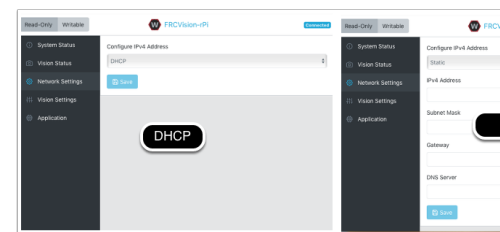
Status Vision



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

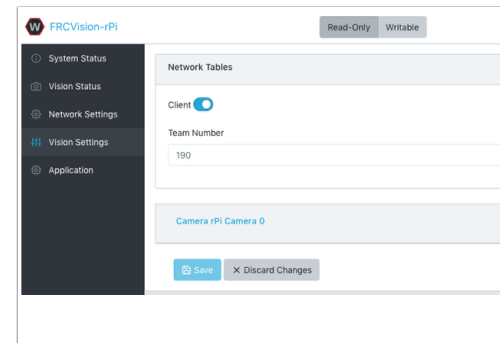
Settings Network

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

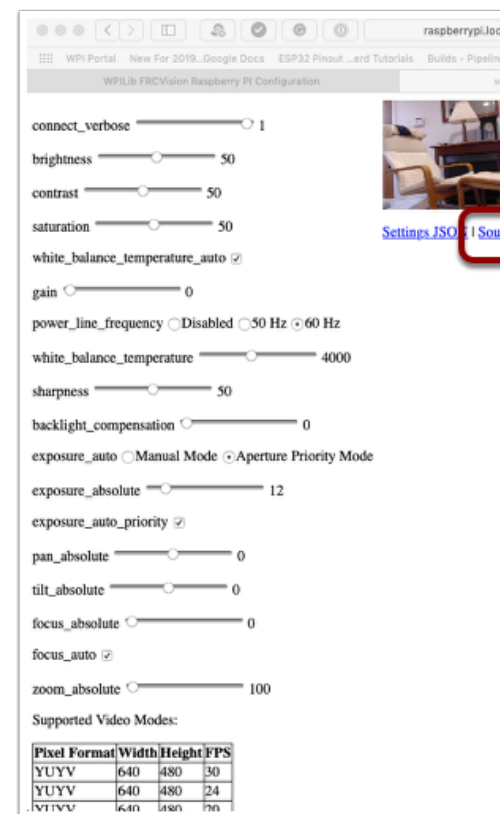


mDNS The Addressing. IP Static and DHCP both for settings the showing is above picture The above. selected options the of regardless work always should rPi the for name

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

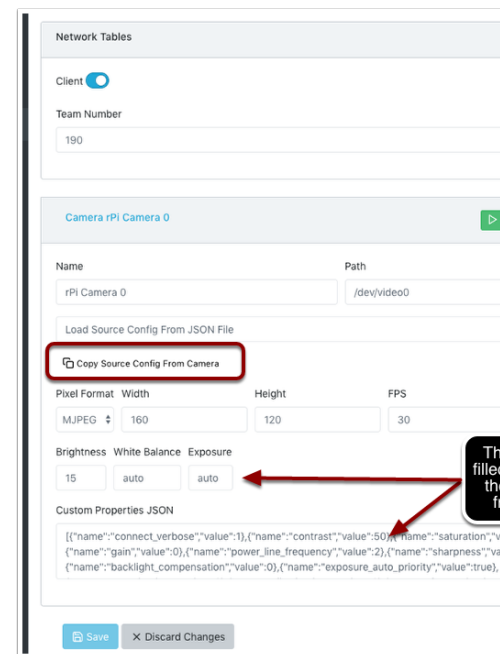


the of bottom The view. camera current the in reflected is settings camera the Manipulating rates) frame and Height, Width, of (combinations modes camera possible the all shows page camera. this by supported are that

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



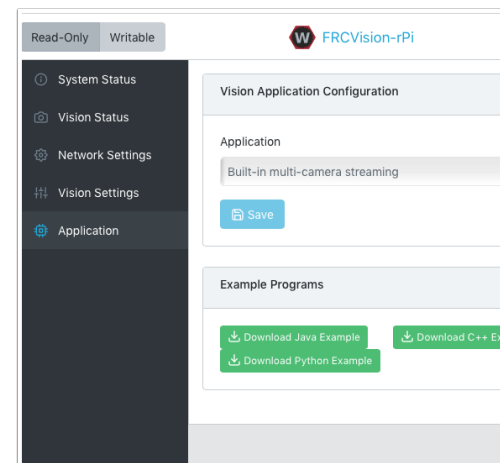
(above). settings camera the in shown values settings camera used commonly some are There
the before camera the into loaded are Exposure and Balance, White Brightness, values These
overwrite will they settings those contains file JSON user a if So applied. is file JSON user
field. text the from ones the

Application

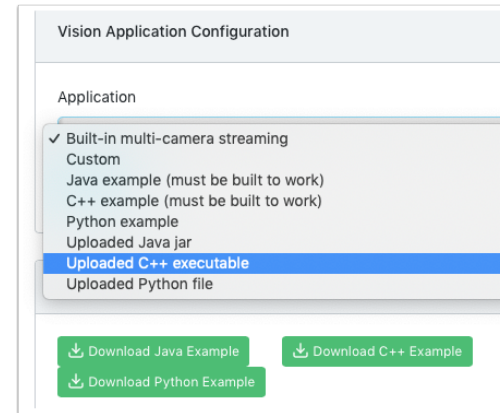
rPi. the on running currently is that application the shows tab Application The

workflows Vision

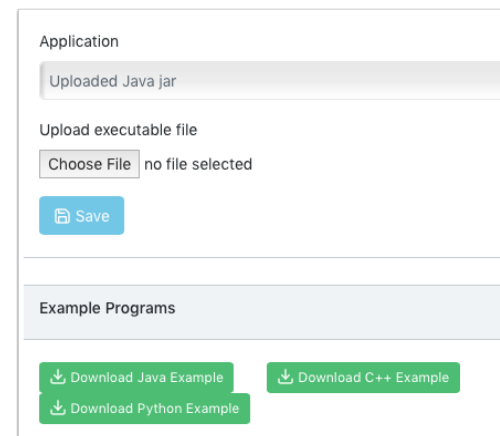
C++, languages, supported the of each in OpenCV using program vision sample a is There addition, In rPi. the from video stream and capture can program sample Each Python. or Java, replace to extended be to up set all are They OpenCV. minimal some have samples the rPi The application. robot the for needed 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 based (probably scripts and applications custom completely using yourself everything Do samples) the of one on



dropdown- 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"



using writeable set be to has system file the rPi, the onto file new a Save to order in Note:
file the set file, new the saving After page. web the of left top the at button "Writable" the
changes. accidental against protected is it that so Only""Read- to back system



CameraServer Using 25.2.7

CameraServer from Frames Grabbing

processing vision own your make to libraries necessary the all with comes image WPILibPi The
CameraServer the use can you camera, the from frame current the get to order In system.
CameraServer Video: Process and Read the CameraServer, about information For library.
.*Class*

PY

```

CameraServer import cscore from
                cv2 import
                np as numpy import

enableLogging().CameraServer

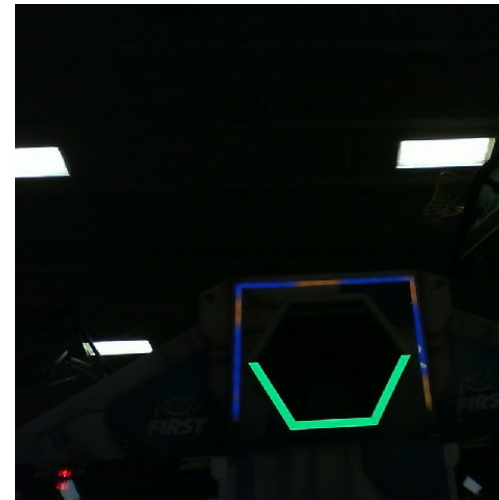
startAutomaticCapture().CameraServer = camera
height) setResolution(width, camera

getVideo().cs = sink

:True while
grabFrame(input_img).cvSink = input_img time,
error an is There # :0 == time if
continue
    
```

cv2.cvtColor Use reasons. historical for **RGB** not ,**BGR** as image the in reads OpenCV :
 RGB. to it change to want you if

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

PY

```
#
# 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

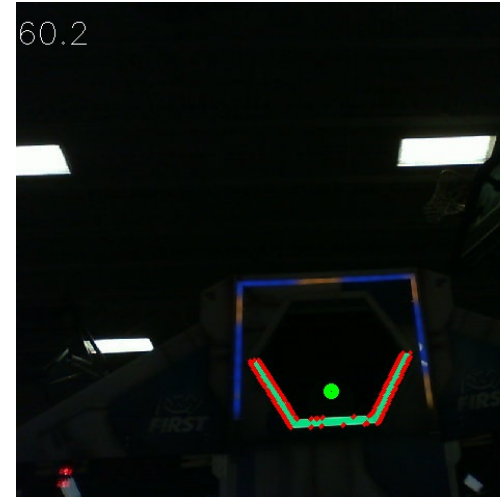


Image an Thresholding 25.2.8

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,

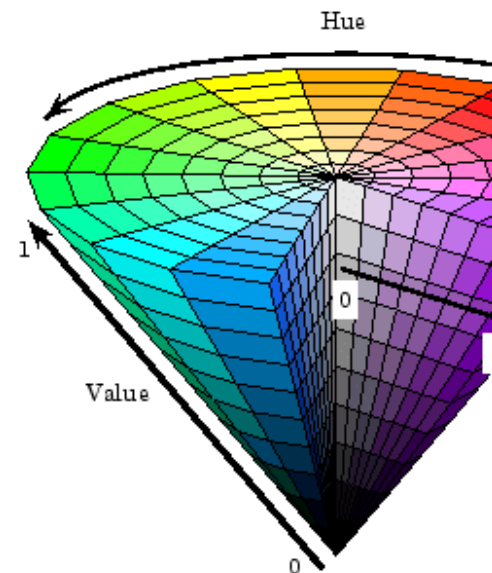
Model HSV The

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

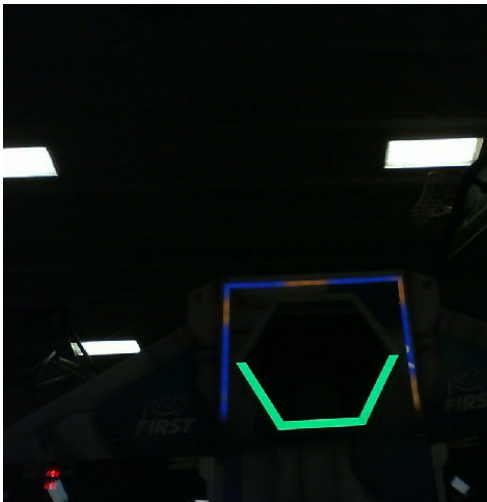
PY

```
COLOR_BGR2HSV) cv2.cvtColor(input_img, cv2.COLOR_BGR2HSV)
```

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

PY

```
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 25.2.9

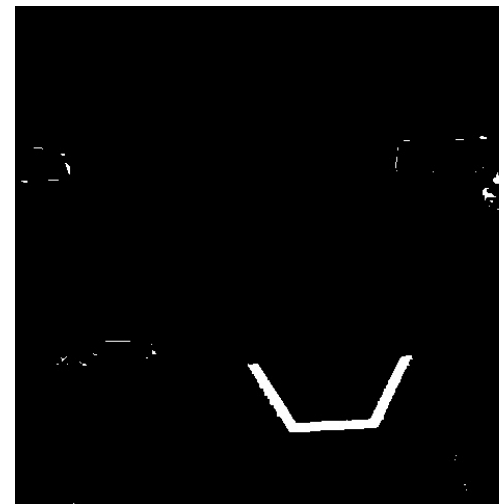
image. binary your in noise unwanted have you image, your thresholding after Sometimes,
image. the from noise that remove help can operations Morphological

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

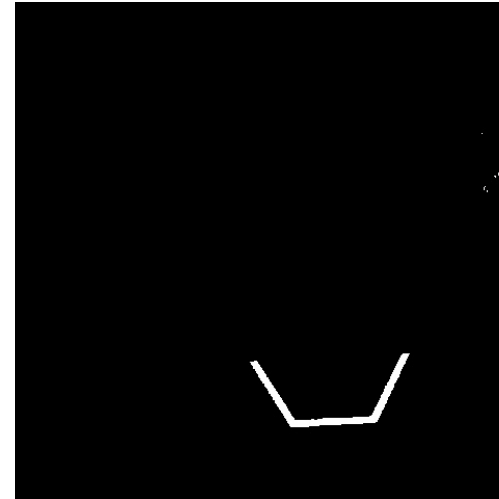


Erosion

of borders the from away takes It soil. on erosion to similar is vision computer in Erosion
background. the from noise remove can process This objects. foreground

PY

```
uint8) np ),3 ,ones((.np = kernel
)1 = iterations kernel, erode(binary_img, cv2 = binary_img
```



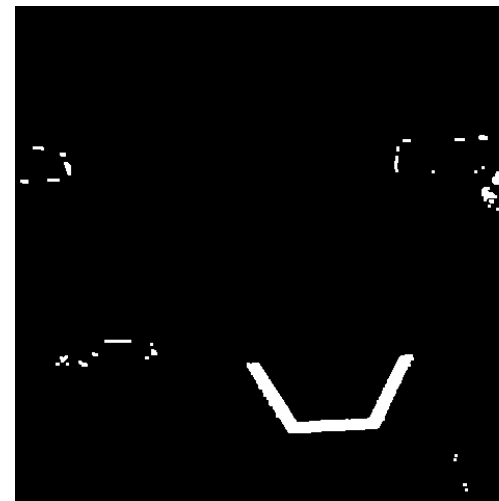
binary the by completely contained not are pixels kernel's superimposed the if erosion, During deleted. is on superimposed was it that pixel the pixels, image's

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

PY

```
uint8) np ),3 ,ones((.np = kernel
)1 = iterations kernel, dilate(binary_img, cv2 = binary_img
```



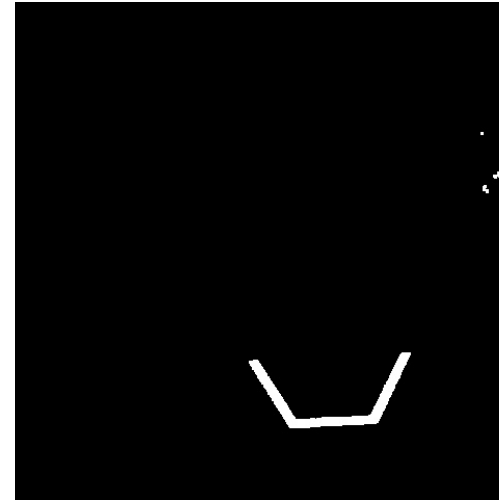
dilation. the in included is kernel superimposed every of pixel every dilation, During

Opening

the affecting without noise removes process This dilation. by followed erosion is Opening features. larger of shape

PY

```
uint8) np ),3 ,3ones((.np = kernel
kernel) MORPH_OPEN, cv2 morphologyEx(binary_img, cv2 = binary_img
```



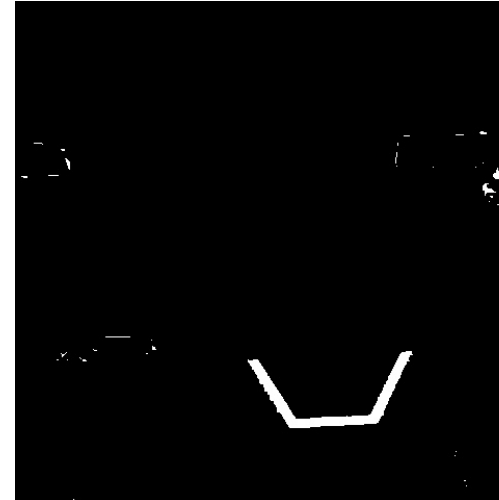
get to order in opening of iterations more do to appropriate is it case, specific this In :□□□□ right. top the in pixels the of rid

Closing

without breaks or holes small removes process This erosion. by followed dilation is Closing features. larger of shape the affecting

PY

```
uint8) np ),3 ,3ones((.np = kernel
kernel) MORPH_CLOSE, cv2 morphologyEx(binary_img, cv2 = binary_img
```



Contours with Working 25.2.10

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

PY

```
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

PY

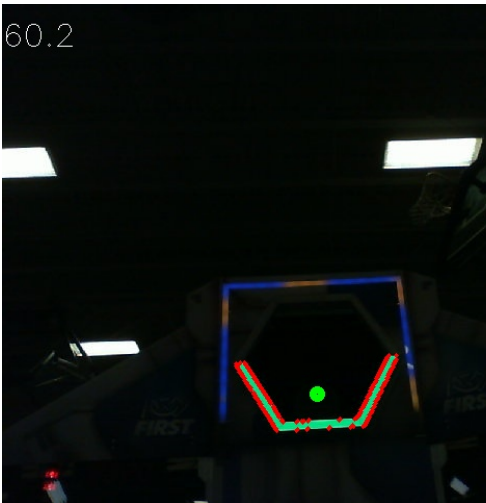
```

:0 > (contours)len if
]0contours[ = largest
contours: in contour for
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

PY

```
minAreaRect(contour).cv2 = rect
rect = _ , _ center,
center = center_y center_x,
```

Corners

PY

```
convexHull(contour).cv2 = corners
)True arcLength(contour), cv2 * 0.1 approxPolyDP(corners, cv2 = corners
```

Rotation

PY

```
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

PY

```
ntcore import
) 'vision'getTable( getDefault().NetworkTableInstance ntcore = nt
#
# here code Initialization #
#
:True while
#
# here code processing Image #
#
center_x) , 'center_x'putNumber( nt
center_y) , 'center_y'putNumber( nt
```

Example Vision Basic 25.2.11

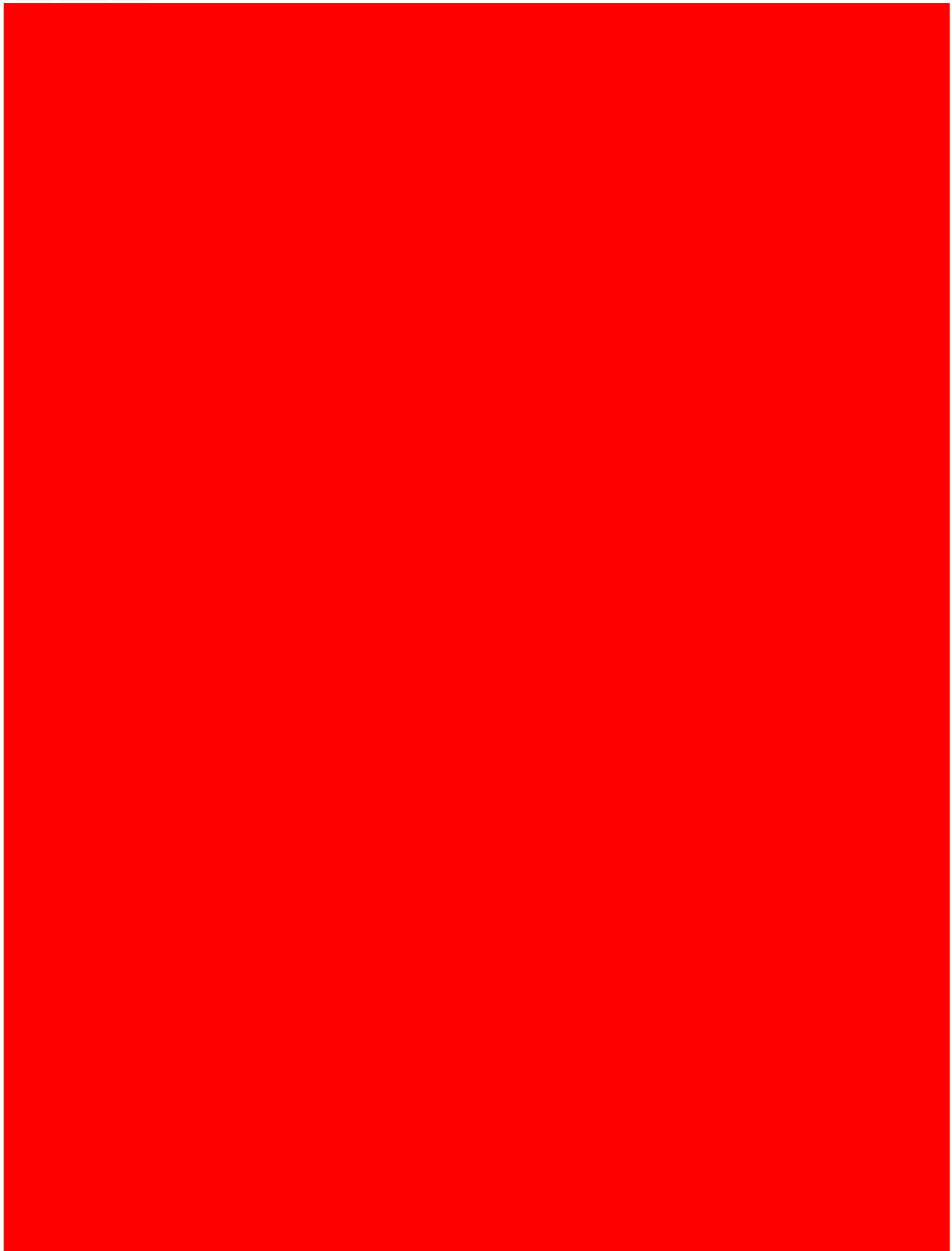
aiming the in location target's the posts that setup vision basic a of example an is This
a display to CameraServer uses and NetworkTables, to *here* described system coordinate
the of framerate the display will example This detected. contour the of rectangle bounding
CameraServer. to sent images the on code processing

PY

```
CameraServer import cscore from
ntcore import
cv2 import
json import
np as numpy import
time import
():main def
f: as )'boot/frc.json/'(open with
load(f).json = config
]0]['cameras'config[ = camera
] 'width'camera[ = width
] 'height'camera[ = height
getDefault() NetworkTableInstance ntcore = nt
```

page) next on (continues

(0000 0000 0000)



page) next on (continues

(0000 0000 0000)

```

))2 / (width / )2 / width - ]'append((center[ x_list
x_list) , 'target_x'putNumberArray( vision_nt
y_list) , 'target_y'putNumberArray( vision_nt

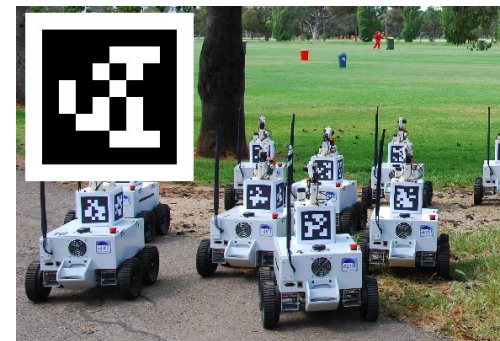
start_time - time() time = processing_time
processing_time / 1 = fps
FONT_HERSHEY_SIMPLEX, .cv2 ),40 ,0( )) ,1 (fps,round(str putText(output_img,.cv2
))255 ,255 ,255( ,1 ↵
putFrame(output_img).output_stream

main()

```

Introduction AprilTag 25.3

AprilTags? Are What 25.3.1

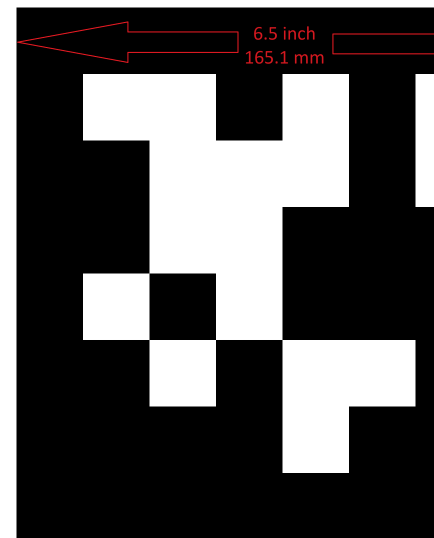


Michigan of University the at researchers by developed tags visual of system a are AprilTags applications. different many for localization accuracy high overhead, low provide to .website their on found be can creators its and system tag the about information Additional purposes. related robotics FIRST 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 36h11 the to updated was family tag the 2024, In 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 6x6 a of made is tags of family This 2024. for family 36h11 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 used. actually are 587 only tags, possible theoretical $2^{36} = 68,719,476,736$ are there While to: chosen are These identified). incorrectly color its has bit a where issues (IE, flips bit some against robust Be 1. tags. not are which things on found be to likely patterns geometric "simple" involve Not 2. etc.) stripes, squares, (IE, which out figure always can you that enough asymmetric is pattern geometric the Ensure 3. up. is way length. in inches 6.5 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

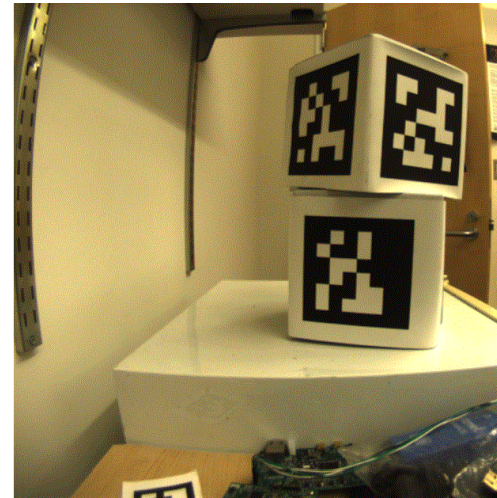
Support Software

.here located is AprilTags decodes and detects that code source the for repository main The include: These FRC. for features new add to repository the forked has WPILib Raspberry and roboRIO the including targets, FRC common for code source the Building 1. Pi. Java from functionality its invoking allow to support (JNI) Interface Native Java Adding 2. support publishing Maven & Gradle 3.

Technique Processing

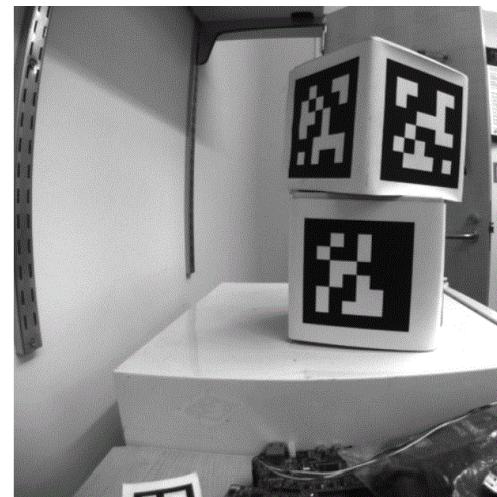
in AprilTags identify to code own their implement to have not should teams FRC most While
function. libraries underlying the how of basics the know to useful is it image, camera a

Image Original



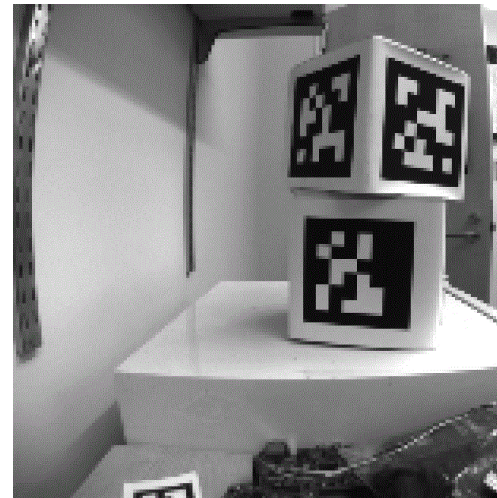
and color the to corresponding values, of array an simply is camera a from image An
pixel. each of brightness

Colors Remove



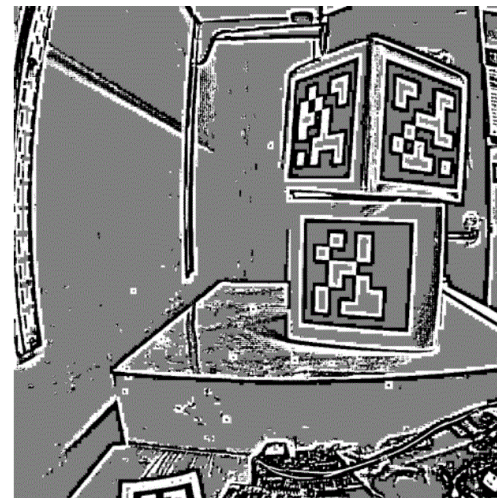
Color image. only)(brightness- scalegrey- a to image the convert to is step first The
tags. whiteand-black- the detect to needed not is information

Decimate



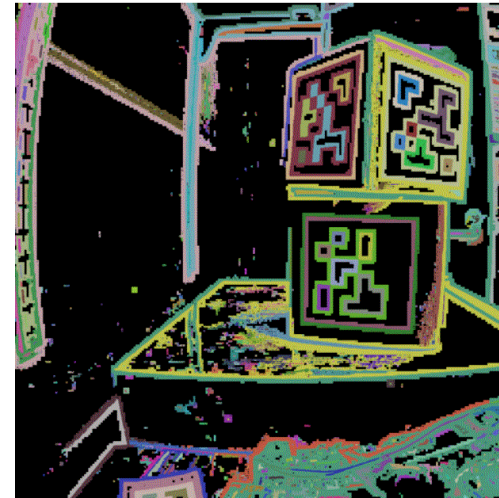
pixels fewer with Working resolution. lower a to image the convert to is step next The
early refine to later used be will image resolutionfull- The faster. work algorithm the helps
estimates.

Threshold Adaptive



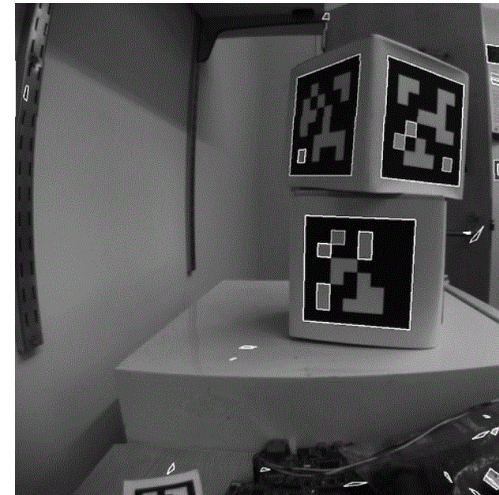
"definitely light", "definitely as pixel each classify to run is algorithm threshold adaptive An
sure". "not or dark",
small a to compared brightness, pixel's the at looking by calculated is threshold The
it. around pixels of neighborhood

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

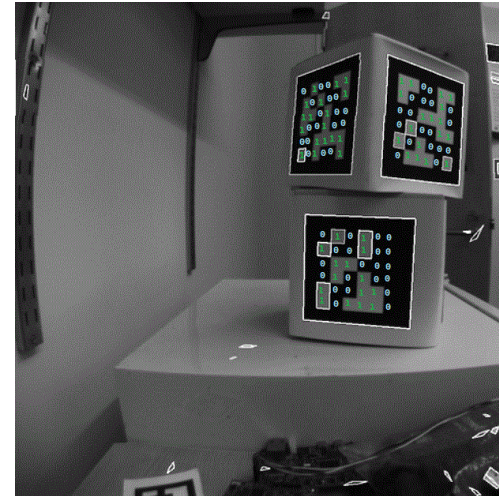
Detection Quad



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 quadrilaterals, 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

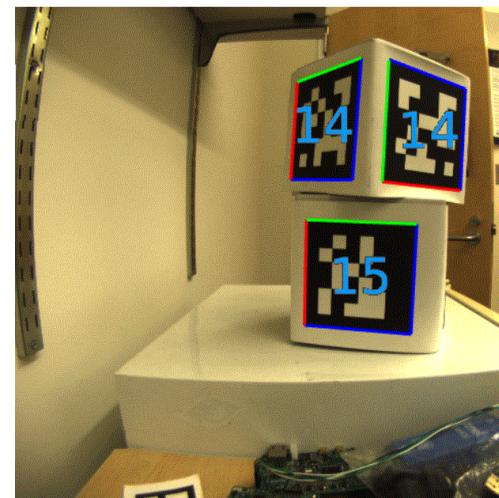


we AprilTag, valid a be to believe we which pixels of regions more or one have we that Now
 light of pattern the "decoding" by done is This at. looking are we tag which identify to need
 inside. the on squares dark and

- Calculate the coordinates of each pixel in the center of the image
- Mark each location by "0" or "1" comparing the pixel intensity to a threshold
- Find the tag ID which most closely matches what was seen in the image, allowing for one or two bit errors.

It is possible that no valid tag ID matches the suspect tags in this case, the decoding process stops.

Quad External Fit



Now we have a tag ID for the region of pixels we need to do something useful with it. For most FRC applications, we care about the precise location of the corners of the tag. In cases where we expect lower resolution operation, we did not expect the operation to be precise, but in the center of the tag, it is precise.

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

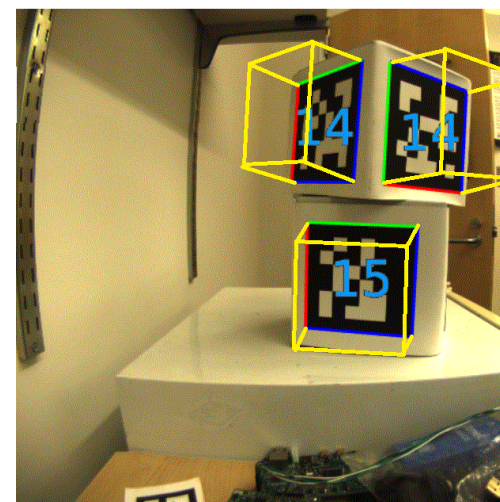
Usage

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



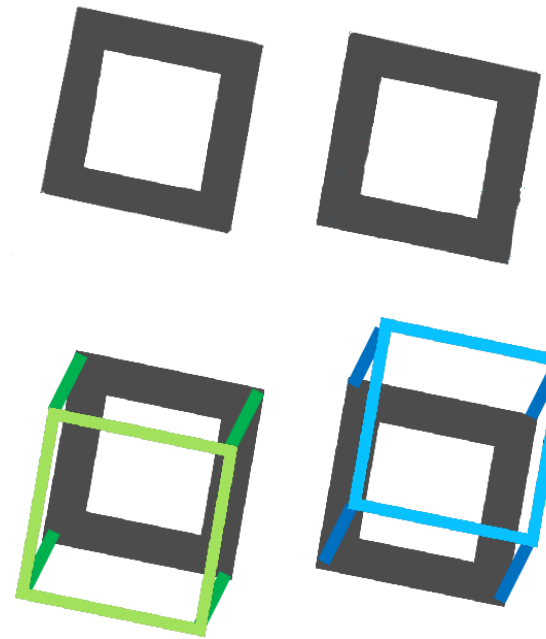
pose perform help to locations corner their use to is AprilTags of usage advanced more A
.estimation

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:



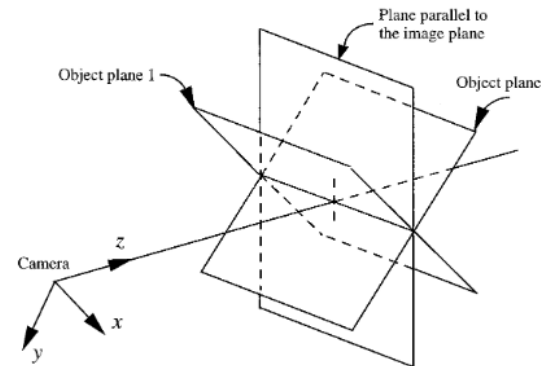
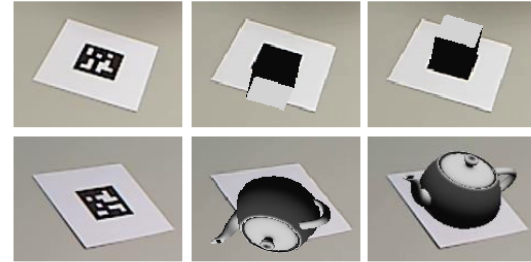


FIG. 4. Two object poses giving the same image under the SOP approximation.

ways: different few a in done be can "correct" is position which Resolving
 expect you where to closest pose the pick to sensors all from history *odometry* your Use 1.
 be. to robot the
 air) the in up or perimeter, field the outside (ex: unlikely very are which poses Reject 2.
 differentiate) to hard (and together close very are which estimates pose Ignore 3.
 can camera one least at that such target, same the at look to cameras multiple Use 4.
 estimate pose good a generate
 Discard estimates. pose multiple generate to each using once, at targets many at Look 5.
 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

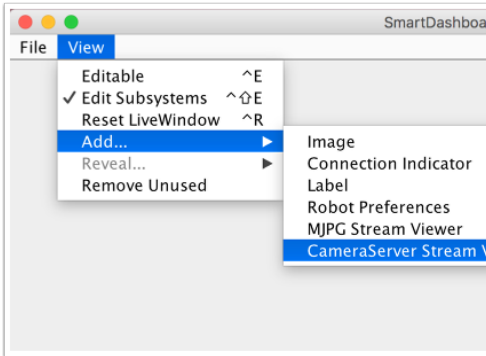
- v1 AprilTags •
- v2 AprilTags •
- v3 AprilTags •
- Ambiguity Pose •

RoboRIO the on Vision 25.4

roboRIO the on CameraServer the Using 25.4.1

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

```

page) next on (continues

(0000 0000 0000)

```

    ();//startAutomaticCapture CameraServer.
    }
}

```

18
19
20
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
    }
}

```

PYTHON

```

wpilib import
CameraServer import cameraserver.wpilib from

TimedRobot):.(wpilibMyRobot class
"""
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
"""

```

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10
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.

```

;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
                        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 //

```

page) next on (continues

(0000 00000 0000)

```
(mat);putFrameoutputStream.
    }
    );};
    );true(setDaemonm_visionThread.
        ());startm_visionThread.
    }
}
```

59
60
61
62
63
64
65

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 ,640 camera.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 //
                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 //
```

page) next on (continues

(0000 0000 0000)

```

),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#

```

PYTHON

C++/Java. from different slightly is Python using when roboRIO the on processing Image a in code processing image the launch to need we thread, separate a using of Instead process. separate completely

Global Python the of because and task, intensive CPU a is processing Image :000000
robot your in directly cscore using recommend NOT do we (GIL) Lock Interpreter
 Really. it. do Don't .**process**

following the read to wish may you effects, its and GIL the on information more For
 resources:

Lock Interpreter Global Wiki: Python
 Python with Cores Multiple Exploiting Efficiently

efficiently to follow must code processing image your that rules of number a introduces This
 RoboRIO: the on run safely and

- file own its in be must code processing image Your •
- memory waste just will it code, robot your from package cscore the import Never •
- file processing image your from packages hal or wpilib the import Never •
- perform to wish you If exits. program robot.py the when killed be will code camera The •
- handler. atexit an register should you cleanup,

happens, this If RoboRIO. the on programs two from imported be not may wpilib :000000
 program. first the kill to attempt will program second the

process: processing image the launch to contain to needs robot.py your what Here's

```

wpiLib import
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10
    TimedRobot): (wpiLibMyRobot class
    """
    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
    """

```

in function run the call and vision.py launch to says function launch("vision.py") The
:vision.py in is what Here's file. that

```

here, robot the access cannot we so process, own its in runs code This NOTE: #
objects wpiLib create/use/see we can nor #
#
you installed), robotpy-cscore have you (if locally out code this try To #
`vision.py:main cscore m- python3` execute can #
#
7
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36
37
38
39
40
    cv2 import
    np as numpy import
    CS as CameraServer import cscore from
    enableLogging() CS
    CameraServer from UsbCamera the Get #
    startAutomaticCapture() CS = camera
    resolution the Set #
    )480 ,640 setResolution(.camera
    camera the from images capture will This CvSink. a Get #
    getVideo() CS = cvSink
    Dashboard the to back images send will This CvSource. a Setup #
    )480 ,640 ,"Rectangle"putVideo(.CS = outputStream
    preallocate to try always expensive, very is images new Allocating #
    uint8) np dtype ),3 ,640 ,480(-zeros(shape np = mat
    :True while
    it put and camera the from frame a grab to CvSink the Tell #
    output. the notify error an is there If image. source the in #
    grabFrame(mat) cvSink = mat time,
    :0 == time if
    error. the output the Send #
    getError().notifyError(cvSink outputStream
    iteration current the of rest the skip #
    continue
    image the on rectangle a Put #

```

page) next on (continues

(0000 0000 0000)

```

)5 ),255 ,255 ,255( ),400 ,400( ),100 ,100( rectangle(mat,.cv2

```

```

display to image new a stream output the Give #
putFrame(mat).outputStream

```

41
42
43
44

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 25.4.2

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
    );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());
        }
    }
}

```

PYTHON

```

contents: robot.py

        wpilib import
NetworkTableInstance import ntcore from

        TimedRobot): (wpilibMyRobot class
        ):self(robotInit def
        )Joystick( wpilib = joy1.self
.)""getTable().getDefault().NetworkTableInstance = cameraSelection.self
        )"CameraSelection"getEntry( ↵
        )"vision.py:main"launch(.CameraServer.wpilib

        ):self(teleopPeriodic def
        getTriggerPressed():.joy1.self if
        )"2 camera Setting"(print
        )"1 Camera USB"setString(.cameraSelection.self
        getTriggerReleased():.joy1.self elif
        )"1 camera Setting"(print
        )"0 Camera USB"setString(.cameraSelection.self

contents: vision.py

CameraServer import cscore from

        ():main def
enableLogging() CameraServer

```

page) next on (continues

(0000 00000 0000)

```

)0startAutomaticCapture( CameraServer = camera1
)1startAutomaticCapture( CameraServer = camera2

waitForever() CameraServer

```

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
);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);
}
}

```

page) next on (continues

(0000 0000 0000)

```
{ prevTrigger) && joy1.GetTrigger()!( if else }
endl;::std << "1 Camera Setting" << cout::std
server.SetSource(camera1);
}
joy1.GetTrigger(); = prevTrigger
}
```

PYTHON

*you Python, in possible t'isn joystick via directly source the Setting #
instead above shown as NetworkTables use should #*

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

@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
    }; joy1{ Joystick::frc
        ; false = prevTrigger bool
        { override () RobotInit void
    }; 0 StartAutomaticCapture(::CameraServer::frc = camera1
    ); 1 StartAutomaticCapture(::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
    }

```

PYTHON

contents: robot.py

```

        wpilib import
        NetworkTableInstance import ntcore from
        TimedRobot): (wpilib MyRobot class
        ): self(robotInit def
        ) joy1{ wpilib = joy1 self
        .)""getTable(.getDefault().NetworkTableInstance = cameraSelection.self
        )"CameraSelection"getEntry( →
        )"vision.py:main"launch(.CameraServer.wpilib
        ): self(teleopPeriodic def
        getTriggerPressed(): .joy1.self if
        )"2 camera Setting"(print
        )"1 Camera USB"setString(.cameraSelection.self
        getTriggerReleased(): .joy1.self elif
        )"1 camera Setting"(print
        )"0 Camera USB"setString(.cameraSelection.self

```

contents: vision.py

```

VideoSource CameraServer, import cscore from
() : main def

```

page) next on (continues

(0000 00000 0000)

```

enableLogging() CameraServer

)0startAutomaticCapture( CameraServer = camera1
)1startAutomaticCapture( CameraServer = camera2

kConnectionKeepOpen) ConnectionStrategy setConnectionStrategy(VideoSource camera1
kConnectionKeepOpen) ConnectionStrategy setConnectionStrategy(VideoSource camera2

waitForEver() CameraServer

```

higher with limitations bandwidth USB into run may you USB, are cameras both If :0000
 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:

```

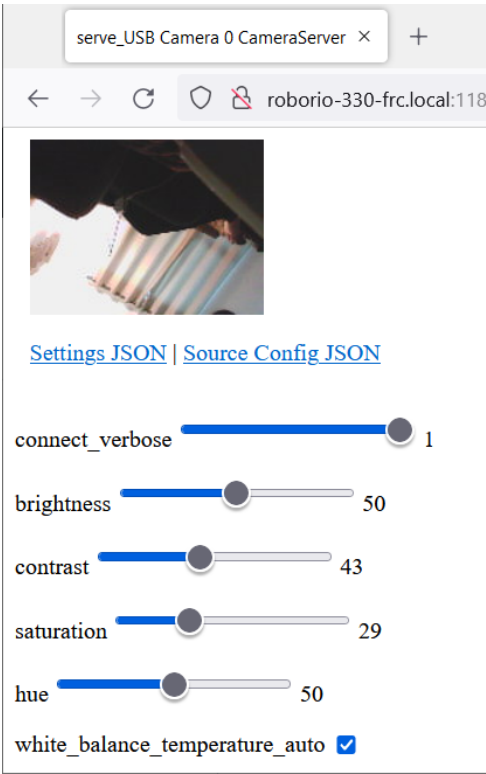
just should you Thus .RobotInit() during error this you give will it 3 Option using you're If
 and error that get don't both you until necessary as adjusting and resolution desired your try
 limitations. bandwidth radio the exceed don't

Interface Web CameraServer 25.4.3

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 :0000
 .1182 with above 1181 replace the cameras, two have you if so

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

serve_USB Camera 0 CameraServer × +

← → ↻ 🛡️ 🌐 roborio-330-frc.local:118

Supported Video Modes:

Pixel Format	Width	Height	FPS
YUYV	640	480	30
YUYV	640	480	15
YUYV	352	288	30
YUYV	352	288	15
YUYV	320	240	30
YUYV	320	240	15
YUYV	176	144	30
YUYV	176	144	15
YUYV	160	120	30
YUYV	160	120	15
YUYV	544	288	30
YUYV	544	288	15
YUYV	432	240	30
YUYV	432	240	15
YUYV	320	176	30
YUYV	320	176	15
YUYV	640	360	30
YUYV	640	360	15
MJPEG	640	480	30
MJPEG	640	480	15
MJPEG	352	288	30

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

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*

26.1 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 basedbasedcommand- 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  
)); <Forward.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 26.1.1

complexity internal the "hide" to users allow Subsystems time. same the at subsystem given the of rest the simplifies both this - code their of rest the from hardware actual their of without hardware subsystem's a of details internal the to changes allows and code, robot code. robot the of rest the changing also

Run Are Commands How 26.1.2

.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 26.1.3

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 26.2

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(class Command the by library based

Command a of Structure The 26.2.1

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 26.2.2

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 command most of list parameter the of end the at parameter (C++) struct `Requirements` / library: the in factories and constructors

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 Command
);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

getInterruptBehavior

another if happens what defines)C++ ,Java(method getInterruptBehavior() 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 getInterruptBehavior
.getInterruptBehavior 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 getInterruptBehavior the overriding by either set be can property This

JAVA

```
intake). (intake::activate,runCommands. = noninterruptible Command
);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 26.2.3

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 Command public
            `this` require implicitly //
            (kForward));setm_hatchSolenoid. >- (()runOnce.this return
        }

        */ hatch. the Releases */
        { ()releaseHatchCommand Command 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, //
(arcadeDrive m_robotDrive. >- RunCommand(() new
    (),getLeftY driverController. -
    ()),getRightX driverController.
    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(
            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(shooterSpeed m_shooter. >- ()
command the of end the at flywheel the Stop //
    ),0.6(shooterSpeed m_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,arcadeDrive m_robotDrive. >- ()
        command the of end the at driving Stop //
        ),0 ,0(arcadeDrive m_robotDrive. >- interrupted
        value desired the exceeds distance driven s'robot the when command the End //
        kAutoDriveDistanceInches, => ()getAverageEncoderDistance m_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[
        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.(WaitCommand( new
```

C++

```
scheduled being after seconds 5 Ends //
    s)_5.(WaitCommand(: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 26.2.4

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 *CRTF* 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

or)java(class Command abstract the subclass class, command custom a write To):C++ ,java(template basedcommand- the in seen as),C++(CommandHelper

JAVA

```

;edu.wpi.first.wpilibj.templates.commandbased.subsystems.ExampleSubsystem import
;edu.wpi.first.wpilibj2.command.Command import

/* subsystem. example an uses that command example An */
{ Command 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/Command.h>< include#
frc2/command/CommandHelper.h>< include#
subsystems/ExampleSubsystem.h" include#
*/

```

page) next on (continues

(0000 00000 0000)

```

subsystem. example an uses that command example An *
Command 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 Command,::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
;}
```

Example Command Simple 26.2.5

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. import
;HatchSubsystem
;edu.wpi.first.wpilibj2.command.Command import
**/
_HatchSubsystem}. @link{ the with hatch a grabs that command simple A *
for explicitly Written
simple this command a inline should code Actual purposes. pedagogical *
@link{ with
edu.wpi.first.wpilibj2.command.InstantCommand}. *
*/
{ Command extends GrabHatch class public
on runs command the subsystem The //
m_hatchSubsystem; HatchSubsystem final private
{ subsystem) (HatchSubsystemGrabHatch public
subsystem; = m_hatchSubsystem
addRequirements(m_hatchSubsystem);
}
@Override
{ ()initialize void public
();grabHatchm_hatchSubsystem.
}
```

page) next on (continues

() () ()

```

        @Override
        { ()isFinished boolean public
            ;true return
        }
    }
}

```

(Header) C++

```

        once pragma#
        frc2/command/Command.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 Command,::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
        }
        { 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
5
6
edu.wpi.first.wpilibj.examples.hatchbottraditional.subsystems. import
7
;DriveSubsystem
8
;edu.wpi.first.wpilibj2.command.Command import
9
;java.util.function.DoubleSupplier import
10
11
/**
12
  @link{ as in (passed input joystick with robot the drive to command A *
    Written DoubleSupplier}s).
13
  @command a inline should code actual - purposes pedagogical for explicitly *
    @link{ with simple this
14
    edu.wpi.first.wpilibj2.command.RunCommand}. *
15
  */
16
{ Command extends DefaultDrive class public
17
  m_drive; DriveSubsystem final private
18
  m_forward; DoubleSupplier final private
19
  m_rotation; DoubleSupplier final private
20
21
  /**
22
    DefaultDrive. new a Creates *
23
    *
24
    on. run wil command this subsystem drive The subsystem @param *
25
    forwards/backwards driving for input control The forward @param *
26
    turning for input control The rotation @param *
27
  */
28
  @forward, DoubleSupplier subsystem, (DriveSubsystemDefaultDrive public
    { rotation) DoubleSupplier
29
    subsystem; = m_drive
30
    forward; = m_forward
31
    rotation; = m_rotation
32
    addRequirements(m_drive);
33
  }
34
35
  @Override
36
  { ()execute void public
37
    ();getAsDoublem_rotation. (),getAsDouble(m_forward.arcadeDrivem_drive.
38
  }
39
  }

```

(Header) C++

```

once pragma# 5
functional>< include# 6
frc2/command/Command.h>< include# 7
frc2/command/CommandHelper.h>< include# 8
subsystems/DriveSubsystem.h" include# 9
*/ 10
through in passed input joystick with robot the drive to command A * 11
lambdas. 12
a inline should code actual - purposes pedagogical for explicitly Written * 13
RunCommand. with simple this command * 14
RunCommand @see * 15
*/ 16
>DefaultDrive Command, ::frc2<CommandHelper::frc2 public : DefaultDrive class 17
{ 18
:public 19
*/ 20
DefaultDrive. new a Creates * 21
on. run wil command this subsystem drive The subsystem @param * 22
forwards/backwards driving for input control The forward @param * 23
turning for input control The rotation @param * 24
*/ 25
forward, >()double<function::std subsystem, *DefaultDrive(DriveSubsystem 26
rotation); >()double<function::std 27
;override ()Execute void 28
:private 29
m_drive; *DriveSubsystem 30
m_forward; >()double<function::std 31
m_rotation; >()double<function::std 32
;} 33

```

(Source) C++

```

commands/DefaultDrive.h" include# 5
utility>< include# 6
subsystem, *DefaultDrive(DriveSubsystem :DefaultDrive 7
forward, >()double<function::std 8
rotation) >()double<function::std 9
m_drive{subsystem}, : 10
move(forward)}, :m_forward{std 11
{ move(rotation)}:m_rotation{std 12
AddRequirements(subsystem); 13
} 14
15
16
17

```

page) next on (continues

(0000 0000 0000)

```

        { Execute(): DefaultDrive void
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}));&{

```

52
53
54
55
56
57
58

Compositions Command 26.3

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

extend they - commands themselves are compositions command however, importantly, Most *recursive* a as composed further be to compositions command allows This class. Command the as compositions command other contain may composition command a is, that - *composition* expressions: inline concise and powerful very allows This components.

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 members composition because is This program. user the crash and exception an throw will those if occur could errors and composition, command encapsulating their through run are composition the as time same the at scheduled independently were instances command same with up end could thus and once, at places multiple from run being be would command the - C++ The behavior. diagnoseto-hard- and unexpected causing state, internal inconsistent

of type this so semantics, only move- with class a ,CommandPtr uses library based command- avoid. to easier is mistake

Types Composition 26.3.1

be can them of All types. composition various includes library based command- 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).andThen(fooCommand);
```

C++

```
move(barCommand)) : move(fooCommand).AndThen(std::move
```

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

```
all with seconds three after ends that composition command parallel a be Will //  
duration. full their running commands three →  
threeSecCommand)); oneSecCommand, (twoSecCommand,parallel(Commands.onTruebutton.  
and two the with second one after ends that composition race parallel a be Will //  
interrupted. getting commands second three →  
threeSecCommand)); oneSecCommand, (twoSecCommand,race(Commands.onTruebutton.  
deadline) (the seconds two after ends that composition deadline parallel a be Will //  
already command second (one interrupted getting command second three the with →  
finished). →  
threeSecCommand)); oneSecCommand, (twoSecCommand,deadline(Commands.onTruebutton.
```

C++

```

    all with seconds three after ends that composition command parallel a be Will //
    duration. full their running commands three →
    move(oneSecCommand),::std move(twoSecCommand),::Parallel(std::cmd::button.OnTrue(frc2
    move(threeSecCommand)));::std →

    and two the with second one after ends that composition race parallel a be Will //
    interrupted. getting commands second three →
    move(oneSecCommand),::std move(twoSecCommand),::Race(std::cmd::button.OnTrue(frc2
    move(threeSecCommand)));::std →

    deadline) (the seconds two after ends that composition deadline parallel a be Will //
    already command second (one interrupted getting command second three the with →
    finished). →
    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 //
    ));(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,
        double...) boolean, //
        = m_exampleSelectCommand Command final private
        (><SelectCommand new
        commands to values selector Maps //
        (ofEntriesMap.

```

page) next on (continues

(0000 0000 0000)

```

        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
SendableChooser with used be may selector command how of example An //
        m_chooser; >CommandSelector<SendableChooser::frc
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
    ,} m_chooser.GetSelected(); 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

are and composition, command the through run are members composition default, By to added are requirements their Accordingly, scheduler. the by seen themselves never undesirable is it sometimes fine, usually is this While requirements. composition's the A command. single a of requirements the gain to composition command entire the for command that schedule and composition command the from off" "fork to is solution good the and composition the between synchronization requires this However, separately. command. scheduledindividually-

),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 without progress command's the track to composition the allows this composition, command composition. the in being it

and requirements compoments« their of union the inherit compositions Command intakes that)C++ ,Java(SequentialCommandGroup a Therefore, immutable. are requirements subsystems three all reserve would it shoots and shooter, a aims it, indexes piece, game a other performing from subsystems those of any precluding shooter), and indexer, intake, (the be only should that subsystems the desired, not is this If "downtime". their in operations their have should it by used being actively are they while composition the for reserved proxied. commands

there and doing are you what of sure are you unless ProxyCommand use not Do : escape an as use for intended only is Proxying need! your accomplish to way other no is unions. requirement composition command from hatch

that leaking not despite subsystem, their require still commands proxied Because : be must subsystem given a require that commands the of all composition, the to requirement requirement its scheduled is command proxied the when Otherwise, is. them of one if proxied composition. the canceling composition, the of that with conflict will

JAVA

```

its during reserved still intake shooter, and indexer are requirements composition //
afterwards not but command →
(sequenceCommands.
another intake intake the let to want we // (),asProxy().intakeGamePieceintake.
one this processing are we while piece game →
(),processGamePieceindexer.
()aimAndShootshooter.
);

```

C++

```

its during reserved still intake shooter, and indexer are requirements composition //
afterwards not but command →
Sequence(::cmd::frc2
another intake intake the let to want we // intake.IntakeGamePiece().AsProxy(),
one this processing are we while piece game →
indexer.ProcessGamePiece(),
shooter.AimAndShoot()
);

```

)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 26.3.2

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 :
    :public
    */
    ComplexAuto. new a Creates *

```

page) next on (continues

(C++ Source Code)

```

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 26.4

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 'sCommandScheduler 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 26.4.1

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

```

import edu.wpi.first.wpilibj2.command.Command;
import edu.wpi.first.wpilibj2.command.SubsystemBase;

public class ExampleSubsystem extends SubsystemBase {
    /**
     * ExampleSubsystem. new a Creates
     */
    public ExampleSubsystem() {
        // ExampleSubsystem constructor
    }

    /**
     * method. factory command Example
     */
    public Command exampleMethodCommand() {
        // here. goes command of construction
        // subsystem. 'this' requires implicitly Subsystem::RunOnce
        return new ExampleMethodCommand(this);
    }

    /**
     * a example, (for subsystem the of state boolean a querying method example An
     * sensor). digital
     */
    public boolean exampleCondition() {
        // sensor. digital a as such state, subsystem boolean some of value
        //
        return false;
    }

    @Override
    public void periodic() {
        // run scheduler per once called be will method This
    }

    @Override
    public void simulationPeriodic() {
        // simulation during run scheduler per once called be will method This
    }
}

```

```

once pragma#
5
6
7 frc2/command/CommandPtr.h>< include#
8 frc2/command/SubsystemBase.h>< include#
9
10 { SubsystemBase:frc2 public : ExampleSubsystem class
11     :public
12     ExampleSubsystem();
13
14     /**
15     method. factory command Example *
16     */
17     ();ExampleMethodCommand CommandPtr:frc2
18
19     /**
20     a example, (for subsystem the of state boolean a querying method example An *
21     sensor). digital *
22     *
23     sensor. digital a as such state, subsystem boolean some of value @return *
24     */
25     ();ExampleCondition bool
26
27     /**
28     runs. CommandScheduler the whenever periodically called be Will *
29     */
30     ;override ()Periodic void
31
32     /**
33     during runs CommandScheduler the whenever periodically called be Will *
34     simulation. *
35     */
36     ;override ()SimulationPeriodic void
37
38     :private
39     be generally should sensors) and controllers motor (e.g. Components //
40     methods. public through only exposed and private declared //
41     ;}

```

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 26.4.2

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
            ,CTREPCM PneumaticsModuleType.
            ,]0[kHatchSolenoidPorts HatchConstants.
            );]1[kHatchSolenoidPorts HatchConstants.

        */ 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# 5
6
frc/DoubleSolenoid.h>< include# 7
frc/PneumaticsControlModule.h>< include# 8
frc2/command/SubsystemBase.h>< include# 9
10
Constants.h" include# 11
12
{ SubsystemBase: frc2 public : HatchSubsystem class 13
:public 14
HatchSubsystem(); 15
16
here. go methods Subsystem // 17
18
**/ 19
hatch. the Grabs * 20
*/ 21
();GrabHatch void 22
23
**/ 24
hatch. the Releases * 25
*/ 26
();ReleaseHatch void 27
28
;override builder) &SendableBuilder::(wpiInitSendable void 29
30
:private 31
be generally should sensors) and controllers motor (e.g. Components // 32
methods. public through only exposed and private declared // 33
m_hatchSolenoid; DoubleSolenoid: frc 34
}; 35

```

(Source) C++

```

subsystems/HatchSubsystem.h" include# 5
6
wpi/sendable/SendableBuilder.h>< include# 7
8
;HatchConstants namespace using 9
10
HatchSubsystem()::HatchSubsystem 11
CTREPCM,::PneumaticsModuleType: m_hatchSolenoid{frc : 12
}{ }kHatchSolenoidPorts[ ],0kHatchSolenoidPorts[ 13
14
{ GrabHatch()::HatchSubsystem void 15
kForward);::DoubleSolenoid: m_hatchSolenoid.Set(frc 16
} 17
18
{ ReleaseHatch()::HatchSubsystem void 19
kReverse);::DoubleSolenoid: m_hatchSolenoid.Set(frc 20
} 21
22
{ builder) &SendableBuilder::InitSendable(wpi::HatchSubsystem void 23

```

page) next on (continues

(0000 00000 0000)

```

        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 it. with change to having subsystem the of outside code the of any without

can we commands, from called are that methods public void writing of instead Alternatively, from following the Consider command. a return that factories as methods public the define):C++ ,Java(project example HatchBotInlined the

Java

```

;edu.wpi.first.wpilibj.examples.hatchbotinlined.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.hatchbotinlined.Constants.HatchConstants import
;edu.wpi.first.wpilibj2.command.Command import
;edu.wpi.first.wpilibj2.command.SubsystemBase import

edu.wpi.first.wpilibj. @link{ single a by actuated mechanism hatch A **/
    /* DoubleSolenoid}.
{ SubsystemBase extends HatchSubsystem class public
    = m_hatchSolenoid DoubleSolenoid final private
        DoubleSolenoid( new
            ,CTREPCM PneumaticsModuleType.
            ,10[kHatchSolenoidPortsHatchConstants.
            );1[kHatchSolenoidPortsHatchConstants.

        /* hatch. the Grabs */
        { ()grabHatchCommand Command public
            `this` require implicitly //
            (kForward));setm_hatchSolenoid. >- (()runOnce.this return
        }

        /* hatch. the Releases */
        { ()releaseHatchCommand Command public
            `this` require implicitly //
            (kReverse));setm_hatchSolenoid. >- (()runOnce.this return
    }

```

page) next on (continues

(0000 00000 0000)

```

    }
    35
    36
    @Override
    37
    { builder) (SendableBuilderinitSendable void public
    38
    (builder);initSendable.super
    39
    telemetry. to state solenoid the Publish //
    40
    kForward, == ()getm_hatchSolenoid. >- () ,"extended"(addBooleanPropertybuilder.
    41
    );null
    42
    }
    43
    }

```

(Header) C++

```

    once pragma#
    5
    6
    frc/DoubleSolenoid.h>< include#
    7
    frc/PneumaticsControlModule.h>< include#
    8
    frc2/command/CommandPtr.h>< include#
    9
    frc2/command/SubsystemBase.h>< include#
    10
    Constants.h" include#
    11
    12
    { SubsystemBase::frc2 public : HatchSubsystem class
    13
    :public
    14
    HatchSubsystem();
    15
    16
    here. go methods Subsystem //
    17
    18
    19
    20
    /**
    21
    hatch. the Grabs *
    22
    */
    23
    ();GrabHatchCommand CommandPtr: frc2
    24
    25
    26
    hatch. the Releases *
    27
    */
    28
    ();ReleaseHatchCommand CommandPtr: frc2
    29
    ;override builder) &SendableBuilder::(wpiInitSendable void
    30
    31
    :private
    32
    be generally should sensors) and controllers motor (e.g. Components //
    33
    methods. public through only exposed and private declared //
    34
    m_hatchSolenoid; DoubleSolenoid: frc
    35
    ;}
    36

```


(Source) C++

```

subsystems/HatchSubsystem.h" include#
6
wpi/sendable/SendableBuilder.h>< include#
7
;HatchConstants namespace using
8
9
HatchSubsystem()::HatchSubsystem
10
CTREPCM,::PneumaticsModuleType::m_hatchSolenoid{frc :
11
}{ }kHatchSolenoidPorts[ ],@kHatchSolenoidPorts[
12
13
{ GrabHatchCommand()::HatchSubsystem CommandPtr::frc2
14
    'this' require implicitly //
15
    RunOnce(>-this return
16
);} kForward);::DoubleSolenoid::m_hatchSolenoid.Set(frc { }this[
17
18
}
19
20
{ ReleaseHatchCommand()::HatchSubsystem CommandPtr::frc2
21
    'this' require implicitly //
22
    RunOnce(>-this return
23
);} kReverse);::DoubleSolenoid::m_hatchSolenoid.Set(frc { }this[
24
25
}
26
{ builder) &SendableBuilder::InitSendable(wpi::HatchSubsystem void
27
    InitSendable(builder);::SubsystemBase
28
29
telemetry. to state solenoid the Publish //
30
    builder.AddBooleanProperty(
31
        ,"extended"
32
    ,} kForward;:: DoubleSolenoid::frc == m_hatchSolenoid.Get() return { }this[
33
        );nullptr
34
    }
35

```

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 26.4.3

(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

```
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

26.5 קישור Commands ל-Triggers

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 26.5.1

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 *classes HID regular* 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 26.5.2

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.
```

52
53

C++

```
pressed. is button 'A' the when horizontal above radians 2 to arm the Move //
    rad));_m_driverController.A().OnTrue(m_arm.SetArmGoalCommand(
```

25
26

.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.
```

114
115
116

C++

```
speed half at drive button, shoulder the holding While //
    m_driverController,&JoystickButton(:frc2
kRightBumper):Button:XboxController:frc
    m_drive).ToPtr());&WhileTrue(HalveDriveSpeed(.
```

75
76
77
78

.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.toggleOnTrue myButton.  
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 26.5.3

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 26.5.4

,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 26.5.5

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 //
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 26.6

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 26.6.1

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 //
     * 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}
    @Override
    { ()autonomousInit void public
        ();getAutonomousCommandm_robotContainer. = m_autonomousCommand
        (example) command autonomous the schedule //
        { )null !=! (m_autonomousCommand if
    }

```

page) next on (continues

(0000 0000 0000)

```

        ();schedulem_autonomousCommand.
    }
}

```

63
64
65

(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
        }
    }
}

```

33
34
35
36
37
38
39
40
41
42
43

the by returned command autonomous an schedules method autonomousInit() The can run to command autonomous which selecting for logic The instance. RobotContainer .RobotContainer of inside handled be

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.
        }
    }
}

```

71
72
73
74
75
76
77
78
79
80

(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
        }
    }
}

```

46
47
48
49
50
51
52
53
54

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 26.6.2

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
```

23

(Header) C++

```
m_subsystem; ExampleSubsystem
```

32

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
```

61

(Source) C++

```
m_subsystem);ExampleAuto(:autos return
```

34

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 →
        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 26.6.3

file header a simply but class, a not is this C++ (in) (Header) C++ ,Java(class Constants The (such constants robot accessible globally- 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 26.6.4

package/directory. this in go should subsystems definedUser-

Commands 26.6.5

package/directory. this in go should commands definedUser-

Projects Robot BasedCommand- Organizing 26.7

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 robot unrelated many for logic the putting example: simplified a For logic. underlying the of 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 26.7.1

does it ability—but competitive team’s a break or make rarely will organization code Good programmers. happier and code, looking nicer- 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 designed well- 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 26.7.2

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}));&{ ,} );intake.Set( { →

    ),0(setintake. >- () ),1.0intake.Set( { intake]&StartEnd([::cmd::frc2 = intakeAndShoot CommandPtr::frc2
                                     intake}&{ ,} );0intake.Set( { intake]&[ →
                                     shooter).ToPtr());&AlongWith(RunShooter(.

                                     Sequence([::cmd::frc2 = autonomousCommand CommandPtr::frc2
&{ ,} );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 preference. personal of matter a is use Their readable. more

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.
        ()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 ,kTurnToAnglePIDController(Constants. new = controller PIDController
    ,returning before state created the on want we configuration whatever do can We //
        factory the from →
    );kTurnToAngleTolerance(Constants.setPositionTolerancecontroller.
```

page) next on (continues

(0000 0000 0000)

```

    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

the represents that class a write to is commands reusable define to way possible Another CommandGroup the of one or Command either subclassing by done typically is This command. classes.

Command 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 Command of subclass

JAVA

```

{ Command 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() //

```

page) next on (continues

(0000 0000 0000)

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.
        );
    }
}
```


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 obey must capture rules	Yes, more be may Yes; than natural approaches other	Yes
Subclassing Command	Stateful commands	Very verbose	Relatively verbose	at Excels them		Yes
and Static Instance Command Factories	Multi-subsystem commands	Yes	Yes	but obey must capture rules		Yes
Subclassing Command Groups	Multi-subsystem command groups	Yes	Yes	but obey must capture rules		Yes

Scheduler Command The 26.8

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 26.8.1

with class accessible globally- 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 classes).

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 based command- provided The work. not will framework command the and run, never included. already call this has template

Method schedule() The 26.8.2

a takes method This).C++ ,Java(method schedule() the call users command, a schedule To it whether pending commands, running currently- 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
                        }

        requireNotComposed(command);

        _command the and disabled is robot the disabled, is scheduler the if nothing Do //
                                                t'doesn't
        scheduled. already is command the or disabled, when run //
                        (m_disabled if
                        isScheduled(command) ||
        { () )runsWhenDisabledcommand.!! && () isDisabledRobotState. ||
                                                ;return
        }
    
```

page) next on (continues

(0000 00000 0000)

```

        ();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. == ()getInterruptBehaviorrequiring. &&
                { )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
    }

    RequireUngrouped(command);

    || scheduledCommands.contains(command)>-m_impl || disabled>-(m_impl if
    { RunsWhenDisabled()))> command! && IsDisabled():RobotState::(frc
        ;return
    }

```

page) next on (continues

(0000 00000 0000)

```

GetRequirements();> command = requirements &auto const
intersection; >8 ,* Command<SmallVector::wpi
;true = isDisjoint bool
;true = allInterruptible bool
{ requirements}>-m_impl : il &&auto( for
{ requirements.end()) != (requirements.find(il.first) if
;false = isDisjoint
== GetInterruptionBehavior()> (il.second =& allInterruptible
kCancelSelf);:: InterruptionBehavior::Command
intersection.emplace_back(il.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
}
}

```

126
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Sequence Run Scheduler The 26.8.3

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
    ();periodic subsystem.
    { ()isSimulation(RobotBase. if
    ();simulationPeriodic subsystem.
    }
};"periodic()." + ()getSimpleName().getClass(subsystem.addEpochm_watchdog.
}
```

278
279
280
281
282
283
284
285

(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(
}
```

183
184
185
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189
190

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 //
    ();poll loopCache.
);"buttons.run()" (addEpochm_watchdog.
```

290
291
292

(Source) C++

```

add. to commands new for buttons Poll //
Poll();>-loopCache
);"buttons.Run()"m_watchdog.AddEpoch(

```

195
196
197

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. ();iterator.m_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
}
{ m_executeActions) : action >Command<(Consumer for
(command);acceptaction.
}
);"execute()." + ()getName(command.addEpochm_watchdog.
{ m_finishActions) : action >Command<(Consumer for
(command);acceptaction.
}
());removeiterator.
());getRequirements(command.removeAll().keySetm_requirements.
);"end(false)." + ()getName(command.addEpochm_watchdog.
}
}

```

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324
325

(Source) C++

```

        { scheduledCommands}>-m_impl : command *(Command for
{ IsDisabled()):RobotState :frc && RunsWhenDisabled()> command!( if
        Cancel(command);
        ;continue
    }
}

    { executeActions}>-m_impl : action &&auto( for
        command);*action(
    }
);"Execute()." + GetName()->m_watchdog.AddEpoch(command

{ 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()});
}
}

```

240
241
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245
246

Scheduler the Disabling 26.8.4

.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

Methods Event Command 26.8.5

certain a whenever action custom a execute scheduler the have to desirable is it Occasionally,
the with done be can This occurs. ending) or execution, (initialization, event command
methods: following

is command a whenever action specified a runs)C++ ,Java(onCommandInitialize •
initialized.

executed. is command a whenever action specified a runs)C++ ,Java(onCommandExecute •
finishes command a whenever action specified a runs)C++ ,Java(onCommandFinish •
true). returned method isFinished() the (i.e. normally

is command a whenever action specified a runs)C++ ,Java(onCommandInterrupt •
one shares that command another by or canceled explicitly being by (i.e. interrupted
requirements). its of

command a whenever log event an in markers adding is methods these for caseuse- typical A
HatchbotInlined the from code following the in demonstrated as place, takes event scheduling
): C++ ,Java(project example

Java

```

interrupt, initialize, command for events Shuffleboard log to scheduler the Set //
finish ↩
()getInstanceCommandScheduler.
(onCommandInitialize.
>- command
(addEventMarkerShuffleboard.
EventImportance. (),getNamecommand. ,"initialized Command"
));kNormal ↩
()getInstanceCommandScheduler.
(onCommandInterrupt.
>- command
(addEventMarkerShuffleboard.

```

73
74
75
76
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78
79
80
81
82

page) next on (continues

(0000 0000 0000)

```

    EventImportance. (),getNamecommand. , "interrupted Command"
    ));kNormal
    (getInstanceCommandScheduler.
    (onCommandFinish.
    >- command
    (addEventMarkerShuffleboard.
    ));kNormalEventImportance. (),getNamecommand. , "finished Command"

```

(Source) C++

```

interrupt finish, execute, initialize, command for events Shuffleboard Log //
GetInstance().OnCommandInitialize(::CommandScheduler::frc2
    { command) &Command::frc2 const[] (
    AddEventMarker(::Shuffleboard::frc
    command.GetName(), , "initialized Command"
    kNormal);::ShuffleboardEventImportance::frc
    );}
GetInstance().OnCommandExecute(::CommandScheduler::frc2
    { command) &Command::frc2 const[] (
    AddEventMarker(::Shuffleboard::frc
    command.GetName(), , "executed Command"
    kNormal);::ShuffleboardEventImportance::frc
    );}
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 26.9

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 26.9.1

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 new AddSequential(
PICKUP));::SetWristSetpoint(Wrist new AddSequential(
OpenClaw()); new AddSequential(
}
```

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 .><Commandstd::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 //
```

page) next on (continues

(0000 0000 0000)

```

    }, "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 26.9.2

extend must you command, new a create to order in that noticed have may You just you that class the and)frc2::Command (usually class base the providing ,CommandHelper this: behind reasoning the at look a take Let's created.

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
you that subclass the in Command the to refers *this class, Command the in is code decorator
to trying be will you Effectively, .Command of type the has and from decorator the calling are
and MyCommand* a to pointer this the cast could We .MyCommand of instead Command a move
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 26.9.3

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
        }

                                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(std::void((
        (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 syntactic a of much make not does it general, in so C++, in than code. user in manually group command the create

Updates 2023 26.9.4

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

```

        drive, *(DriveSubsystem autos::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 //
                                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 thisvalue- `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 26.10 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 26.10.1

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++

```
;@ = ()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++

```
;@ = 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()` defined user- 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
;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.
```

page) next on (continues

(0000 0000 0000)

```

        ,1[kEncoderPort:ShooterConstants.
        );kEncoderReverseShooterConstants.
        = m_shooterFeedforward SimpleMotorFeedforward final private
        SimpleMotorFeedforward( new
        );kVVoltsPerRotationShooterConstants. ,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.
        }
    }
}

```

C++

```

        once pragma#
        frc/Encoder.h>< include#
        frc/controller/SimpleMotorFeedforward.h>< include#
        frc/motorcontrol/PWMSparkMax.h>< include#
        frc2/command/PIDSubsystem.h>< include#
        units/angle.h>< include#

        { PIDSubsystem: frc2 public : ShooterSubsystem class
        :public
        ShooterSubsystem();

        ;override setpoint) double output, double(UseOutput void

```

page) next on (continues

(0000 00000 0000)

```

;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{frc :
m_shooterMotor(kShooterMotorPort),
m_feederMotor(kFeederMotorPort),
}), kEncoderPorts[ ], m_shooterEncoder(kEncoderPorts[
{ kV) m_shooterFeedforward(kS,
m_controller.SetTolerance(kShooterToleranceRPS.value());
m_shooterEncoder.SetDistancePerPulse(kEncoderDistancePerPulse);
SetSetpoint(kShooterTargetRPS.value());
}
{ setpoint) double output, double UseOutput():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
}
{ RunFeeder():ShooterSubsystem void
m_feederMotor.Set(kFeederSpeed);
}
{ StopFeeder():ShooterSubsystem void

```

page) next on (continues

(0000 00000 0000)

```
);m_feederMotor.Set(
}
```

42
43

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.
```

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
```

45
46
47
48
49

(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());
```

25
26
27
28
29
30
31

PIDCommand 26.10.2

PIDController. inbuilt- a with commands create easily to users allows class PIDCommand The

PIDCommand a Creating

defining by or class, PIDCommand the subclassing by - ways two created be can PIDCommand A of choice the ultimately and similar, extremely ultimately methods Both *.inline* command the located. be code relevant the that desires user the where to down comes use to which

super the call to sure make methods, any overriding and PIDCommand subclassing If :□□□□ properly. work not will functionality PID Otherwise, methods! those of version

constructor its to parameters necessary the passing by created is PIDCommand a case, either In call): *super()* a with done be can this subclass, a defining (if

Java

```

    /**
     * PIDController. a with output given the controls which PIDCommand, new a Creates
     *
     * output. the controls that controller the controller @param
     * variable process the of measurement the measurementSource @param
     * setpoint s'controller the setpointSource @param
     * output s'controller the useOutput @param
     * command this by required subsystems the requirements @param
     */
    (PIDCommand public
        controller, PIDController
        measurementSource, DoubleSupplier
        setpointSource, DoubleSupplier
        useOutput, DoubleConsumer
        { requirements) Subsystem...

```

C++

```

    /**
     * a with output given the controls which PIDCommand, new a Creates
     * PIDController.
     *
     * output. the controls that controller the controller @param
     * variable process the of measurement the measurementSource @param
     * setpoint) (aka reference s'controller the setpointSource @param
     * output s'controller the useOutput @param
     * command this by required subsystems the requirements @param
     */
    controller, PIDController: PIDCommand(frc
    measurementSource, >()double-function: std
    setpointSource, >()double-function: std
    useOutput, >)double(void-function: std
    );}{ = requirements 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(arcadeDrive>- 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
            }
        }
    }
}

```


C++

```

once pragma#
5
6
frc2/command/CommandHelper.h>< include#
7
frc2/command/PIDCommand.h>< include#
8
9
subsystems/DriveSubsystem.h" include#
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26

```

(Source) C++

```

5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

```

page) next on (continues

(0000 00000 0000)

} 33

example: *inlined* an for And,**Java**

```

held is bumper left when gyro with straight drive to robot Stabilize //
)value.kL1Button. JoystickButton(m_driverController, new
                                (whileTrue.
                                    PIDCommand( new
                                        PIDController( new
                                            ,kStabilizationI,DriveConstants.
                                            ,kStabilizationI,DriveConstants.
                                        ),kStabilizationI,DriveConstants.
                                    rate turn the on loop the Close //
                                    m_robotDrive::getTurnRate,
                                    0 is Setpoint //
                                    ,0
                                controls turning the to output the Pipe //
    1(),getLeftYm_driverController.-(arcadeDrive m_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:frc
                                        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 26.11

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 26.11.1

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 generated automatically- the constrain to serves This subclass. acceleration. and velocity

mechanism. the for position initial an in pass also must Users main standard non- 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});_3 m,_5examplePIDSubsystem.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

Example TrapezoidProfileSubsystem Full

following The practice? in used when like look TrapezoidProfileSubsystem a does What):C++ ,Java(project example ArmbotOffboard the from taking are examples

Java

```

;edu.wpi.first.wpilibj.examples.armbotoffboard.subsystems package
    ;edu.wpi.first.math.controller.ArmFeedforward import
    ;edu.wpi.first.math.trjectory.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 import

    /* profile. motion a with moves that subsystem arm robot A */
    { TrapezoidProfileSubsystem extends ArmSubsystem class public
        = m_motor ExampleSmartMotorController final private
    );kMotorPortExampleSmartMotorController(ArmConstants. new
        = m_feedforward ArmFeedforward final private
        ArmFeedforward( new
        ,kGVoltsArmConstants. ,kSVoltsArmConstants.
    );kAVoltSecondSquaredPerRadArmConstants. ,kVVoltSecondPerRadArmConstants.

        /* ArmSubsystem. new a Create */
        { ()ArmSubsystem public
            (super
            (ConstraintsTrapezoidProfile. new
            ArmConstants. ,kMaxVelocityRadPerSecondArmConstants.
            ),kMaxAccelerationRadPerSecSquared →

```

page) next on (continues

(0000 00000 0000)

```

        ); kArmOffsetRads ArmConstants.
    ); 0 , 0 , kP(ArmConstants.setPIDm_motor.
    }

    @Override
    { setpoint) State(TrapezoidProfile.useState 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 //
        (setSetpointm_motor.
    feedforward , positionsetpoint. , kPosition.PIDModeExampleSmartMotorController.
        ); 12.0 /
    }

    { kArmOffsetRads) double(setArmGoalCommand Command public
    ); this setGoal(kArmOffsetRads), >- (()runOnceCommands. return
    }
    }
    }

```

(Header) C++

```

        once pragma#
    frc/controller/ArmFeedforward.h>< include#
        frc2/command/Commands.h>< include#
    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# 5
Constants.h" include# 6
;ArmConstants namespace using 7
State;::>radians::units<TrapezoidProfile::frc = State using 8
ArmSubsystem()::ArmSubsystem 9
(>radians::units<TrapezoidProfileSubsystem::frc2 : 10
kArmOffset), kMaxAcceleration}, kMaxVelocity,{ 11
    m_motor(kMotorPort), 12
    { kA) kV, kG, m_feedforward(kS, 13
    );0 ,0 m_motor.SetPID(kP, 14
    } 15
    { setpoint) UseState(State::ArmSubsystem void 16
    sepoint the from feedforward the Calculate // 17
    = feedforward volt_t::units 18
    setpoint.velocity); m_feedforward.Calculate(setpoint.position, 19
    output motor the get to output PID the to feedforward the Add // 20
    kPosition,::PIDMode::m_motor.SetSetpoint(ExampleSmartMotorController 21
    V);_12 / feedforward setpoint.position.value(), 22
    } 23
    { goal) radian_t::SetArmGoalCommand(units::ArmSubsystem CommandPtr::frc2 24
    );}this{ ,} SetGoal(goal);>-this { goal] ,thisRunOnce([::cmd :frc2 return 25
    } 26
    } 27
    } 28
    } 29
    } 30
    } 31

```

simple: quite be can commands with TrapezoidProfileSubsystem a Using

Java

```

pressed. is button 'A' the when horizontal above radians 2 to arm the Move // 52
));2(setArmGoalCommand(m_robotArm.onTrue().am_driverController. 53
pressed. is button 'B' the when position neutral to arm the Move // 54
m_driverController 55
())b. 56
));kArmOffsetRads.ArmConstants(Constants.setArmGoalCommand(m_robotArm.onTrue. 57
58

```

C++

```

pressed. is button 'A' the when horizontal above radians 2 to arm the Move // 25
rad));_m_driverController.A().OnTrue(m_arm.SetArmGoalCommand( 26
pressed. is button 'B' the when position neutral to arm the Move // 27
m_driverController.B().OnTrue( 28
kArmOffset));::m_arm.SetArmGoalCommand(ArmConstants 29
30

```

TrapezoidProfileCommand 26.11.2

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
 to down comes use to which of choice the ultimately and similar, extremely ultimately are
 located. be code relevant the that desires user the where

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 *
     * output. profile the for consumer The output @param *
     * state desired the for supplier The goal @param *
     * state current The currentState @param *
     * command. this by required subsystems The requirements @param *
     */
    "this-escape"(@SuppressWarnings
    (TrapezoidProfileCommand public
    profile, TrapezoidProfile
    output, >State<Consumer
    goal, >State<Supplier
    currentState, >State<Supplier
  
```


C++

```

    /**
     * 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 *
     * state desired the for supplier The goal @param *
     * state current The currentState @param *
     * requirements. of list The requirements @param *
     */
    profile, >Distance<TrapezoidProfile::TrapezoidProfileCommand(frc
        output, >(State)void<function::std
        goal, >State()<function::std
        currentState, >State()<function::std
    )}{ = requirements Requirements

```

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profile

the by executed be will that object TrapezoidProfile the is parameter profile The
the that profile the of constraints motion the specify users in, this passing By command.
use. will command

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

goal

This profile. motion the of state desired the supplies that function a is parameter goal The
desired. if runtime at goal the change to used be can

currentState

motion the of state starting the supplies that function a is parameter currentState The
motion any follow and generate dynamically to used be can this ,goal with Combined profile.
runtime. at profile

its specify to use 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
;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.
                drive the to state profile the Pipe //
                setpointState), (setpointState,setDriveStatesdrive. >- setpointState
                0 at starts implicitly meters; in position desired at End //
                ),0 (meters,StateTrapezoidProfile. new >- ()
                position Current //
                ,new::StateTrapezoidProfile.
                drive the Require //
                drive);
                0 at starting re'we since encoders drive Reset //
                ();resetEncodersdrive.
            }
        }
    }

```

(Header) C++

```

once pragma# 5
6
frc2/command/CommandHelper.h>< include# 7
frc2/command/TrapezoidProfileCommand.h>< include# 8
9
subsystems/DriveSubsystem.h" include# 10
11
DriveDistanceProfiled class 12
, meters::units<TrapezoidProfileCommand::frc2 CommandHelper::frc2 public : 13
{ >DriveDistanceProfiled 14
:public 15
drive); *DriveSubsystem distance, meter_t::DriveDistanceProfiled(units 16
;}; 17

```

(Source) C++

```

commands/DriveDistanceProfiled.h" include# 5
6
Constants.h" include# 7
8
;DriveConstants namespace using 9
10
distance, meter_t::DriveDistanceProfiled(units::DriveDistanceProfiled 11
drive) *DriveSubsystem 12
CommandHelper{ : 13
{>meters::units<TrapezoidProfile::frc 14
velocity and acceleration max the Limit // 15
kMaxAcceleration}}, kMaxSpeed,{ 16
drive the to state profile the Pipe // 17
{ setpointState) auto[drive]( 18
setpointState); SetDriveStates(setpointState,> drive 19
,} 20
0 at starts implicitly meters; in position desired at End // 21
{ [distance] 22
mps};_0 State{distance,::>meters::units<TrapezoidProfile::frc return 23
,} 24
,} State{};::>meters::units<TrapezoidProfile::frc return { [] 25
drive the Require // 26
{ drive}}{ 27
0 at starting re'we since encoders drive Reset // 28
ResetEncoders();> drive 29
} 30

```

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
                            , kMaxSpeedMetersPerSecond DriveConstants.
                                ), kMaxAccelerationMetersPerSecondSquared DriveConstants.
                                    drive the to state profile the Pipe //
                                )(setpointState, setDriveStates m_robotDrive. >- setpointState
                                    setpointState), ↵
                                0 at starts implicitly meters; in position desired at End //
                                    ), 0, 3(StateTrapezoidProfile. new >- ()
                                        position Current //
                                        , new::StateTrapezoidProfile.
                                            drive the Require //
                                                m_robotDrive)
                                            (m_robotDrive::resetEncoders)beforeStarting.
                                                ));10(withTimeout.

```

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C++

```

s));_10(m_drive).WithTimeout(& m,_3DriveDistanceProfiled(
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{
                        drive the to state profile the Pipe //
                        { setpointState) auto](this[
                            setpointState); m_drive.SetDriveStates(setpointState,
                                ,}
                                0 at starts implicitly meters; in position desired at End //
                                    { []
                                mps};_0 m,_3State{::>meters::units<TrapezoidProfile :frc return
                                    ,}
                                    position Current //
                                ,} State{};::>meters::units<TrapezoidProfile::frc return { []
                                    drive the Require //
                                        m_drive})&{
                                        CommandPtr to Convert //
                                            ToPtr().
                                                BeforeStarting(.

```

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Command- in PID and Profiling Motion Combining 26.12 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 26.12.1

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
```

page) next on (continues

(Header) C++

```

    */ profile. motion a with moves that subsystem arm robot A */
    { ProfiledPIDSubsystem extends ArmSubsystem class public
    ); kMotorPort PWMSparkMax(ArmConstants. new = m_motor PWMSparkMax final private
    = m_encoder Encoder final private
    ); ]1[kEncoderPorts ArmConstants. , ]0[kEncoderPorts Encoder(ArmConstants. new
    = m_feedforward ArmFeedforward final private
    ArmFeedforward( new
    , kGVolts ArmConstants. , kSVolts ArmConstants.
    ); kAVoltSecondSquaredPerRad ArmConstants. , kVVoltSecondPerRad ArmConstants.

    */ ArmSubsystem. new a Create */
    { () ArmSubsystem public
    (super
    ProfiledPIDController( new
    , kF ArmConstants.
    , 0
    , 0
    (Constraints TrapezoidProfile. new
    , kMaxVelocityRadPerSecond ArmConstants.
    ), kMaxAccelerationRadPerSecSquared ArmConstants.
    ); 0
    ); kEncoderDistancePerPulse(ArmConstants. setDistancePerPulse m_encoder.
    position neutral in rest at arm Start //
    ); kArmOffsetRads setGoal(ArmConstants.
    }

    @Override
    { setpoint) State TrapezoidProfile. output, double (useOutput void public
    sepoint the from feedforward the Calculate //
    setpoint. , position(setpoint. calculate m_feedforward. = feedforward double
    ); velocity
    output motor the get to output PID the to feedforward the Add //
    feedforward); + (output setVoltage m_motor.
    }

    @Override
    { () getMeasurement double public
    ; kArmOffsetRads ArmConstants. + () getDistance m_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 */
    */

```

page) next on (continues

(0000 00000 0000)

```
{ >radians::units ProfiledPIDSubsystem :frc2 public : ArmSubsystem class
    State;::>radians::units<TrapezoidProfile::frc = State using
                                :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.
                                { >- ()
                                );2(setGoalm_robotArm.
                                ());enablem_robotArm.
                                ,}
                                m_robotArm));

```

55
56
57
58
59
60
61
62
63
64

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}));&{

```

32
33
34
35
36
37
38

ProfiledPIDCommand 26.12.2

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
     * 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 Requirements

```

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.
                ,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# 5
6
frc2/command/CommandHelper.h>< include# 7
frc2/command/ProfiledPIDCommand.h>< include# 8
9
subsystems/DriveSubsystem.h" include# 10
11
12
motion a using angle specified the to robot the turn will that command A * 13
profile. * 14
*/ 15
TurnToAngleProfiled class 16
,>radians :units ProfiledPIDCommand::frc2 CommandHelper::frc2 public : 17
{ >TurnToAngleProfiled 18
19
:public 19
20
profile. motion a using angle specified the to robot to Turns * 21
* 22
to turn to angle The targetAngleDegrees @param * 23
use to subsystem drive The drive @param * 24
*/ 25
targetAngleDegrees, degree_t::TurnToAngleProfiled(units 26
drive); *DriveSubsystem 27
28
;override ()IsFinished bool 29
;} 30

```

(Source) C++

```

commands/TurnToAngleProfiled.h" include# 5
6
frc/controller/ProfiledPIDController.h>< include# 7
8
;DriveConstants namespace using 9
10
target, degree_t::TurnToAngleProfiled(units::TurnToAngleProfiled 11
drive) *DriveSubsystem 12
13
CommandHelper{ :
{>radians :units ProfiledPIDController::frc 14
kMaxTurnAcceleration}}, kMaxTurnRate,{ kTurnD, kTurnI, kTurnP, 15
heading on loop Close // 16
,} GetHeading();>-drive return { [drive] 17
target to reference Set // 18
target, 19
robot turn to output Pipe // 20
{ setpointState) auto output, double[drive]( 21
output); ,0ArcadeDrive(> drive 22
,} 23
drive the Require // 24
{ drive}}{ 25
controller) angle an is it (because continuous be to controller the Set // 26
deg);_180 deg,_180-GetController().EnableContinuousInput( 27
is robot the ensures tolerance delta the - tolerance controller the Set // 28

```

page) next on (continues

(0000 0000 0000)

```
the reached having as considered is it before setpoint the at stationary //
reference //
```

```
kTurnRateTolerance); GetController().SetTolerance(kTurnRateTolerance,
```

```
AddRequirements(drive);
```

29
30
31
32
33
34
35
36
37
38

```
{ IsFinished(): TurnToAngleProfiled bool
  GetController().AtGoal(); return
}
```

Parameters As Functions Passing 26.13

functions accepts often library based command- 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 26.13.1

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 *Method* see references, method on information further For needed. when it call can code .*References*

(Java) Expressions Lambda 26.13.2

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 26.13.3

lambda C++ a in this capturing semantics, C++ in complications to Due :000000 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
.C++ in Expressions Lambda see expressions, lambda C++ write to how on

ChassisSpeeds The and Kinematics to Introduction 27.1

Class

to wish may You system. coordinate common a uses odometry and Kinematics :
 details. for section *System Coordinate* the reference

kinematics? is What 27.1.1

mecanum and drive, swerve drive, differential for classes contains suite kinematics The universal a between convert help classes kinematics The odometry. and kinematics drive robot a for velocities angular and linear containing)object,Python,C++,Java(ChassisSpeeds a for speeds wheel right and left i.e. drivetrain of type individual each for speeds usable to (speed states module individual or drive, mecanum a for speeds wheel four drive, differential drive. swerve a for angle) and

odometry? is What 27.1.2

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 ChassisSpeeds The 27.1.3

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 27.1.4

three accepting straightforward, very is object ChassisSpeeds the for constructor The second. per meters in be must vy and vx Python, and Java In .omega and ,vy ,vx for arguments velocity linear any using velocity linear a provide to used be may library units the C++, In unit.

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::fr
pi));::numbers::radians_per_second_t(std::units
```

PYTHON

```
math import
ChassisSpeeds import kinematics.wpimath from
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 #
pi) math ,2.0- ,3.0ChassisSpeeds( = speeds
```

Speeds RelativeField- from Object ChassisSpeeds a Creating 27.1.5

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

/ Python) / (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 //
(fromFieldRelativeSpeeds ChassisSpeeds. = speeds ChassisSpeeds
);45.0(fromDegrees Rotation2d. ,2.0 / P.Math. ,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 //
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)); ↵
```

PYTHON

```
math import
ChassisSpeeds import kinematics.wpimath from
Rotation2d import geometry.wpimath from

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 = speeds
))45.0fromDegrees( Rotation2d ,2.0 / pi math ,2.0 ,2.0
```

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 27.2

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 27.2.1

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

can library units the C++, In meters. in be must width track the Python, and Java In :`inches` unit. length any using width track the in pass to used be

Speeds Wheel to Speeds Chassis Converting 27.2.2

/ Python) / (Java speeds) `toWheelSpeeds(ChassisSpeeds` The a convert to used be should method (C++) `speeds) ToWheelSpeeds(ChassisSpeeds` in useful is This object. `DifferentialDriveWheelSpeeds` a to object `ChassisSpeeds` to `omega(` velocity angular an and `vx(` velocity linear a convert to have you where situations velocities. wheel right and left

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

    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

```

PYTHON

```

DifferentialDriveKinematics import kinematics.wpimath from
ChassisSpeeds import kinematics.wpimath from
inchesToMeters import units.wpimath from

    inches 27 of width track object: kinematics my Creating #
))27.0inchesToMeters( DifferentialDriveKinematics(Units = kinematics
    velocity, linear second per meters 2 speeds: chassis Example #
    velocity. angular second per radian 1 #
    )1.0 ,0 ,2.0ChassisSpeeds( = chassisSpeeds
    speeds wheel to Convert #
    toWheelSpeeds(chassisSpeeds) kinematics = wheelSpeeds
    velocity Left #
    left wheelSpeeds = leftVelocity
    velocity Right #
    right wheelSpeeds = rightVelocity

```

Speeds Chassis to Speeds Wheel Converting 27.2.3

to right) and (left speeds wheel individual convert to object kinematics the use also can One
 toChassisSpeeds(DifferentialDriveWheelSpeeds The object. ChassisSpeeds singular a
 (C++) speeds) ToChassisSpeeds(DifferentialDriveWheelSpeeds / Python) / (Java speeds)
 this. achieve to used be should method

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::fr

second per meters 2 speeds: wheel drive differential Example //
side. right the for second per meters 3 side, left the for //
mps};_3 mps,_wheelSpeeds{ DifferentialDriveWheelSpeeds::fr

        bindings structured s'C++17 use can we Here speeds. chassis to Convert //
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

```

PYTHON

```

DifferentialDriveKinematics import kinematics.wpimath from
DifferentialDriveWheelSpeeds import kinematics.wpimath from
        inchesToMeters import units.wpimath from

        inches 27 of width track object: kinematics my Creating #
    ))27.0DifferentialDriveKinematics(inchesToMeters( = kinematics

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( = wheelSpeeds

        speeds. chassis to Convert #
toChassisSpeeds(wheelSpeeds) kinematics = chassisSpeeds

        velocity Linear #
vx.chassisSpeeds = linearVelocity

```

page) next on (continues

(0000 00000 0000)

```
velocity Angular #
omega.chassisSpeeds = angularVelocity
```

Odometry Drive Differential 27.3

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 :0000 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 27.3.1

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 •

that number a are these Python, / Java In readings. encoder right and left initial The • must *library units* the C++, In meters. in side each by traveled distance the represents 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 :0000 should angle gyroscope your left, the to turns robot your As station. alliance opponent's your for use can you that `GetRotation2d/getRotation2d` supplies interface Gyro The increase. system. coordinate the about information more for *System Coordinate* See purpose. this

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
    (),getRotation2d(m_gyro.
    (),getDistance(m_rightEncoder. (),getDistance(m_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 //
// 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,_5 Pose2d{::frc

```

PYTHON

```

DifferentialDriveOdometry import kinematics.wpimath from
    Pose2d import geometry.wpimath from
    Rotation2d import geometry.wpimath from

// 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( = m_odometry
    getRotation2d(), m_gyro
    getDistance(), m_rightEncoder getDistance(), m_leftEncoder
    Rotation2d())) ,13.5 ,5.0 Pose2d(

```

Pose Robot the Updating 27.3.2

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 `:0000` positive. be must change of rate the - positively increasing be

JAVA

```

@Override
{ ()periodic void public
    gyro. the from robot the of rotation the Get //
    ();getRotation2d m_gyro. = gyroAngle var

    pose the Update //
    (gyroAngle,update m_odometry. = m_pose
        (),getDistance m_leftEncoder.
        ());getDistance m_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
        }
    
```

PYTHON

```

        ):self( periodic def
            gyro. the from robot the of rotation the Get #
            getRotation2d() .m_gyro = gyroAngle

            pose the Update #
            update(gyroAngle, m_odometry = m_pose
            getDistance(), m_leftEncoder
            getDistance()) m_rightEncoder
    
```

Pose Robot the Resetting 27.3.3

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 : Python /

to used be can methods Python) / (Java getPoseMeters / (C++) GetPose the addition, In update. an without pose robot current the retrieve

Kinematics Drive Swerve 27.4

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

reference to wish may You system. coordinate common a uses kinematics drive Swerve :
 details. for section *System Coordinate* the

class state module swerve The 27.4.1

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

the C++, In second. per meters in be must wheel the of velocity the Python, / Java In :
 unit. velocity linear any using velocity the provide to used be can library units

forward. facing modules the to corresponds 0 of angle An :
 forward. facing modules the to corresponds 0 of angle An

object kinematics the Constructing 27.4.2

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 :
 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 //
```

page) next on (continues

(0000 00000 0000)

```
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};
```

PYTHON

```
have you modules of number the for class right the using requires Python #

Translation2d import geometry.wpimath from
SwerveDrive4Kinematics import kinematics.wpimath from

center. robot the to relative modules drive swerve the for Locations #
)0.381 ,0.381Translation2d( = frontLeftLocation
)0.381- ,0.381Translation2d( = frontRightLocation
)0.381 ,0.381-Translation2d( = backLeftLocation
)0.381- ,0.381-Translation2d( = backRightLocation

locations module the using object kinematics my Creating #
SwerveDrive4Kinematics( = kinematics self
backRightLocation backLeftLocation, frontRightLocation, frontLeftLocation,
)
```

states module to speeds chassis Converting 27.4.3

/ Python) / (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

        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
    
```

PYTHON

```

        ChassisSpeeds import kinematics.wpimath from

        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( = speeds

        states module to Convert #
        .kinematics.self = backRight backLeft, frontRight, frontLeft,
        toSwerveModuleStates(speeds) →
    
```

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
```

PYTHON

```
SwerveModuleState import kinematics.wpimath from  
Rotation2d import geometry.wpimath from  
optimize(frontLeft, SwerveModuleState = frontLeftOptimized  
getDistance())) m_turningEncoder.set(Rotation2d(
```

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 / P.Math. ,2.0 ,2.0  
  
kinematics our in this use Now //  
(speeds);toSwerveModuleStates kinematics. = 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

```

PYTHON

```

ChassisSpeeds import kinematics.wpimath from
math import
Rotation2d import geometry.wpimath from

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 = speeds
))45.0fromDegrees( Rotation2d ,2.0 / pi math ,2.0 ,2.0

kinematics our in this use Now #
toSwerveModuleStates(speeds) kinematics self = moduleStates self

```

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 rotation. of center the from measured be will object ChassisSpeeds the

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 27.4.4

to objects SwerveModuleState of array an convert to object kinematics the use also can One states) toChassisSpeeds(SwerveModuleState... The object. ChassisSpeeds singular a be can method (C++) states) ToChassisSpeeds(SwerveModuleState... / Python) / (Java this. achieve to used

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,

```

PYTHON

```

SwerveModuleState import kinematics.wpimath from
Rotation2d import geometry.wpimath from

states module Example #
))140.19-fromDegrees(.Rotation2d ,23.43SwerveModuleState( = frontLeftState
))39.81-fromDegrees(.Rotation2d ,23.43SwerveModuleState( = frontRightState
))109.44-fromDegrees(.Rotation2d ,54.08SwerveModuleState( = backLeftState
))70.56-fromDegrees(.Rotation2d ,54.08SwerveModuleState( = backRightState

speeds chassis to Convert #
toChassisSpeeds(.kinematics.self = chassisSpeeds

```

page) next on (continues

(0000 00000 0000)

```
backRightState) backLeftState, frontRightState, frontLeftState,

    speeds individual Getting #
    vx chassisSpeeds = forward
    vy chassisSpeeds = sideways
    omega chassisSpeeds = angular
```

AdvantageScope with visualization state Module 27.4.5

,logs data WPILib or NetworkTables using states module swerve of set a recording By shows below code The drive. swerve a of state the visualize to used be can AdvantageScope NetworkTables. to published be can objects SwerveModuleState of set a how

JAVA

```

{ Example class public
publisher; >SwerveModuleState StructArrayPublisher final private

    { ()Example public
    key SwerveStates"/" the with states module of array an publishing Start //
    ()getDefaultNetworkTableInstance. = publisher
    ();publish().structSwerveModuleState. , "SwerveStates/"(getStructArrayTopic.
    }

    { ()periodic void public
    states module of set a send Periodically //
    { ][SwerveModuleState new(setpublisher.
    frontLeftState,
    frontRightState,
    backLeftState,
    backRightState
    );}
    }
}
```

C++

```

{ Example class
publisher >SwerveModuleState::frc StructArrayPublisher::nt

    :public
    { Example()
    key SwerveStates"/" the with states module of array an publishing Start //
    GetDefault()::NetworkTableInstance::nt = publisher
    ).Publish(); "SwerveStates/"(>SwerveModuleState::frc GetStructArrayTopic.
    }

    { Periodic() void
    states module of set a send Periodically //
    swervePublisher.Set(
```

page) next on (continues

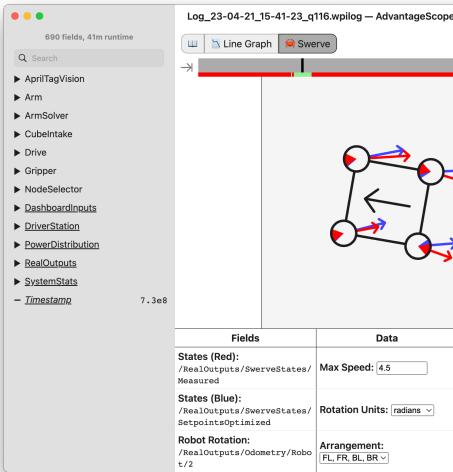
(C++ C++ C++)

```
vector<::std
frontLeftState,
frontRightState,
backLeftState,
backRightState
};
};
};
```

PYTHON

```
SwerveModuleState import kinematics.wpimath from
NetworkTables of instance default the get #
getDefault().NetworkTableInstance.ntcore = nt
key SwerveStates"/" the with states module of array an publishing Start #
SwerveModuleState) ,"SwerveStates/"getStructArrayTopic(.nt = topic
publish() topic = pub.self
):self(
periodic def
states module of set a send Periodically #
set([frontLeftState,frontRightState,backLeftState,backRightState]).pub.self
```

using data this visualizing on details more for tab swerve the for documentation the See AdvantageScope.



Odometry Drive Swerve 27.5

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 27.5.1

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 `.theta = 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 for use can you that `GetRotation2d/getRotation2d` supplies interface `Gyro` The increase. system. coordinate the about information more for *System Coordinate* See purpose. this

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
);0.381,0.381Translation2d( new = m_backLeftLocation Translation2d
);0.381,0.381Translation2d( 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,
);
```

page) next on (continues

(0000 00000 0000)

```

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
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

```

PYTHON

```

have you modules of number the for class right the using requires Python #
classes Odometry and Kinematics the both For #

Translation2d import geometry.wpimath from
SwerveDrive4Kinematics import kinematics.wpimath from
SwerveDrive4Odometry import kinematics.wpimath from
Pose2d import geometry.wpimath from
Rotation2d import geometry.wpimath from

:MyRobot class
):self(robotInit def
center. robot the to relative modules drive swerve the for Locations #
)0.381 ,0.381Translation2d( = frontLeftLocation
)0.381- ,0.381Translation2d( = frontRightLocation
)0.381 ,0.381-Translation2d( = backLeftLocation

```

page) next on (continues

(0.381 0.381 0.381)

```

        )0.381- ,0.381-Translation2d( = backRightLocation
        locations module the using object kinematics my Creating #
        SwerveDrive4Kinematics( = kinematics.self
        backRightLocation backLeftLocation, frontRightLocation, 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 #
        SwerveDrive4Odometry( = odometry.self
        getRotation2d(),.gyro.self kinematics,.self
        (
        getPosition(),.frontLeftModule.self
        getPosition(),.frontRightModule.self
        getPosition(),.backLeftModule.self
        getPosition(),.backRightModule.self
        ),
        Rotation2d())) ,13.5 ,5.0Pose2d(
    
```

pose robot the Updating 27.5.2

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 //
        ();getRotation2d;m_gyro. = gyroAngle var

        pose the Update //
        (gyroAngle,update;m_odometry. = m_pose
        { }SwerveModulePosition new
        (),getPosition;m_frontRightModule. (),getPosition;m_frontLeftModule.
        ()getPosition;m_backRightModule. (),getPosition;m_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(),
            };
        }
    }
}

```

PYTHON

```

        ):self(
            gyro. the from robot the of rotation the Get #
            getRotation2d() gyro self = gyroAngle.self

            pose the Update #
            gyroAngle,.self.update( odometry.self = pose.self
            getPosition(), frontRightModule.self getPosition(), frontLeftModule.self
            getPosition().backRightModule.self getPosition(), backLeftModule.self
        )
    )

```

Pose Robot the Resetting 27.5.3

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 :`resetPosition` 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 :`resetPosition` example, full a For module. each from angle) and (distance position module the get to is idea [Python / Java / C++ here: see](#)

to used be can methods Python) / (Java `getPoseMeters` / (C++) `GetPose` the addition, In update. an without pose robot current the retrieve

Kinematics Drive Mecanum 27.6

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

reference to wish may You system. coordinate common a uses kinematics Mecanum :□□□□ details. for section *System Coordinate* the

Object Kinematics the Constructing 27.6.1

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};

```

PYTHON

```

Translation2d import geometry.wpimath from
MecanumDriveKinematics import kinematics.wpimath from

center. robot the to relative wheels the of Locations #
    )0.381 ,0.381Translation2d( = frontLeftLocation
    )0.381- ,0.381Translation2d( = frontRightLocation
    )0.381 ,0.381-Translation2d( = backLeftLocation
    )0.381- ,0.381-Translation2d( = backRightLocation

locations. wheel the using object kinematics my Creating #
    MecanumDriveKinematics( = kinematics self
backRightLocation backLeftLocation, frontRightLocation, frontLeftLocation,
    )

```

Speeds Wheel to Speeds Chassis Converting 27.6.2

/ Python) / (Java speeds) toWheelSpeeds(ChassisSpeeds The
a convert to used be should method (C++) speeds) ToWheelSpeeds(ChassisSpeeds
situations in useful is This object. MecanumDriveWheelSpeeds a to object ChassisSpeeds
into velocity angular an and velocity, sideways velocity, forward a convert to have you where
speeds. wheel individual

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);toWheelSpeeds kinematics. = wheelSpeeds MecanumDriveWheelSpeeds

speeds wheel individual the Get //
frontLeftMetersPerSecond wheelSpeeds. = frontLeft double
frontRightMetersPerSecond wheelSpeeds. = frontRight double
rearLeftMetersPerSecond wheelSpeeds. = backLeft double
rearRightMetersPerSecond wheelSpeeds. = 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,_1 speeds{ 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

```

PYTHON

```

ChassisSpeeds import kinematics.wpimath from
    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( = speeds
    speeds wheel to Convert #
toWheelSpeeds(speeds).kinematics.self = backRight backLeft, frontRight, frontLeft,

```

drive orientedField-

speeds. orientedfield- desired of set a from created he can object ChassisSpeeds a that *Recall*
 speeds. orientedfield- desired of set a from speeds wheel get to used he 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 / P.Math. ,2.0 ,2.0
    kinematics our in this use Now //
(speeds);toWheelSpeedskinematics. = wheelSpeeds MecanumDriveWheelSpeeds

```

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.ToWheelSpeeds(speeds); = br] bl, fr, [fl, auto

```


PYTHON

```

ChassisSpeeds import kinematics.wpimath from
                math import
Rotation2d import geometry.wpimath from

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 = speeds
))45.0fromDegrees( Rotation2d ,2.0 / pi math ,2.0 ,2.0

kinematics our in this use Now #
toWheelSpeeds(speeds).kinematics.self = wheelSpeeds

```

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. a (as rotation of center the for parameter second a accepts method ToWheelSpeeds() of center the representing Translation2d the locations, wheel the like Just).Translation2d center. robot the to relative be should rotation

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 rotation. of center the from measured be will object ChassisSpeeds the

provided the if and wheel 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 wheel. particular that around rotate

speeds chassis to speeds wheel Converting 27.6.3

a to object MecanumDriveWheelSpeeds a convert to object kinematics the use also can One speeds) toChassisSpeeds(MecanumDriveWheelSpeeds The object. ChassisSpeeds singular can method (C++) speeds) ToChassisSpeeds(MecanumDriveWheelSpeeds / Python) / (Java this. achieve to used be

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 //

```

page) next on (continues

(0000 00000 0000)

```

;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

```

PYTHON

```

MecanumDriveWheelSpeeds import kinematics.wpimath from
speeds wheel Example #
)16.26 ,13.44- ,20.51 ,17.67 MecanumDriveWheelSpeeds( = wheelSpeeds
speeds chassis to Convert #
toChassisSpeeds(wheelSpeeds).kinematics.self = chassisSpeeds
speeds individual Getting #
vx chassisSpeeds = forward
vy chassisSpeeds = sideways
omega chassisSpeeds = angular

```

Odometry Drive Mecanum 27.7

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 :0000 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 27.7.1

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 •

Python, / Java In).MecanumDriveWheelPositions (as wheels the of positions initial The •
library units the C++, In meters. in position wheel each with constructed be must this
positions. wheel your represent to used be must

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
for use can you that GetRotation2d/getRotation2d supplies interface Gyro The increase.
system. coordinate the about information more for *System Coordinate* See purpose. this

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 //
        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

```

PYTHON

```

        Translation2d import geometry.wpimath from
        MecanumDriveKinematics import kinematics.wpimath from
        MecanumDriveOdometry import kinematics.wpimath from
        MecanumDriveWheelPositions import kinematics.wpimath from
        Pose2d import geometry.wpimath from
        Rotation2d import geometry.wpimath from

        center. robot the to relative wheels the of Locations #
        )0.381 ,0.381Translation2d( = frontLeftLocation
        )0.381- ,0.381Translation2d( = frontRightLocation
        )0.381 ,0.381-Translation2d( = backLeftLocation
        )0.381- ,0.381-Translation2d( = backRightLocation

        locations. wheel the using object kinematics my Creating #
        MecanumDriveKinematics( = kinematics self
        backRightLocation backLeftLocation, frontRightLocation, 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( = odometry.self
        kinematics,.self
        getRotation2d(),.gyro.self

```

page) next on (continues

(0000 0000 0000)

```

        MecanumDriveWheelPositions(
getDistance(), frontRightEncoder.self getDistance(), frontLeftEncoder.self
getDistance().backRightEncoder.self getDistance(), backLeftEncoder.self
),
Rotation2d()) ,13.5 ,5.0Pose2d(
)

```

pose robot the Updating 27.7.2

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
    (),getDistance m_frontRightEncoder. (),getDistance m_frontLeftEncoder.
    ());getDistance m_backRightEncoder. ()),getDistance m_backLeftEncoder.

    gyro. the from robot the of rotation the Get //
    ());getRotation2d m_gyro. = gyroAngle var

    pose the Update //
    wheelPositions); (gyroAngle,update m_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
}

```


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 28.1

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
application. dashboard a on time real in plotted and read be can those and

built is and LabVIEW, or C++, Java, in robot the on programs by used be can NetworkTables
WPILib. of version each into

on information more For 2023. in substantially changed has NetworkTables :
3.0 NetworkTables from Migrating see features, new the use to code 2023pre- migrating
.4.0 NetworkTables to

Concepts NetworkTables 28.1.1

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 other of updates value receive won't thus and topic a on receive to expecting they're type types.

Topics Persistent and Retained 28.1.2

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 28.1.3

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 28.1.4

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 28.1.5

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:
/SmartDash	the using Shuffleboard or SmartDashboard the to written values store to Used methods. of set SmartDashboard.put()
/LiveWindo	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 28.1.6

(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 28.1.7

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 28.2

Class NetworkTable the Using 28.2.1

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 28.2.2

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"(getDoubleTopicinst. = 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_GetDefaultInstance(); = inst NT_Instance

    NetworkTableInstance a from topic a get //
);"datatable/X/" NT_GetTopic(inst, = topic NT_Topic

```

Python

```

ntcore import

getDefault() NetworkTableInstance ntcore = inst
)"datatable"getTable(.inst = table

    NetworkTableInstance a from topic a get #
    name full the is case this in name topic the #
)"datatable/X/"getDoubleTopic( inst = dblTopic

    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

    Topic generic a from topic type-specific a get #
)"datatable/X/"getTopic( inst = genericTopic
    DoubleTopic(genericTopic) ntcore = dblTopic

```

Topic a to Subscribing and Publishing 28.3

Topic a to Publishing 28.3.1

`.publisher` a create to necessary it's it, to values publish and `topic` a create to order In (e.g. objects Publisher specifictype- as represented are publishers NetworkTable Publisher the as long as active only are Publishers). Python , C++ , Java : BooleanPublisher function, a of scope local the than longer publishing keep to want you Typically exists. object instance an in e.g. term, longer somewhere object Publisher the store to necessary it's so is this C++ in publishing; stop to called be needs method `close()` the Java, In variable. the Python In `copyable.non-` and `moveable` are publishers C++ destructor. the by handled object the when closed be also will it but publishing, stop to called be should method `close()` collected. garbage is

is user the handle; `NT_Publisher` specifictype-non- the only is there APIs, basedhandle- the In specifictype- correct the using and publisher the of type the of track keeping for responsible methods. set

current the uses operation this default, By operation. `set()` a via done is values Publishing when useful be can timestamp a Specifying specified. be optionally may timestamp a but time, integer are units timestamp The timestamp. update same the have should values multiple with consistent is that timestamp current a get to how for code example (see microseconds library). the

Java

```

        { Example class public
        of that matches lifetime its so variable instance an is publisher the //
        class the →
        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 //
        string type custom a Using string. type custom a using and properties //
        for →
        properties The recommended. not is string and raw than other types //
        string →
        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 //

```

page) next on (continues

```
(0000 00000 0000)

);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.

functional Consumer appropriate the implement also publishers //
interface; →
exists func) myFunc(DoubleConsumer void assumes example this //
myFunc(dblPub);
}

for exist t'doesn class this unless code, robot in required not often //
needs close() case which in program, robot entire the of lifetime the //
be to →
publishing stop to called //
{ ()close void public
publishing stop //
();closedblPub.
}
}
```

C++

```
{ Example class
of that matches lifetime its so variable instance an is publisher the //
class the →
the by destroyed is dblPub when stopped automatically is publishing //
destructor class →
dblPub; DoublePublisher::nt

:public
{ dblTopic) DoubleTopic::Example(nt explicit
via case, this (in retained be must value return the publishing; start //
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 //
string type custom a Using string. type custom a using and properties //
for →
properties The recommended. not is string and raw than other types //
must →
map. JSON a be //
);};5 , "myprop"{{ , "double"dblTopic.PublishEx( = dblPub
}

{ Periodic() void
value default a publish //
```

page) next on (continues

(0000 0000 0000)

```
);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
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
}
;}
```

```

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
case, this (in retained be must value return the publishing; start #
via →
variable) instance an #
publish().dblTopic = dblPub.self
PubSubOption using specified be may options publish #
.publish(ntcore.dblTopic = dblPub.self
))True=PubSubOptions(keepDuplicates →
initial setting as such options additional provides publishEx #
type custom a Using string. type custom a using and properties #
for string →
properties The recommended. not is string and raw than other types #
string →
map. JSON a be must #

```

page) next on (continues


```
(
) 5} : "myprop"{' , "double"publishEx( dblTopic = dblPub.self
):self(
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

microsecond with timestamp specific a with value a publish #
resolution.
(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 #
needs close() case which in program, robot entire the of lifetime the #
be to
publishing stop to called #
):self(close def
publishing stop #
close().dblPub.self
```

Topic a to Subscribing 28.3.2

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
of that matches lifetime its so variable instance an is subscriber the //
class the
dblSub; DoubleSubscriber final

{ dblTopic) (DoubleTopicExample public
retained. be must value return the subscribing; start //
when available is value no if value default the is parameter the //
called is get()
);0.0(subscribedblTopic. = dblSub

PubSubOption using specified be may options subscribe //
= dblSub
),true(keepDuplicatesPubSubOption. ,0.0(subscribedblTopic.
));10(pollStoragePubSubOption.
```

page) next on (continues

```
(~~~~ ~~~~~ ~~~~~)
    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/ to call last the since changes value all read //
                                readQueueValues →
    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 //
    needs close() case which in program, robot entire the of lifetime the //
                                be to →
                                subscribing stop to called //
                                { ()close void public
                                subscribing stop //
                                ();closedblSub.
                                }
                                }
```

C++

```
{ Example class
of that matches lifetime its so variable instance an is subscriber the //
                                class the →
the by destroyed is dblSub when stopped automatically is subscribing //
                                destructor class →
                                dblSub; DoubleSubscriber::nt

                                :public
                                { dblTopic) DoubleTopic::Example(nt explicit
    retained. be must value return the subscribing; start //
    when available is value no if value default the is parameter the //
                                called is get() →
                                );0.0dblTopic.Subscribe( = dblSub
```

page) next on (continues

(0000 00000 0000)

```

    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/ to call last the since changes value all read //
                                ReadQueueValues ↵
    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 //
    page) next on (continues

```

(□□□□ □□□□ □□□□)

```

                                value default passed-in the //
                                );0.0 GetDouble(dblSub,::nt = val double

                                timestamp its with along value, recent most the get //
                                );0.0 GetAtomic(dblSub,::nt = tsVal TimestampedDouble::nt

                                ReadQueue/ to call last the since changes value all read //
                                ReadQueueValues ←
                                not. does ReadQueueValues() timestamps; returns ReadQueue() //
                                _ = tsUpdates >TimestampedDouble::nt<vector::std
                                ReadQueueDouble(dblSub);::nt ←
                                ReadQueueValuesDouble(dblSub);::nt = valUpdates >double<vector::std
                                }

                                { Example()~
                                subscribing stop //
                                Unsubscribe(dblSub);::nt
                                }

```

C

```

                                exists already variable dblTopic NT_Topic a that assumes code This //
                                subscribing start //
                                _not is string and raw than other types for string type custom a Using //
                                recommended. ←
                                );0 ,NULL ,"double" NT_DOUBLE, NT_Subscribe(dblTopic, = dblSub NT_Subscriber

                                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
                                ;10 = options.pollStorage
                                options);& ,"double" NT_DOUBLE, NT_Subscribe(dblTopic, = dblSub NT_Subscriber

                                returns published, been has value no if value; recent most the get //
                                value default passed-in the //
                                );0.0 NT_GetDouble(dblSub, = val double

                                timestamp its with along value, recent most the get //
                                tsVal; NT_TimestampedDouble struct
                                tsVal);& ,0.0 NT_GetAtomic(dblSub,
                                tsVal);&NT_DisposeTimestamped(

                                ReadQueue/ReadQueueValues to call last the since changes value all read //
                                not. does ReadQueueValues() timestamps; returns ReadQueue() //
                                tsUpdatesLen; size_t
                                & NT_ReadQueueDouble(dblSub, = tsUpdates *NT_TimestampedDouble struct
                                tsUpdatesLen); ←
                                tsUpdatesLen); NT_FreeQueueDouble(tsUpdates,

                                valUpdatesLen; size_t
                                valUpdatesLen);& NT_ReadQueueValuesDouble(dblSub, = valUpdates *double
                                page) next on (continues

```

(0000 00000 0000)

```
valUpdatesLen); NT_FreeDoubleArray(valUpdates,
    subscribing stop //
    NT_Unsubscribe(dblSub);
```

Python

```

:Example class
DoubleTopic): ntcore dblTopic: ,self(init____ def
    retained. be must value return the subscribing; start #
    when available is value no if value default the is parameter the #
        called is get() ↪
    )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 #
    is string and raw than other types for string type custom a Using #
        recommended. not ↪
    )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 #
    needs close() case which in program, robot entire the of lifetime the #
        be to ↪
        subscribing stop to called #
        ):self(close def
        subscribing stop #
        close().dblSub.self

```

Publish and Subscribe Both to Entry Using 28.3.3

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
        the of that matches lifetime its so variable instance an is entry the //
        class →
        dblEntry; DoubleEntry final

        { dblTopic) (DoubleTopicExample public
        retained. be must value return the subscribing; start //
        when available is value no if value default the is parameter the //
        called is get() →
        );0.0(getEntrydblTopic. = dblEntry

        PubSubOption using specified be may options subscribe and publish //
        = dblEntry
        ),true(keepDuplicatesPubSubOption. ,0.0(getEntrydblTopic.
        ));10(pollStoragePubSubOption. →

        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

        first the publishers; as methods same the all support also entries //
        time →
        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 //
        page) next on (continues

```

(0000 00000 0000)

```
() ;unpublish dbEntry.
}
```

```
for exist t' doesn't class this unless code, robot in required not often //
needs close() case which in program, robot entire the of lifetime the //
be to →
    subscribing stop to called //
    { () close void public
    subscribing/publishing stop //
    () ; closed dbEntry.
    }
}
```

C++

```
{ Example class
the of that matches lifetime its so variable instance an is entry the //
class →
    is dbEntry when stopped automatically is subscribing/publishing //
    by destroyed →
    destructor class the //
    dbEntry; DoubleEntry::nt

    :public
    { dbTopic) DoubleTopic::Example(nt explicit
    retained. be must value return the subscribing; start //
    when available is value no if value default the is parameter the //
    called is get() →
    ); 0.0 dbTopic.GetEntry( = dbEntry

    PubSubOptions using specified be may options subscribe and publish //
    = dbEntry
    , 0.0 dbTopic.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" dbTopic.GetEntryEx( = dbEntry
    }

    { Periodic() void
    subscribers: as methods same the all support entries //
    dbEntry.Get(); = val double
    ); 1.0 - dbEntry.Get( = val double
    dbEntry.GetAtomic(); = tsVal TimestampedDouble::nt
    dbEntry.ReadQueue(); = tsUpdates > TimestampedDouble::nt < vector::std
    dbEntry.ReadQueueValues(); = valUpdates > double < vector::std

    first the publishers; as methods same the all support also entries //
    time →
    created automatically is publisher internal an called, is these of one //
    ); 0.0 dbEntry.SetDefault(
    ); 1.0 dbEntry.Set(
```

page) next on (continues

(0000 00000 0000)

```

time current use = 0 // );0 ,2.0 dblEntry.Set(
Now();::nt = time int64_t
time); ,3.0 dblEntry.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

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
= tsUpdates >TimestampedDouble::nt<vector::std
ReadQueueDouble(dblEntry);::nt →
ReadQueueValuesDouble(dblEntry);::nt = valUpdates >double<vector::std

first the publishers; as methods same the all support also entries //
time →
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
}

```

page) next on (continues

(0000 00000 0000)

```

{ Example()~
  subscribing and publishing stop //
  ReleaseEntry(dblEntry);::nt
}

```

C

```

exists already variable dblTopic NT_Topic a that assumes code This //
subscribing start //
not is string and raw than other types for string type custom a Using //
recommended. ↪
);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
& NT_ReadQueueDouble(dblEntry, = tsUpdates *NT_TimestampedDouble struct
tsUpdatesLen); ↪
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);

```

```

                                :Example class
DoubleTopic): ntcore dblTopic: ,self( init____ def
    retained. be must value return the subscribing; start #
    when available is value no if value default the is parameter the #
                                called is get() ↪
                                )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 #
    is string and raw than other types for string type custom a Using #
                                recommended. not ↪
                                )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
    first the publishers; as methods same the all support also entries #
                                time ↪
    automatically is publisher internal an called, is these of one #
                                created ↪
                                )0.0setDefault(.dblEntry.self
                                )1.0set(.dblEntry.self
    time current use = 0 # )0 ,2.0set(.dblEntry.self
                                now()_.ntcore = time
                                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 #
    needs close() case which in program, robot entire the of lifetime the #
                                be to ↪
                                subscribing stop to called #
                                ):self(close def
    subscribing/publishing stop #
                                close().dblEntry.self

```

GenericSubscriber and GenericPublisher, GenericEntry, Using 28.3.4

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
        the of that matches lifetime its so variable instance an is entry the //
        class →
        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

        not if optional; also is string type the entry, an getting when //
        provided →
        publisher- first the by determined be will type data publisher the //
        call creating →
        );getGenericEntrytopic. = entry
        );"double"(getGenericEntrytopic. = entry

        PubSubOption using specified be may options subscribe and publish //
        , "double"(genericPublishtopic. = pub
        ));10(pollStoragePubSubOption. ),true(keepDuplicatesPubSubOption.
        = sub
        ),true(keepDuplicates(PubSubOption.genericSubscribetopic.
        ));10(pollStoragePubSubOption. →
        = entry
        ),true(keepDuplicates(PubSubOption.getGenericEntrytopic.
        ));10(pollStoragePubSubOption. →

        properties. initial setting of option the provides genericPublishEx //
        , "true} :\"retained\"{\" , "double"(genericPublishExtopic. = pub
        ));10(pollStoragePubSubOption. ),true(keepDuplicatesPubSubOption.
        }

        { ()periodic void public
        default a operations; get typed have entries and subscribers generic //
        provided be must →
        );1.0-(getDoublesub. = val double
        );1.0-(getDoubleentry. = val double

```

page) next on (continues

(0000 0000 0000)

```

Supplier meets (also get untyped an support also they //
interface) <NetworkTableValue> →
();getsub. = val NetworkTableValue
();getentry. = val NetworkTableValue

readQueue support also they //
();readQueuesub. = updates ][NetworkTableValue
();readQueueentry. = updates ][NetworkTableValue

false return these operations; set typed have entries and publishers //
the if →
type mismatched a with exists already topic //
);1.0(setDefaultDoublepub. = success boolean
);true(setBooleanpub. = success boolean

Consumer<NetworkTableValue> and set generic a implement also they //
interface →
(...));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 //
needs close() case which in program, robot entire the of lifetime the //
be to →
subscribing/publishing stop to called //
{ ()close void public
();closepub.
();closepub.
();closeentry.
}
}

```

C++

```

{ Example class
the of that matches lifetime its so variable instance an is entry the //
class →
is dblEntry when stopped automatically is subscribing/publishing //
by destroyed →
destructor class the //
pub; GenericPublisher::nt
sub; GenericSubscriber::nt
entry; GenericEntry::nt

:public
{ topic) Topic::Example(nt
retained. be must value return the subscribing; start //
provided be must string type a publishing, when //
);"double"topic.GenericPublish( = pub

```

page) next on (continues

(□□□□ □□□□ □□□□)

```

        string type a include optionally can subscribing //
        provided is value default no subscribers, type-specific unlike //
        topic.GenericSubscribe(); = sub
    );"double"topic.GenericSubscribe( = sub

    _not if optional; also is string type the entry, an getting when //
        provided →
    publisher- first the by determined be will type data publisher the //
        call creating →
        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
    _default a operations; get typed have entries and subscribers generic //
        provided be must →
        );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

    _false return these operations; set typed have entries and publishers //
        the if →
        type mismatched a with exists already topic //
        );1.0pub.SetDefaultDouble( = success bool
        );truepub.SetBoolean( = success bool

    _Consumer<NetworkTableValue> and set generic a implement also they //
        interface →
        MakeDouble(...));::NetworkTableValue::entry.Set(nt = success bool
    }

        { Unpublish() void
    alive subscriber the keeping while entry an publishing stop can you //
        entry.Unpublish();
    }
    ;}

```

```

Topic): ncore topic: ,self(____ 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

    not if optional; also is string type the entry, an getting when #
    publisher- first the by determined be will type data publisher the #
    call creating →
    getGenericEntry().topic = entry.self
    )"double"getGenericEntry(.topic = entry.self

    PubSubOption using specified be may options subscribe and publish #
    genericPublish(.topic = pub.self
    ,True=PubSubOptions(keepDuplicates.ncore ,"double"
    )10=pollStorage →
    )
    genericSubscribe(.topic = sub.self
    )10=pollStorage ,True=PubSubOptions(keepDuplicates.ncore
    )
    getGenericEntry(.topic = entry.self
    )10=pollStorage ,True=PubSubOptions(keepDuplicates.ncore
    )

    properties. initial setting of option the provides genericPublishEx #
    genericPublishEx(.topic = pub.self
    ,"double"
    ,true} : "retained"{'
    ),10=pollStorage ,True=PubSubOptions(keepDuplicates.ncore
    )

    ):self(periodic def
    a operations; get typed have entries and subscribers generic #
    provided be must default →
    )1.0-getDouble(.sub.self = val
    )1.0-getDouble(.entry.self = val

    Supplier meets (also get untyped an support also they #
    interface) <NetworkTableValue> →
    get().sub.self = val
    get().entry.self = val

    readQueue support also they #
    readQueue().sub.self = updates
    readQueue().entry.self = updates

    return these operations; set typed have entries and publishers #
    the if false →

```

page) next on (continues

(0000 00000 0000)

```

type mismatched a with exists already topic #
)1.0setDefaultDouble( pub.self = success
)True)setBoolean( pub.self = success

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 #
needs close() case which in program, robot entire the of lifetime the #
be to ↪
subscribing/publishing stop to called #
):self(close def
close().pub.self
close().sub.self
close().entry.self

```

Topics Multiple to Subscribing 28.3.5

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
of that matches lifetime its so variable instance an is subscriber the //
class 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.

create to necessary s'it MultiSubscriber, a from updates value get to //
listener a ↪
details) more for documentation listener the (see //
NetworkTableListenerPoller(inst); new = poller
.Kind(NetworkTableEvent.ofEnumSet. (multiSub,addListenerpoller.
page) next on (continues

```

(~~~~ ~~~~~ ~~~~~)

```

    ));kValueAll
    }

    { ()periodic void public
      events value read //
    };readQueuepoller. = events ][NetworkTableEvent

    { events) : event (NetworkTableEvent for
    ;value.valueDataevent. = value NetworkTableValue
    }
  }

  for exist t'doesn class this unless code, robot in required not often //
  needs close() case which in program, robot entire the of lifetime the //
  be to
  subscribing stop to called //
  { ()close void public
    listener close //
    ();closepoller.
    subscribing stop //
    ();closemultiSub.
  }
}

```

C++

```

    { Example class
  of that matches lifetime its so variable instance an is subscriber the //
    class the
  the by destroyed is multiSub when stopped automatically is subscribing //
    destructor class
    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.{

  create to necessary s'it MultiSubscriber, a from updates value get to //
    listener a
    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

```

page) next on (continues

(0000 00000 0000)

```

    { 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

    :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.{

    create to necessary s'it MultiSubscriber, a from updates value get to //
    listener a ↪
    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
  }

```

```

exists already variable inst NT_Inst a that assumes code This //
                                subscribing start //
                                prefixes name topic of array an provide //
                                ]; prefixes[ NT_String struct
                                ; "table1/" = ].str prefixes[
                                ; 8 = ].len prefixes[
                                ; "table2/" = ].str prefixes[
                                ; 8 = ].len prefixes[
    , NULL , 2 prefixes, NT_SubscribeMultiple(inst, = multiSub NT_MultiSubscriber
                                ); 0 ↵

    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
    & , 2 prefixes, NT_SubscribeMultiple(inst, = multiSub NT_MultiSubscriber
                                options); ↵

    , a create to necessary s'it MultiSubscriber, a from updates value get to //
                                listener ↵
                                details) more for documentation listener the (see //
    NT_CreateListenerPoller(inst); = poller NT_ListenerPoller
    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

```

page) next on (continues

(0000 00000 0000)

```
.ntcore ], "table2//" , "table1//"[ inst,
    )True=PubSubOptions(keepDuplicates ↪
    )

    ↪to necessary s'it MultiSubscriber, a from updates value get to #
    listener a create ↪
    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 #
    ↪needs close() case which in program, robot entire the of lifetime the #
    be to ↪
    subscribing stop to called #
    ):self(close def
    listener close #
    close().poller.self
    subscribing stop #
    close().multiSub.self
```

Options Publish/Subscribe 28.3.6

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 28.3.7

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 28.4

"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 //
nt = defaultInst NetworkTableInstance::nt
GetDefault();::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 28.5

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 28.5.1

Java

```

();getDefaultNetworkTableInstance. = inst NetworkTableInstance
();startServerinst.

```

C++

```
GetDefault(); NetworkTableInstance nt = inst NetworkTableInstance nt
inst.StartServer();
```

based)(Handle- C++

```
GetDefaultInstance(); nt = inst NT_Instance
NT_DEFAULT_ NT_DEFAULT_PORT3, , " " , "networktables.json" StartServer(inst, nt
PORT4); ↵
```

C

```
NT_GetDefaultInstance(); = inst NT_Instance
NT_DEFAULT_ NT_DEFAULT_PORT3, , " " , "networktables.json" NT_StartServer(inst,
PORT4); ↵
```

Python

```
ntcore import
get_default().NetworkTableInstance ntcore = inst
start_server().inst
```

Client NetworkTables a Starting 28.5.2

Java

```
();get_default().NetworkTableInstance. = inst NetworkTableInstance
client NT4 a start //
);"client example"(startClient4inst.
TEAM number team with roboRIO a to connect //
(Team);setServerTeaminst.
DS the from address roboRIO the get to try will client DS a starting //
application ↵
());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 //
inst.SetServerTeam(TEAM);
// DS the from address roboRIO the get to try will client DS a starting //
// application ↪
inst.StartDSClient();
// host/port specific a to connect //
NT_DEFAULT_PORT4) ,"host"inst.SetServer(
```

based)(Handle- C++

```
GetDefaultInstance();::nt = inst NT_Instance
// client NT4 a start //
);"client example" StartClient4(inst,::nt
// TEAM number team with roboRIO a to connect //
TEAM); SetServerTeam(inst,::nt
// DS the from address roboRIO the get to try will client DS a starting //
// application ↪
StartDSClient(inst);::nt
// host/port specific a to connect //
NT_DEFAULT_PORT4) ,"host" SetServer(inst,::nt
```

C

```
NT_GetDefaultInstance(); = inst NT_Instance
// client NT4 a start //
);"client example" NT_StartClient4(inst,
// TEAM number team with roboRIO a to connect //
TEAM); NT_SetServerTeam(inst,
// DS the from address roboRIO the get to try will client DS a starting //
// application ↪
NT_StartDSClient(inst);
// host/port specific a to connect //
NT_DEFAULT_PORT4) ,"host" NT_SetServer(inst,
```


Python

```

ntcore import
getDefault() NetworkTableInstance ntc = inst

    client NT4 a start #
    )"client example"startClient4(.inst

    TEAM number team with roboRIO a to connect #
    setServerTeam(TEAM).inst

    _DS the from address roboRIO the get to try will client DS a starting #
    application ↪
    startDSClient().inst

    host/port specific a to connect #
    kDefaultPort4).NetworkTableInstance.ntcore , "host"setServer(.inst

```

Changes for Listening 28.6

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

```

page) next on (continues

(0000 0000 0000)

```

        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 //
    { ()readQueueeySub. : tsValue (TimestampedDouble for
    local at " + value + " value: changed X"(println.outSystem.
    );timestamptsValue. + " time ←
    }
    }

    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

```

page) next on (continues

(0000 00000 0000)

```

    }

    timestamps provides but ReadQueueValues(), to similar is ReadQueue() //
    well as change each for //
    { ySub.ReadQueue() ) : tsValue TimestampedDouble::(nt for
    _tsValue.value, ,"n\"){ time local at ){ value: changed X"print(::fmt
    tsValue.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 //
    NT_DOUBLE, ),"datatable/Y/" GetTopic(inst,::Subscribe(nt::nt = ySub
    );"double" ↵
    }

    { Periodic() void
    value previous the to detection change simple with used be can Get() //
    );0.0 GetDouble(ySub,::nt = 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 ReadQueue() //
    slowly too polling by change a miss to possible not s'it way this //
    { ReadQueueDouble(ySub)::nt : value TimestampedDouble::(nt for
    _tsValue.value, ,"n\"){ time local at ){ value: changed X"print(::fmt
    tsValue.timestamp); ↵
    }
    }
    ;}

```

```

                                :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
                                _previous the to detection change simple with used be can get() #
                                value ↵
                                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
                                .tsValue{ time local at }value.tsValue{ value: changed X"f(print
                                )"}time ↵

                                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 28.6.1

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 28.6.2

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.
              }
            );}

            datatable" called subtable the get //
            );"datatable"(getTableinst. = datatable NetworkTable

```

page) next on (continues

```

(0000 00000 0000)

    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.
                }
            }

    the for exists class this if programs robot for needed be not may //
        program the of lifetime //
        { ()close void public
            ());getDefaultNetworkTableInstance. = inst NetworkTableInstance
            (topicListenerHandle);removeListenerinst.
            (valueListenerHandle);removeListenerinst.
            (connListenerHandle);removeListenerinst.
            ());closeySub.
        }
    }

```

```

        { Example class
        ySub; DoubleSubscriber::nt
        thread-safe flag and value the updating make to mutex a use //
        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 //
        _const( [] ,trueinst.AddConnectionListener( = connListenerHandle
        { event) &Event::nt →
        { kConnected))::EventFlags::(event.Is(nt if
        remote_>-event.GetConnectionInfo() ,"n\"){ to Connected"print(::fmt
        id); →
        { kDisconnected))::EventFlags::(event.Is(nt if else }
        >-event.GetConnectionInfo() ,"n\"){ from Disconnected"print(::fmt
        remote_id); →
        }
        );}

        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 //
        page) next on (continues

```

```
(
name);> event.GetTopicInfo() ,"n\"){ published newly"print(::fmt
}
);}
}

{ Periodic() void
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__ ,TrueaddConnectionListener( inst = connListenerHandle.self
cb) ↪

datatable"" called subtable the get #
)"datatable"getTable(.inst = datatable

Y"" called datatable"" in topic the to subscribe #
)0.0subscribe(.)"Y"getDoubleTopic(.datatable = ySub.self
```

page) next on (continues

(0000 00000 0000)

```

        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
on_ysub_ kValueAll,.EventFlags.ntcore ySub,.self
        )

        within published are topics new when see to listener a add #
        datatable ←
        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 28.7

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

    { ()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"(getDoubleTopic table. = xPub
        ();publish)."y"(getDoubleTopic table. = 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; int
    yPub; DoublePublisher; int

    { ()RobotInit void

```

page) next on (continues

(0000 00000 0000)

```

        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
                                ).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

```

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

```

page) next on (continues

(0000 0000 0000)

```

0 = x.self
0 = y.self

:None >- )self(teleopPeriodic def
increasing. constantly are that values Publish #
x).self.set( xPub self
y).self.set( yPub self
0.05 += x.self
1.0 += y.self

```

Program sideClient- a Creating 28.8

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) }(String main void static public
);false(setExtractOnStaticLoad.Helper NetworkTablesJNI.
);false(setExtractOnStaticLoad.Helper WPIUtilJNI.
);false(setExtractOnStaticLoad.Helper WPIMathJNI.
);false(setExtractOnStaticLoad.Helper CameraServerJNI.

,"wpiutiljni" ,class(Program.loadLibrariesCombinedRuntimeLoader.
,"ntcorejni" ,"wpimathjni" →
);"cscorejni"cvstatic"
);runProgram(). new
}

{ ()run void public
();getDefaultNetworkTableInstance. = inst NetworkTableInstance
);"datatable"(getTableinst. = table NetworkTable
);0.0(subscribe)."x"(getDoubleTopicTable. = xSub DoubleSubscriber
page) next on (continues

```

```
(
);0.0(subscribe). "y"(getDoubleTopic table. = ySub DoubleSubscriber
);"client example"(startClient4inst.
use or etc, 294, TEAM=190, where // );"localhost"(setServerinst.
similar or inst.setServer("hostname") →
this computer; DS on running if recommended // ();startDSClientinst.
DS the from IP robot the gets →
{ )true( while
{ try
);1000(sleepThread.
{ ex) (InterruptedException catch }
);"interrupted"(println.outSystem.
;return
}
);getxSub. = x double
);getySub. = y double
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. use or etc, 294, TEAM=190, where // inst.SetServerTeam(Team);
similar or setServer("hostname") →
gets this computer; DS on running if recommended // inst.StartDSClient();
DS the from IP robot the →
{ )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#
        ntc core_cpp.h>< include#

        { ()main int
            GetDefaultInstance();nt = inst NT_Instance
            = 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
            use or etc, 294, TEAM=190, where // );0 TEAM, SetServerTeam(inst,::nt
            similar or inst.setServer("hostname") →
            computer; DS on running if recommended // );0 StartDSClient(inst,::nt
            DS the from IP robot the gets this →
            { )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
            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
        ),"double" NT_DOUBLE, ),"datatable/x/" NT_Subscribe(NT_GetTopic(inst,
            );0 ,NULL →
            = ySub NT_Subscriber
        ),"double" NT_DOUBLE, ),"datatable/y/" NT_Subscribe(NT_GetTopic(inst,
            );0 ,NULL →
            );"client example" NT_StartClient4(inst,
            inst. use or etc, 294, TEAM=190, where // TEAM); NT_SetServerTeam(inst,
            similar or setServer("hostname") →
            this computer; DS on running if recommended // NT_StartDSClient(inst);
            DS the from IP robot the gets →
            { )true( while
            );NULL ,}1=){.tv_sec timespec struct(&thrd_sleep(
            );0.0 NT_GetDouble(xSub, = x double
            );0.0 NT_GetDouble(ySub, = y double
            y); x, ,"n\% Y: f% X:"printf(
            }
        }
    }

```

Python

```
python3 usr/bin/env/#!/#
ntcore import
time import

:"main__" == name__ if
getDefault() NetworkTableInstance ntcore = inst
) "datatable"getTable( inst = table
) subscribe( ) "x"getDoubleTopic( table = xSub
) subscribe( ) "y"getDoubleTopic( table = ySub
) "client example"startClient4( inst
inst. use or etc, 294, TEAM=190, where # setServerTeam(Team).inst
similar or setServer("hostname") →
gets this computer; DS on running if recommended # startDSClient().inst
DS the from IP robot the →

: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 28.8.1

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
  '8.1.1' version 'com.github.johnrengelman.shadow' id
  '1.3.0' version 'edu.wpi.first.WpilibTools' id
}

{ application
  'Program' = mainClass
```

page) next on (continues

(0000 0000 0000)

```

    }
    11
    )(get.wpilibVersion.versions.wpi = wpilibVersion.deps.wpilibTools
    12
    'wpilibNatives' = nativeConfigName def
    13
    nativeConfigName(create.configurations = nativeConfig def
    14
    { createExtractionTasks wpilibTools = nativeTasks def
    15
    nativeConfigName = configurationName
    16
    }
    17
    )main.sourceSets(addToSourceSetResources.nativeTasks
    18
    )wpimath""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
    19
    )wpinet""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
    20
    )wpiutil""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
    21
    )ntcore""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
    22
    )cscore""(wpilib.deps.wpilibTools add.dependencies.nativeConfig
    23
    .wpi + frc""(wpilibOpenCv.deps.wpilibTools add.dependencies.nativeConfig
    24
    )(get.opencvVersion.versions.wpi ,)(get.frcYear →
    25
    { dependencies
    26
    )wpiutil""(wpilibJava.deps.wpilibTools implementation
    27
    )wpimath""(wpilibJava.deps.wpilibTools implementation
    28
    )wpinet""(wpilibJava.deps.wpilibTools implementation
    29
    )ntcore""(wpilibJava.deps.wpilibTools implementation
    30
    )cscore""(wpilibJava.deps.wpilibTools implementation
    31
    )cameraserver""(wpilibJava.deps.wpilibTools implementation
    32
    .frcYear.wpi + frc""(wpilibOpenCvJava.deps.wpilibTools implementation
    33
    )(get.opencvVersion.versions.wpi ,)(get →
    34
    jackson-" name: ,com.fasterxml.jackson.core"" group: implementation
    35
    )(get.jacksonVersion.versions.wpi version: ,annotations" →
    36
    ,jackson-core"" name: ,com.fasterxml.jackson.core"" group: implementation
    37
    )(get.jacksonVersion.versions.wpi version: →
    38
    jackson-" name: ,com.fasterxml.jackson.core"" group: implementation
    39
    )(get.jacksonVersion.versions.wpi version: ,databind" →
    40
    .wpi version: ,ejml-simple"" name: ,org.ejml"" group: implementation
    41
    )(get.ejmlVersion.versions →
    42
    ,quickbuf-runtime"" name: ,us.hebi.quickbuf"" group: implementation
    43
    ;)(get.quickbufVersion.versions.wpi version: →
    44
    }
    45
    { shadowJar
    46
    TestApplication"" = archiveBaseName
    47
    "" = archiveVersion
    48
    )module-info.class""(exclude
    49
    )platformName.currentPlatform.wpilibTools(set.archiveClassifier
    50
    }
    51
    { wrapper
    52
    '8.5' = gradleVersion
    53
    }
    54
    55
    56

```


highlighted. as platform appropriate the Uncomment

```

        { plugins
        cpp"" id
    }

    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

    { model
    { components
    { )NativeExecutableSpec(appName)"{"$

    { 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

    )it(wpilibStatic.deps.cpp.wpi
    }
    }
    }

    { wrapper
    '8.5' = gradleVersion
    }

```

Python Building 28.8.2

.documentation install RobotPy the to refer Python, For

NetworkTables to 3.0 NetworkTables from Migrating 28.9 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 28.9.1

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
                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
        }
    }
}

```

page) next on (continues

(0000 00000 0000)

```

                { Periodic() void
2 by multiplied value that to Out set and Y, from value double a read //
                ySub.Get(); = value double
                );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 28.9.2

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 28.9.3

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 28.9.4

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 28.9.5

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++ 28.9.6

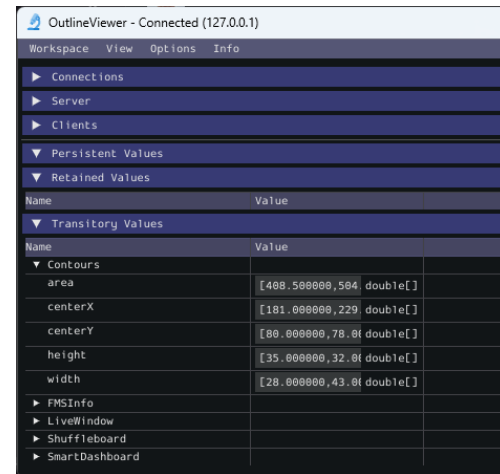
shared of instead)nt::Value (plain objects value as returned/used now are values C++).><nt::Valuestd::shared_ptr(them to pointers

NetworkTables by Published Values Array Reading 28.10

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 python a like robot the on tool a or pi, raspberry a like processor vision separate a using processing. image the do to program

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 28.10.1



Name	Value
area	[488.580000, 584 double[]
centerX	[181.000000, 229 double[]
centerY	[80.000000, 78.8 double[]
height	[35.000000, 32.8 double[]
width	[28.000000, 43.8 double[]

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 28.10.2

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.

```

page) next on (continues

(0000 0000 0000)

```

        { areas) : area double( for
    );" " + (areaprint.outSystem.
    }

    ();println.outSystem.
}

```

C++

```

areasSub; DoubleArraySubscriber::nt

{ override ()Robot::RobotInit void
GRIP/myContoursReport"GetDefault().GetTable(::NetworkTableInstance::nt = table auto
);" →
).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 ntc = table
subscribe([]).)"area"getDoubleArrayTopic( table = areasSub.self

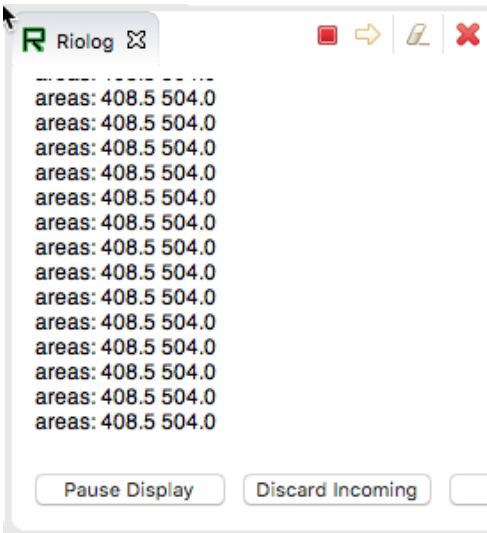
):self(teleopPeriodic def
get() areasSub.self = areas
areas) , "Areas:"(print

```

are: them printing program, this in and, values the getting to steps The values. the have that subtable the of instance the hold will that variable table the Declare 1.

values. the retrieving for later used be can it that so instance subtable the Initialize 2.
 programs, communicating a of case the In NetworkTables. from values of array the Read 3.
 be yet not might here read being output the producing program the that possible it's
 being not data the of issues avoid To up. starts program robot the when available
 the if returned be will value default This supplied. is values of array default a ready,
 of value the over loop will code This published. been yet hasn't topic NetworkTables
 20ms. every areas

Output Program 28.10.3



the all example real a in but areas, of array the at looking only is program the case this In
you log Station Driver the or Code VS in Riolog the Using used. be likely more would values
they so image static sample a using is program This retrieved. are they as values the see can
be would values the robot, your on camera a with imagine can you but change, don't areas
constantly. changing

the use paths These trajectories. following and creating of process the is Planning Path section This following. for *Controller Ramsete* a and generation for APIs trajectory WPILib trajectory identification, system for robot your characterizing of process the highlights *trajectory generic* the read to want also may Users PathWeaver. of usage and following usage. commandbasednon- and API the about information additional for *documents following*

Support Swerve on Notice 29.1

of: aware be to need teams that limitations of couple a has following path in support Swerve request. pull [this](#) see please simulation, in swerve support not does currently WPILib •
 and project Mechanism General a using heading swerve the tuning supports only SysId •
 module's the lock to is workaround A data. velocity module support regularly not does like something using rotation module blocking via done be can This place. into heading wood. of block a
 heading. independent incorporate not do currently following Trajectory and Pathweaver •
 a as same the be will swerve on framework trajectory WPILib the using following Path robot. DifferentialDrive
 inconvenience. the for sorry are We

Tutorial Trajectory 29.1.1

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. drivetrain differential- 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
 with: equipped),AM14U5 AndyMark the as (such robot drivedifferential- A 1.
 drive. the of side each of rotation wheel the measuring for encoders Quadrature •
 heading. robot measuring for gyroscope A •
 with: configured computer stationdriver- A 2.
.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

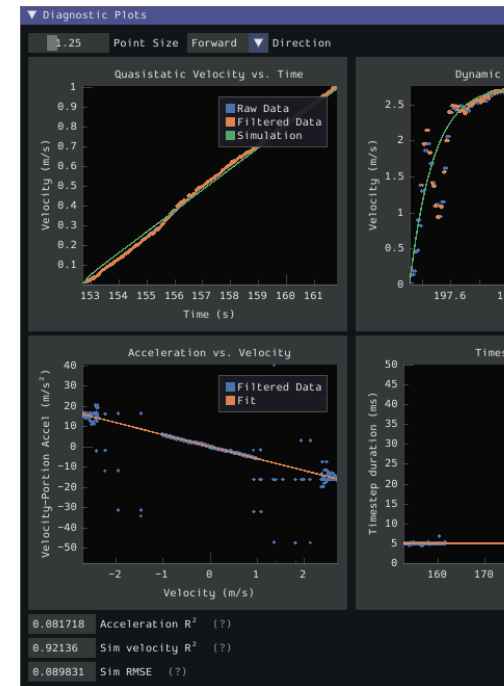
data. identification drive our gathering by begin We
.project robot your Deploy and Configure 1.
.Routine identification the Run 2.

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:

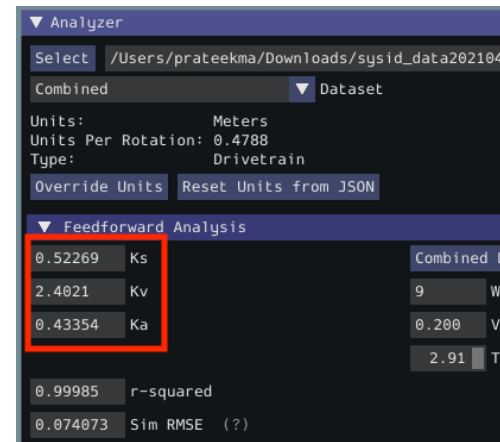


we parameters, acceptable within are metrics fit the and linear, reasonably look data our As
 step. next the to proceed

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



following the in are gains feedforward our meters, in specified was diameter wheel our Since units:

- Volts :kS •
- Meters / Seconds * Volts :kV •
- Meters / Seconds² * 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

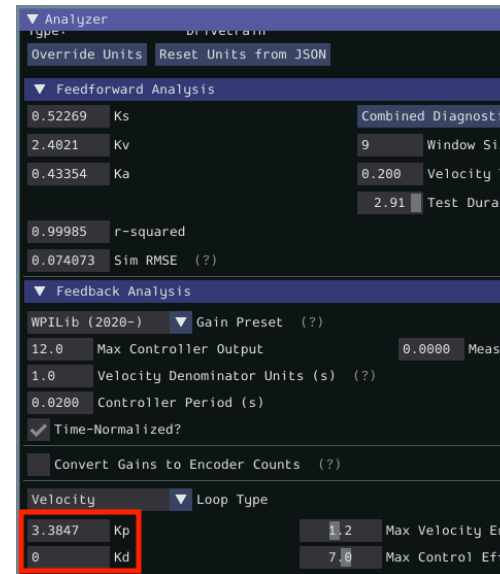
path. the follow to use will we that control PID the for *gains feedback the calculate* now We so control, loopclosed- velocity uses controller RAMSETE WPILib's with following Trajectory tool: identification the in mode Velocity select first we



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



velocity a is it Since loop. control our for gains feedback the record and calculate we Finally, required: is gain P a only controller,



* 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 //
                                                                    these →
    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

```

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 inline
    m;_1 / s_1 * V_1 * 1.98 = kv auto constexpr inline
    m;_1 / s_1 * s_1 * V_1 * 0.2 = ka auto constexpr inline
                                                                    drive! your for tuned be must this above, as - only value Example //
                                                                    ;8.5 = kPDriveVel double constexpr inline

```

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

```

C++

```
m;_0.69 = kTrackwidth auto constexpr inline
kDriveKinematics; DifferentialDriveKinematics: frc const extern
```

38
39

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

trajectory during only applied are here, defined as acceleration, and velocity Max :
to values give may which itself, RamseteCommand the limit not do They generation.
and velocities these exceed greatly to robot the cause can that DriveSubsystem the
accelerations.

JAVA

```
;3 = kMaxSpeedMetersPerSecond double final static public
;1 = kMaxAccelerationMetersPerSecondSquared double final static public
```

57
58

C++

```
mps;_3 = kMaxSpeed auto constexpr inline
mps_sq;_1 = kMaxAcceleration auto constexpr inline
```

61
62

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
```

60
61
62

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 inline
                                                                    rad;_1 / 0.7 = kRamseteZeta auto constexpr inline

```

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
                                                                    ;edu.wpi.first.util.sendable.SendableRegistry import
                                                                    ;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.motorcontrol.PWMSparkMax import
                                                                    ;edu.wpi.first.wpilibj2.command.SubsystemBase import

{ SubsystemBase extends DriveSubsystem class public
    drive. the of side left the on motors The //
    PWMSparkMax(DriveConstants. new = m_leftLeader PWMSparkMax final private
                                                                    );kLeftMotor1Port →
    PWMSparkMax(DriveConstants. new = m_leftFollower PWMSparkMax final private
                                                                    );kLeftMotor2Port →

    drive. the of side right the on motors The //
    PWMSparkMax(DriveConstants. new = m_rightLeader PWMSparkMax final private
                                                                    );kRightMotor1Port →
    PWMSparkMax(DriveConstants. new = m_rightFollower PWMSparkMax final private
                                                                    );kRightMotor2Port →

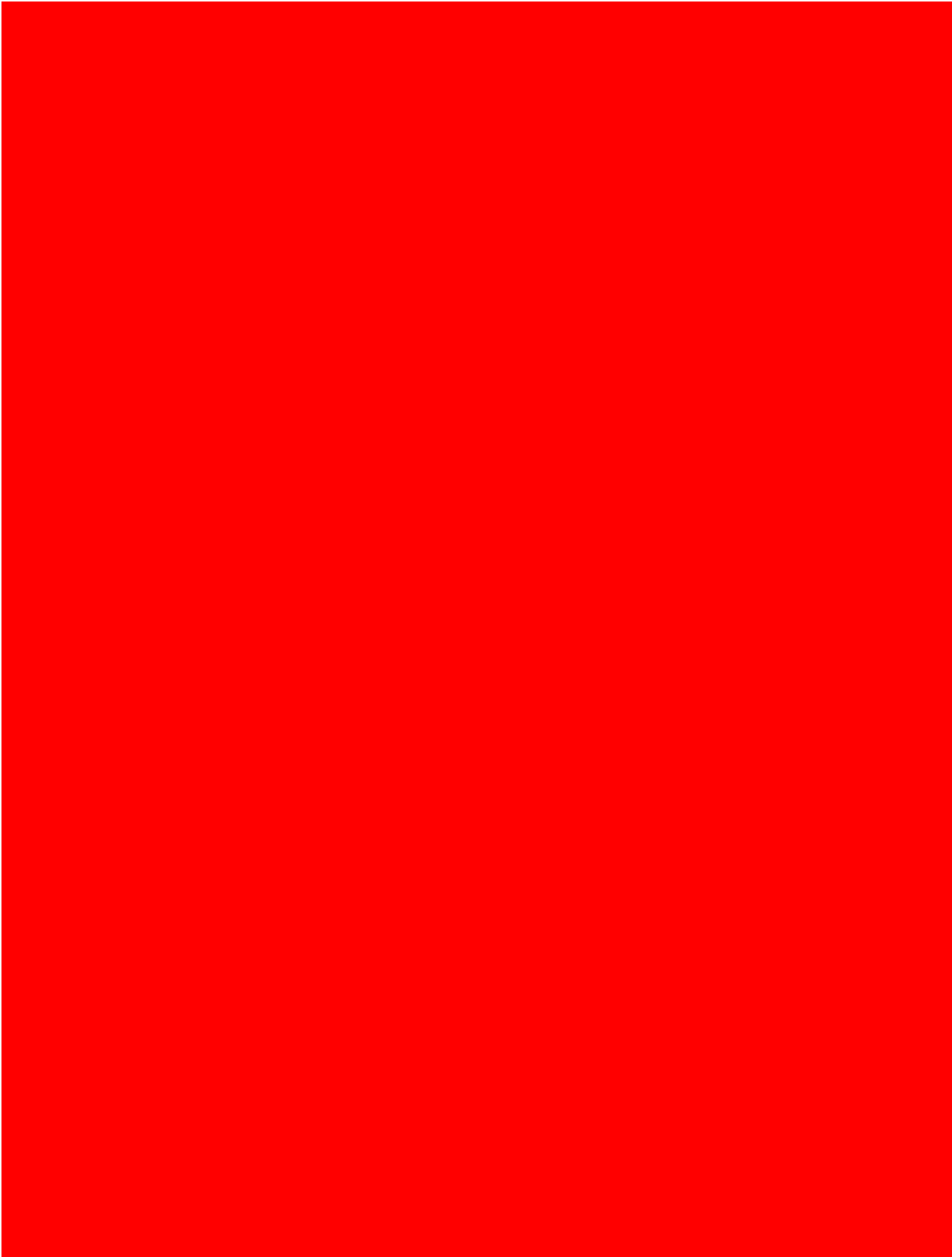
    drive s'robot The //
    = m_drive DifferentialDrive final private
    m_rightLeader::set); DifferentialDrive(m_leftLeader::set, new

    encoder drive left-side The //
    = m_leftEncoder Encoder final private
                                                                    Encoder( new
                                                                    ,]0[kLeftEncoderPortsDriveConstants.
                                                                    ,]1[kLeftEncoderPortsDriveConstants.
                                                                    );kLeftEncoderReversedDriveConstants.

```

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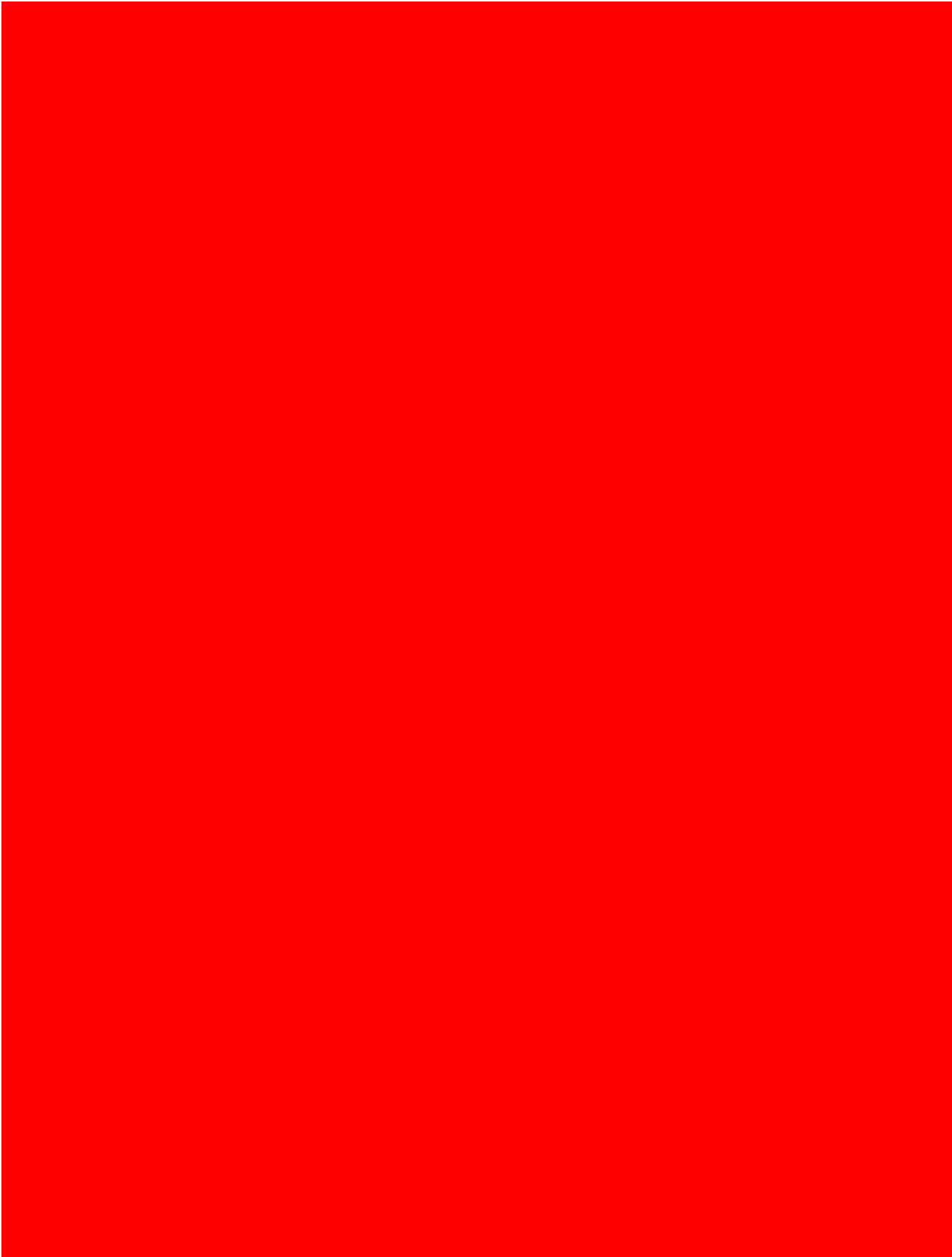
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```

encoder. drive left the Gets * 147
* 148
encoder drive left the @return * 149
*/ 150
{ ()getLeftEncoder Encoder public 151
    m_leftEncoder; return 152
} 153
*/ 154
encoder. drive right the Gets * 155
* 156
encoder drive right the @return * 157
*/ 158
{ ()getRightEncoder Encoder public 159
    m_rightEncoder; return 160
} 161
*/ 162
more drive to drive the scaling for Useful drive. the of output max the Sets * 163
slowly. 164
* 165
constrained be will drive the which to output maximum the maxOutput @param * 166
*/ 167
{ maxOutput) double(setMaxOutput void public 168
    (maxOutput);setMaxOutputm_drive. 169
} 170
*/ robot. the of heading the Zeroes */ 171
{ ()zeroHeading void public 172
    ();resetm_gyro. 173
} 174
*/ 175
robot. the of heading the Returns * 176
* 177
180 to 180- from degrees, in heading s'robot the @return * 178
*/ 179
{ ()getHeading double public 180
    ();getDegrees().getRotation2dm_gyro. return 181
} 182
*/ 183
robot. the of rate turn the Returns * 184
* 185
second per degrees in robot, the of rate turn The @return * 186
*/ 187
{ ()getTurnRate double public 188
    ();getRate m_gyro.- return 189
} 190
*/ 191
} 192
} 193
} 194
} 195

```

(Header) C++

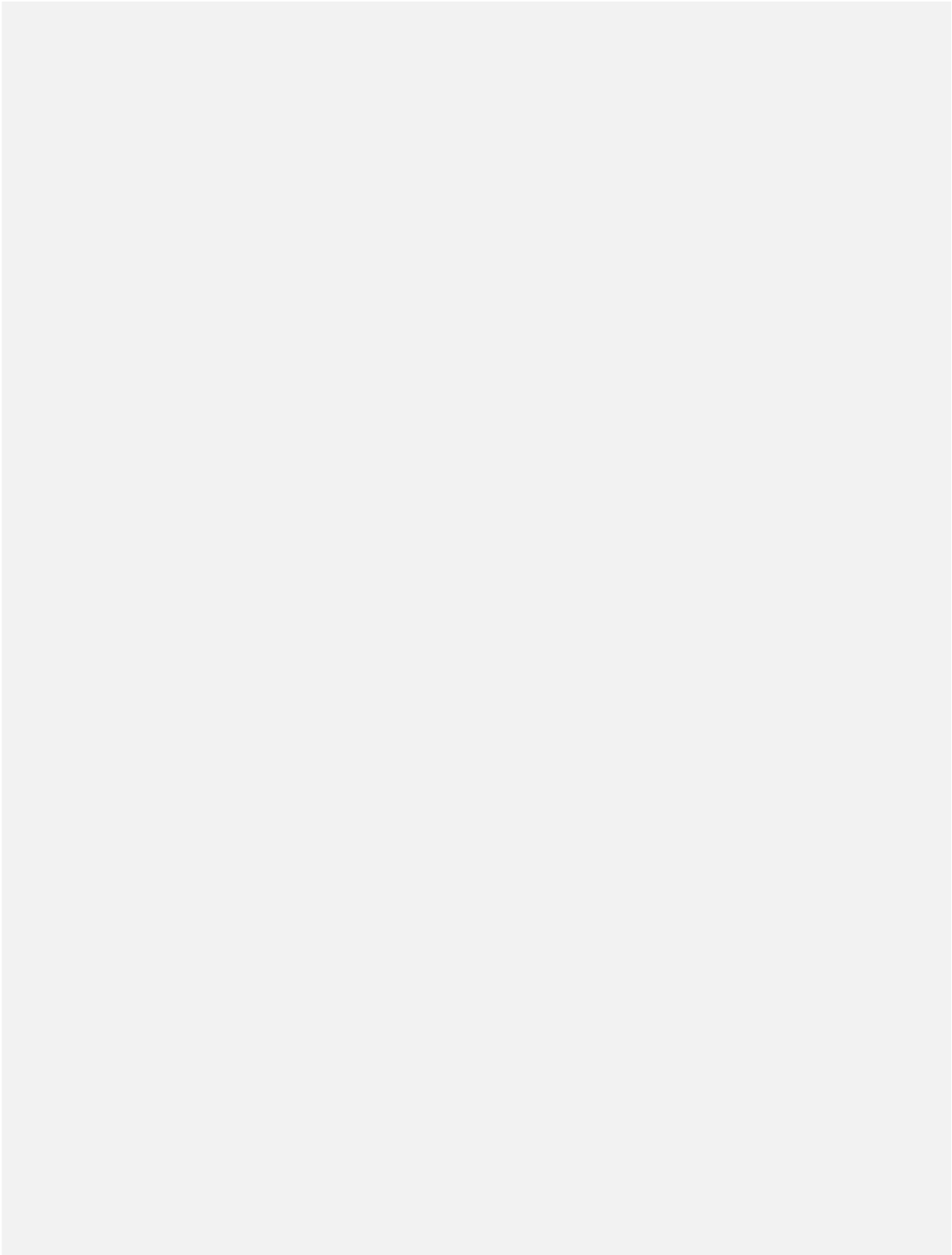
```

once pragma#
5
6
frc/ADXR5450_Gyro.h>< include#
7
frc/Encoder.h>< include#
8
frc/drive/DifferentialDrive.h>< include#
9
frc/geometry/Pose2d.h>< include#
10
frc/kinematics/DifferentialDriveOdometry.h>< include#
11
frc/motorcontrol/PWMSparkMax.h>< include#
12
frc2/command/SubsystemBase.h>< include#
13
units/voltage.h>< include#
14
15
Constants.h" include#
16
17
{ SubsystemBase:frc2 public : DriveSubsystem class
18
:public
19
DriveSubsystem();
20
21
22
*/
23
runs. CommandScheduler the whenever periodically called be Will *
24
*/
25
;override ()Periodic void
26
27
here. go methods Subsystem //
28
29
*/
30
controls. arcade using robot the Drives *
31
*
32
movement forward commanded the fwd @param *
33
rotation commanded the rot @param *
34
*/
35
rot); double fwd, double(ArcadeDrive void
36
37
*/
38
voltage. a with directly drive the of side each Controls *
39
*
40
output left commanded the left @param *
41
output right commanded the right @param *
42
*/
43
right); volt_t::units left, volt_t::(unitsTankDriveVolts void
44
45
*/
46
0. of position a read currently to encoders drive the Resets *
47
*/
48
();ResetEncoders void
49
50
*/
51
encoders. TWO the of distance average the Gets *
52
*
53
readings encoder TWO the of average the @return *
54
*/
55
();GetAverageEncoderDistance double
56
57
*/
58
encoder. drive left the Gets *
59
*

```

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```

        controllers motor The //
        m_left1; PWMSparkMax::frc
        m_left2; PWMSparkMax::frc
        m_right1; PWMSparkMax::frc
        m_right2; PWMSparkMax::frc

        drive s'robot The //
    }, m_left1.Set(output); { output) double](m_drive{ DifferentialDrive::frc
    ;}} m_right1.Set(output); { output) double](m_drive{ 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(),
        m_left1);& m_drive,&AddChild(::SendableRegistry::wpi
        m_right1);& m_drive,&AddChild(::SendableRegistry::wpi

        m_left1.AddFollower(m_left2);
        m_right1.AddFollower(m_right2);

        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 m_right1.SetInverted(

        encoders the for pulse per distance the Set //
        m_leftEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());

```

page) next on (continues

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```

meters_per_second_t{m_rightEncoder.GetRate()}};::units
}

{ pose) Pose2d::ResetOdometry(frc::DriveSubsystem void
    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
,10[kLeftEncoderPortsDriveConstants.
,11[kLeftEncoderPortsDriveConstants.
);kLeftEncoderReversedDriveConstants.

encoder drive right-side The //
= m_rightEncoder Encoder final private
Encoder( new
,10[kRightEncoderPortsDriveConstants.
,11[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.
```

65

66

(Source) C++

```
m_leftEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
m_rightEncoder.SetDistancePerPulse(kEncoderDistancePerPulse.value());
```

32

33

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 :`getRate()` 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
    }

```

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(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
was which ,Board Gyro FRC ADXRS450 Devices Analog the use we example, our In on).
years: several for parts of kit the in included

Java

```

        sensor gyro The //
ADXRS450_Gyro(); new = m_gyro ADXRS450_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
```

.DifferentialDriveOdometry the initialize we Then

Java

```

                                = m_odometry
DifferentialDriveOdometry( new
m_rightEncoder. (),getDistance m_leftEncoder. (),getRotation2d m_gyro.
                                ());getDistance ↩
```

(Source) C++

```
{ } meter_t{::units }, meter_t{::units m_odometry{m_gyro.GetRotation2d(),
```

Odometry the Updating

encoder the from readings new incorporate to updated regularly be must class odometry The is which method, periodic subsystem's the inside this accomplish We gyroscope. and iteration: loop main per once called automatically

Java

```

        @Override
        { ()periodic void public
            block periodic the in odometry the Update //
                (update m_odometry.
m_rightEncoder. (),getDistance m_leftEncoder. (),getRotation2d m_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
            ();getPoseMeters m_odometry. return
        }

```

(Source) C++

```

        { ()DriveSubsystem::GetPose Pose2d::frc
            m_odometry.GetPose(); return
        }

```

test and deploy to encouraged strongly are teams ,RamseteCommand a running Before :
 during Shuffleboard or SmartDashboard the to sent values with alone, code odometry the
 RamseteCommand a for correct be must odometry This .periodic() 'sDriveSubsystem the
 in speeds high at move to robot a cause can errors unit or sign as work, successfully to
 directions. unpredictable

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);setVoltage(m_leftLeader.
        (rightVolts);setVoltage(m_rightLeader.
        ());feedm_drive.
    }

```

(Source) C++

```

{ right) volt_t::units left, volt_t::(unitsDriveSubsystem::TankDriveVolts void
    m_left1.SetVoltage(left);
    m_right1.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),

acceleration or speed any enforce internally not does itself RamseteCommand : code initial During method. this to parameters voltage motor providing before limits bounds minimum and maximum both apply to encouraged strongly are teams development, the ensuring while setVoltage() to values these passing before variables input the on trajectory a generate example, For achievable. are acceleration and velocity trajectory volts. 6 to voltage limit and velocity maximum Robot's the of half than less little a with

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

```

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*/
class Robot {
    // main the to command autonomous the pass to this Use *
    // autonomous in run to command the @return *
    //
    public Command getAutonomousCommand() {
        // Create a voltage constraint, ensuring we don't accelerate too fast
        var autoVoltageConstraint = new DifferentialDriveVoltageConstraint(
            new SimpleMotorFeedforward(
                new DriveConstants(
                    ksVolts, kvVoltSecondsPerMeter, kaVoltSecondsSquaredPerMeter,
                    kDriveKinematics
                )
            ), autoVoltageConstraint
        );

        // Create a trajectory config
        var config = new TrajectoryConfig(
            kMaxSpeedMetersPerSecond, kMaxAccelerationMetersPerSecondSquared
        );
        // Add kinematics to ensure max speed is obeyed actually
        config.setKinematics(kDriveKinematics);
        // Apply the voltage constraint
        config.addConstraint(autoVoltageConstraint);

        // Example trajectory
        var exampleTrajectory = new TrajectoryGenerator(
            // Start at the origin facing +X
            new Pose2d(0, 0, 0),
            // Pass through two waypoints
            new List<Pose2d>(
                new Pose2d(1, 1, 0),
                new Pose2d(3, 0, 0)
            ),
            // End at 3 meters ahead straight forward, facing the starting direction
            new Pose2d(3, 0, 0)
        );

        // Create a RamseteCommand
        var ramseteCommand = new RamseteCommand(
            exampleTrajectory, m_robotDrive::getPose,
            new AutoConstants(), kRamseteB, new RamseteController(
                new AutoConstants(), kRamseteZeta
            )
        );
    }
}

```

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```

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);
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following path run trajectory, the of pose initial the to odometry Reset //
    end. the at stop then command, //
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130
(exampleTrajectory.resetOdometrym_robotDrive. >- (()runOnceCommands. return
    ()))getInitialPose →
131
    (ramseteCommand)andThen.
132
    ));0 ,0(tankDriveVoltsm_robotDrive. >- (()runOnce(Commands.andThen.
133
    }
134
    }
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```

(Source) C++

```

{ ()RobotContainer::GetAutonomousCommand CommandPtr::frc2
45
    fast too accelerate t'don we ensure to constraint voltage a Create //
46
    autoVoltageConstraint{ DifferentialDriveVoltageConstraint::frc
47
        {>meters::units SimpleMotorFeedforward::frc
48
        ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
49
        V};_10 kDriveKinematics,::DriveConstants
50
        trajectory for config up Set //
51
        kMaxSpeed,::config{AutoConstants TrajectoryConfig::frc
52
        kMaxAcceleration};::AutoConstants
53
        obeyed actually is speed max ensure to kinematics Add //
54
        kDriveKinematics);::config.SetKinematics(DriveConstants
55
        constraint voltage the Apply //
56
        config.AddConstraint(autoVoltageConstraint);
57
58
59
        meters. in units All follow. to trajectory example An //
60
        GenerateTrajectory(::TrajectoryGenerator::frc = exampleTrajectory auto
61
        direction +X the facing origin the at Start //
62
        deg},_0 m,_0 m,_0Pose2d{::frc
63
        path curve 's' an making waypoints, interior two these through Pass //
64
        m}},_1- m,_2Translation2d{::frc m},_1 m,_1Translation2d{::frc{
65
        forward facing started, we where of ahead straight meters 3 End //
66
        deg},_0 m,_0 m,_3Pose2d{::frc
67
        config the Pass //
68
        config);
69
70
        RamseteCommand(::ramseteCommand{frc2 CommandPtr::frc2
71
        ,} m_drive.GetPose()); return { ]this[ exampleTrajectory,
72
        kRamseteB,::RamseteController{AutoConstants::frc
73
        kRamseteZeta},::AutoConstants
74
        { meters::units SimpleMotorFeedforward::frc
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```

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```

        ka},::DriveConstants kv,::DriveConstants ks,::DriveConstants
            kDriveKinematics,::DriveConstants
        },} m_drive.GetWheelSpeeds(); return { }this[
        ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc
        ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc
        ,} right); m_drive.TankDriveVolts(left, { right) auto left, auto](this[
            m_drive}));&{
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        following path run trajectory, the of pose initial the to odometry Reset //
        end. the at stop then command, //
        RunOnce(::cmd::frc2 return
        { exampleTrajectory.InitialPose() = initialPose ,this[
            m_drive.ResetOdometry(initialPose);
            ,}
            )}{
            move(ramseteCommand))::AndThen(std.
            AndThen(.
        ));}{ ,} 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.
            ,kDriveKinematicDriveConstants.
        );10
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```

(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

```

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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.

```

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(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);

```

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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 //
    ),0,Rotation2d( new ,0 ,0Pose2d( new
path curve 's' an making waypoints, interior two these through Pass //
    ),1- ,2Translation2d( new ),1 ,1Translation2d( new(0,List.
forward facing started, we where of ahead straight meters 3 End //
    ),0,Rotation2d( new ,0 ,3Pose2d( new
    config Pass //
    config);

```

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110

(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);

```

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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

```

following path run trajectory, the of pose initial the to odometry Reset //
    end. the at stop then command, //
(exampleTrajectory.resetOdometrym_robotDrive. >- (()runOnceCommands. return
    ()))getInitialPose →

```

129
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131

(Source) C++

```

following path run trajectory, the of pose initial the to odometry Reset //
end. the at stop then command, //
RunOnce(::cmd :frc2 return

```

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. ,kRamseteB RamseteController(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::frc
        ,}0 ,0 kPDriveVel,::PIDController{DriveConstants::frc
,} 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 29.1.2

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-

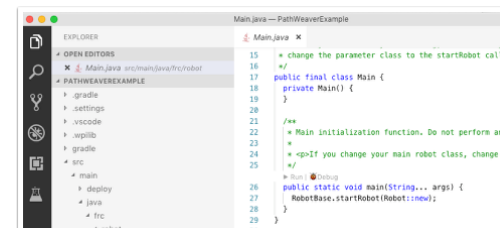
you that recommend We PathWeaver. use to required is code following Trajectory :
 can you there From paths. simple with working that get and following Trajectory with start
 PathWeaver. by generated paths complicated more testing to on continue

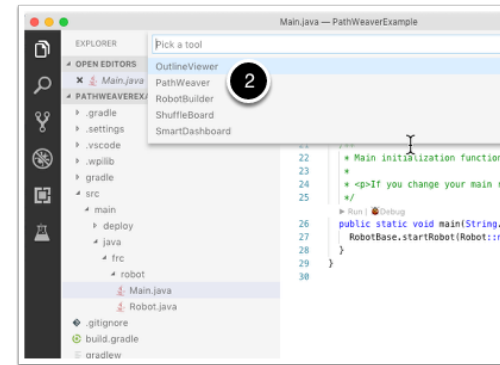
Project Pathweaver a Creating

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

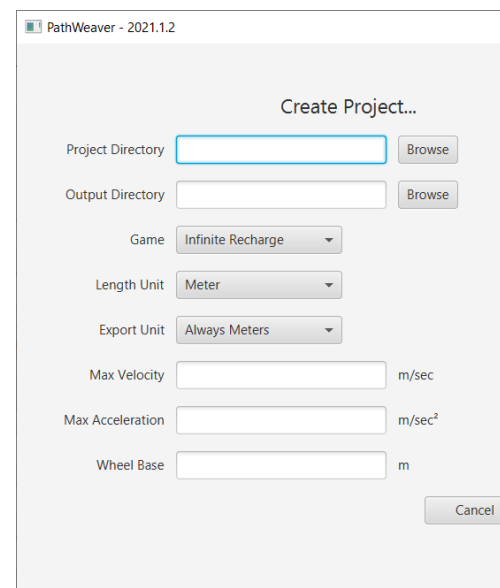
Visual the of corner the of right top the in icon ellipsis the on clicking by started is PathWeaver
 icon. the see to project WPILib the from file source a select must You interface. Code Studio
 below. shown as "PathWeaver" on click then and tool" "Start on click Then





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)

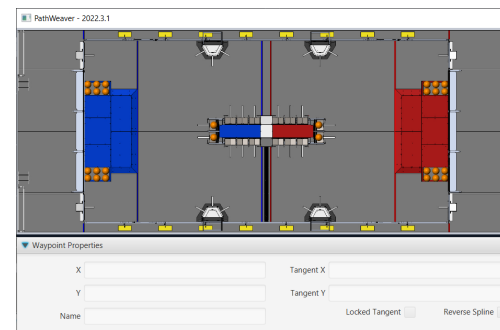
overlay image field correct the cause will used) being is game FRC® (which game The **Game:** described be will procedure the and images field own your create also can You used. be to series. this in later

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** $.m/sec \sim 3$ is which ft/sec a Using tracking. trajectory for robot the of acceleration max The **Acceleration: Max** characteristics. drivetrain'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.

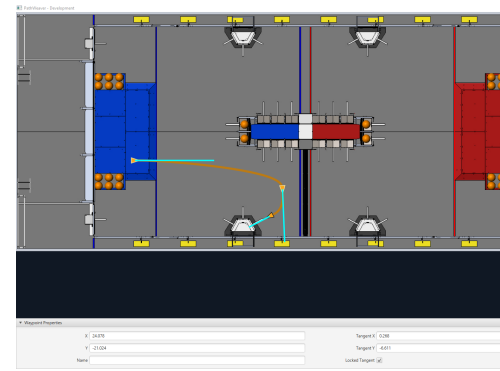
Interface User PathWeaver



following: the of consists interface user PathWeaver The window. PathWeaver the of most up takes which corner, left top the in area field The 1. program. the of part this on drawn are Trajectories pane. bottom the in displayed are waypoint selected currently the of properties The 2. point. each at tangents the with along Y, and X the include properties These the of side right upper the on displayed is mode) "autonomous" an (or paths of group A 3. mode. auto single a in trajectories the of all seeing of way convenient a is This window. the of side right lower the in displayed are follow might robot a that paths individual The 4. window. files JSON These format. JSON a in trajectories the export will button Paths" "Build The 5. trajectory. the follow to code robot the from used be can properties. project the edit to you allows button Project" "Edit The 6.

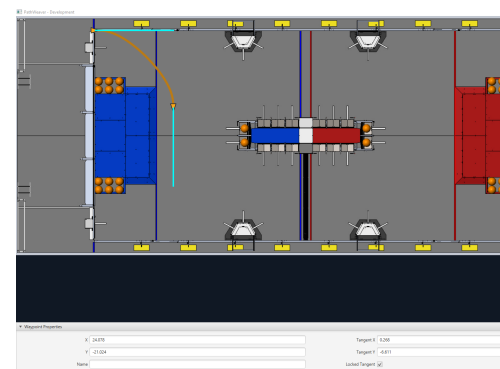
Trajectories PathWeaver Visualizing

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



Trajectory Initial the Creating

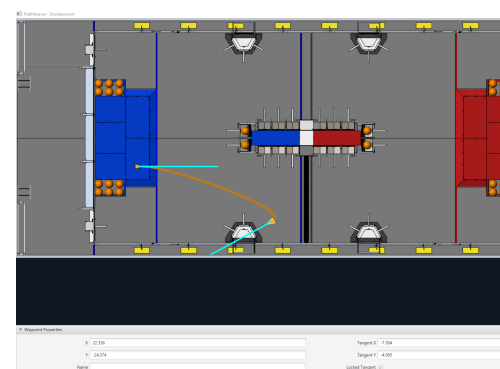
trajectory default A window. path the in button (plus) + the click trajectory, a creating start To desire. you that points end and start proper the have not does probably that created be will Changing points. end and start the for lines) (teal vectors tangent the shows also path The trajectory. the of shape the changes vectors tangent the of angle the



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

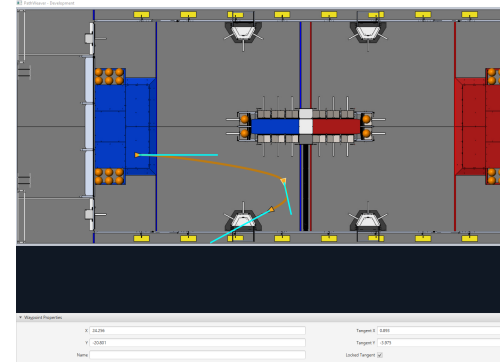
Heading Waypoint a Changing

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



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,



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
(trajjectoryJSON); resolve →
(trajjectoryPath); fromPathweaverJsonTrajectoryUtil. = trajectory
{ ex) (IOException catch }

```

page) next on (continues

(□□□□ □□□□ □□□□)

```
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
specificgame- a either in be can files The Windows. on directory PathWeaver/Games
as layout same the follow must file ZIP The directory. Games the in file zip a in or subdirectory,
subdirectory). a in be (cannot file ZIP the of root the in be must file JSON the directory; game a
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": "
  }
```

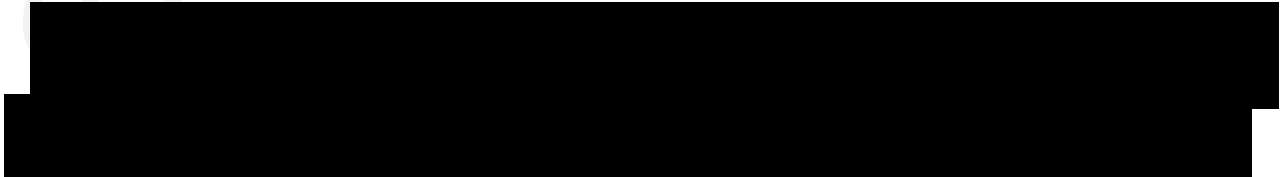
should file image the simplicity, For file. JSON the to relative is image field the to path The
file. JSON the as directory same the in be

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

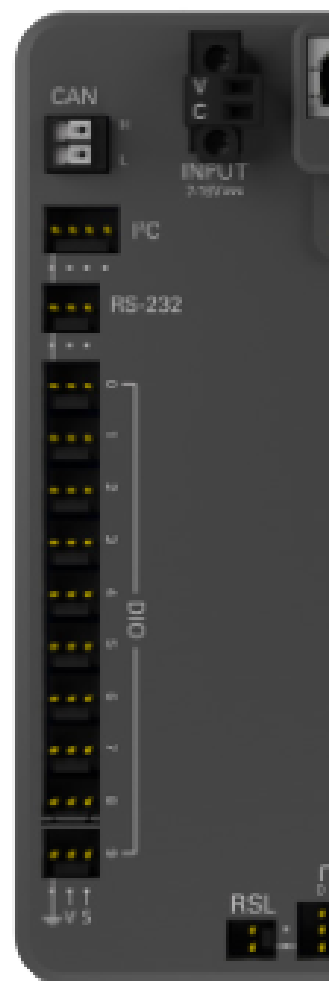
units. provided the in field the of area playable the of length and width the is size field The
or yards, feet, inches, mm, cm, meters, in be can and insensitivecase- are units field The
and“m”are “meter”,“meters”, (e.g. supported are abbreviations and plural, Singular, miles.
meters) specifying for valid all

recommended) is pixels 20 of (minimum border a image, field new a making When :□□□□
accessible. are edge field the on waypoints that so outside the around left be should

03



Introduction roboRIO 30.1



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

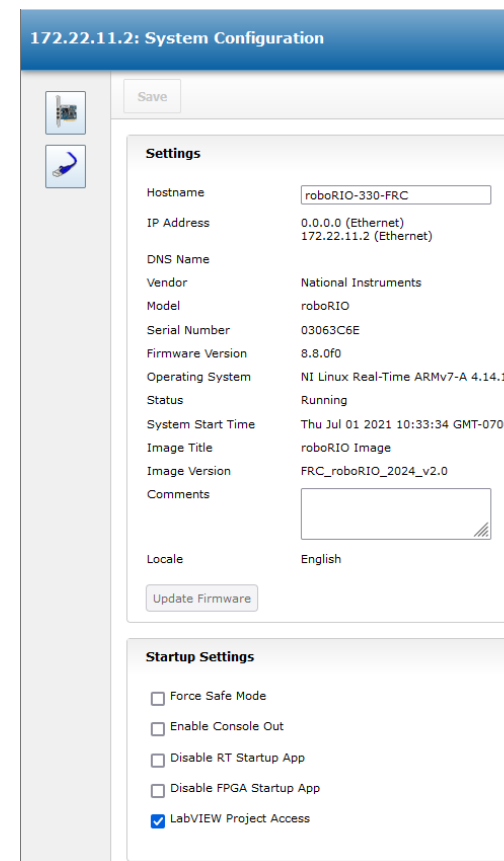
the in and Manual User roboRIO the in found be can roboRIO the on information Detailed .specifications technical roboRIO

1 roboRIO roboRIO: the image first must you roboRIO, your to programs deploying Before
.2 roboRIO

Dashboard Web roboRIO 30.2

checking for used be can that roboRIO the into built webpage a is dashboard web roboRIO The roboRIO. the of settings updating and status

WebDash the Opening 30.2.1



The screenshot shows the '172.22.11.2: System Configuration' web interface. It features a sidebar with a roboRIO icon and a 'Save' button. The main content area is divided into 'Settings' and 'Startup Settings' sections.

Settings	
Hostname	roboRIO-330-FRC
IP Address	0.0.0.0 (Ethernet) 172.22.11.2 (Ethernet)
DNS Name	
Vendor	National Instruments
Model	roboRIO
Serial Number	03063C6E
Firmware Version	8.8.0f0
Operating System	NI Linux Real-Time ARMv7-A 4.14.1
Status	Running
System Start Time	Thu Jul 01 2021 10:33:34 GMT-0700
Image Title	roboRIO Image
Image Version	FRC_roboRIO_2024_v2.0
Comments	
Locale	English

Update Firmware

Startup Settings	
<input type="checkbox"/>	Force Safe Mode
<input type="checkbox"/>	Enable Console Out
<input type="checkbox"/>	Disable RT Startup App
<input type="checkbox"/>	Disable FPGA Startup App
<input checked="" type="checkbox"/>	LabVIEW Project Access

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,
IP networking: roboRIO and mDNS about

Tab Configuration System 30.2.2

main 5 has which tab Configuration System the is dashboard web the of screen home The sections:

web the of sections different to navigate to you allows section This - Bar Navigation 1.
discussed are bar navigation this through accessible pages different The dashboard.
below.

The Settings. System the about information contains section This - Settings System 2.
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

are These roboRIO. the for settings Startup contains section This - Settings Startup 3.
below stepsub- the in described

resources system of snapshot a provides section This - pictured) (not Resources System 4.
load. CPU and memory as such

Settings Startup

Startup Settings

- ☐ Force Safe Mode
- ☒ Enable Console Out
- ☐ Disable RT Startup App
- ☐ Disable FPGA Startup App
- ☒ Enable Secure Shell Server (sshd)
- ☒ LabVIEW Project Access

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

a as used be to port RS232 boardon- the enables This - Out Console Enable
many to connected be not should and levels RS232 uses port This output. Console
unchecked. is Default levels). TTL use which microcontrollers

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 •

setting This **checked. box this leave to recommended is It** - Access Project LabVIEW • roboRIO. the access to projects LabVIEW allows

Configuration Network 30.2.3

172.22.11.2: Network Configuration

Save

Ethernet Adapter eth0

Settings

MAC Address	00:80:2F:30:49:8A
Configure IPv4 Address	DHCP or Link Local
IPv4 Address	0.0.0.0
Subnet Mask	0.0.0.0
Gateway	0.0.0.0
DNS Server	0.0.0.0
Current Link Speed	10Mbit/Half Duplex
Preferred Link Speed	Autonegotiate

Ethernet Adapter usb0

Settings

MAC Address	00:80:2F:40:49:8A
Configure IPv4 Address	DHCP Only
IPv4 Address	172.22.11.2
Subnet Mask	255.255.255.248
Gateway	0.0.0.0
DNS Server	0.0.0.0
Current Link Speed	Autonegotiate
Preferred Link Speed	Autonegotiate

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** *IP* article: this see networking

FTP roboRIO 30.3

how describes article This enabled. FTP anonymous and SFTP both has roboRIO The : system. file roboRIO the access to each use to

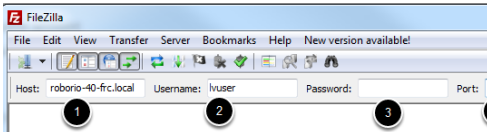
SFTP 30.3.1

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



- roboRIO: your to connect To
- box "Host" the in frc.local)TEAM-(roboRIO- name mDNS the Enter 1.
 - under) runs program your account the is (this box Username the in "lvuser" Enter 2.
 - blank box Password the Leave 3.
 - port) default SFTP (the box port the in "22" Enter 4.
 - Quickconnect Click 5.

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

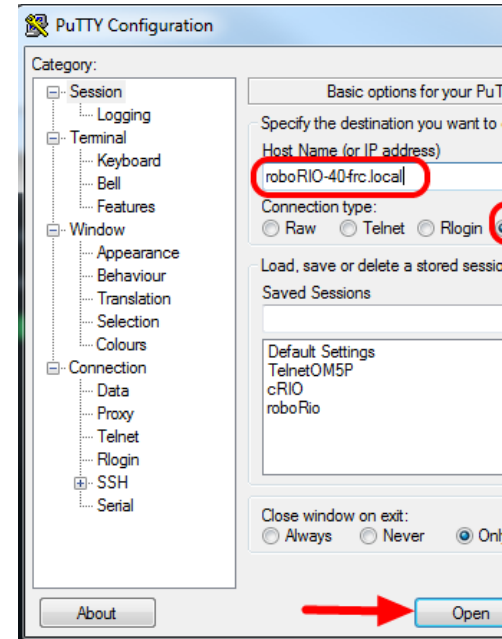
The languages. three all for code user run to used account the is account "lvuser" The account this use to wish may Teams changed. be not should account this for credentials changes settings or files any that ensure to roboRIO the with working when sftp) or ssh (via under. run will code their as account same the on made being are

prevent will "admin" or "lvuser" either for passwords ssh default the Changing :□□□□
code. uploading from teams Python and Java, C++,

SSH 30.4.2

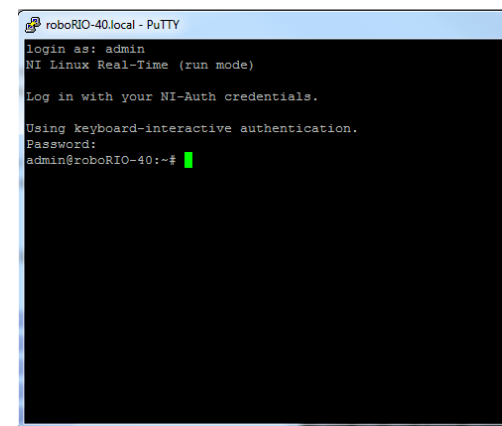
referred broadly When communication. data secure for used protocol a is SHell) (Secure SSH to refers generally it roboRIO) the on running one the as (such system Linux a regarding to execute to used be can This protocol. SSH the using console line command the accessing https: PuTTY: is SSH for used be can which client free A system. remote the on commands [//www.chiark.greenend.org.uk/~sgtatham/putty/latest.html](https://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



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 30.5

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 30.5.1

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

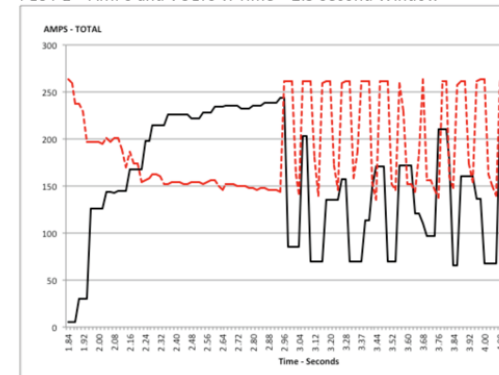
4.5V - Trigger Voltage

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 30.5.2

PLOT 1 – AMPS and VOLTS v. Time – 2.5 Second Window



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
180A. at limit our set we'll exercise, this of purposes the For draw. current

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 30.5.3

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

```
);7.6(setBrownoutVoltageRobotController.
```

C++

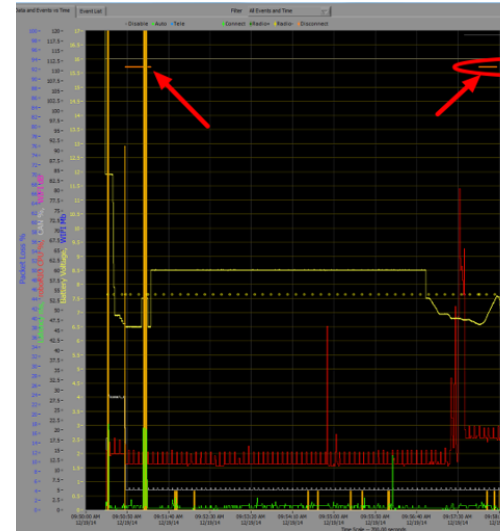
```
V);_7SetBrownoutVoltage(:RobotController::frc
```

PDP/PDH the using Draw Current Measuring 30.5.4

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 30.5.5



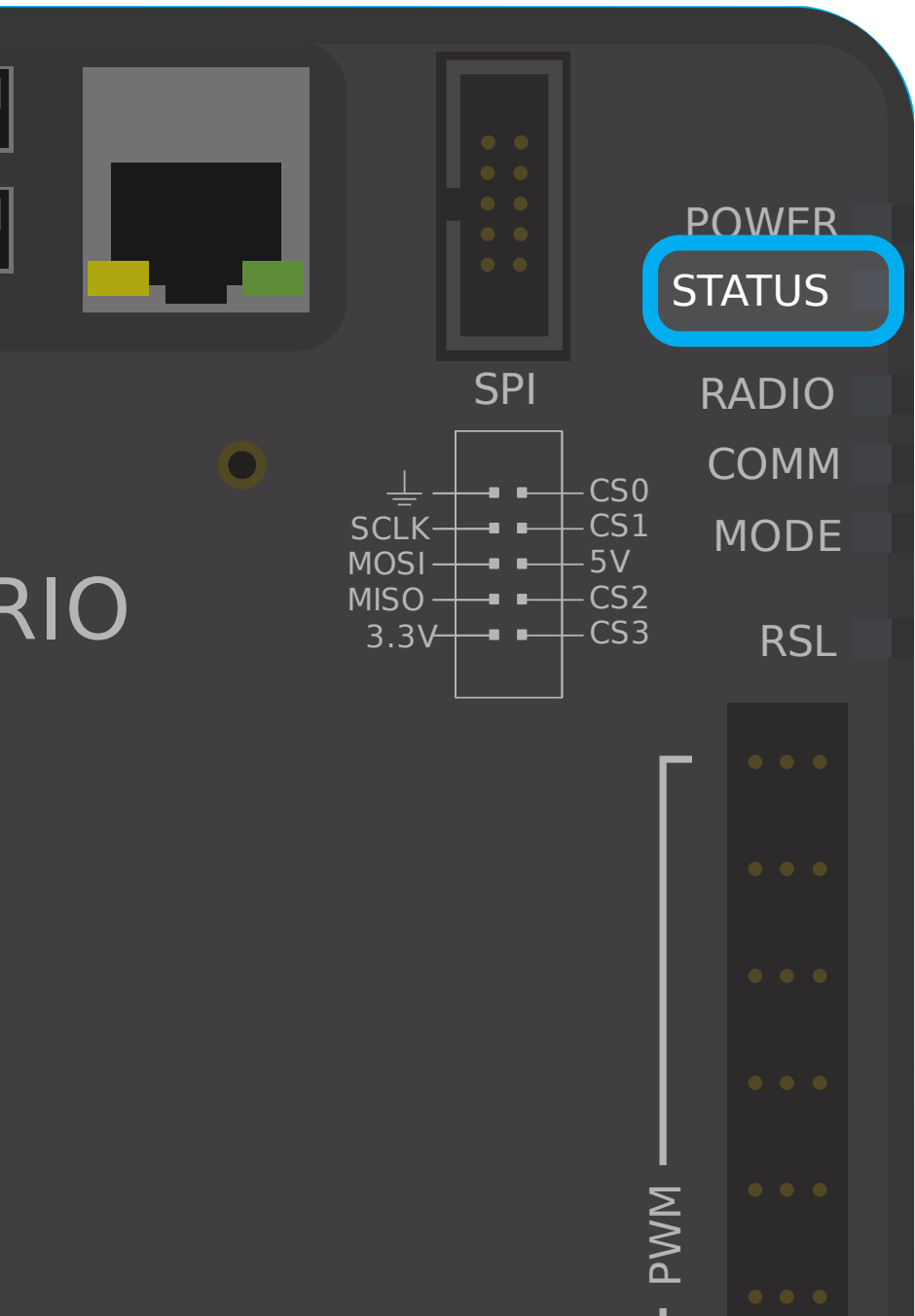
and DS the of tab CAN\Power the on clicking by is brownout a identify to way easiest The the after Log Station Driver the review can you Alternately, count. fault 12V the checking orange bright a with brownouts identify will log The Viewer. Log Station Driver the using fact benchtop a with induced were 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 30.6

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 30.6.1



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 31.1

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 31.1.1

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++ 31.1.2

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 31.2

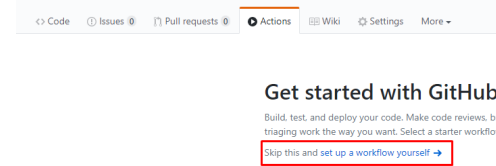
pushed is that code test to able being is environment team a in working of aspect important An developer lead or manager project a example, For GitHub. as such repository central a to ensure to want might or request pull a merging before tests unit of set a run to want might order. working in is repository 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 31.2.1

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 #
wpi/lib/roborio-cross-ubuntu:2024-22.04 : container

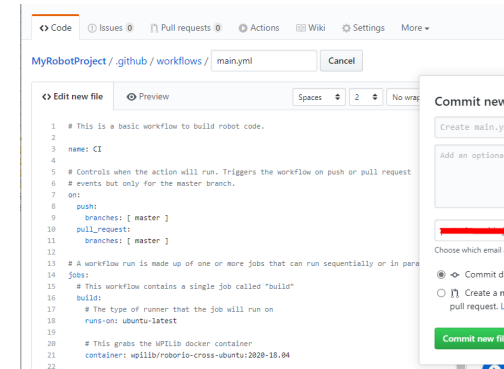
job the of part as executed be will that tasks of sequence a represent Steps #
: steps
it access can job your so GITHUB_WORKSPACE,$ under repository your Checks-out #
actions/checkout@v4 : uses -

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

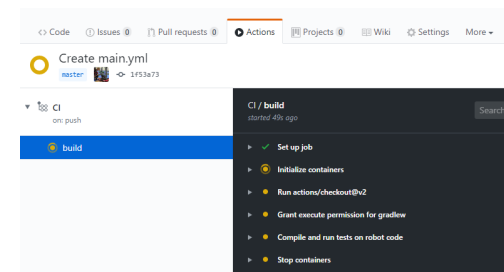
gradlew for permission execute Grant #
gradlew for permission execute Grant : name -
gradlew +x chmod : run

shell runners the using command single a Runs #
code robot on tests run and Compile : name -
build gradlew/. : run
```

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



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 31.2.2

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 #
wpi/lib/roborio-cross-ubuntu:2024-22.04 :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@v4 :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

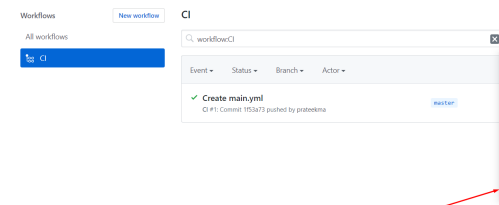
shell runners the using command single a Runs #
code robot on tests run and Compile :name -
build gradlew/. :run

```

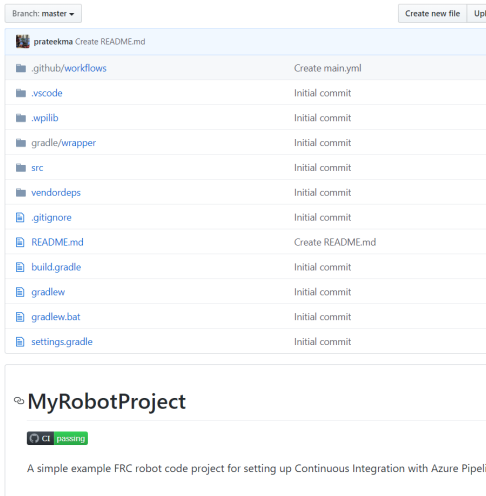
involves step first The steps. four has job This executed. be will that steps certain has job Each a for workaround a is step second The code. robot the access to repository the out checking execute to permission machine virtual the giving involves step third The .issue Actions GitHub code robot compile 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 31.2.3

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 31.3

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 31.3.1

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
2024.1.1" version edu.wpi.first.GradleRIO " id
      '6.20.0' 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
```

page) next on (continues

(0000 00000 0000)

```

        )(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
    )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@v4 :uses -
:with

```

page) next on (continues

(0000 0000 0000)

```

0 :fetch-depth
actions/setup-java@v4 :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

```

{ } )'.'(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 explanatory.self- fairly are options the of rest The directory.

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 31.3.2

דרישות

higher or 3.6 Python •

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@v4 :uses -
                    :with
0 :fetch-depth
metadata and history all Fetch :name -
| :run
pr b- checkout git
origin/main main f- branch git
3.8 Python up Set :name -
actions/setup-python@v5 :uses
                        :with
3.8 :python-version
wpiformat Install :name -
wpiformat==2024.32 install pip3 :run
Run :name -
wpiformat :run
output Check :name -
HEAD exit-code-- diff no-pager-- git :run

```


Tasks Gradlew 31.4

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 31.4.1

project your prebuilding for Useful project. this tests and Assembles - build gradlew/. roboRIO. the to deploying without directory. build the Deletes - clean gradlew/.

tasks CompileCommands 31.4.2

C++ for compile_commands.json Generate - generateCompileCommands gradlew/. Development Integrated many by supported is that file configuration a is This programs. tools. build and Environments

tasks DeployUtils 31.4.3

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 31.4.4

IE, tool. the of name the with \$T00L\$ (Replace \$T00L\$ tool the Runs - \$T00L\$ gradlew/. etc) Shuffleboard, Glass, of name the with \$T00L\$ (Replace \$T00L\$ tool java the Installs - \$T00L\$Install gradlew/. etc) SmartDashboard, Shuffleboard, IE, tool. the 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 executable. native for Task External Simulate - simulateExternalNativeRelease gradlew/. tools / editors by use for file JSON a Exports Java/Kotlin/JVM. for Task External Simulate - simulateExternalJavaRelease gradlew/. tools / editors by use for file JSON a Exports 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/. See also

Deploy in Data Git Including 31.5

gversion the using code robot in Git from metadata include to how explain will article This robot in metadata Git accessing for used be can which file a generates This plugin. Gradle or printing by as such robot, the on is code of revision what track to used be can This code. it. logging

the during robot your to copied always is metadata Git teams, Python For :
stored the retrieve to `wpilib.deployinfo.getDeployData()` use can You process. deploy information.

gversion Installing 31.5.1

tells This `.build.gradle` of block plugins the to line following the add gversion install To project. the in gversion use to Gradle

```

        { plugins
            ... //
            1.10" version com.peterabeles.gversion" id
        }

```

bottom the to block following the add project, the building when file the generate to order In `.build.gradle` of

```

        createVersionFile(dependsOn.compileJava project
        { gversion
            src/main/java/" = srcDir
            frc.robot" = classPackage
            BuildConstants" = className
            z" HH:mm:ss yyyy-MM-dd" = dateFormat
            zone time preferred Use // America/New_York" = timeZone
            " " = indent
        }

```

the put to where plugin the tell parameters `className` and `classPackage` ,`srcDir` The zone time team's your to set be can field `timeZone` The it. name to what and file, manifest `.class Java this` on based is parameter `dateFormat` The `.IDs timezone of list this` on based

Once right. top the in menu WPILib the through project your of build a run this, test To your in `BuildConstants.java` called file a be should there building, finished has code the like: look should file this what of example an is following The folder. `src/main/java`

```

        ;frc.robot package
        /**
        information. version build containing file generated Automatically */
        /**
        { BuildConstants class final public
            ;" = MAVEN_GROUP String final static public
            ;"GitVersionTest" = MAVEN_NAME String final static public
            ;"unspecified" = VERSION String final static public
            ;1 = GIT_REVISION int final static public
            ;"fad108a4b1c1dcdfc8859c6295ea64e06d43f557" = GIT_SHA String final static public
        }
    }

```

page) next on (continues

(0000 00000 0000)

```

; "EDT 17:38:59 2023-10-26" = GIT_DATE String final static public
; "main" = GIT_BRANCH String final static public
; "EDT 12:29:57 2023-10-27" = BUILD_DATE String final static public
; 1698424197122L = BUILD_UNIX_TIME long final static public
; 0 = DIRTY int final static public

(){}BuildConstants private
}

```

indicates 0 of value A project. the in changes uncommitted are there whether indicates DIRTY
1- value a and changes, uncommitted are there that indicates 1 of value a repository, clean a
error. an indicates

Git with Files Generated Ignoring

track to necessary isn't it so deployed, or built is code time every regenerated are files These
should and files listed any track to not Git tells file `.gitignore` named aptly The Git. with them
line the is Below extension. Code VS WPILib the by generated project any in default by exist
file: generated the ignore to gitignore. to add should you

```
java BuildConstants / robot / frc / java / main / src
```

Arguments Compiler Using 31.6

making includes This compiler. our of behavior the change to us allow arguments Compiler
When level. optimization choosing and warnings certain ignoring errors, into warnings
.here found be can which default by included already are flags of variety a code compiling
compiling when flags as in them pass to is solution the that proposed be could it Normally
build.gradle. the modify Instead GradleRIO. in work doesn't this but code our

behavior. unexpected cause can and dangerous is arguments Modifying :000000

C++ 31.6.1

Platforms

to Therefore flags. different of variety a use platforms different and compilers Different
The platform. per flags all configure flags compiler with platforms different breaking avoid
here listed are supported are that platforms

Platform a for Configuring

```
{ configure. )'windowsx86-64'(named.platformConfigs.nativeUtils
    )utf-8"/"(add.args.cppCompiler.it
    }
```

be can This `.64windowsx86-` case, this in platform, the configure to used is `utilsnative-` is `8/utf-` as such arguments, Then section. previous the in listed platform any for replaced compiler. C++ the to appended

Java 31.6.2

`build.gradle` editing by accomplished be can This Java. for configured be also can Arguments below. shown is this of example An `.FRCJavaArtifact` the to arguments appending and

```
{ })'FRCJavaArtifact'(getArtifactClass(frcJava
    )XX:+DisableExplicitGC"-"(add.jvmArgs
    }
```

VisualVM with Profiling 31.7

VisualVM is that tool diagnostic the with reader the familiarize to intended is document This applications, based JVM profiling for tool a is **VisualVM** programs. robot Java debugging for document This memory. of amount large a using is application an why viewing as such build. robot their modifying with associated *risks* the with familiar is reader the assumes terminal/commandline basic knows user the that assumes also tutorial This `.gradle` knowledge.

VisualVM Unpacking 31.7.1

is folder The folder. installation WPILib the to it unpack and **VisualVM** download begin, To `\C:` is this Windows, On directory. home users the indicates `~` where `~/wpilib/` at located `.wpilib\Public\Users`

Gradle up Setting 31.7.2

enable to necessary is what is this and arguments, launch JVM passing supports **GradleRIO** the as (such machine local a allows that feature a is debugging Remote debugging. remote roboRIO). a case, our (in target remote a about information important view to desktop) user's what is Below `.build.gradle` projects the in located block code `frcJava` the locate begin, To like. looks is

```

    { deploy
    { targets
    { })'RoboRIO'(getTargetTypeClass roborio
wpilib/wpilib_preferences.json. the from either loaded is number Team //
    thrown. be will exception an found not If line. command from or //
    you if getTeamNumber of instead getTeamOrDefault(team) use can You //
page) next on (continues
15
16
17
18
19
20
```

(0000 0000 0000)

```

file. this in number team a store to want //
      )(getTeamNumber.frc project = team
      )false(getDebugOrDefault.frc project = debug

      { artifacts
type artifact is 2nd name, artifact is part First //
a using type class the get to shortcut a is getTargetTypeClass //
string ↩

```

```

      artifact files Static //
{ })'FileTreeArtifact'(getArtifactTypeClass(frcStaticFileDeploy
      )'src/main/deploy'(fileTree.project = files
      'home/lvuser/deploy/' = directory
      }
      }
      }
      }
      }

```

with: lines highlighted the replacing be will We

```

{ })'FRCJavaArtifact'(getArtifactTypeClass(frcJava
      connection VisualVM Enable //
      )Dcom.sun.management.jmxremote=true"- "(add.jvmArgs
      )Dcom.sun.management.jmxremote.port=1198"- "(add.jvmArgs
      )Dcom.sun.management.jmxremote.local.only=false"- "(add.jvmArgs
      )Dcom.sun.management.jmxremote.ssl=false"- "(add.jvmArgs
      )Dcom.sun.management.jmxremote.authenticate=false"- "(add.jvmArgs
team with XX.XX Replace // )Djava.rmi.server.hostname=10.XX.XX.2"- "(add.jvmArgs
number ↩
}

```

order: In here. arguments few a adding are We

- debugging remote Enable •
- 1198 to port debugging remote the Set •
- targets remote from listening Allow •
- required being authentication SSL Disable •
- this. replace to sure Be number. team roboRIOs the to hostname the Set •

.172.22.11.2 be should BUSB- via connected when hostname The :□□□□

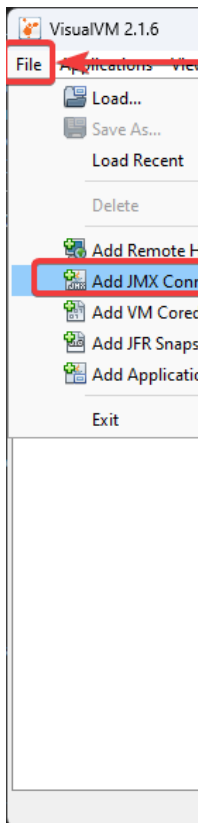
VisualVM Running 31.7.3

navigate we First, parameters. few a with commandline the via done is VisualVM Launching
WPILib the it passing parameters, with it launch Then, VisualVM. containing directory the to
following: the like looks it machine, Windows a On path. JDK

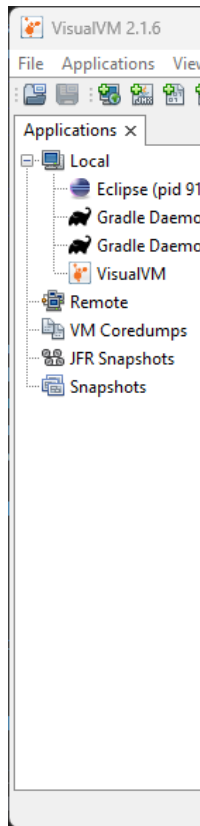
```
C:\Users\Public\wpilib\visualvm_217\bin" cd  
C:\Users\Public\wpilib\2024\jdk" jdkhome-- visualvm/.
```

VisualVM of version the on depends and vary may visualvm_217 path exact The :
downloaded.

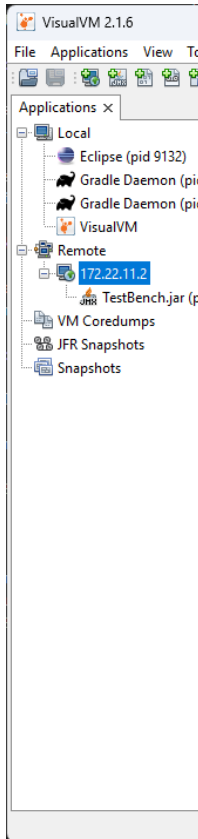
dialog. *Connection JMX Add* the open launched, Once VisualVM. launch should This



require not Do that Ensure hostname. and details connection the configure opened, Once
ticked. is *connection SSL*

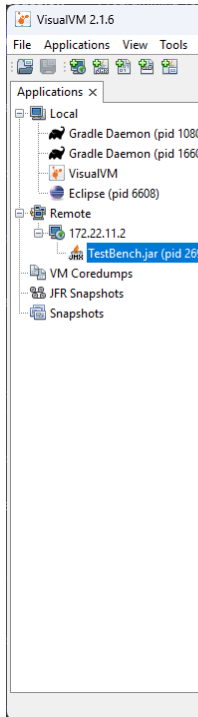


will it on Clicking appear. will sidebar handleleft- the in option menu new a done, correctly If application. JVM running the of dashboard detailed a you show



Timings Function Analyzing 31.7.4

is function specific a time much how view to ability the is VisualVM of feature important An *Sampler* the on click begin, To attached. debugger code a having *without* is This up. taking are functions what of breakdown a give immediately will This *.CPU* on click then and tab time. CPU taking



can You takes. function specific a time total the of breakdown a shows screenshot above The We time. CPU program robot the of 61.9% for accounts `totallyNotSlowFunction()` that see the have we ,`totallyNotSlowFunction()` In program. robot our to this correlate then can code. following

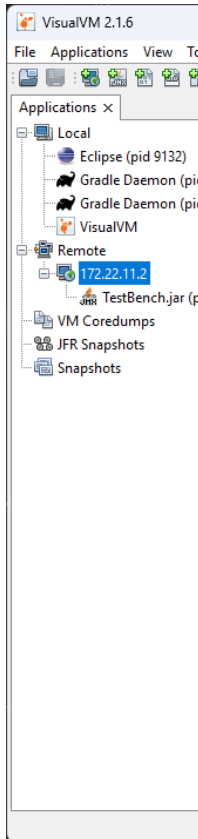
```
{ ()totallyNotSlowFunction void static public
    { )++i ;2000 < i ;0 = i int( for
    ); "HAHAHAHA"(println.outSystem.
    }
}
```

loop for running long A concern. of causes major 2 identify can we snippet, code this In calls `System.out.println()` Additionally, running. from program robot the of rest the blocks Java the profiling by information this found We expensive. quite typically are roboRIO the on roboRIO! the on application

Dump Heap a Creating 31.7.5

by useful most is VisualVM usage, memory and CPU systems remote the viewing Besides memory of area an in resides it created, is object Java a When **.Dump Heap** a creating Garbage begins. `collection garbage` called process a full, is heap the When heap. the called program. robot Java traditional a in overruns loop of cause common a be can collection

.Dump Heap click and tab *Monitor* the on are you ensure begin, To



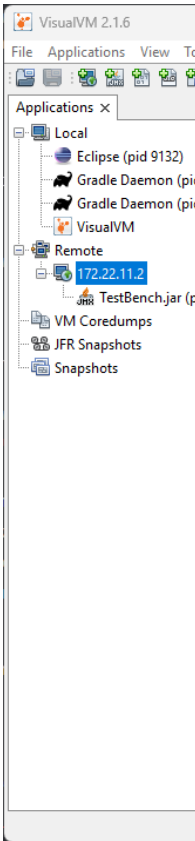
using retrieved be must and (roboRIO) system target the on stored be will dump heap This roboRIO. the from dump the retrieving on information for *article this* See SFTP.

VisualVM. with analyzed be can dump the downloaded, Once

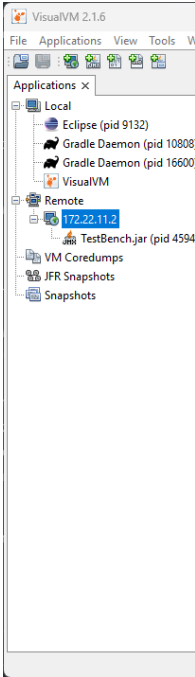
robot your when automatically dump heap a take to JVM the configure also can You :□□□
.memory of out runs code

Dump Heap a Analyzing 31.7.6

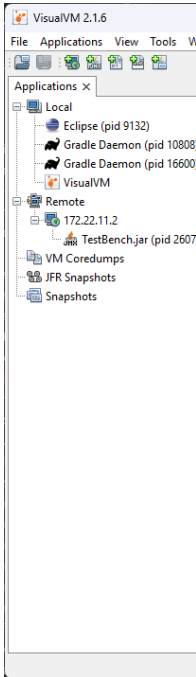
.Load and *File* on click Then instructions. previous the using closed if VisualVM Reopen it. load and file dump retrieved the to Navigate



by objects of breakdown a show will instead *Objects* selecting and *Summary* on Clicking one then and program, robot empty completely a showcases screenshot below The quantity. integers. of ArrayList large million an creates that
program: robot Blank



integers. ~10000 of ArrayList an with



Info Additional 31.7.7

.pages documentation VisualVM the out check VisualVM, on information more For



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

of Validation Based Model of Walkthrough Video A 32.1

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

32.2 מבוא לבקורות מתקדמות

Basics System Control 32.2.1

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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

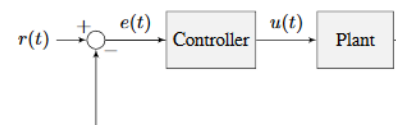


Figure 1.1: Control system nomenclature for a closed-loop system

$r(t)$	reference	$u(t)$	control input
$e(t)$	error	$y(t)$	output

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

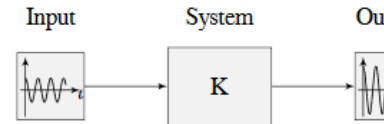


Figure 1.2: Demonstration of system with a gain K

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

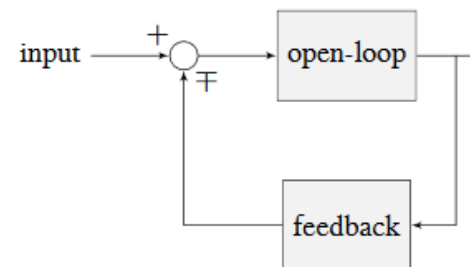


Figure 1.3: Block diagram with negative feedback

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

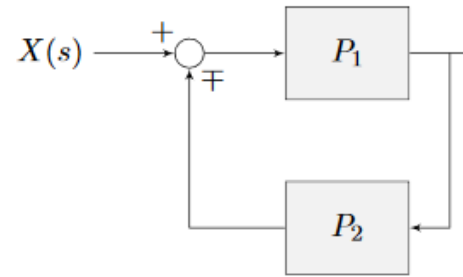


Figure 1.4: Feedback block diagram

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 32.2.2

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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
time over accumulate errors so system, the of position the controlling are We 1.
mechanism the with interacting forces external dynamicto-difficult- of lot a are There 2.
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-

loading. to relative overpowered fairly are motors The 1.

controlled. being is velocity) (not position mechanism's The 2.

mechanism. the on forces external varying or substantial no are There 3.

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 k_G and k_A , k_V 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 k_A and k_V 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 k_P and k_V as (such parameters two or
process. difficult and involved very a become can it scenarios

found well- 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 based model- 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 32.2.3

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

$$V = K_s \cdot \text{sgn}(\dot{d}) + K_v \cdot \dot{d} + K_a \cdot \ddot{d}$$

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 K_s . 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

$$V = K_g + K_s \cdot \text{sgn}(\dot{d}) + K_v \cdot \dot{d} + K_a \cdot \ddot{d}$$

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

$$V = K_g \cdot \cos(\theta) + K_s \cdot \text{sgn}(\dot{\theta}) + K_v \cdot \dot{\theta} + K_a \cdot \ddot{\theta}$$

its is $\dot{\theta}$ arm, the of (position) displacement angular the is θ 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*

PID-ל 32.2.4

.WPIlib [PID](#) [see WPIlib](#), with control PID implementing on guide a For :[video A](#)

controller. PID a of workings mathematical and conceptual the explains page This *available also is WPI from explanation*

Controller? PID a is What

and integral, proportional, of consisting *controller feedback* common a is controller PID The controller PID a of definition the up build will article This name. the hence terms, derivative behaves. term each how for intuition some provide to trying while term by term we context, PID a In way. the of out controllers PID for nomenclature some get we'll First, term the and mechanism, the of state desired the mean to *setpoint* or *reference* term the use some are Below mechanism. the of state measured the to refer to *variable process* or *output* quantities. relevant for conventions naming variable common

$r(t)$	<i>reference ,setpoint</i>	$u(t)$	<i>effort control</i>
$e(t)$	<i>error</i>	$y(t)$	<i>variable process ,output</i>

$r(t) - y(t)$,*output* the and *reference* the between difference the is $e(t)$ *error* The the with consistent be not may interpretation this control, PID with familiar already those For "present", "past", to response to corresponding terms D and I, P, the of explanation classical control PID approaching be instead will we merit, has model that While errors. "future" and different to applied controllers proportional as theory, control modern of viewpoint the from the of explanation complete more a provide will This about. care we quantities physical *setpoints* moving and constant for behavior term's derivative term derivative the zero, to error position the drives term proportional the speaking: Roughly over-error- accumulated total the drives term integral the and zero, to error velocity the drives into go We'll *signal control* the produce to together added are terms three All zero. to time below. these of each on detail more

tunable the writing of ways two see you'll documentation, WPIlib the Throughout :[video A](#) controller. PID the of constants

gain: proportional the for example, For

constant. the notate to way focusedequation-math- standard the is K_p •

software. in variable a as written it see to way common a is K_P •
concept. same the to refer formats two the capitalization, in differences the Despite

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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

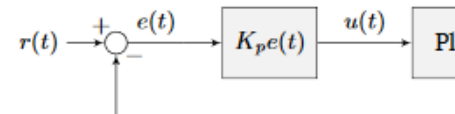


Figure 2.1: P controller block diagram

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

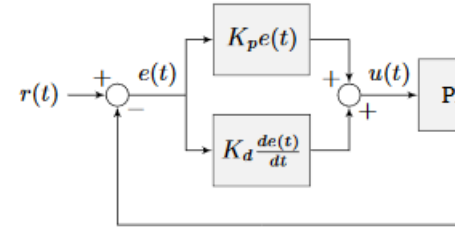


Figure 2.2: PD controller block diagram

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

$$u_k = K_p e_k + K_d \frac{e_k - e_{k-1}}{dt}$$

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

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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*

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau$$

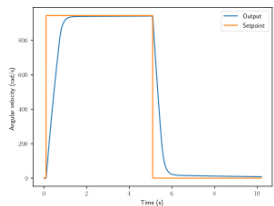


Figure 2.5: PI controller without steady-state error

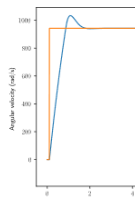


Figure 2.6: PI controller with large K_i gain

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 τ and , t time current the at error controller. PID a for diagram block a shows figure below The

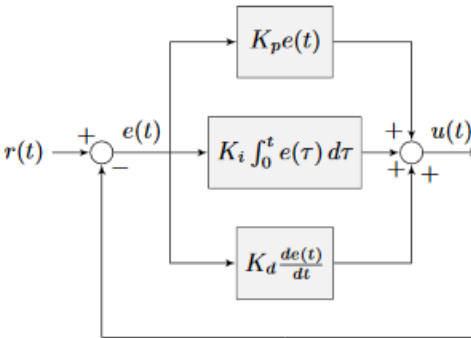


Figure 2.7: PID controller block diagram

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

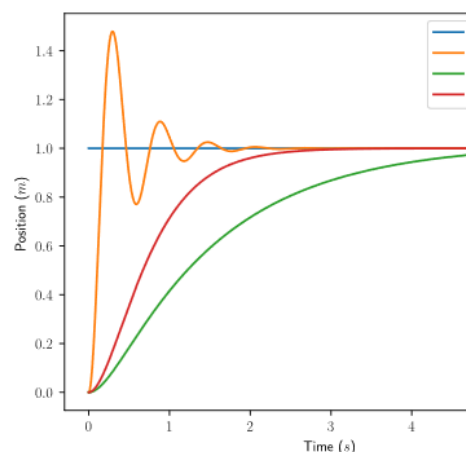


Figure 2.8: PID controller response

the has response *damped critically* A .reference the overshoot not does and rise to slow is
 .reference the overshooting without *time rise* fastest

32.2.5 סרטון מבוא ל-PID מאת WPI

הסרטון מפרט את התהליך של תכנון וטיון של בקרת PID. הוא כולל הסבר על המושגים הבסיסיים של בקרת PID, וכן דוגמאות ליישומים של בקרת PID. הסרטון מפרט גם את התהליך של תכנון וטיון של בקרת PID, וכן דוגמאות ליישומים של בקרת PID.

32.2.6 Tutorials Tuning Controls To Introduction

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 ,*search exponential* 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

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

After tune. to easiest the are *mechanisms Flywheel* difficult. to easy from work Furthermore, .*example arm vertical* the with off finish Then, .*tuning turret* the into look that,

Controller Velocity Flywheel a Tuning 32.2.7

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

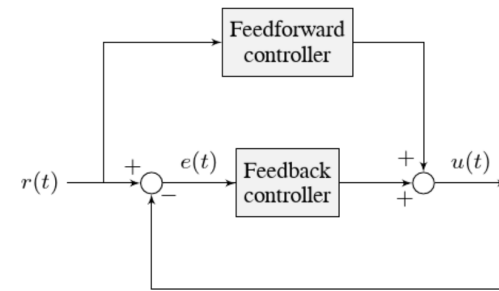
of: consists "Flywheel" Our

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:

- The plant's output is the flywheel rotational velocity $y(t)$
- The controller's setpoint is the desired velocity of the flywheel $r(t)$
- The controller's effort control is the voltage applied to the driving motor $u(t)$, motion flywheel's

A more detailed description of the mathematics of the system can be found here. □□□□

Controller Velocity Flywheel a for Strategy Control the Picking

In general: the more voltage is applied to the motor, the faster the flywheel will spin. Once the voltage is removed, and friction/EMF^{back} is opposed, the motion and the flywheel will stop.

Flywheels are commonly used to propel game pieces through the air toward a target. In this simulation, a gamepiece is injected into the flywheel halfway through the simulation. To consistently launch a gamepiece, a good first step is to make it spin at a particular speed before putting a gamepiece into it. Thus, we want to control the flywheel's velocity accurately.

This is fundamentally different from the *turret* and *arm vertical* controllers, which control both *position* and *velocity*. □□□□

The following tutorials will demonstrate the behavior of the system under pure bang-bang, combined (PID), pure feedback, and pure feedforward control strategies. Follow the instructions to learn how to manually tune these controllers and expand the parameters. "tuning of set based model- optimal an view to solution"

¹For this simulation, we model a ball being injected into the flywheel as a velocity-dependent (frictional) torque. The first mark is very a is This. The second mark is the right rotation around a wheel of a quarter, for the spinning of the fighting ball. The model is too simplistic but sufficient to illustrate the controller's behavior under a sudden load. The output in "pulldown" actual the or trajectory, ball's the predict to sufficient be not system.

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 launching game piece- A involves autonomous in path defined pre- a following - control drive train 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 state steady- motor's DC magnet permanent- 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 bang-bang simulation. bang-bang-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 EMF back- 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

state steady- eliminate to way optimal sub- 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* controller. feedforward a with controller PID the combine to is approach better a

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. induced self-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 bang-bang-* called

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 command. "jump" a after time over setpoint the to converge accurately also and setpoint,

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 following velocity- smooth the gives controller controller. feedback a of elimination error term

Performance Ideal Non- 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 32.2.9

tuning same The arm. vertical a for controller position simple a tune will we section, this In the under scenarios control position- all almost for also work will below explained principles gravity. of load

Description Model Arm

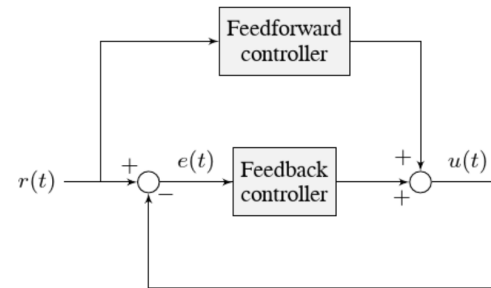
position. scoring a to up ground the from gamepieces lift to used commonly are arms Vertical elevators. and hoods shooter include examples similar Other

of: consists arm "vertical Our

axle. an around pivoting gravity, of force the under stick, a on mass A •

attached is stick-a-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:

- The plant's output is the arm's rotational position $y(t)$
- The controller's setpoint is the desired angle of the arm $r(t)$
- The controller's effort control is the voltage applied to the driving motor $u(t)$

Arm Vertical a for Strategy Control the Picking

Applying voltage to the motor causes a force that drives the arm up or down. Generally, it pulls the arm down against gravity. If down, no voltage is applied. If up, voltage is applied. The effect is to keep the arm at a specific angle.

The tutorials below will demonstrate the behavior of the system under pure feedforward, pure feedback, and combined (PID) control strategies. The pure feedback 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

Interact with the simulation below to examine how the turret system responds when controlled by a feedforward controller.

To change the arm's setpoint, click on the desired angle along the perimeter of the indicator. To command smooth motion, drag the setpoint. To command turret.

To tune the feedforward controller, perform the following:

1. Set K_v and K_g to zero.
2. Increase K_g until the arm can hold its position with as little movement as possible. If stationary, it remains until K_g decreases in the opposite direction (moves arm places). decimal four least (at precisely fairly K_g on in zero to have
3. Increase the feedforward velocity gain K_v until the arm tracks the setpoint during motion. Note that the gain reduces overshoots, slows motion, and corrects the "lag" in the commanded motion. 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

zero. to K_g 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

.*setpoint* the to converging before "stuck" gets *output* the when K_i Increase 3.

reduce further and setpoints movingsmoothly- track system the help to K_d Increase 4.
 oscillation.

not Do arms! vertical for scheme control viable a not is control only Feedback- :□□□□
 "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 zero non- a Because
 order In flawed. is strategy only feedback- this equal, are *setpoint* and *output* the when even
 needed. is strategy feedback feedforward- 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, only feedback- the in as procedure same the following
 PID that Notice section. only feedback- 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
 command. "jump" a after time over setpoint the to converge accurately also and

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 feedback feedforward-

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 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 32.2.10

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

possible. if zero to down , K_i of value the Decrease 1.

.*setpoint* the from far too is *output* the if zero to term integrator the reset to logic Add 2.
a with this implement PIDController WPILib's and controllers motor smart Some
method. `setIZone()`

this implements PIDController WPILib's value. maximum some at integrator the Cap 3.
method. `setIntegratorRange()` the with

seem that systems and control, integral any require not do FRC in mechanisms Most :□□□□
model. feedforward inaccurate an have probably well respond to control integral require to

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 32.3

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 32.3.1

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 32.3.2

- *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

).Python , ,C++ ,Java(class LinearFilter the through WPILib in supported are filters Linear

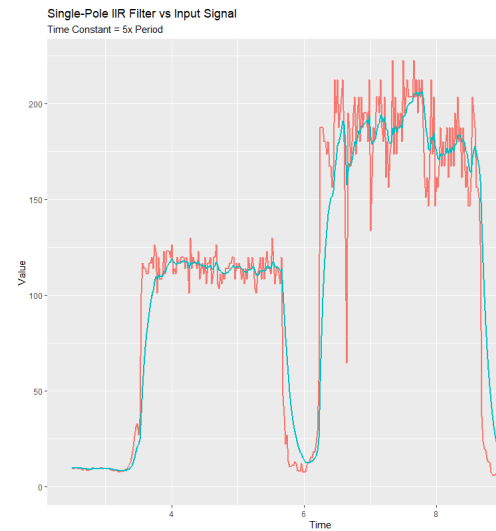
LinearFilter a Creating

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 ↵
```

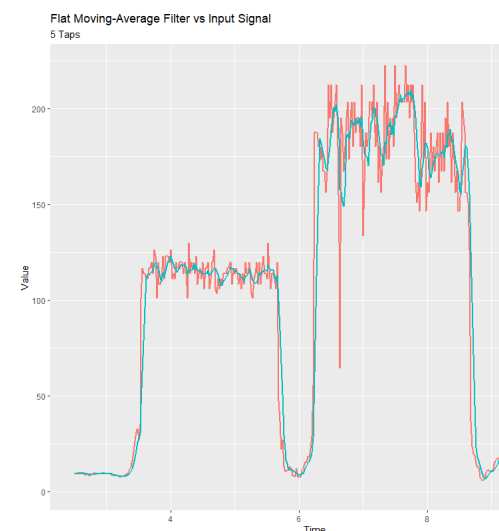
PYTHON

```
LinearFilter import filter.wpimath from
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 ,0.1singlePoleIIR(.LinearFilter = filter
```

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 π , 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++

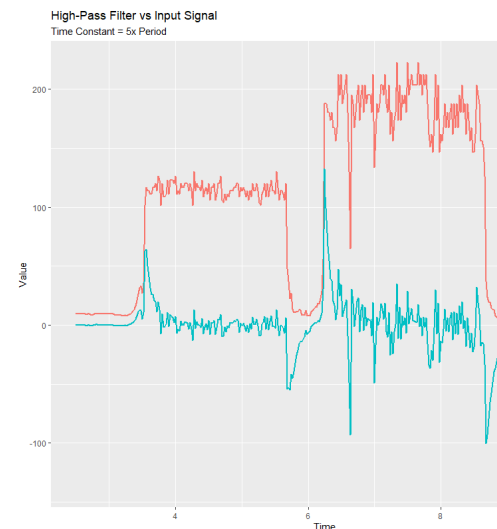
```
filter average moving flat new a Creates //
samples 5 last the over taken be will Average //
); MovingAverage(:>double<LinearFilter::frc = filter >double<LinearFilter::frc
```

PYTHON

```
LinearFilter import filter.wpimath from
filter average moving flat new a Creates #
samples 5 last the over taken be will Average #
) movingAverage(.LinearFilter = filter
```

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

```

PYTHON

```

LinearFilter import filter.wpimath from
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 ,0.1highPass(.LinearFilter = filter

```

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

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 //
);MedianFilter( new = filter MedianFilter
```

C++

```
samples 5 of size window a with MedianFilter a Creates //
);filter( >double MedianFilter::frc
```

PYTHON

```
MedianFilter import filter.wpimath from
samples 5 of size window a with MedianFilter a Creates #
)MedianFilter( = filter
```

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++

```
filter.Calculate(input);
```

PYTHON

```
output the of value next the Calculates #
)inputcalculate(.filter
```

Limiter Rate Slew 32.3.4

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).Python

SlewRateLimiter a Creating

more For input. the of type unit the on templated is class `SlewRateLimiter` C++ The `units` 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

```

PYTHON

```

SlewRateLimiter import filter.wpimath from
units 0.5 to signal the of change of rate the limits that SlewRateLimiter a Creates #
second per →
)0.5SlewRateLimiter( = filter

```

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);

```

PYTHON

```

output the of value next the Calculates #
)inputcalculate(.filter

```

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,arcadeDrive drivetrain.

acceleration forward/backward limiting input, forward/backward the limits Slew-rate //
                                turn); (forward),calculate(filter.arcadeDrive drivetrain.

```

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),

```

PYTHON

```

                                applied ramping no with call Ordinary #
                                turn) arcadeDrive(forward, drivetrain
acceleration forward/backward limiting input, forward/backward the limits Slew-rate #
                                turn) calculate(forward),.filterarcadeDrive( drivetrain

```

Debouncer 32.3.5

"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.

which), Python , C++ , Java(class Debouncer the by WPILib in implemented is Debouncing for change a sustains input the if changes only output the that so stream boolean a filters period. time nominal some

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 //
);DigitalInput( 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 //
};input{ 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 //
}

```

PYTHON

```

DigitalInput import wpilib from
Debouncer import filter.wpimath from

0 DIO on DigitalInput a Initializes #
)DigitalInput( = input self

seconds 0.1 of time debounce a with mode both"" in Debouncer a Creates #
kBoth) DebounceType Debouncer ,0.1Debouncer( = debouncer self

being before seconds 0.1 least at for true go must signal the false, currently If #
page) next on (continues

```

(`get()` `input` `self` `calculate` `debouncer` `self` `if` `True` `is` `DI` `the` `that` `now` `something` `Do` `#` `pass`)

```
signal. True a as read →
get():.input.selfcalculate(.debouncer.self if
True. is DI the that now something Do #
pass
```

32.4 מחלקות גיאומטריה

WPILib-`Translation2d` `Rotation2d` `Translation2d` `Rotation2d` `Translation2d` `Rotation2d`

Pose and Rotation, Translation, 32.4.1

Translation

,C++ ,Java(class Translation2d WPILib's by represented is dimensions 2 in Translation
vector the or (x, y) point the representing component, y and x an has class This).Python
system. coordinate dimensional2- a on
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 :`Translation2d`
sure make generator, trajectory the as such Java/Python, in Translation2d use that classes
meters. use to

Rotation

).Python ,C++ ,Java(class Rotation2d WPILib's by represented is dimensions 2 in Rotation
axis an to relative rotation robot's the represents which component, angle an has class This
counterclockwise. are rotations Positive system. coordinate dimensional2- a on

either accepts Java/Python in constructor The library. Units C++ the uses Rotation2d :`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 :`Rotation2d`
calls. value subsequent in returned be will degrees 400 then constructor, the into

[illegible]

Twist2d and Transform2d

a represents which), Python, C++, Java(Transform2d classes, 2 provides WPILib movement a represents which) Python, C++, Java(Twist2d and pose, a to transformation components. θ and y x , have all Twist2d and Transform2d arc. an along

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 θ 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

Identification System 32.5

Identification System to Introduction 32.5.1

Identification?" "System is What

model mathematical a determining of process the is **identification system** Theory, Control In outputs. and inputs its of analysis statistical through system a of behavior the for

(typically measurements our way the affects voltage input how describing rule a is model This a and model a such takes routine identification" "system A time. in evolve data) encoder matchclosely- most model your make would which parameters fit to attempts and dataset 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

user's the on runs that application SysId the of consists tool identification system WPILib The
 generate will routine The robot. user's the on running code the in lives that routine a and PC
 characterized, being motors the to send will callbacks defineduser- which signals control
 retrieve will user the completes, routine the After file. log a into data records robot the while
 determines and data the processes then SysId SysId. into it load and roboRIO the from file this
 plots. diagnostic producing as well as mechanism, robot user's the for parameters model

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 •

Elevators •

Arms •

analysis the in only differ and code, siderobot- identical nearly use options these of Several
 data. the interpret to SysId by used

Identification Motor Simple

equation: the for parameters fitbest- the determines tool identification motor simple The

$$V = kS \cdot \text{sgn}(\dot{d}) + kV \cdot \dot{d} + kA \cdot \ddot{d}$$

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 Elevator

equation: the for parameters fitbest- the determines tool identification elevator The

$$V = kG + kS \cdot \text{sgn}(\dot{d}) + kV \cdot \dot{d} + kA \cdot \ddot{d}$$

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

$$V = kG \cdot \cos(\theta) + kS \cdot \text{sgn}(\dot{\theta}) + kV \cdot \dot{\theta} + kA \cdot \ddot{\theta}$$

its is $\dot{\theta}$ arm, the of (position) displacement angular the is θ 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

SysId Installing

Installer. WPILib the with included is SysId

supported. longer no is years previous from tool characterization Python old The :□□□□

Tool SysId 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

Routine Identification and Creating 32.5.2

Tests of Types

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

be can tests The total. in tests four for backwards, and forwards both run is type test Each generally is test "forwards" a after directly test "backwards" a running but order, any in run SysIdRoutine position). original its to mechanism the reset less or more will it (as advisable an of part as example for tests, the run to used be may that factories command provides deploy and create to generator project a used SysId of versions Previous routine. autonomous The maintain. to difficult and fragile very be to proved it but tests, these run to code robot works, know already they code mechanism use to teams enables workflow basedcode- user limits. hard and soft including

Setup Code User

how knowing and recommended is library units language's your with familiarity Some :□□□□ framework. Commands the using are you assumes page This required. is Consumers use to

the provides WPILib routines, identification compatibleSysId- creating in assist To Config a both take which object, SysIdRoutine a create should Users class. SysIdRoutine will routine the how describing object Mechanism a and settings test the describing object fit. the perform to needed measurements the log and motors relevant the control

Config Routine

steady a tests, Quasistatic in use for rate ramp voltage a a in takes object Config The for duration test maximum the as use to time a tests, Dynamic in use for voltage step state "dynamic- as (such state test current the accepts that method callback a and reasons, safety default to blank left be may constructor The solution. logging party 3rd a by use for forward") volts. 7 to voltage step the and second per volt 1 to rate ramp the

do who users CTRE directly. SysIdRoutine with interact will loggers party 3rd all Not :□□□□ use and API **SignalLogger** the use should logging for directly SysIdRoutine use to wish not CompatibleREV- Unofficial 6328's Team use may users REV wpilog. to convert to X Tuner in is file log the Once .null to set be should callback log the cases both In .(URCL) Logger other. any like just SysId with used be may it hand,

will (which null and seconds 10 to defaulted and optional are callback state and timeout The respectively. file) WPILog normal a to data the log

Mechanism the Declaring

being subsystem the consumer, log a consumer, voltage a takes object Mechanism The callback drive The log). the in record (to mechanism the of name the and characterized, The motors. relevant the to it passes and command voltage generated routine- the in takes adds and motor relevant each for velocity and position, voltage, motor the reads callback log requirements the to added be may it that so required is subsystem The log. running the to it returned string the to defaulted be will and optional is name The commands. routine the of getName(). by

own their be can or expressions Lambda via place in- created be either can callbacks The the create to is practice Best references. method via in passed be and functions standalone leakage. prevent to subsystem, the inside callbacks and routine

JAVA

```

        SysIdRoutine a Creates //
        SysIdRoutine( new = routine SysIdRoutine
                      (), Config SysIdRoutine. new
        ) this :: logMotors, this :: voltageDrive, this (Mechanism SysIdRoutine. new
    );
    
```

Callbacks Mechanism

motors your and routine the between plumbing just essentially are callbacks Mechanism The sensors. and
 motor your to directly voltage requested the pass can you that so exists callback drive The controller(s).
 velocity and position, voltage, the log can routine the that so sensors reads callback log The timestep. each at
 callbacks. example for project example)C++ ,Java(SysIdRoutine the See

Factories Test

return each that functions or "factories", test exposes SysIdRoutine tests, the run to able be To test. given a execute will that command a

JAVA

```

    { direction) Direction(SysIdRoutine.sysIdQuasistatic Command public
      (direction); quasistatic routine. return
    }

    { direction) Direction(SysIdRoutine.sysIdDynamic Command public
      (direction); dynamic routine. return
    }
    
```

routine autonomous an create or buttons controller either to methods factory the bind Either the for down hold must user the that buttons to them bind to recommended is It them. with limits. safe exceeds it if quickly routine the stop can user the that so test the of duration

Routine Identification the Running 32.5.3

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

motors Multiple analysis. for usable are them in routine single a with files log Only :□□□□□ one on routine a run you If time. same the at run be must they but routine, one in run be can cyclingpower- or log the extracting without motor another on routine a run then and motor fail. will analysis between, in roboRIO the

Tests Running

section. previous the in created you bindings the using tests the Perform

The limits! safe exceeds it if early test the stop and mechanism your for out Watch :□□□□□ you to up is it motors, your to connect to you for commands voltage creates only routine damage. or injury prevent to limits soft or hard up set to

this: like something look should routine entire The

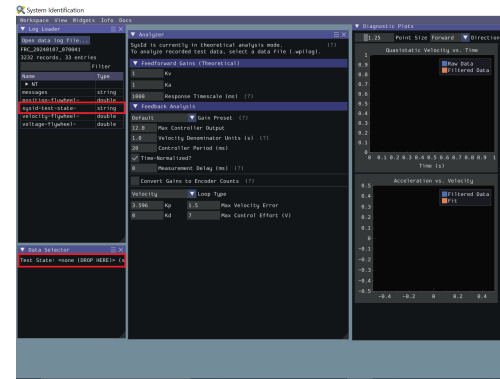
any on occur will motions same the but below, shown is routine drivetrain A :□□□□ mechanism.

the from file log the retrieve to DataLogTool the use completed, been have tests four all After roboRIO.

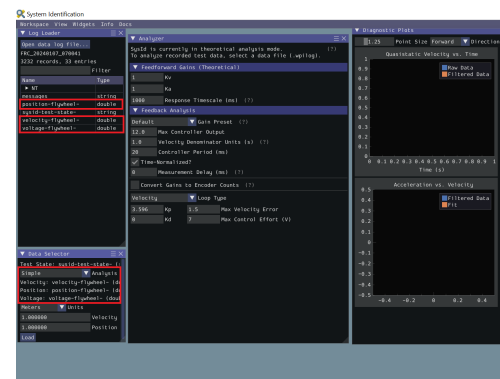
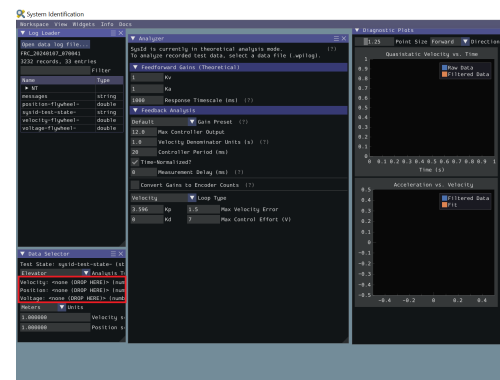
Data Loading 32.5.4

Loader Log the to go roboRIO, the from tests the containing WPILog the downloading After .file... log data Open click and SysId in pane this Drag "state". containing name a with entry type string a for look loads, file the After slot. State Test pane's Selector Data the into entry

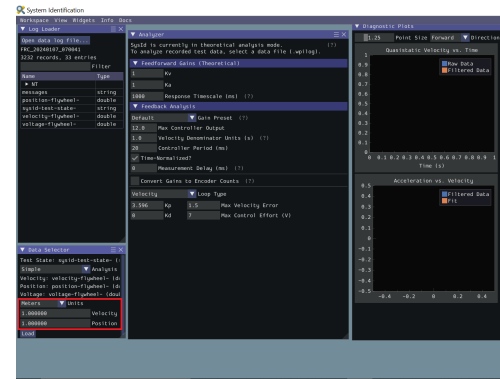
"mechanism" where mechanism",state-test-"sysid- entry the name will SysIdRoutine :□□□□ name. subsystem the or constructor Mechanism the to passed name the is



Log the In slots. Voltage and ,Velocity ,Position present will pane Selector Data the Now name motor the containing and terms those of each with starting entries find pane, Loader slots. Selector Data the into those drag and callback, log the in set you



the in set been have would entries velocity and position the for units correct the Ideally, Data the in dropdown Units the use case, the not was this If tests. the running before code other some or ratio gear a for account not did you if Additionally, it. correct to pane Selector by that for compensate can you uniformly, down or up values recorded the scales that factor boxes. provided the in factors scaling velocity and position setting

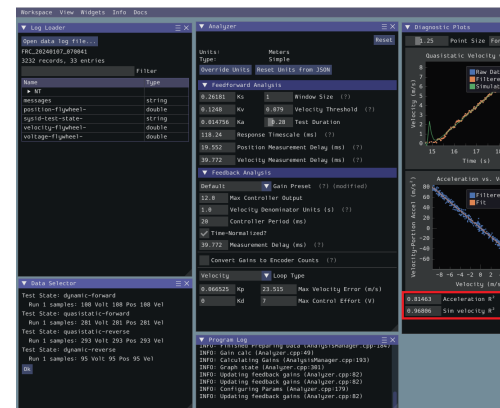


on move and button Load the click then selected, been has type analysis correct the Ensure pane. Diagnostics the in diagnostics fit the checking to

Diagnostics Viewing 32.5.5

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-*



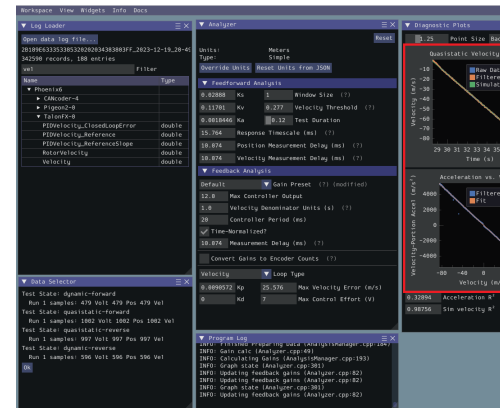
as (used acceleration measured in variance the of fraction the is squaredr- acceleration The be can This model. linear the by explained regression) SysId the in variable independent the tend Mechanisms noise. system to susceptible very is acceleration because variable, quite If datasets. good very on even ,0.5 above goes rarely value this so bit, a quite vibrate to and quality dubious of be will gain kA the ,0.2 around below goes squaredr- acceleration the this outside is squaredr- your if Even possible. if reduced be should vibration mechanism the practical. if data the improve to recommended is it but valid, be still may it range

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

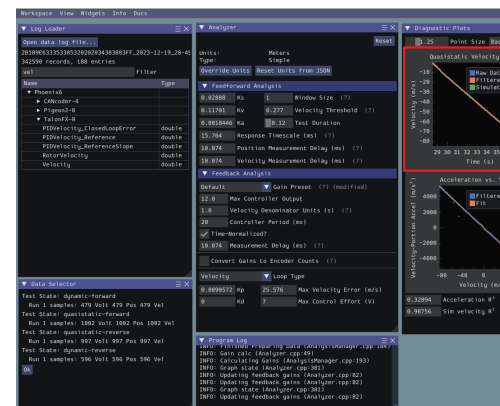
model their of quality the evaluate users help to plots diagnostic several produces also SysId fit.



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



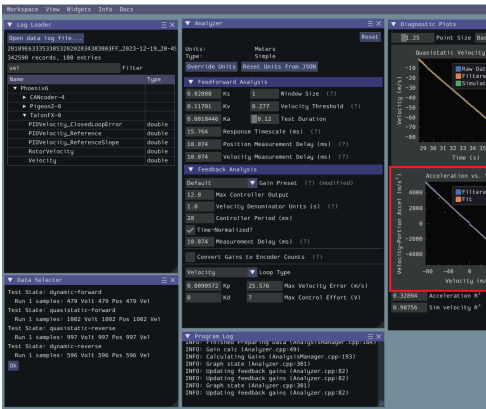
and Data, Filtered Data, Raw data: of sets three contain plots domain time velocity The the is Data Filtered the robot, your from data recorded the is Data Raw The Simulation. the represents Simulation the and data, the to applied been has filter median a after data are (these tool the from gains feedforward 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

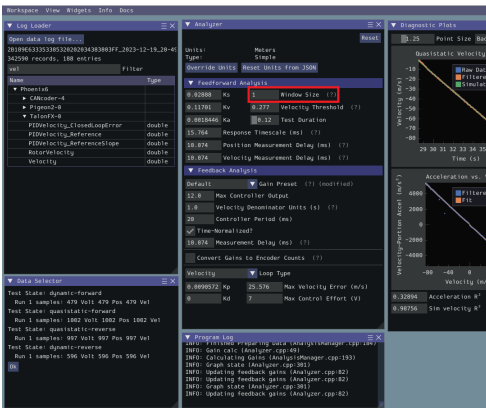
settings, analysis setup, robot your in either ,error an of sign a is behavior this from Deviation procedure. test your or

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)



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



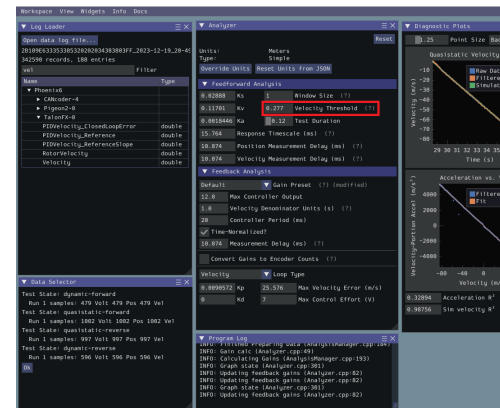
may this power, motor the to compared mass low has mechanism or robot your if However, towards tend will kA cases these In have. you data acceleration meaningful little what "eat" accurately be cannot kA if However, purposes. feedforward for ignored be can and zero may tuning manual and inaccurate, be to likely are gains feedback calculated the measured, required. be

Modes Failure Common

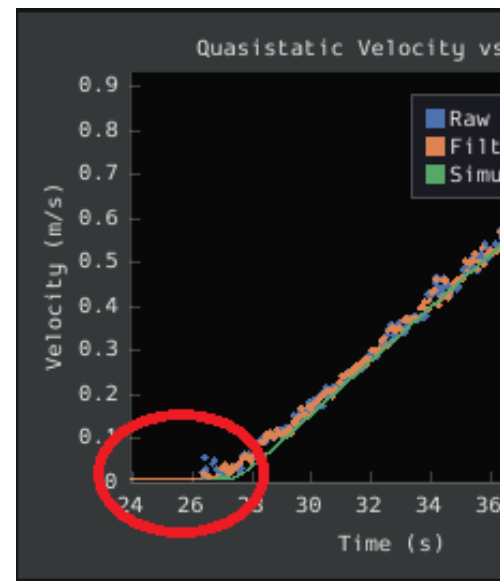
output console and plots diagnostic identification, the with wrong gone has something When failures common some describes section This wrong. gone has *what* to as clues crucial provide their of features identifying the tool, identification system the running while encountered them. fix to taken be can that steps the and plots, diagnostic

Threshold Motion Set Improperly

threshold. motion the for value inappropriate an is errors commonmost- the of One

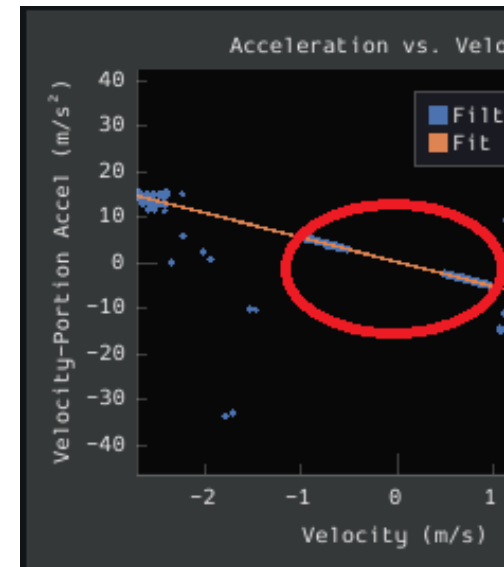


Low Too Threshold Velocity



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

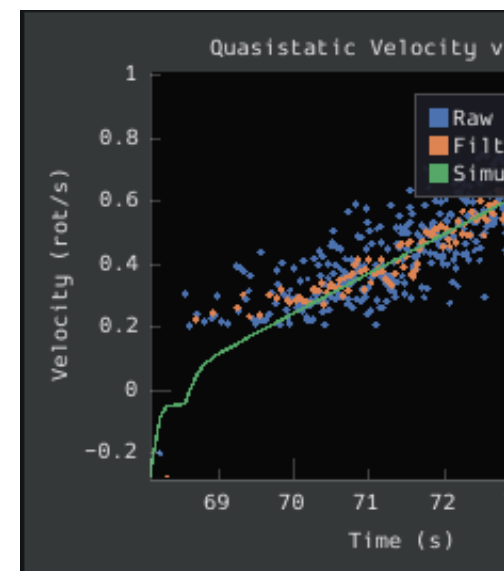
High Too Threshold Motion

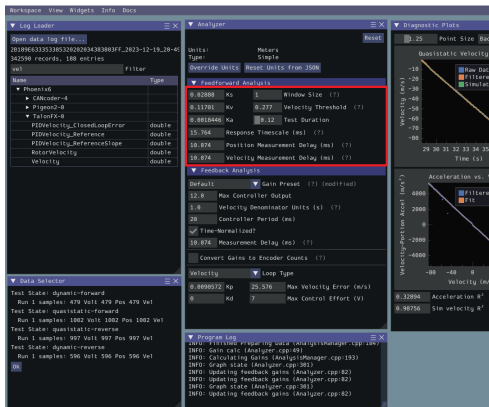


high too is that threshold velocity a threshold, lowtoo- a as problematic as nearly not While plot. velocityversus-acceleration- the in "gap" large a in result will data. the analyzere- and threshold velocity the decrease this, solve To

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

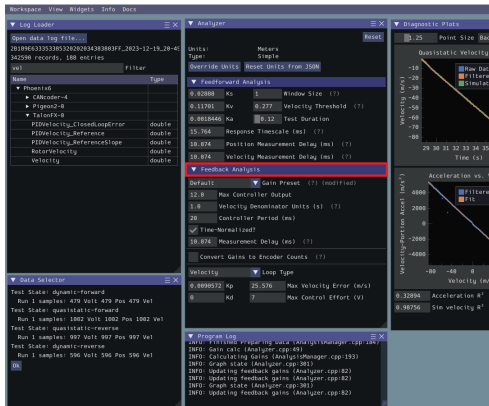




Analysis Feedback

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



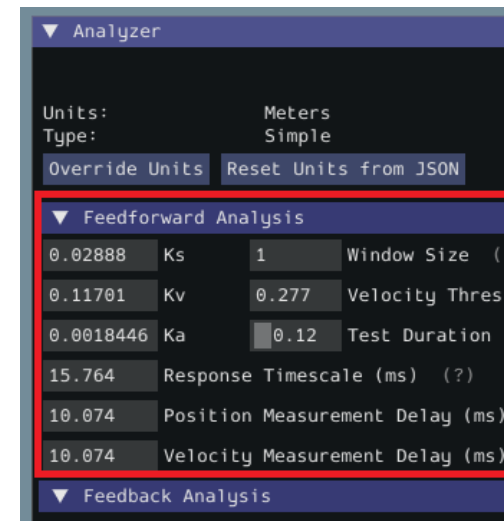
your for controller P or PD a for gains feedback optimal calculate to used be can view This).*LQR* (via mechanism

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



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

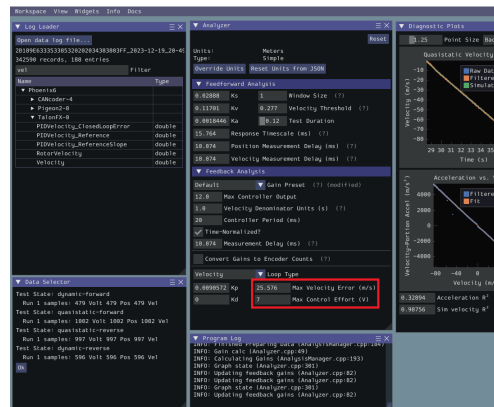
settings filtering custom own their implement to decides user the if applies only following The motorcontroller smart changing or loop PID WPILib a to filter average moving a adding (e.g. be must delay measurement the as size) window measurement and/or period measurement windows moving with filters for 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

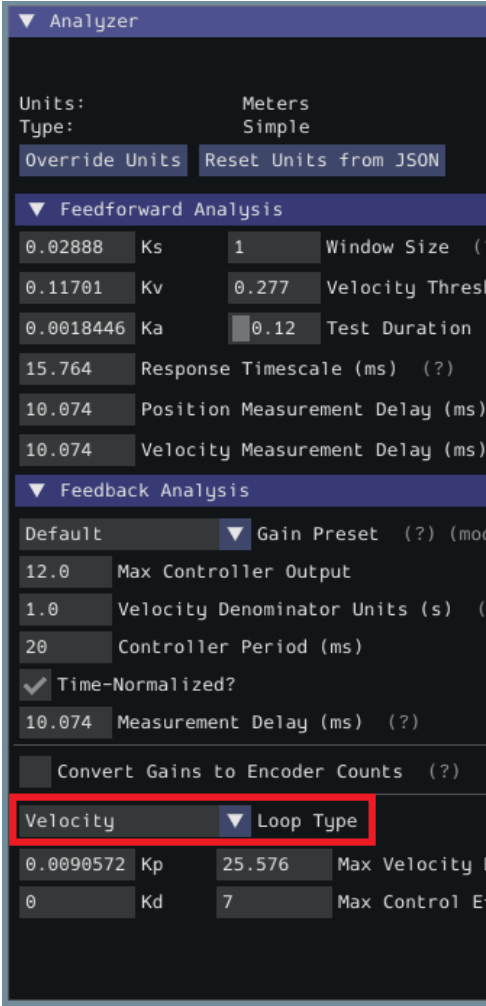


Max the for values larger and *Error Acceptable Max* the for values smaller rule, a As efforts, control larger in result will this - gains larger in result will *Effort Control Acceptable* greater and behavior violent more cause may but trackingsetpoint- better grant can which components. on wear

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* dropdown- the using selected be can Either application.



Tools and Utilities Additional 32.5.7

tool this that functionality additional about information useful covers mainly page This provides.

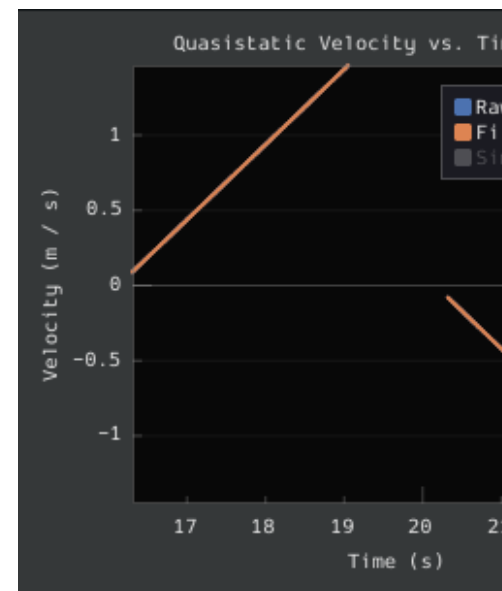
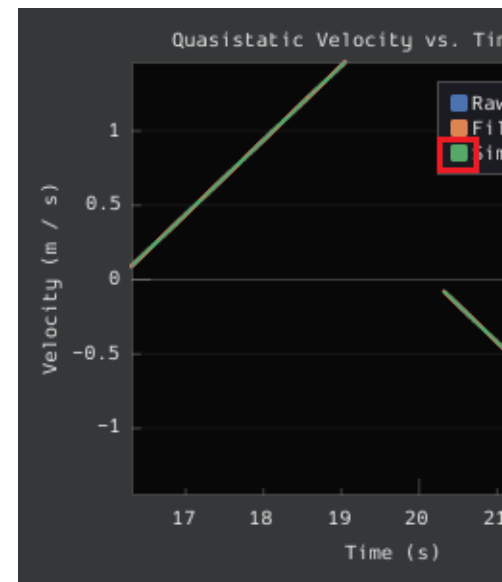
Tips ImGui

SysId that framework ImGui the with come that features handy essentially are following The uses:

Data Plot Hiding and Showing

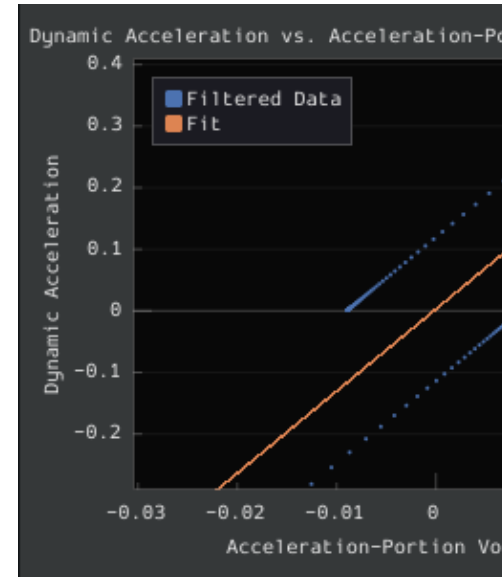
would you that data the of color the on click plots, the from data certain remove or add To remove. or hide to like

box. color green the click can we data, sim hide to want we if example, For

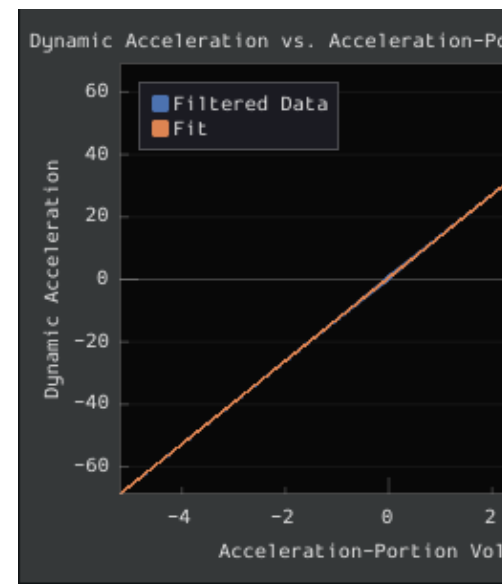


Plots Sizing Auto

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

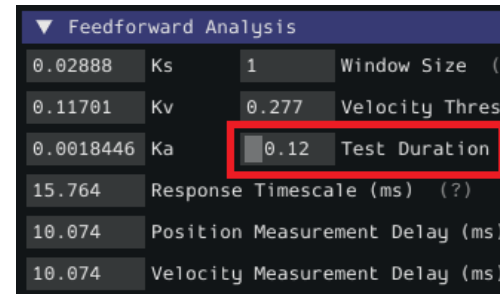


resized: automatically is it clicking, double After

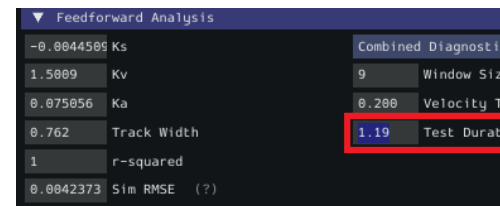


Values Slider Setting

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



slider: the clicking double after input the is Here



Controllers 32.6

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 בקרת PID עם 32.6.1

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 offering as well as user, the for calculation loop feedback the handles class This).Python has loop control the if checking and tolerances, setting error, the returning for methods tolerances. specified the within setpoint its reached

שימוש במחלקה PIDController

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::frc
```

PYTHON

```
PIDController import controller.wpimath from
kD and kI, kP, gains with PIDController a Creates #
kD) kI, PIDController(kP, = pid
```

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

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(),

```

PYTHON

```

reading sensor the on based algorithm PID the of output the Calculates #
motor a to it sends and #
setpoint)) getDistance(), calculate(encoder.set(pid motor

```

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());
```

PYTHON

```
second per 10 to tolerance derivative error the and 5, to tolerance error the Sets #
)10 ,5setTolerance( pid

the and units, 5 than less is error the if true Returns #
units 10 than less is derivative error #
atSetpoint().pid
```

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(
```

PYTHON

```
from 0.5 than more subtract or add never will term gain integral The #
output loop total the #
)0.5 ,0.5-setIntegratorRange( pid
```

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 the ,IZone than more is error the If .IZone setting by achieved be can This active. is gain less or to equal is error the When gain. integral disabling reset, is error accumulated total enabled. is gain integral IZone, than disabled. is IZone default, By infinity. to it set it, disable To method. `setIZone()` the using set be may IZone

JAVA

```
IZone Disable //
);POSITIVE_INFINITY(Double.setIZonepid.
is error the of value absolute the if applied be not will gain Integral //
2 than more //
);2(setIZonepid.
```


JAVA

```
180 to 180- from range a on input continuous Enables //
);180 ,180-(enableContinuousInput pid.
```

C++

```
180 to 180- from range a on input continuous Enables //
);180 ,180 pid.EnableContinuousInput(
```

PYTHON

```
180 to 180- from range a on input continuous Enables #
)180 ,180 enableContinuousInput( pid
```

Output Controller Clamping
JAVA

```
0.5 and 0.5- between to output controller the Clamps //
);0.5 ,0.5- setpoint), (),getDistance(encoder.calculate(pid.clampMathUtil.
```

C++

```
0.5 and 0.5- between to output controller the Clamps //
);0.5 ,0.5- setpoint), clamp(pid.Calculate(encoder.GetDistance(),::std
```

PYTHON

```
function clamp builtin a have t'doesn Python #
        maxval): minval, (v,clamp def
        minval) maxval), (v,min(max return

0.5 and 0.5- between to output controller the Clamps #
)0.5 ,0.5- setpoint), getDistance(), calculate(encoder.clamp(pid
```

WPILib in Control Feedforward 32.6.2

For WPILib, in control feedforward of implementation code in- 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 K_A and K_V , K_G of estimates empirically. measured be must and model, to impossible nearly is K_S .ReCalc from

control: feedforward for classes helper three following the provides currently WPILib

[Python](#) , [C++](#) , [Java](#) ([SimpleMotorFeedforward](#) •

Python, C++, Java(*ArmFeedforward* •

)Python , 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

is unit which indicate components feedforward Python for documentation API The :
Python as units, correct use to care take *must* Users .wpimath.units.NAME as used being
system. unit safetype- a have not does

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
```

PYTHON

```
SimpleMotorFeedforwardMeters import controller.wpimath from
kA and kV, kS, gains with SimpleMotorFeedforward new a Create #
meters in measured is Distance #
kA) kV, SimpleMotorFeedforwardMeters(kS, = feedforward
```

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(

```

PYTHON

```

    acceleration an and meters/second 10 of velocity a for feedforward the Calculates #
                                                    meters/second^2 20 of ↵
                                                    volts in is Output #
    )20 ,10calculate(.feedforward

```

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

is unit which indicate components feedforward Python for documentation API The :□□□□ Python as units, correct use to care take *must* Users .wpimath.units.NAME as used being system. unit safetype- a have not does

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
```

PYTHON

```
ArmFeedforward import controller.wpimath from
```

```
kA and kV, kG, kS, gains with ArmFeedforward new a Create #
kA) kV, kG, ArmFeedforward(kS, = feedforward
```

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, ↵
radians/second^2 3 of acceleration an //
volts in is Output //
s));_1 * s_1(/rad_3 rad_per_s,_2 rad,_1feedforward.Calculate(

```

PYTHON

```

radians/ 2 of velocity a radians, 1 of position a for feedforward the Calculates #
                                                    and second, ↵
radians/second^2 3 of acceleration an #
volts in is Output #
)3 ,2 ,1calculate(.feedforward

```

ElevatorFeedforward

or units, distance the with consistent units have *must* gains inpassed- the C++, In :`wpilib` 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 :`wpilib` consistent, units keep to care take *must* Users gains. feedforward provideduser- the of units system. unit safetype- a have not does WPILibJ as

is unit which indicate components feedforward Python for documentation API The :`wpilib` Python as units, correct use to care take *must* Users .wpimath.units.NAME as used being system. unit safetype- a have not does

of consist that elevators for feedforwards calculates class ElevatorFeedforward The This elevator. the of mass the and inertia, 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 :`wpilib` 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
```

PYTHON

```
ElevatorFeedforward import controller.wpimath from
kA and kV, kS, gains with ElevatorFeedforward new a Create #
meters in measured is Distance #
kA) kV, kG, ElevatorFeedforward(kS, = feedforward
```

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(
```

PYTHON

```
meters/second 20 of velocity a for feedforward the Calculates #
meters/second^2 30 of acceleration an and #
volts in is Output #
)30 ,20calculate(.feedforward
```

Mechanisms Control to Feedforward Using

the use to best is it meaningful, physically are voltages feedforward Since :
compensate to motors to them applying when method) python ,C++ ,Java(setVoltage()
battery. the from sag" "voltage for

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.setVoltage rightMotor.
}
```

C++

```
leftVelocity, meters_per_second_t::(unitsTankDriveWithFeedforward void
{ rightVelocity) meters_per_second_t::units
leftMotor.SetVoltage(feedforward.Calculate(leftVelocity));
rightMotor.SetVoltage(feedforward.Calculate(rightVelocity));
}
```

PYTHON

```
):float rightVelocity: ,float leftVelocity: ,self(tankDriveWithFeedforward def
calculate(leftVelocity)) .setVoltage(feedForward.leftMotor.self
calculate(rightVelocity)) .setVoltage(feedForward.rightMotor.self
```

Control PID and Feedforward Combining 32.6.3

control feedforward/PID combined of implementation code in- 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

to it sending before controller the of output the to like they feedforward any add may Users motors: their

JAVA

```
motor the to it sending before output loop the to feedforward a Adds //
feedforward); + setpoint) (),getDistance(encoder.calculate(pid.setVoltage(motor.
```

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 : compensate to motors to them applying when method) python ,C++ ,java(setVoltage() battery. the from sag" "voltage for

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 rightVelocitySetpoint) {
    // Tank Drive with Feedforward PID
    leftMotor.calculate(leftVelocitySetpoint);
    leftPID.calculate(leftEncoder.getRate(), leftVelocitySetpoint);
    leftMotor.setVoltage(leftPID.calculate(leftVelocitySetpoint));
    rightMotor.calculate(rightVelocitySetpoint);
    rightPID.calculate(rightEncoder.getRate(), rightVelocitySetpoint);
    rightMotor.setVoltage(rightPID.calculate(rightVelocitySetpoint));
}
```

C++

```
double leftVelocitySetpoint, double rightVelocitySetpoint) {
    // Tank Drive with Feedforward PID
    leftMotor.calculate(leftVelocitySetpoint);
    leftPID.calculate(leftEncoder.getRate(), leftVelocitySetpoint);
    leftMotor.SetVoltage(leftPID.calculate(leftVelocitySetpoint));
    rightMotor.calculate(rightVelocitySetpoint);
    rightPID.calculate(rightEncoder.getRate(), rightVelocitySetpoint);
    rightMotor.SetVoltage(rightPID.calculate(rightVelocitySetpoint));
}
```

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 32.6.4

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

).Python ,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 achievable simultaneously- .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):Python ,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
```

PYTHON

```
TrapezoidProfile import trajectory.wpimath from
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 ,10Constraints( TrapezoidProfile
```

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).Python ,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
```

PYTHON

```
TrapezoidProfile import trajectory.wpimath from
meters 5 of position a with state new a Creates #
second per meters 0 of velocity a and #
)0 ,5State( TrapezoidProfile
```

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
 parameter: 1 takes constructor TrapezoidProfile The profile. motion our create to ready
 constraints. the

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 //
_5(ConstraintsTrapezoidProfile. newTrapezoidProfile( new = profile TrapezoidProfile
));10 ↵

```

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 //
profile{ >meters::units<TrapezoidProfile::frc
mps_sq}};_10 mps,_5Constraints{::meters::units<TrapezoidProfile::frc

```

PYTHON

```

TrapezoidProfile import trajectory.wpimath from
// 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 #
))10 , "Constraints( TrapezoidProfile(TrapezoidProfile = profile

```

TrapezoidProfile a Using

Profile the Sampling

at state profile the get to simple: very is it using ,TrapezoidProfile a created we've Once
 state goal the with method calculate() the call started, has profile the after time given the
 state: initial and

JAVA

```

        position zero at stationary start will Profile //
        meters 5 at stationary end will Profile //
        motion of seconds 5 after state profile motion the Returns //
        ,5(StateTrapezoidProfile. new ),0 ,0(StateTrapezoidProfile. new ,5(calculateprofile.
        ));0 ↵
    
```

C++

```

        position zero at stationary start will Profile //
        meters 5 at stationary end will Profile //
        motion of seconds 5 after state profile motion the Returns //
        s,_5profile.Calculate(
        mps},_0 m,_6State{:>meters::units<TrapezoidProfile::frc
        mps});_0 m,_5State{:>meters::units<TrapezoidProfile::frc
    
```

PYTHON

```

        position zero at stationary start will Profile #
        meters 5 at stationary end will Profile #
        motion of seconds 5 after state profile motion the Returns #
        ))0 ,5State(.TrapezoidProfile ),0 ,6State(.TrapezoidProfile ,5calculate( profile
    
```

State the Using

was that one same (the class TrapezoidProfile.State a returns method calculate The actual for this use To state). profile the calculating when states initial/end the specify to used you controller whatever to values velocity and position contained the pass simply control, PIDController): a example, (for wish

JAVA

```

        goalState); initialState, (elapsedTime,calculateprofile. = setpoint var
        );positionsetpoint. (),getDistance(encoder.calculatecontroller.
    
```

C++

```

        goalState); initialState, profile.Calculate(elapsedTime, = setpoint auto
        setpoint.position.value()); controller.Calculate(encoder.GetDistance(),
    
```


PYTHON

```
goalState) initialState, calculate(elapsedTime, profile = setpoint
position) .setpoint getDistance(), calculate(encoder.controller
```

Example Usage Complete

somewhat a is This timestep. every computedre- is state initial the example, this In :□□□□ principles same the to according works but above, detailed is than technique usage different the for setpoint the get to period loop the to corresponding time a at sampled is profile the - iteration. loop next

the in provided is usage TrapezoidProfile of example complete more A
) :Python ,C++ ,Java(project example ElevatorTrapezoidProfile

JAVA

```
;edu.wpi.first.wpilibj.examples.elevatortrapezoidprofile package
;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 import

{ TimedRobot extends Robot class public
;0.02 = kDt double static private

);1Joystick( new = m_joystick Joystick final private
new = m_motor ExampleSmartMotorController final private
);1ExampleSmartMotorController(
robot. your for tuned be to have will and fake, are gains These Note: //
new = m_feedforward SimpleMotorFeedforward final private
);1.5

maximum and velocity maximum given the with profile motion a Create //
setpoint. next the for constraints acceleration //
= m_profile TrapezoidProfile final private
));0.75 ,1.75(ConstraintsTrapezoidProfile. newTrapezoidProfile( new
());StateTrapezoidProfile. new = m_goal StateTrapezoidProfile. private
());StateTrapezoidProfile. new = m_setpoint StateTrapezoidProfile. private

@Override
{ ()robotInit void public
robot. your for tuned be to have will and fake, are gains These Note: //
);0.7 ,0.0 ,1.3(setPIDm_motor.

@Override
{ ()teleopPeriodic void public
{ })2(getRawButtonPressed(m_joystick. if
);0 ,5(StateTrapezoidProfile. new = m_goal
```

page) next on (continues

(0000 0000 0000)

```

{ })3(getRawButtonPressed(m_joystick. if else }
    ());StateTrapezoidProfile. new = m_goal
    }

moves setpoint This timestep. next the for setpoint profiled the Retrieve //
constraints. the obeying while goal the toward //
m_goal); m_setpoint, (kDt,calculatem_profile. = m_setpoint

PID controller offboard to setpoint Send //
(setSetpointm_motor.
,kPosition.PIDModeExampleSmartMotorController.
,positionm_setpoint.
);12.0 / )velocity(m_setpoint.calculatem_feedforward.
    }
    }

```

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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
{ })3(m_joystick.GetRawButtonPressed( if else }
mps};_0 m,_0{ = m_goal
}
moves setpoint This timestep. next the for setpoint profiled the Retrieve //
constraints. the obeying while goal the toward //
m_goal); m_setpoint, m_profile.Calculate(kDt, = m_setpoint
PID controller offboard to setpoint Send //
kPosition,::PIDMode :m_motor.SetSetpoint(ExampleSmartMotorController
page) next on (continues

```

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(0000 00000 0000)

```

        m_setpoint.position.value(),
V);_12 / m_feedforward.Calculate(m_setpoint.velocity)
    }

private
    ;}m_joystick{ Joystick::frc
    ;}m_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

    maximum and velocity maximum given the with profile motion a Create //
    setpoint. next the for constraints acceleration //
mps_sq}};_0.75 mps,_1.75m_profile{{ >meters::units<TrapezoidProfile::frc
    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#

```

PYTHON

```

        wpilib import
        controller.wpimath import
        trajectory.wpimath import
        examplesmartmotorcontroller import

    TimedRobot):.(wpilibMyRobot class
        0.02 = kDt

        ):self(robotInit def
            )1Joystick(.wpilib = joystick self
            )1ExampleSmartMotorController( examplesmartmotorcontroller = motor.self
            robot. your for tuned be to have will and fake, are gains These Note: #
            )1.5 ,1SimpleMotorFeedforwardMeters( controller.wpimath = feedforward.self
            )0.75 ,1.75Constraints(.TrapezoidProfile trajectory wpimath = constraints self

                State() TrapezoidProfile.trajectory wpimath = goal.self
                State() TrapezoidProfile.trajectory wpimath = setpoint.self

            robot. your for tuned be to have will and fake, are gains These Note: #
                )0.7 ,0.0 ,1.3setPID( motor self

                ):self(teleopPeriodic def
                    ):getRawButtonPressed( joystick.self if
                    )0 ,State(.TrapezoidProfile.trajectory wpimath = goal.self
                    ):getRawButtonPressed( joystick.self elif
                    )0 ,State(.TrapezoidProfile.trajectory wpimath = goal.self

```

page) next on (continues

(0000 0000 0000)

```

        maximum and velocity maximum given the with profile motion a Create #
        the and goal, desired the setpoint, next the for constraints acceleration #
                                setpoint. current #
        TrapezoidProfile( trajectory wpimath = profile
        setpoint self goal, self constraints, self
                                )

        moves setpoint This timestep. next the for setpoint profiled the Retrieve #
        constraints. the obeying while goal the toward #
        kDt).self.calculate(.profile = setpoint.self

        PID controller offboard to setpoint Send #
                                setSetPoint( motor.self
kPosition, PIDMode ExampleSmartMotorController.examplesmartmotorcontroller
                                position, setpoint.self
                                ,12 / velocity).setpoint self.calculate(.feedforward.self
                                )

```

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with Control PID and Profiling Motion Combining 32.6.5 ProfiledPIDController

basedcommand- the in class ProfiledPIDController the implementing on guide a For :0000
.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

a with combined setpoints generating for profile motion (a functionality of combination This
with comes WPILib this, facilitate To common. extremely is them) following for controller PID
combining of work the of most does that) python , C++ , java(class ProfiledPIDController a
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 :0000
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

that to identical effectively is ProfiledPIDController of functionality the of Much :0000
substantially- are that features cover only will article this Accordingly, .PIDController of
standard on information For functionality. profiling motion the accommodate to changed

.WPILib PID see features, PIDController

ProfiledPIDController a Constructing

initializer simple a thus and classes, inner the of type the infer to able often is C++ :
in included is name class full The parameter. a as sent be can name) class the (without list
clarity. for below example the

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

```

PYTHON

```

ProfiledPIDController import controller.wpimath from
TrapezoidProfile import trajectory.wpimath from

        ProfiledPIDController a Creates #
        second per meters 5 is velocity Max #
        second per meters 10 is acceleration Max #
        ProfiledPIDController( = controller
                                kD, kI, kP,
                                ))10 ,5Constraints(.TrapezoidProfile

```

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(),
```

PYTHON

```
reading sensor the on based algorithm PID the of output the Calculates #
motor a to it sends and #
goal)) getDistance(), calculate(encoder.set(controller motor
```

,`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
page) next on (continues
```

(0000 0000 0000)

```
(Timer. / lastSpeed) - velocity().getSetpoint(controller. = acceleration double
lastTime); - ()getFPGATimestamp() →
(setVoltage motor.
pidVal
acceleration)); ,velocity().getSetpoint(controller.calculatefeedforward. +
;velocity().getSetpoint controller. = lastSpeed
();getFPGATimestamp Timer. = 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 //
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
}
```

PYTHON

```
Timer import wpilib from
ProfiledPIDController import controller.wpilib from
SimpleMotorFeedforward import controller.wpilib from

):self(init____ def

defined already are controller motor, encoder, Assuming #
_0 = lastSpeed.self
getFPGATimestamp() Timer = lastTime.self

object SimpleMotorFeedforward a is feedforward Assuming #
)0.0=ka ,0.0=kv ,0.0=SimpleMotorFeedforward(ks = feedforward.self

):float goalPosition: ,self(goToPosition def

goalPosition) getDistance(), encoder.self.calculate(.controller.self = pidVal
.(Timer / lastSpeed).self - velocity.getSetpoint().controller.self( = acceleration
lastTime).self - getFPGATimestamp() →

setVoltage(.motor.self
pidVal
```

page) next on (continues

(□□□□ □□□□ □□□□)

```
velocity, .getSetpoint().controller.selfcalculate(.feedforward.self +
                                                    acceleration)) ↵
```

```
velocity.getSetpoint().controller = lastSpeed.self
getFPGATimestamp().Timer = lastTime.self
```

Example Usage Complete

the in provided is usage ProfiledPIDController of example complete more A
).Python ,C++ ,Java(project example ElevatorProfilePID

JAVA

```
;edu.wpi.first.wpilibj.examples.elevatorprofiledpid package
;edu.wpi.first.math.controller.ElevatorFeedforward 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.Joystick import
;edu.wpi.first.wpilibj.TimedRobot import
;edu.wpi.first.wpilibj.motorcontrol.PWMSparkMax import

)"PMD.RedundantFieldInitializer"(@SuppressWarnings
{ TimedRobot extends Robot class public
;0.02 = kDt double static private
;1.75 = kMaxVelocity double static private
;0.75 = kMaxAcceleration double static private
;1.3 = kP double static private
;0.0 = kI double static private
;0.7 = kD double static private
;1.1 = kS double static private
;1.2 = kG double static private
;1.3 = kV double static private

);1Joystick( new = m_joystick Joystick final private
);2 ,1Encoder( new = m_encoder Encoder final private
);1PWMSparkMax( new = m_motor PWMSparkMax final private

maximum to subject is change s'setpoint whose controller PID a Create //
constraints. acceleration and velocity //
= m_constraints ConstraintsTrapezoidProfile. final private
kMaxAcceleration); (kMaxVelocity,ConstraintsTrapezoidProfile. new
= m_controller ProfiledPIDController final private
kDt); m_constraints, kD, kI, ProfiledPIDController(kP, new
kG, ElevatorFeedforward(kS, new = m_feedforward ElevatorFeedforward final private
kV); ↵

@Override
{ ()robotInit void public
);1.5 * PIMath. * 2.0 * 360.0 / 1.0(setDistancePerPulsem_encoder.
}
```

page) next on (continues

(0000 00000 0000)

```

                                @Override
                                { ()teleopPeriodic void public
                                { })2(getRawButtonPressed(m_joystick. if
                                    );5(setGoalm_controller.
                                { })3(getRawButtonPressed(m_joystick. if else }
                                    );0(setGoalm_controller.
                                    }
                                output motor update and controller Run //
                                    (setVoltage(m_motor.
                                (())getDistance(m_encoder.calculatem_controller.
                                ));velocity().getSetpoint(m_controller.calculatem_feedforward. +
                                    }
                                }

```

C++

```

                                numbers>< include#
                                frc/Encoder.h>< include#
                                frc/Joystick.h>< include#
                                frc/TimedRobot.h>< include#
                                frc/controller/ElevatorFeedforward.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#
                                units/voltage.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.SetVoltage(
                                    volt_t{::units
                                + meter_t{m_encoder.GetDistance()}}::m_controller.Calculate(units
                                    m_feedforward.Calculate(m_controller.GetSetpoint().velocity));
                                }

```

page) next on (continues

(0000 00000 0000)

```

                                :private
mps;_1.75 = kMaxVelocity meters_per_second_t::units constexpr static
= kMaxAcceleration meters_per_second_squared_t::units constexpr static
                                mps_sq;_0.75
                                ;1.3 = kP double constexpr static
                                ;0.0 = kI double constexpr static
                                ;0.7 = kD double constexpr static
V;_1.1 = kS volt_t::units constexpr static
V;_1.2 = kG volt_t::units constexpr static
mps;_1 / V_1.3 = kV auto constexpr static

                                ;}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 //
m_constraints{ Constraints::meters::units TrapezoidProfile::frc
                                kMaxAcceleration}; kMaxVelocity,
                                kD, kI, m_controller{kP, >meters::units<ProfiledPIDController::frc
kDt}; m_constraints,
                                kV}; kG, m_feedforward{kS, ElevatorFeedforward::frc
                                ;}

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

```

PYTHON

```

                                wpilib import
                                controller.wpimath import
                                trajectory.wpimath import
                                math import

                                TimedRobot):.(wpilibMyRobot class
                                0.02 = kDt

                                :None >- )self(robotInit def
                                )1Joystick(.wpilib = joystick self
                                )2 ,1Encoder(.wpilib = encoder.self
                                )1PWMSparkMax(.wpilib = motor.self

maximum to subject is change s'setpoint whose controller PID a Create #
constraints. acceleration and velocity #
)0.75 ,1.75Constraints(.TrapezoidProfile trajectory wpimath = constraints self
                                ProfiledPIDController(.controller.wpimath = controller.self
                                kDt.self constraints,.self ,0.7 ,0 ,1.3
                                )

                                )1.5 * pi.math * 2 * 360 / 1setDistancePerPulse(.encoder.self

```

page) next on (continues

(0000 00000 0000)

```

        :None >- )self(teleopPeriodic def
    ): getRawButtonPressed( joystick.self if
        ) setGoal( controller.self
    ): getRawButtonPressed( joystick.self elif
        ) setGoal( controller.self

        output motor update and controller Run #
getDistance())) .encoder.self.calculate( controller.self.set( motor.self

```

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BangBangController with Control BangBang- 32.6.6

(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).Python ,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 import controller.wpimath from
BangBangController a Creates #
BangBangController() = 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.setVoltage(motor.
(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 ↵
```

32.7 יצירה ומעקב מסלולים עם WPILib

and trajectories spline parameterized generating for support WPILib describes section This drives. robot FRC® typical with trajectories those following

Generation Trajectory 32.7.1

with curve, smooth a is trajectory A trajectories. generating help that classes contains WPILib the on endpoints two connecting curve, the along point each at accelerations and velocities autonomous performing for useful incredibly is trajectories of following and Generation field. stopping, forward, moving involves which - routine autonomous simple a of Instead tasks. motion for allows trajectories using - forward moving then right, the to degrees 90 turning creating routines, autonomous up speeding of advantage the has This curve. smooth a along more navigation autonomous makes well, implemented when and tasks; other for time more precise. and accurate

go will series this in articles few next The trajectory. a generate to how over goes article This robot your that things few a are There trajectory. generated the follow actually to how over trajectories: of world the into dive you before have must

the is encoder An robot. the of side each of velocity and position the measure to way A •
etc. sensors, flow optical include may options other however, this; do to way best

best the is gyroscope A chassis. robot the of rate angular or angle the measure to way A •
velocities, encoder using calculated be can rate angular the Although this. do to way
scrubbing. wheel of because recommended NOT is method this

on section the see navigation, autonomous perform to way simpler a for looking are you If
.distance a to driving

Splines

connecting as it of Think points. between interpolate that curves of set a to refers spline A
and cubic clamped hermite splines: of types two supports WPILib curves. with except dots,
quintic. hermite

of Generation users. most for option recommended the is This cubic: clamped Hermite •
and points, all of coordinates y) (x, the specifying involves splines these using trajectories
are waypoints interior the at headings The waypoints. end and start the at headings the
heading) the of change of (rate curvature continuous ensure to determined automatically
throughout.

y) (x, specify to user the requires which option advanced more a is This quintic: Hermite •
with unhappy are you if used be should This waypoints. *all* for headings and coordinates
want you if or splines cubic clamped the by generated being are that trajectories the
points. interior the at headings of control finer

have not does itself spline the however, trajectories; generate to tool a as used are Splines
that recommended not is it Therefore, accelerations. and velocities about information any
and velocities with path smooth a generate to order In directly. classes spline the use you
generated. be must *trajectory* a accelerations,

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/Python) startVelocityMetersPerSecond)      setStartVelocity(double •  
    (C++) startVelocity) SetStartVelocity(units::meters_per_second_t  
/ (Java/Python) endVelocityMetersPerSecond)        setEndVelocity(double •  
    (C++) endVelocity) SetEndVelocity(units::meters_per_second_t  
(C++) reversed) SetReversed(bool / (Java/Python) reversed) setReversed(boolean •  
/ (Java/Python) 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.
    
```

page) next on (continues

(□□□□ □□□□ □□□□)

```

    ));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,
}

```

Python

```

():generateTrajectory def
    waypoints. auto scale cross 2018 #
))180-fromDegrees( Rotation2d ,23.23 ,1.54fromFeet(.Pose2d = sideStart
))160-fromDegrees( Rotation2d ,6.8 ,23.7fromFeet( Pose2d = crossScale

    [ = interiorWaypoints
        ),23.23 ,14.54fromFeet(.Translation2d
        ),18.23 ,21.04fromFeet(.Translation2d
    ]

    )12 ,12fromFps(.TrajectoryConfig = config
        )True.setReversed(.config

generateTrajectory(.TrajectoryGenerator = trajectory
    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
two the)+(add simply can users C++/Python function. concatenate(trajectory)
together. trajectories

appended the of start and initial the of end the that ensure to user the to up is It :□□□□□□
end and start the that ensure to responsibility user's the also is It match. trajectory
match. trajectories their of velocities

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

```

```

Translation2d Rotation2d, Pose2d, import geometry.wpimath from
TrajectoryConfig TrajectoryGenerator, import trajectory.wpimath from

generateTrajectory( TrajectoryGenerator = trajectoryOne
    ),0fromDegrees( Rotation2d ,0 ,0Pose2d(
    )],1- ,2Translation2d( ),1 ,1[Translation2d(
    )],0fromDegrees( Rotation2d ,0 ,3Pose2d(
    ),3.0 ,3.0fromFps(.TrajectoryConfig
    )

generateTrajectory( TrajectoryGenerator = trajectoryTwo
    ),0fromDegrees( Rotation2d ,0 ,3Pose2d(
    )],3 ,6Translation2d( ),4 ,4[Translation2d(
    )],0fromDegrees( Rotation2d ,0 ,6Pose2d(
    ),3.0 ,3.0fromFps(.TrajectoryConfig
    )

trajectoryTwo + trajectoryOne = concatTraj

```

Constraints Trajectory 32.7.2

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 drivendifferential- 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
        public double getMinMaxAccelerationMetersPerSecondSq(
            Pose2d pose, double curvatureRadPerMeter,
            double velocityMetersPerSecond) {
            // here code //
        }

        @Override
        public double getMinMaxVelocityMetersPerSecond(
            Pose2d pose, double curvatureRadPerMeter,
            double velocityMetersPerSecond) {
            // 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(
        { override speed) meters_per_second_t units
            // here code //
        }
    
```

PYTHON

```

units import wpimath from
Pose2d import geometry.wpimath from
TrajectoryConstraint import constraint.trajectory.wpimath from

class MyConstraint (TrajectoryConstraint):
    def __init__(self, maxVelocity: Pose2d, pose: Pose2d,
                 radians_per_meter: units.curvature,
                 meters_per_second: units.velocity,
                 meters_per_second: units.velocity) >:
        ...

    def __init__(self, minMaxAcceleration: Pose2d, pose: Pose2d,
                 radians_per_meter: units.curvature,
                 meters_per_second: units.velocity,
                 MinMax: TrajectoryConstraint >: ) >:
        ...

```

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 provided WPILib- the for) C++ , Java (code source the See
 constraints. trajectory custom own your write to how

Trajectories Manipulating 32.7.3

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
the determine to used be can method (Python) totalTime / (Java) getTotalTimeSeconds()
trajectory. the traverse to takes it time

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
```

PYTHON

```
trajectory the of time total the Get #
totalTime().trajectory = duration
```

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
parameter The timestep. any at trajectory the sample to used be can method (Java/Python)
This trajectory). the of point starting (the seconds 0 since passed time of amount the to refers
point. sample that about information with Trajectory::Sample a returns method

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
```

PYTHON

```
robot the where represents This seconds. 1.2 at trajectory the Sample #
traversal. of seconds 1.2 after be should #
)1.2sample( trajectory = point
```

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

calling by trajectory the of states all of list a get can user advanced more A
 state Each method. (Python) states / (Java) getStates() / (C++) States() the
 the using *created is trajectory the When* trajectory. the on point a represents
 states / points trajectory of list a method, TrajectoryGenerator::GenerateTrajectory(...)
 sample new a timestep, particular a at trajectory the samples user the When created. are
 list. the in states / points existing two between interpolated is point

Trajectories Transforming 32.7.4

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

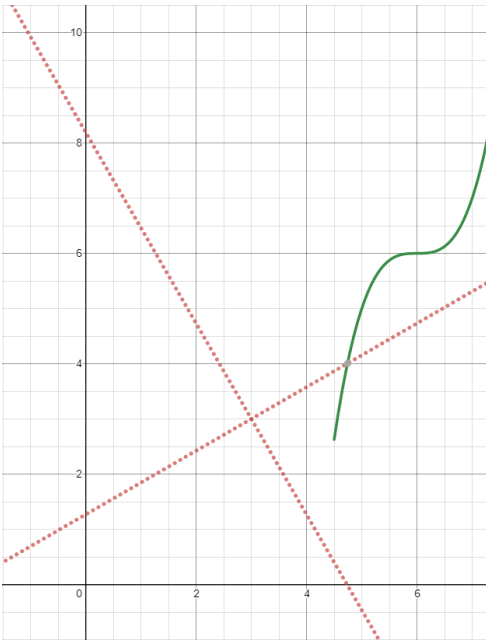
```
));30(fromDegreesRotation2d. ,3 ,3Pose2d( new = b0origin Pose2d  
(b0origin);relativeToaTrajectory. = bTrajectory Trajectory
```

C++

```
deg));_30Rotation2d::frc m,_3 m,_3b0origin{ Pose2d::frc  
aTrajectory.RelativeTo(b0origin); = bTrajectory Trajectory::frc
```

PYTHON

```
Rotation2d Pose2d, import geometry.wpimath from  
))30fromDegrees( Rotation2d ,3 ,3Pose2d( = b0origin  
relativeTo(b0origin) aTrajectory = bTrajectory
```



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

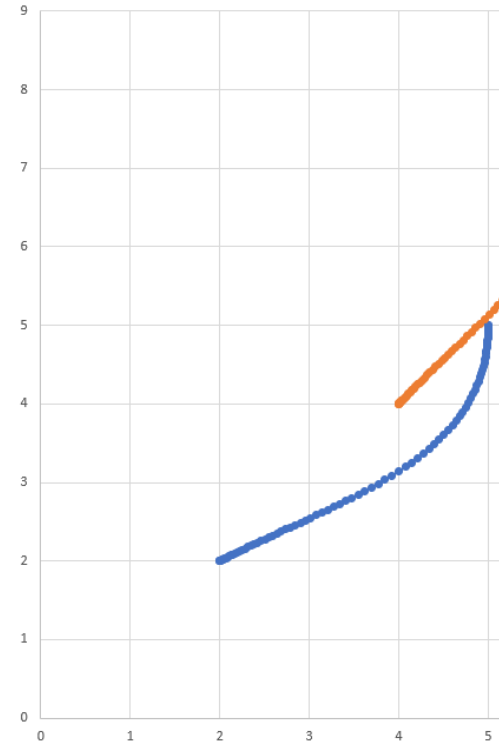
```
(trajectory.minus)).50(fromDegreesRotation2d. ,4 ,4Pose2d( new = transform Transform2d
    ());getInitialPose ↵
    (transform);transformBytrajectory. = newTrajectory Trajectory
```

C++

```
trajectory. - deg))_50Rotation2d( m,_4 m,_4Pose2d( = transform Transform2d::frc
    InitialPose(); ↵
    trajectory.TransformBy(transform); = newTrajectory Trajectory::frc
```

PYTHON

```
Rotation2d Pose2d, import geometry.wpimath from
initialPose() trajectory - ))50fromDegrees( Rotation2d ,4 ,4Pose2d( = transform
transformBy(transform).trajectory = newTrajectory
```

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 32.7.5

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

```

PYTHON

```

RamseteController import controller.wpimath from
Here RamseteController. of constructor default the Using #
0.7. and 2.0 to initialized are gains the #
RamseteController() = controller1

where RamseteController of constructor secondary the Using #
gains. other any choose can user the #
)0.8 ,2.1RamseteController( = controller2

```

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.

method. (Java/Python) calculate / (C++) Calculate the using updated be can controller The robot current the accept overloads these of Both method. this for overloads two are There in takes overloads these of one parameters, other the For parameter. first the as position

whereas velocity) angular and velocity, linear (pose, parameters separate three as goal the the about information contains which object, Trajectory.State a accepts overload other the trajectories. tracking when method latter the use should users ease, its For pose. goal

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
```

PYTHON

```
the from seconds 3.4 at trajectory the sample # )3.4sample(.trajectory = goal
beginning →
goal) calculate(currentRobotPose,.controller = adjustedSpeeds
```

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
```

PYTHON

```
goal) calculate(currentRobotPose, controller = adjustedSpeeds
toWheelSpeeds(adjustedSpeeds) kinematics = wheelSpeeds
left wheelSpeeds = left
right wheelSpeeds = right
```

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, motor smart on feature PID Velocity the or used, be can)Python ,java ,C++(PIDController used. be can MAX SPARK the and TalonSRX the as such controllers

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 32.7.6

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](#) :[PID](#)

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{::frc,0,0,1PIDController{::frc
{>radian::unitsTrapezoidProfile::frc
Constraints{::>radian::unitsTrapezoidProfile::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 //
```

PYTHON

```
( import controller.wpimath from
HolonomicDriveController,
PIDController,
ProfiledPIDControllerRadians,
)
TrapezoidProfileRadians import trajectory.wpimath from

HolonomicDriveController( = controller
),0,0,1PIDController(
),0,0,1PIDController(
ProfiledPIDControllerRadians(
)3.14,6.28Constraints(TrapezoidProfileRadians,0,0,1
),
)
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

method. (Java/Python) calculate / (C++) Calculate the using updated be can controller The robot current the accept overloads these of Both method. this for overloads two are There middle the For parameter. last the as heading desired the and parameter first the as position the while reference velocity linear the and pose desired the accepts overload one parameters, pose. goal the about information contains which object, Trajectory.State a accepts other trajectories. tracking for preferred is method latter The

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 trajectory 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,
```

PYTHON

```
Rotation2d import geometry.wpimath from
beginning. the from seconds 3.4 at trajectory the Sample #
)3.4sample( trajectory = goal

facing be to robot the want we Here, speeds. adjusted the Get #
system). coordinate field-relative the (in degrees 70 #
calculate( controller = adjustedSpeeds
)70.0fromDegrees( Rotation2d 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); toSwerveModuleStates kinematics. = moduleStates ] SwerveModuleState
;]0[moduleStates = frontLeft SwerveModuleState
;]1[moduleStates = frontRight SwerveModuleState
;]2[moduleStates = backLeft SwerveModuleState
;]3[moduleStates = backRight SwerveModuleState
```

C++

```
kinematics.ToSwerveModuleStates(adjustedSpeeds); = br] bl, fr, [fl, auto
```

PYTHON

```
toSwerveModuleStates(adjustedSpeeds) kinematics = br bl, fr, fl,
```

PID use to need will you angles, and speeds still are states module swerve these Because
angles. and speeds these set to controllers

32.7.7 פתרון בעיות

פתרון כשלונות מוחלטים

אם אתם מקבלים שגיאות אלו, הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.
הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

• הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

- אם אתם מקבלים שגיאות אלו, הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

- אם אתם מקבלים שגיאות אלו, הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.
הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

- אם אתם מקבלים שגיאות אלו, הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

• My robot swings around the drive trajectory facing the other direction.

- Are the start and end headings of your trajectory wrong?

- Is your robot's gyro getting reset to the wrong heading?

- Do you have the *reverse* flag set *incorrectly*?

- Are your gyro angles clockwise? If so, you should negate them.

• הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

- אם אתם מקבלים שגיאות אלו, הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

- Are you passing your gyro heading to your odometry object with the correct units?

- Is your track width correct? Is it in the correct units?

• הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.
הסיבה היא שיש לכם בעיה עם ה-`MalformedSplineException`.

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 -

.
•

?
-

?
-

.
•

.
-

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
know to difficult be can it so parts, moving many and tune to knobs many have followers and
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 .
: 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.

    ());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 that sure you're if incorrect; be may wheel) right the of center the to wheel left the of wheels robot's your then measure tape a with correctly width track the measured you the increasing try so width, track by for accounted not is that way a in slipping be may programmatically. it measuring or number width track

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
```

123
124

C++

```
,}0,0 kPDriveVel,::PIDController{DriveConstants::frc
},}0,0 kPDriveVel,::PIDController{DriveConstants::frc
```

81
82

isolate to easier it make to controller Ramsete the disable to want we Next, 1. 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 →
        ());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, ::(DriveConstants leftController PIDController::frc
    ); 0, 0 kPDriveVel, ::(DriveConstants rightController PIDController::frc
        (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

velocity desired vs. actual logs that step previous the from code the all usere- must You 1.
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

desired vs. actual your that check and trajectories, of variety a on again robot the Run 2.
 good. look graphs

desired) the from different very is velocity actual the (i.e. good look not do graphs the If 3.
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- 32.8

control. spacestate- for support WPILib describes and to introduction an provides section This

32.8.1 מובא לבקרת SpaceState-

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 based Model-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 5 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

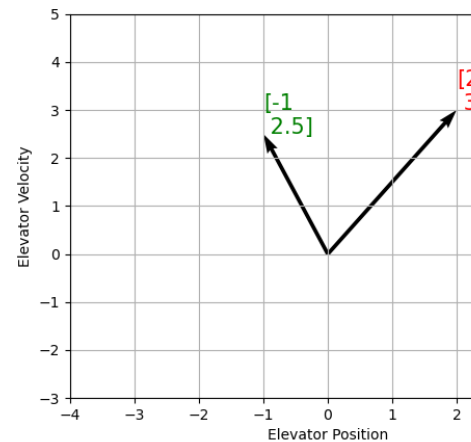
.*Glossary* the see article, this throughout used be will that vocabulary background the For

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 :[position, 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 ,*y* *output* the and ,*x* state in change the relate equations These time. .*u* vector *input* and *x* vector state current the of

the In systems. timediscrete- and timecontinuous- with deal can control spaceState-linear a as expressed is *x* state system's the of change of rate the case, timecontinuous-.*u* input and *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 *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

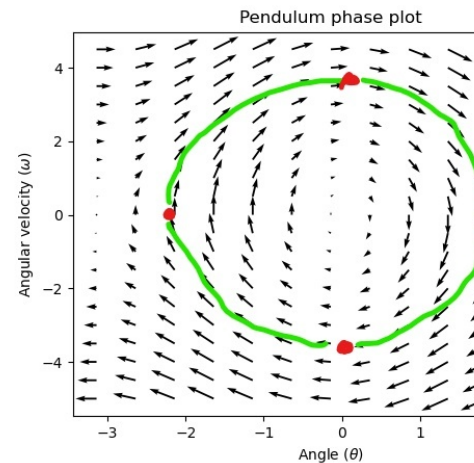
$$\begin{aligned}\text{Continuous: } \dot{\mathbf{x}} &= \mathbf{Ax} + \mathbf{Bu} \\ \mathbf{y} &= \mathbf{Cx} + \mathbf{Du}\end{aligned}$$

$$\begin{aligned}\text{Discrete: } \mathbf{x}_{k+1} &= \mathbf{Ax}_k + \mathbf{Bu}_k \\ \mathbf{y}_k &= \mathbf{Cx}_k + \mathbf{Du}_k\end{aligned}$$

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 \mathbf{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 \mathbf{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



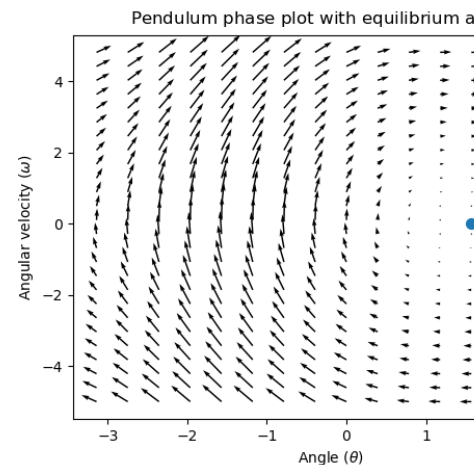
π of rotation a as around wraps axis X the portrait, phase the of edges the near that Note point. same the at end will clockwise radians π of rotation a and clockwise counter radians

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 $\mathbf{0} = \mathbf{Ax} + \mathbf{Bu}$ equation $:(\frac{\pi}{2}, 0)$ at gravity of force the opposes that



Control Feedback

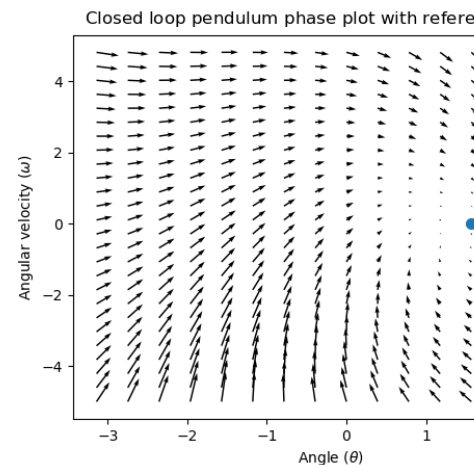
states current all of knowledge and model mathematical a just with motor, DC a of case the In voltage future the given states future all predict can we velocity), angular (i.e., system the of like equations, our by modeled isn't that way any in disturbed is system the if But inputs. model the from deviate 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 \mathbf{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*

$$J = \sum_{k=0}^{\infty} (\mathbf{x}_k^T \mathbf{Q} \mathbf{x}_k + \mathbf{u}_k^T \mathbf{R} \mathbf{u}_k)$$

.error the is $r_k - x_k$ where $\mathbf{u} = \mathbf{K}(\mathbf{r}_k - \mathbf{x}_k)$ as written be can **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. 'sr 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 //
    = elevatorSystem >1 ,1 ,2<LinearSystem
    );0.5 ,5IdentifyVelocitySystem(::LinearSystemId::frc →
    controller{ >1 ,2<LinearQuadraticRegulator
        elevatorSystem,
        elements s'q //
        },0.4 ,0.02{
        elements s'r //
        },12.0{
```

page) next on (continues

(0000 0000 0000)

```
dt our //
s};_0.020
```

PYTHON

```
LinearQuadraticRegulator_2_1 import controller.wpimath from
LinearSystemId import plant.system.wpimath from

robot. your match to changed be must -- system Example #
)0.5 ,5identifyPositionSystemMeters(.LinearSystemId = elevatorSystem
LinearQuadraticRegulator_2_1( = controller
elevatorSystem,
elements s'q #
),0.4 ,0.02(
elements s'r #
),,12.0(
dt our #
,0.020
)
```

application example LQR:

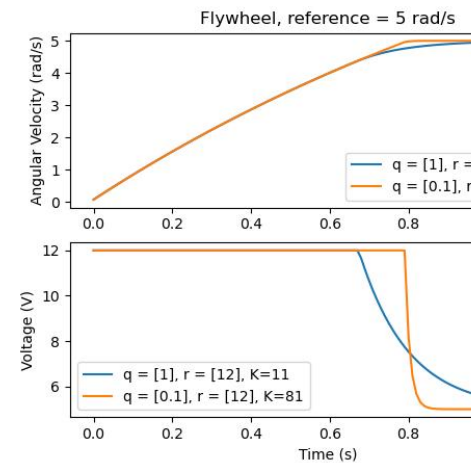
flywheel a have we Say example. worldreal- a to Regulator QuadraticLinear- a apply Let's
and $K_v = 1 \frac{\text{volts}}{\text{second per radian}}$ have to identification system through determined system velocity
linear following the have we above, example flywheel the Using $K_a = 1.5 \frac{\text{volts}}{\text{squared second per radian}}$
:system

$$\mathbf{x} = \begin{bmatrix} -K_v \\ K_a \end{bmatrix} v + \begin{bmatrix} 1 \\ K_a \end{bmatrix} V$$

an and $q = [0.1 \text{ rad/sec}]$ of error) (maximum excursion state desired a choose arbitrarily We
K This $K = 81$ of *gain* a find we 20ms, of timestep a with discretization After $[12 \text{ volts}]$ of \mathbf{r}
velocity. flywheel's on loop PID a of component proportional the as acts *gain*

elements \mathbf{r} the decreasing or elements \mathbf{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 \mathbf{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

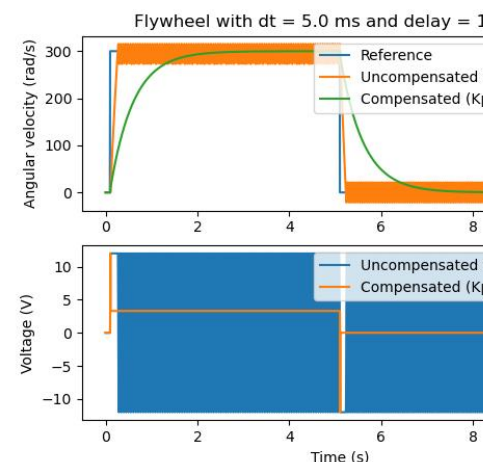
the example For measurements. their with associated delay a have sensors our Oftentimes, velocity with associated delay of 30ms to up have can CAN over controller motor MAX SPARK measurements.

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

$$\mathbf{K}_{\text{compensated}} = \mathbf{K} \cdot (\mathbf{A} - \mathbf{BK})^{\text{delay}/dt}$$

we case, this In timestep. one by gains the advances essentially $\mathbf{A} - \mathbf{BK}$ by **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++

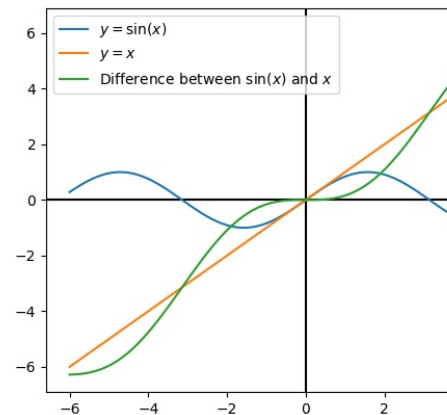
```
We delay. input sensor of ms 25 for controller s'LQR our Adjust //
sensor the and timestep, discretization system, linear the provide //
arguments. as delay input //
ms);_25 ms,_20 controller.LatencyCompensate(elevatorSystem,
```

PYTHON

```
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 ,0.020 latencyCompensate(elevatorSystem, controller
```

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

Walkthrough Controller SpaceState- 32.8.2

□□□□□ □□□□ an read have to recommended are readers tutorial, this following Before :□□□□ *.SpaceState-*

spacestate- a implementing on instructions end“to-”end- provide to is tutorial this of goal The to: how learn will readers tutorial, this following By flywheel. a for controller

CAD or *identification system* using flywheel a of model spacestate- accurate an Create 1. software.

lag. without measurements velocity encoder filter to Filter Kalman a Implement 2. basedmodel- with combined when which, controller feedback *LQR* a Implement 3. *.reference* a to flywheel the drive to *inputs* voltage generate will feedforward,

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 control spacestate- variety a for reused be can which structure basic a with teams provide should tutorial this in systems. spacestate- of

spacestate- and)Python/C++/Java(flywheel spacestate- the in available is example full The projects. example)Python/C++/Java(*identification system* flywheel

Control? SpaceState- Use Why

can we system, our of model accurate an creating on focuses control spacestate- Because simulate to us allows This .inputs control to respond will model our how predict accurately we that gains choose easily as well as robot, physical a to access without mechanisms our Kalman as such filters, lagless create to us allows also model a Having well. work will know readings. sensor filter optimally to Filters,

Flywheel Our Modeling

of system following the using modeled are systems spacestate- continuous that Recall equations:

$$\begin{aligned}\dot{\mathbf{x}} &= \mathbf{Ax} + \mathbf{Bu} \\ \mathbf{y} &= \mathbf{Cx} + \mathbf{Du}\end{aligned}$$

is \mathbf{u} state, current system's the is \mathbf{x} ,state 's system the of change of rate the is dotx- Where .output system's the is \mathbf{y} and system, the to input the

first We'll ways. different two in flywheel our model to equations of system this use Let's the on based it model then and toolsuite, SysId the using identification system using it model .inertia of moment flywheel's and motor

can We states. system's our picking is system spacestate- our up building of step first The wanted we if states unrelated completely pick could we - state a as want we anything pick state our in states hidden include can We important. are that states pick to helps it but - Kalman our let and position) its measure to able only were we if velocity elevator as (such their towards driven be will choose we states the that Remember values. their estimate Filter 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 \mathbf{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-*

$$V = kV \cdot \mathbf{v} + kA \cdot \mathbf{a}$$

$$\mathbf{a} = \mathbf{v} = \begin{bmatrix} \frac{-kV}{kA} \end{bmatrix} v + \begin{bmatrix} \frac{1}{kA} \end{bmatrix} V$$

Rewriting voltage. is V and acceleration, flywheel are \mathbf{v} and \mathbf{a} velocity, flywheel is \mathbf{v} Where
 find: we vector, input the for \mathbf{u} and vector state the for \mathbf{x} of convention standard the with this

$$\mathbf{x} = \begin{bmatrix} \frac{-kV}{kA} \end{bmatrix} \mathbf{x} + \begin{bmatrix} \frac{1}{kA} \end{bmatrix} \mathbf{u}$$

the to *inputs* and *state* current system's the relates notation spacestate- of part second The
 measure) can sensors our that things (or \mathbf{y} vector output our flywheel, a of case the In *.output*
 Therefore, \mathbf{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

$$\mathbf{x} = \begin{bmatrix} \frac{-kV}{kA} \end{bmatrix} \mathbf{x} + \begin{bmatrix} \frac{1}{kA} \end{bmatrix} \mathbf{u}$$

$$\mathbf{y} = [1] \mathbf{x} + [0] \mathbf{u}$$

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
//
// 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);

```

Python

```

second) per (radian per Volts #
0.023 = kFlywheelKv
squared) second per (radian per Volts #
0.001 = kFlywheelKa

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 #
( = flywheelPlant.self
identifyVelocitySystemRadians(.LinearSystemId.plant.system.wpimath
kFlywheelKa kFlywheelKv,
)
)

```

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 12.3 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).Python/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 :assert dimensionality.

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, <LinearSystem final private
(createFlywheelSystemLinearSystemId.
kFlywheelGearing); kFlywheelMomentOfInertia, ),2(getNEODCMotor.
```

C++

```
frc/system/plant/LinearSystemId.h>< include#
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
```

Python

```

kg/m^2 # 0.00032 = kFlywheelMomentOfInertia
    spins flywheel the If input. over output as encoder, and motors between Reduction #
                                                than slower →
                                one. than greater be should number this motors, the #
                                                1 = kFlywheelGearing

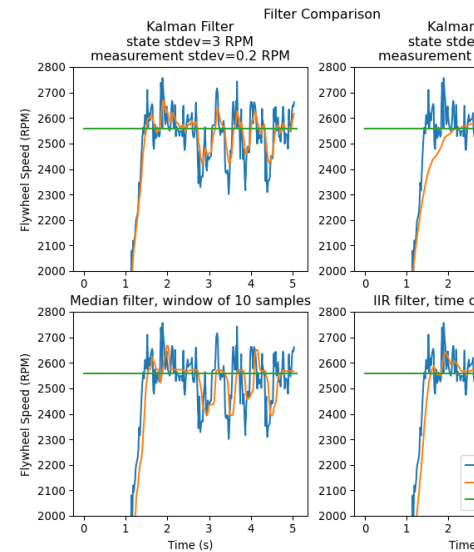
    the has system This flywheel. our of model state-space a holds plant The #
                                                properties: following →
                                                #
                                second. per radians in [velocity], States: #
                                volts. in [voltage], in"): put" can we (what Inputs #
                                second. per radians in [velocity], measure): can we (what Outputs #
flywheelSystem(.LinearSystemId.plant.system.wpimath = flywheelPlant.self
                                ),2NEO(.DCMotor.plant.system.wpimath
                                kFlywheelMomentOfInertia,
                                kFlywheelGearing,
                                )

```

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 .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.
(),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
```

48
49
50
51
52
53
54
55
56
57

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
```

Python

```
noise. reject to inputs voltage and data encoder our fuses observer The #
KalmanFilter_1_1_1(.estimator.wpimath = observer.self
                    flywheelPlant,.self
                    is model our think we accurate How # ],3[
                    is data encoder our think we accurate How # ],0.01[
                    ,0.020
                    )
```

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 **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 //
page) next on (continues
```

(□□□□ □□□□ □□□□)

```

                                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 //
                                battery. →
        be can but TimedRobot, for 0.020 loops. between time Nominal // );0.020
                                notifiers. using if lower //

```

C++

```

frc/controller/LinearQuadraticRegulator.h>< include#
11

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,

```

Python

```

commands. voltage create to feedback uses LQR A #
LinearQuadraticRegulator_1_1( controller.wpimath = controller.self
    flywheelPlant,.self
Decrease second. per radians in tolerance, error Velocity qelms. # ],8[
_controller the make or excursion, state penalize heavily more to this #
                                more behave →
                                aggressively. #
more to this Decrease tolerance. (voltage) effort Control relms. # ],12[
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 #
                                battery. →
_be can but TimedRobot, for 0.020 loops. between time Nominal # ,0.020
page) next on (continues

```


()

```

        notifiers.using if lower
    )

```

66

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

```

72

73

74

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,

```

15

71

72

73

74

Python

```

    plant and feedforward observer, controller, a combines loop state-space The #
    control. easy for
    LinearSystemLoop_1_1_1(.system.wpimath = loop.self
    0.020 ,12.0 observer,.self controller,.self flywheelPlant,.self
    )

```

68

69

70

71

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
    { ()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);setVoltageem_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 //

```

page) next on (continues

(0000 0000 0000)

```

    );}0.0{>1<Vectord:m_loop.SetNextR(frc
    }
    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
    }

```

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Python

```

:None >- )self(teleopPeriodic def
the setting to similar is This flywheel. our of speed target the Sets #
a of setpoint →
controller. PID #
getTriggerPressed():.joystick.self if
reference next our set s'let so trigger, the pressed just We #
setNextR([kSpinUpRadPerSec]).loop.self
getTriggerReleased():.joystick.self elif
down spin s'let so trigger, the released just We #
])0.0setNextR([.loop.self
data. encoder with estimate vector state s'filter Kalman our Correct #
getRate()))).encoder.selfcorrect([.loop.self
to voltages the use and commands voltage new generate to LQR our Update #
next the predict →
filter. Kalman out with state #
)0.020predict(.loop.self
motors. the to voltage calculated new the Send #
so voltage, battery * cycle duty = voltage #
voltage battery / voltage = cycle duty #
U().loop.self = nextVoltage
setVoltage(nextVoltage).motor.self

```

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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().getKlqr. = 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 = )error(
error; * lqr.K() = u >2 ,double<Vector::Eigen
```

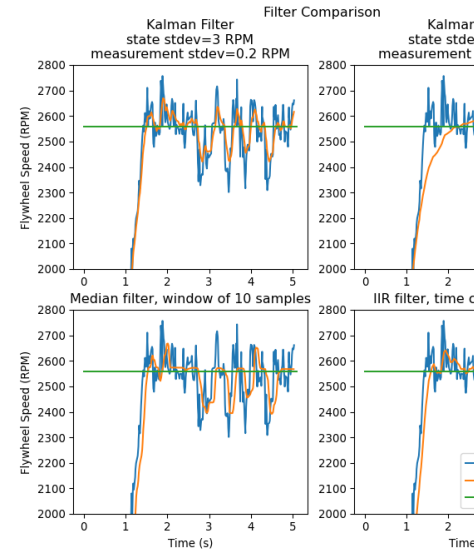
PYTHON

```
x - R().lqr = error
])angleModulus(error[ wpimath = ]error[
error * K().lqr = u
```

Filters Kalman and Observers State 32.8.3

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

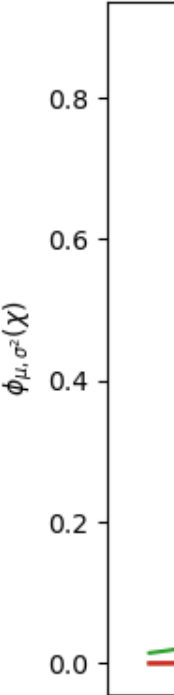
a of case the In . process a in noise the model to *distribution Gaussian* a utilize filters Kalman measure a is variance the while mean, the is system the of *state* estimated the filter, Kalman .*state* true the about is filter the uncertain) (or certain how of

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 $\text{var}(\mathbf{x}_1)$ variance the containing matrix a or, $\text{cov}(\mathbf{x}_1, \mathbf{x}_1)$ simply is matrix covariance the Gaussian the of deviation standard the of square the is variance this of magnitude The x_1 state 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

$$\Sigma = \begin{bmatrix} \text{COV}(x_1, x_1) & \text{COV}(x_1, x_2) & \dots & \text{COV}(x_1, x_n) \\ \text{COV}(x_2, x_1) & \text{COV}(x_2, x_2) & \dots & \text{COV}(x_2, x_n) \\ \vdots & \vdots & \ddots & \vdots \\ \text{COV}(x_n, x_1) & \text{COV}(x_n, x_2) & \dots & \text{COV}(x_n, x_n) \end{bmatrix}$$

voltages extra adds radiation electromagnetic Stray sources. of sorts all from comes noise robot, real a In ¹ 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



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 framerate low- a from example, (for available

filter: Kalman time discrete- a of equations the shows following The

step Predict

$$\hat{\mathbf{x}}_{k+1}^- = \mathbf{A}\hat{\mathbf{x}}_k^+ + \mathbf{B}\mathbf{u}_k$$

$$\mathbf{P}_{k+1}^- = \mathbf{A}\mathbf{P}_k^-\mathbf{A}^T + \mathbf{Q}\mathbf{Q}^T$$

step Update

$$\mathbf{K}_{k+1} = \mathbf{P}_{k+1}^-\mathbf{C}^T(\mathbf{C}\mathbf{P}_{k+1}^-\mathbf{C}^T + \mathbf{R})^{-1}$$

$$\hat{\mathbf{x}}_{k+1}^+ = \hat{\mathbf{x}}_{k+1}^- + \mathbf{K}_{k+1}(\mathbf{y}_{k+1} - \mathbf{C}\hat{\mathbf{x}}_{k+1}^- - \mathbf{D}\mathbf{u}_{k+1})$$

$$\mathbf{P}_{k+1}^+ = (\mathbf{I} - \mathbf{K}_{k+1}\mathbf{C})\mathbf{P}_{k+1}^-$$

A	matrix system	$\hat{\mathbf{x}}$	vector estimate state
B	matrix input	\mathbf{u}	vector input
C	matrix output	\mathbf{y}	vector output
D	matrix feedthrough	\mathbf{Q}	vector intensity noise process
P	matrix covariance error	Q	matrix covariance noise process
K	matrix gain Kalman	R	matrix covariance noise measurement

Gaussian the of covariance and mean the describe ,**P** with together ,**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 [position] measurements and $\begin{bmatrix} \text{position} \\ \text{velocity} \end{bmatrix}$ states with matrices: **R** and **Q** following the have would [0.01] deviation standard measurement

$$\mathbf{Q} = \begin{bmatrix} 0.01 & 0 \\ 0 & 1.0 \end{bmatrix}, \mathbf{R} = [0.0001]$$

Matrix Covariance Error

Informally, $\hat{\mathbf{x}}$ estimate state the of covariance the describes \mathbf{P} matrix covariance error The the about uncertainty our large, is \mathbf{P} If $\hat{\mathbf{x}}$ estimated the about certainty our describes \mathbf{P} about uncertainty less imply would elements smaller with \mathbf{P} a Conversely, large, is state true state. true our state true system's the about certainty our as increases \mathbf{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 \mathbf{P} covariance error our Furthermore, $\hat{\mathbf{x}} = \mathbf{A}\hat{\mathbf{x}} + \mathbf{B}\mathbf{u}$ is \mathbf{P} This quickly. more grow \mathbf{P} covariance error our make will \mathbf{Q} of values Larger \mathbf{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 \mathbf{K} gain Kalman the by $\hat{\mathbf{x}}$ estimate state the against weighted is information new This more \mathbf{K} of values smaller while measurements, incoming weight highly more \mathbf{K} of values increase will \mathbf{P} of values larger, \mathbf{P} to related is \mathbf{K} Because prediction. state our weight highly long a for predicted is filter a example, for If, measurements. weight heavily more and \mathbf{K} information. new the weight heavily would \mathbf{P} large the duration, estimate. state the in confidence our increase to decreases \mathbf{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 \mathbf{R} and \mathbf{Q} (and deviation standard state's a decreasing By measurement. or state each of variances, more. measurements incoming distrust will filter the \mathbf{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.
```

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page) next on (continues

(0000 00000 0000)

```
is data //
);0.020
```

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57

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
```

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Python

```
noise. reject to inputs voltage and data encoder our fuses observer The #
KalmanFilter_1_1_1(.estimator.wpimath = observer.self
flywheelPlant,.self
is model our think we accurate How # ],3[
is data encoder our think we accurate How # ],0.01[
,0.020
)
```

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Footnotes

Estimators Pose 32.8.4

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 $[x \ y \ \theta]^T$ 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.
```

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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{
```

158
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165

.Update() calling by loop every measurements odometry Add

JAVA

```
(updatem_poseEstimator.
m_rightEncoder. (),getDistancem_leftEncoder. (),getRotation2dm_gyro.
    ());getDistance →
```

227
228

C++

```
m_poseEstimator.Update(m_gyro.GetRotation2d(),
    meter_t{m_leftEncoder.GetDistance()},::units
    meter_t{m_rightEncoder.GetDistance()});::units
```

84
85
86

.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

```

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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

```

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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

C++

```
GetDefault().Flush(); { ()RobotPeriodic void
NetworkTableInstance }
```

PYTHON

```
NetworkTableInstance import ntcore from
):self(robotPeriodic def
flush() getDefault() 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 32.9

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 $\text{input} * \text{gain} = \text{output}$ 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

advanced other with used be that features convenience general some covers section This
features. programming

Frequencies Custom at Functions Scheduling 33.1

faster rate a at methods custom run to one allows method `addPeriodic()` 'sTimedRobot
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
); Joystick( new = m_joystick Joystick private
); 2 , 1 Encoder( new = m_encoder Encoder private
); Spark( new = m_motor Spark private
0. , 0.5 , 0.0 , 1.0 PIDController( new = m_controller PIDController private
); 01 ↵
{ () Robot public
{ >- addPeriodic((
)); getRate(m_encoder.calculate(m_controller.setm_motor.
page) next on (continues
```


EventLoop With Programming BasedEvent- 33.2

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 33.2.1

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
);@Joystick( new = m_joystick Joystick 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 33.2.2

/)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 33.2.3

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()

t 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] = intakeIfHigh([.

```

|| / 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.
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] = intakeIfHigh([.

```

! / 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.

```


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] = kickerIfHigh([.

```

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++

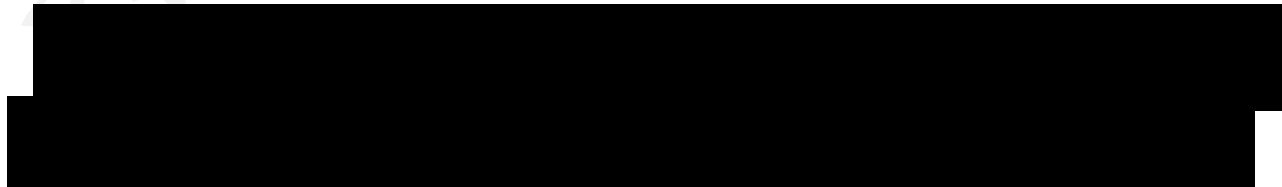
```

();>Trigger::frc2booleanEvent.CastTo = trigger Trigger::frc2

```

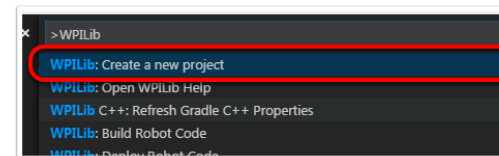
an accepting constructor a to reference method a expects parameter the Java, In :
this references, method of lack the to Due .BooleanSupplier a and instance EventLoop
Type(frc::EventLoop*, form the of constructor a as long as C++ in defaulted is parameter
exists. ><bool()std::function

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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



34.1 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.

- drive differential simple a Demonstrates):Python ,C++ ,Java(**Drive Arcade** •
 class. DifferentialDrive the through controls style"arcade"- using implementation
- same the Demonstrates):Python ,C++ ,Java(**Controller Xbox Drive Arcade** •
 instead XboxController an using except example, previous the in seen functionality
 joystick. ordinary an of
- that routine autonomous simple a Demonstrates):Python ,C++ ,Java(**Started Getting** •
 speed. half at seconds two for forwards drives
- drive mecanum simple a Demonstrates):Python ,C++ ,Java(**Drive Mecanum** •
 class. MecanumDrive the using implementation

a of output the control to how Demonstrates):Python ,C++ ,Java(**Controller Motor** •
position. motor read to encoder an with joystick a with motor

USB a from video stream to how Demonstrates):Python ,C++ ,Java(**Vision Simple** •
dashboard. the to camera

relay a control to class Relay the of use the Demonstrates):Python ,C++ ,Java(**Relay** •
buttons. joystick of set a with output

and Solenoid the of use the Demonstrates):Python ,C++ ,Java(**Solenoids** •
buttons. joystick of set a with outputs solenoid control to classes DoubleSolenoid

drive differential simple a Demonstrates):Python ,C++ ,Java(**TankDrive** •
class. DifferentialDrive the through controls style"tank"- using implementation

functionality same the Demonstrates):Python ,C++ ,Java(**Controller Xbox Drive Tank** •
ordinary an of instead XboxController an using except example, previous the in seen
joystick.

Examples Control 34.2

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):Python ,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

of use the Demonstrates):Python ,C++ ,Java(**controller PID profiled with Elevator** •
mechanism. elevator an of position the control to class ProfiledPIDController the

of use the Demonstrates):Python ,C++ ,Java(**PID profiled trapezoid with Elevator** •
control to controller" motor "smart a with conjunction in class TrapezoidProfile the
mechanism. elevator an of position the

mecanum a of control orientedfield- Demonstrates):Python ,C++ ,Java(**Mecanum Gyro** •
gyro. a with conjunction in class MecanumDrive the through robot

mecanum advanced an Demonstrates):Python ,C++ ,Java(**MecanumBot** •
the through odometry gyroand-encoder- including implementation, drive
through control velocity PID with composition and class, MecanumDriveOdometry
classes. PIDController and MecanumDriveKinematics the

PIDController the of use the Demonstrates):Python ,C++ ,Java(**PotentiometerPID** •
mechanism. elevator an of position the control to potentiometer a and class

the of use the Demonstrates):Python ,C++ ,Java(**RamseteController** •
period. autonomous the during trajectory a follow to class RamseteController

swerve advanced an Demonstrates):Python ,C++ ,Java(**SwerveBot** •
the through odometry gyroand-encoder- including implementation, drive
control velocity and position PID with composition and class, SwerveDriveOdometry
classes. PIDController and SwerveDriveKinematics the through

class PIDController the of use the Demonstrates):Python ,C++ ,Java(**UltrasonicPID** •
object. an from distance set a to drive to sensor ultrasonic an with conjunction in

Examples Sensor 34.3

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

Demonstrates):Python ,C++ ,Java(**Monitoring CAN Distribution Power** •
the using CAN over module Distribution Power a from information sensor obtaining
class. PowerDistribution

the of use the Demonstrates):Python ,C++ ,Java(**Encoder Cycle Duty** •
encoder. absolute typePWM- a from values read to class DutyCycleEncoder

DutyCycleInput the of use the Demonstrates):Python ,C++ ,Java(**DutyCycleInput** •
input. *PWM* a of cycle duty fractional and frequency the read to class

values read to class Encoder the of use the Demonstrates):Python ,C++ ,Java(**Encoder** •
encoder. quadrature a from

measure to class AnalogGyro the of use the Demonstrates):Python ,C++ ,Java(**Gyro** •
driving. stabilize and heading robot

USB a and OpenCV of use the Demonstrates):Python ,C++ ,Java(**Vision Intermediate** •
dashboard. the to it stream and feed video captured a on rectangle a overlay to camera

using AprilTags of detection roboRIOon- Demonstrates):C++ ,Java(**AprilTagsVision** •
camera. USB attached an

read to class Ultrasonic the of use the Demonstrates):Python ,C++ ,Java(**Ultrasonic** •
reduce to class MedianFilter the with conjunction in sensor ultrasonic an from data
noise. signal

to API SysIdRoutine the of use the Demonstrates):Python ,C++ ,Java(**SysIdRoutine** •
drivetrain. differential a for data characterization gather

Examples BasedCommand- 34.4

.framework BasedCommand- the of use the demonstrate examples These

to ProfiledPIDSubsystem a of use the Demonstrates):Python ,C++ ,Java(**ArmBot** •
arm. robot a control

a of use the Demonstrates):Python ,C++ ,Java(**ArmBotOffboard** •
control to controller" motor "smart a with conjunction in TrapezoidProfileSubsystem
arm. robot a

a of use the Demonstrates):Python ,C++ ,Java(**DriveDistanceOffboard** •
drive to controller" motor "smart a with conjunction in TrapezoidProfileCommand
profile. motion trapezoidal a with distance set a by forward

frisbee- simple a for code robot of set complete A):Python ,C++ ,Java(**FrisbeeBot** •
simple Demonstrates *Ascent Ultimate* game FRC® 2013 the of typical robot shooting
class. PIDSubsystem the through control PID

robot, demonstration WPI the for code robot of set complete A):C++ ,Java(**Bot Gears** •
GearsBot.

- PIDCommand of use the Demonstrates):Python ,C++ ,Java(**Commands Drive Gyro** • specified a face to robot a turn to gyro a with conjunction in ProfiledPIDCommand and driving. while heading stabilize to and heading
- hatch- simple a for code robot of set complete A):Python ,C++ ,Java(**Hatchbot Inlined** • are Commands .*Space Deep Destination*: game FRC 2019 the of typical bot delivery avoided. is Command of subclassing explicit which in style, "inline" an in written
- simple a for code robot of set complete A):Python ,C++ ,Java(**Hatchbot Traditional** • Commands .*Space Deep Destination*: game FRC 2019 the of typical bot delivery hatch- each for written are Command of subclasses which in style, "traditional" a in written are action. robot
- generation trajectory Demonstrates):C++ ,Java(**MecanumControllerCommand** • and TrajectoryGenerator the using drive mecanum a with following and classes. MecanumControllerCommand
- and generation trajectory Demonstrates):Python ,C++ ,Java(**RamseteCommand** • RamseteCommand and TrajectoryGenerator the using drive differential a with following .*here found be can tutorial stepby-step- matching A* classes.
- the of use the Demonstrates):Python ,C++ ,Java(**Example Command Select** • runtime- a on depending commands of selection a of one run to class SelectCommand condition. evaluated
- generation trajectory Demonstrates):C++ ,Java(**SwerveControllerCommand** • and TrajectoryGenerator the using drive swerve a with following and classes. SwerveControllerCommand

Examples SpaceState- 34.5

- .*Control SpaceState-* the of use the demonstrate examples These
- a of control spacestate- Demonstrates):Python ,C++ ,Java(**StateSpaceFlywheel** • flywheel.
- control spacestate- Demonstrates):Python ,C++ ,Java(**StateSpaceFlywheelSysId** • flywheel. a controlling for Identification System SysId's using
- 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 34.6

simulation. physics the of use the demonstrate examples These
 simulation physics of use the Demonstrates):Python ,C++ ,Java(**ElevatorSimulation** •
 elevator. simple a with
 with simulation physics of use the Demonstrates):Python ,C++ ,Java(**ArmSimulation** •
 arm. jointedsingle- simple a
 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 34.7

of any into fit not does that functionality WPILib miscellaneous demonstrate examples These
 categories. above the
 AddressableLED the of use the Demonstrates):Python ,C++ ,Java(**LED Addressable** •
 feedback. driver and/or decoration robot for LEDs RGB control to class
 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
 functionality "rumble" the of use the Demonstrates):Python ,C++ ,Java(**Rumble HID** •
 XboxControllers). as (such HID's supported on feedback tactile for
 on layouts tab/widget configuring Demonstrates):Python ,C++ ,Java(**Shuffleboard** •
 fluent class's Shuffleboard the through code robot from dashboard "Shuffleboard" the
 API. builder
 the run to how of example based command A):Python ,C++ ,Java(**RomiReference** •
.robot Romi
.Mechanism2d using of example simple A):Python ,C++ ,Java(**Mechanism2d** •

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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 tutorials, called examples, (additional Limelight •

PhotonVision •

Robotics REV •

Practices Best Wiring 36.1

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 36.1.1

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 36.1.2

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 36.1.3

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 36.1.4

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 36.1.5

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 36.1.6

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 36.1.7

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- 36.1.8

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 36.1.9

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

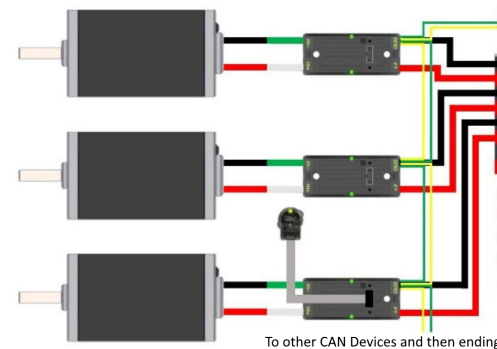
commercially of number a are There health. monitor to possible if batteries test Load • designed one least at including batteries, test load to use teams products available measuring by health battery of indicator an provide can test load A FRC. for specifically match to comes it when meaningful more much is measurement This resistance. internal multimeter. a by provided number voltage loadno- simple a than performance

Logs DS Check 36.1.10

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

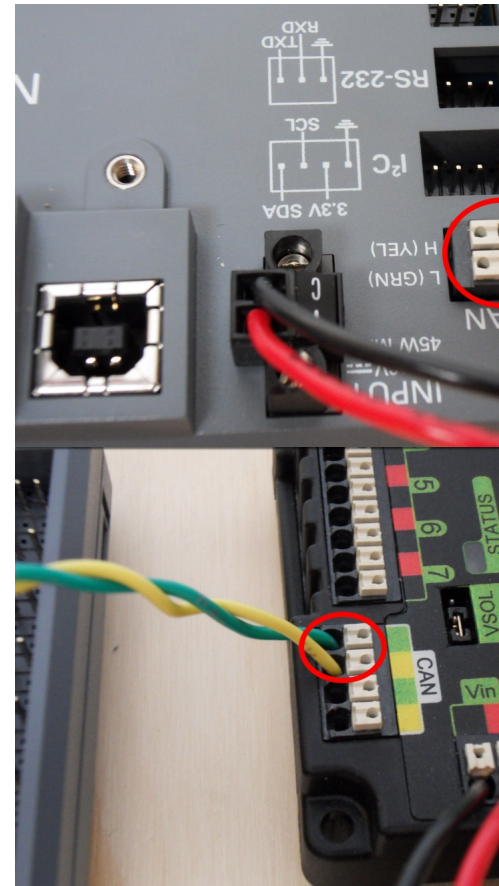
Basics Wiring CAN 36.2

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

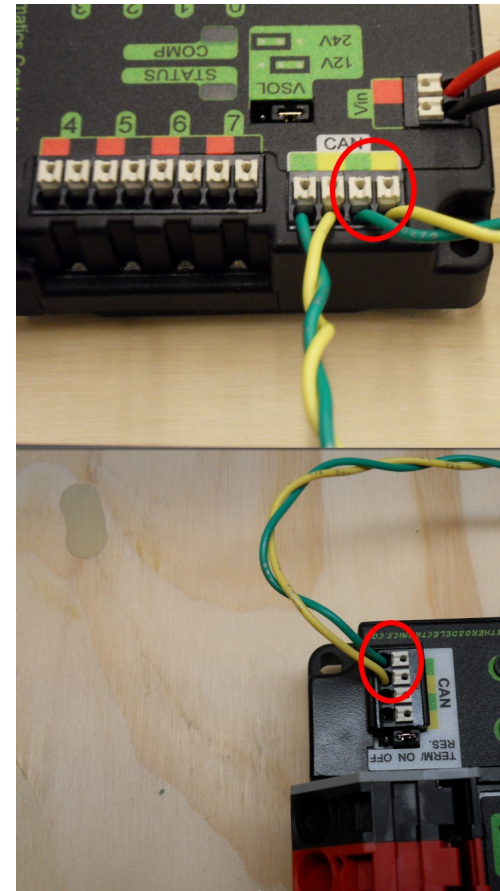


Wiring Standard 36.2.1

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



Termination 36.2.2

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 36.3

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

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 36.3.1

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 36.3.2



Solenoids 36.3.5

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

Jumper Voltage Solenoid 36.3.6

Hub Pneumatic REV - Pneumatics Wiring 36.4

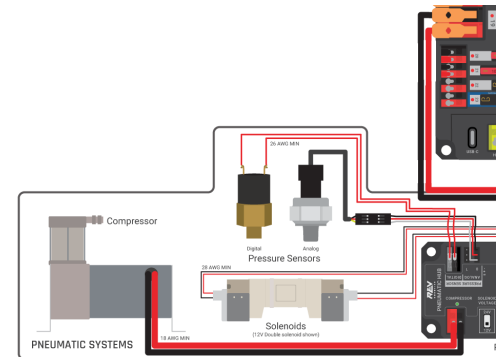
instructions For).*PH*(Hub Pneumatic REV the with pneumatics wiring describes page This
.page this see)*PCM*(Module Control Pneumatic CTRE the with pneumatics wiring on

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 36.4.1

the for output an providing applications, pneumatics most support will PH single A
 (12V channels solenoid 16 to up for outputs and switch, pressure a for input compressor,
 powered and bus *CAN* the over roboRIO the to connected is module The selectable). 24V or
 PDP/PDH. the from 12V via
 voltages, solenoid multiple or channels more requiring designs robot complicated For
 system. control the to added be can PCMs or PHs additional

Wiring Control and Power PCM 36.4.2



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 36.4.3

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 36.4.4

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 :□□□□□ tips more for Sensor Pressure Analog an Wiring REV See

Solenoids 36.4.5

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

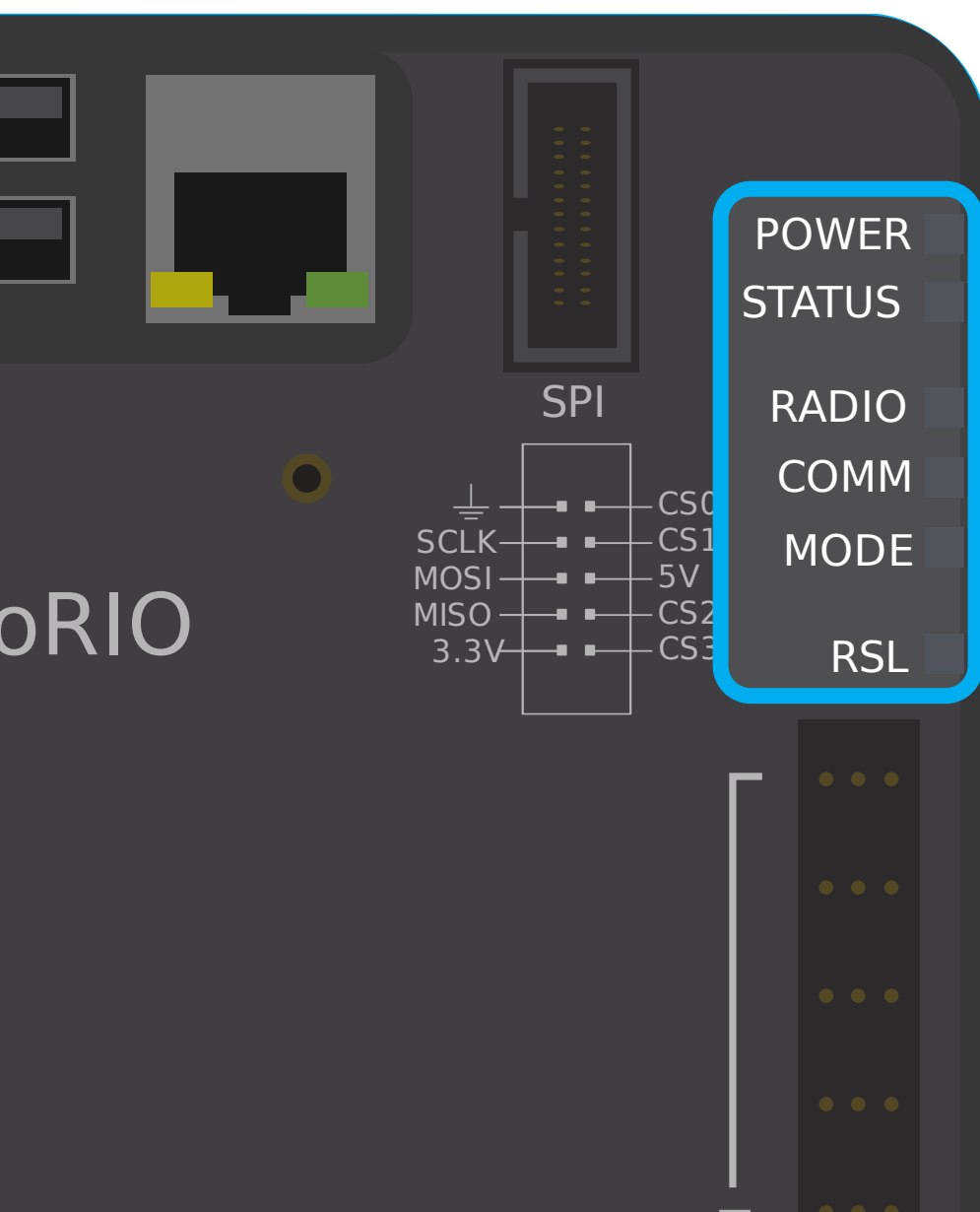
Switch Voltage Solenoid 36.4.6

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

36.5 הסבר קצר על Light Status

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 36.5.1



Radio OpenMesh 36.5.3



Power	0000	0000 00 0000
	00000 0000	0000
Link Eth	0000	00000
	00000 0000	000000 00000
WiFi	0000	firmware FRCnon- or Unlinked mode, Bridge
	0000	Unlinked AP,
	0000/0000	Linked AP,
	0000	Linked mode, Bridge

Panel Distribution Power 36.5.4

LEDs Status/Comm PDP

LED	Strobe	Slow
0000	Enabled Robot - Fault No	Disabled Robot - Fault No
0000	NA	Fault Sticky
0000	NA	Comm CAN No

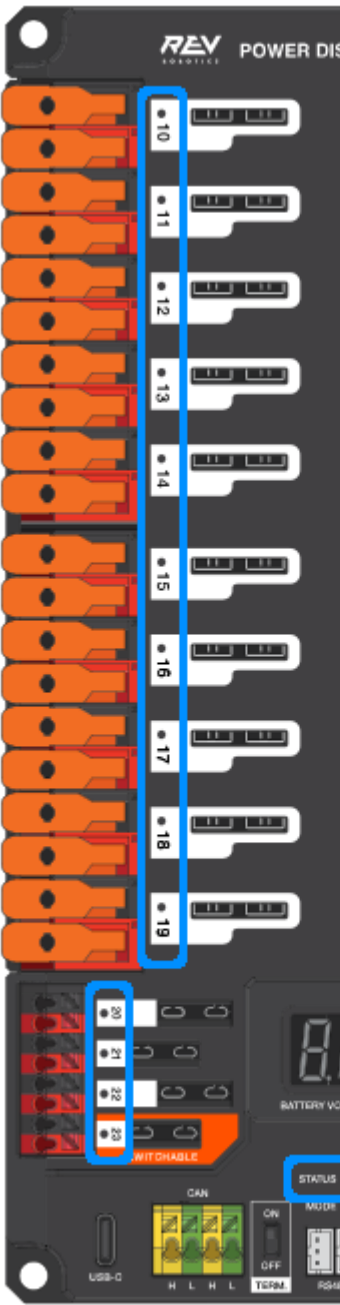
table states special LED PDP the see color, one than more showing is LED PDP a If :0000
Manual. User PDP the see faults PDP resolving on information more For below.

the with communicate cannot PDP the if occur will fault Comm CAN No the that Note :0000
Bus. CAN via roboRIO

States Special PDP

Colors LED	Problem
0000/0000	Hardware Damaged
0000/0000	Bootloader In
LED No	Polarity Incorrect Power/ No

Hub Distribution Power 36.5.5



later and 21.1.7 version firmware to apply only patterns led These :□□□□

LED Status PDH 36.5.6

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	Status
Color	
□□□□	expected as operating is and voltage has Channel
□□□□	missing or tripped for Check fault. active an is there and voltage NO has Channel
□□□□	fuse / breaker circuit
□□□□	fuse. / breaker circuit tripped for Check channel. the on fault Sticky
□□□□□	

Module Regulator Voltage 36.5.7

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 36.5.8

Manual. User PCM the see faults PCM resolving on information more For below.

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

LED		Problems
XXXX/XXXX		Hardware Damaged
XXXX/XXXX		Bootloader In
LED No	Polarity Power/Incorrect No	

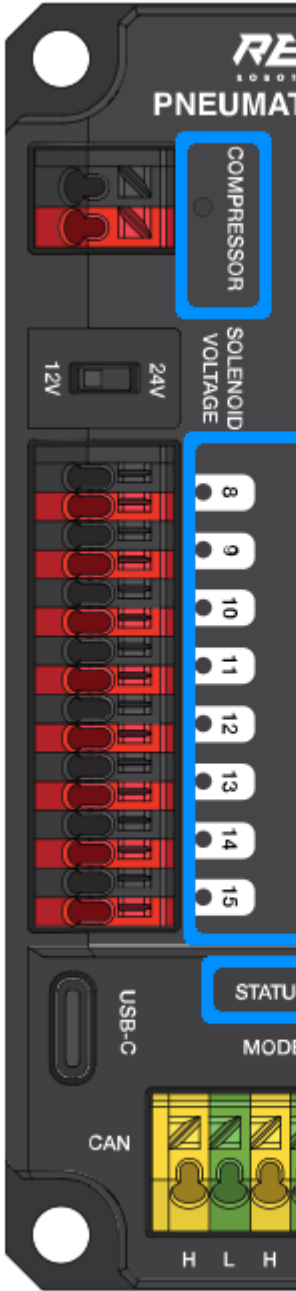
LED Comp PCM

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 36.5.9



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

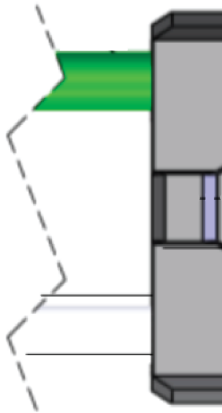
Color LED	Status
□□□□ □□□□	On Compressor
Solid Black	Off Compressor

LEDs Solenoid

Color LED	Status
□□□□ □□□□	On Solenoid
Solid Black	Off Solenoid

Controllers Motor FX Talon & SPX Victor & SRX Talon 36.5.10

Sta
LE



Operation Normal During LEDs Status

LEDs		Colors		State SRX Talon	
	Both	Blinking	is rate Blink	applied. is throttle Forward	Cycle. Duty to proportional
	Both	Blinking	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	detected not is bus/PWM CAN		
	Alternate LEDs	Off/Fast	Detected Fault		
	Alternate LEDs	□□□□/□□□□	Hardware Damaged		
towards	Strobe LEDs	□□□□/□□□□	Limit Soft Forward or Switch Limit Forward		
towards	Strobe LEDs	□□□□/□□□□	Limit Soft Reverse or Switch Limit Reverse		
to (closest	Only LED1	□□□□/□□□□	loaderBoot- In		
towards	Strobe LEDs	Off/Orange	Only) FX (Talon Shutoff / Fault Thermal		

Calibration During LEDs Status

Code Blink LEDs Status	State SRX Talon
Red/Green Flashing	Mode Calibration
Green Blinking	Calibration Successful
Red Blinking	Calibration Failed

Codes Blink CAL B/C

Color Button CAL B/C	State SRX Talon
□□□□ □□□□	Mode Brake
□□□□	Mode Coast

Controller Motor MAXSPARK- 36.5.11

Operating Mode	Idle Mode	State	Color
Brushed	Brake	No Signal	Blue Blink
		Valid Signal	Blue Solid
	Coast	No Signal	Yellow Blink
		Valid Signal	Yellow Solid
Brushless	Brake	No Signal	Cyan Blink
		Valid Signal	Cyan Solid
	Coast	No Signal	Magenta Blink
		Valid Signal	Magenta Solid
Partial Forward	-	-	Green Blink
Full Forward	-	-	Green Solid
Partial Reverse	-	-	Red Blink
Full Reverse	-	-	Red Solid
Forward Limit	-	-	Green/White
Reverse Limit	-	-	Red/White Blink
Firmware Update Mode	-	-	Dark (LED off)
Fault Conditions			
12V Missing	-	-	Orange/Blue
Brushless Encoder Error	-	-	Orange/Magenta
Gate Driver Fault	-	-	Orange/Cyan
CAN Fault	-	-	Orange/Yellow

SPARK Robotics REV 36.5.12

		LED Status Code	
Time Scale		1 second	
State		Normal Operation	
No Signal	Brake		
	Coast		
Full Forward			
Proportional Forward			
Neutral	Brake		
	Coast		
Proportional Reverse			
Full Reverse			
Forward Limit Tripped			
Reverse Limit Tripped			
		Calibration	
Calibration Mode			
Successful Calibration			
Failed Calibration			
		Factory Reset	
		Mode button held during power up	
Reset to Factory Defaults			

Controller Motor SPVictor- 36.5.13



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 36.5.14



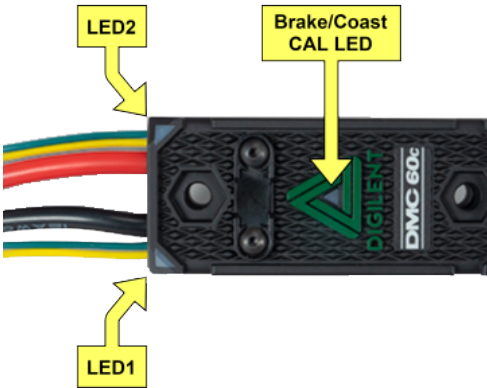
□□□□	Solid	output forward Full
□□□□	□□□□	voltage output forward to Proportional
□□□□	Solid	output reverse Full
□□□□	□□□□	voltage output reverse to Proportional
□□□□	Solid	connected are devices CAN No
□□□□	□□□□	deadband in signal or disabled, robot FRC lost, signal PWM state, Disabled output) 4% (+/- range
□□□□/□	Flashi	Talon to power input No
□□□□/□	Flashi	successful indicates flashes green Several calibration. for Ready calibration. unsuccessful indicates times several red and calibration,

Controller Motor Jaguar 36.5.16



State LED	Status Module
Yellow Solid	0) to set (speed Neutral
Green Flashing Fast	Forward
□□□ □□□□□ □□□□	Reverse
Green Solid	forward speedFull-
□□□□ □□□□	reverse speedFull-
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	condition fault Current
Yellow	
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 36.5.17



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 or Input Invalid Width Pulse	No Signal	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 the of cycle duty the to proportional is rate update LED The LED1). → LED4 4 all cycle, duty 100% At cycle. duty increased with increases and output Green. illuminated are LEDs
Negative Pulse Input Width		→ LED4 → (LED1 pattern circular clockwise counter- 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 clockwise counter- a in Red blink LEDs LED The LED1). → LED2 → LED3 → LED4 → (LED1 the of cycle duty the to proportional is rate update 100% At cycle. duty increased with increases and output Red. illuminated are LEDs 4 all cycle, duty

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 36.5.18

LED Pattern	Description
	Venom is initializing. This state should last less than 10 seconds.
	The 'Identify Device' feature is active. This particular Playing With Fusion device when motion is detected. See the Motor Configuration section for more information.
	Venom is initialized and in PWM mode. Wait for the PWM pulse.
	Venom successfully entered a valid CAN or PWM mode.
	Faults are active and motion may be commanded.
	Venom is initialized and detected a valid CAN device.
	CAN communication fault. Check harness connection and termination.
	Missing heartbeat in CAN control mode. Ensure the device ID used by CANVenom class. See the Motor Configuration section for more information and instructions to change the device ID.
	Lead motor heartbeat is missing while in Follow mode.
	The lead motor ID is same as the motor ID. On the other hand, ensure the leader and follower have different IDs.
	An invalid control mode was specified by the user. This can occur when using PlayingWithFusionDriver. Check the documentation for support.
	Another Venom with the same device ID was detected. All Venom device IDs must be unique.
	The forward limit switch is enabled and is active.
	The reverse limit switch is enabled and is active.
	Motor temperature is too high.
	Average motor current is too high.

(PWM) SD540B Mindsensors 36.5.19

PWM Signal Indicator LED

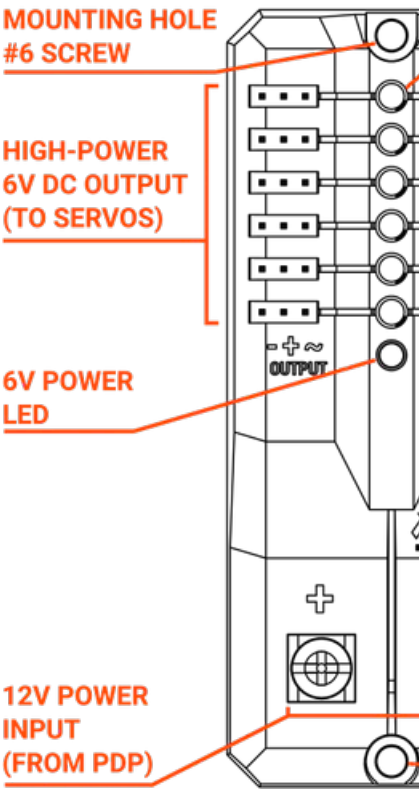
LED Power		Power supplied not is Power supplied is Power
LED Motor		direction Forward direction Reverse
LED Signal PWM		detected is signal PWM valid No detected is signal PWM Valid

Bus) (CAN SD540C Mindsensors 36.5.20

CAN Signal
Indicator LED

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 36.5.21



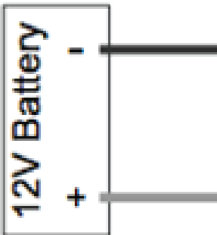
LEDs Status

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 •

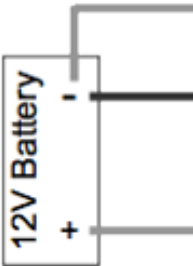
switch solenoid or light, motor, a as configured relay Spike 36.5.22



Forward		Reverse		M+M-		Output		Function	Motor
(White)		(Red)							
□□□□		□□□□		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 36.5.23



Forward		Reverse		M+M-		Indicator	Function
(White)		(Red)					Motor
□□□□		□□□□		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 36.5.24

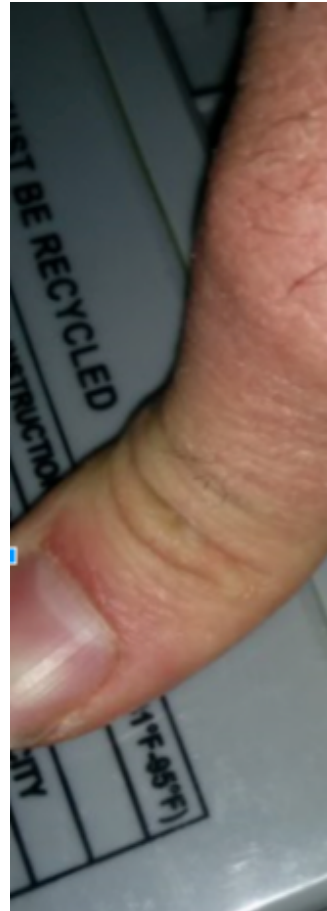


LED Color	LED Brightn	Bus	CAN detection	Strength Field Magnet	Description
□□□□	□□□□			not is	CANCoder powered
Yellow/G	Bright			loader.boot-	in is Device See
				for manual	information. more
Slow Red Blink	Bright	has	bus CAN lost been		
Rapid Red Blink	Dim	bus	CAN never detected	range of out is Magnet >135mT) or (<25mT	
Rapid Yellow Blink		boot since		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 36.6

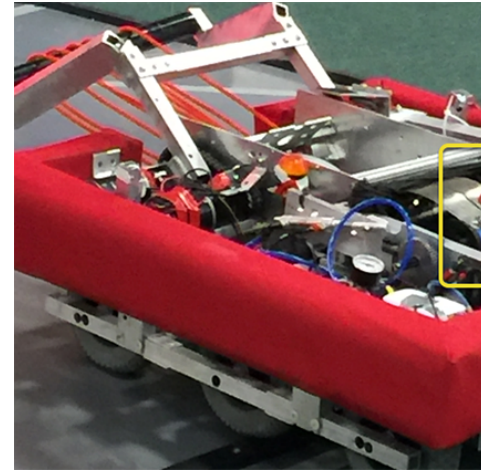
around driving while stress of lot a take robots Competition, Robotics ®FIRST In :□□□□ securely bolted are parts tight, are connections that sure make to important is It field. the not does field the around bouncing robot a that so mounted is everything that and place in break.

36.6.1 בדיקת חיבורי מצבר



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 36.6.2



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 peace 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 36.6.3

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 36.6.4

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 36.6.5



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 36.6.6

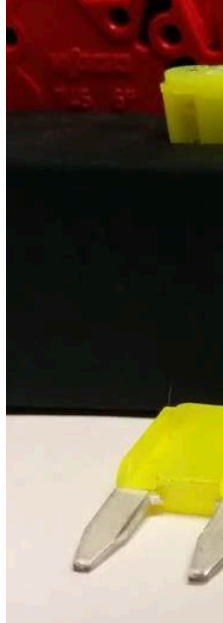




radio and connector, power roboRIO output, compressor power, for contacts Weidmuller The none that sure Make shown. as connections the on tugging by verify to important are power out. pull connections the of each to close are that connections Weidmuller with shorts impending or possible for Look long). 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 36.6.7

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 36.6.8

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 36.6.9

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 36.6.10

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 36.6.11

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 36.6.12

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 36.6.13

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 36.6.14

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 36.6.15



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 36.7

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 36.7.1

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 36.7.2

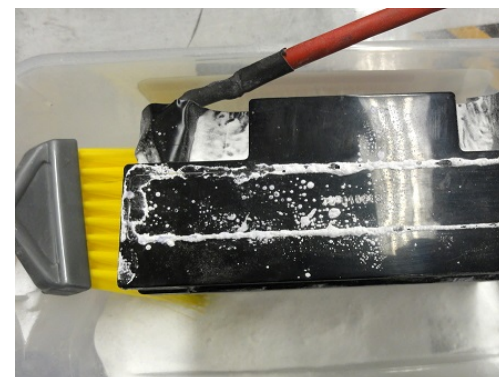
polarities the If energized. **always** are terminals the and "On" **always** is battery healthy A two between gap the bridges and falls can aerosol or wrench a example, for - together short drives risk This arc. dangerous a in released be will energy stored the all - terminals bare and uncovering only 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 36.7.3

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 copperton- 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 shows. copper some if tape electrical with



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 A
V1: 13.443 @ 1 A
V2: 13.153 @ 18 A
Rint: 0.017 Ohms
```

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 36.7.4

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

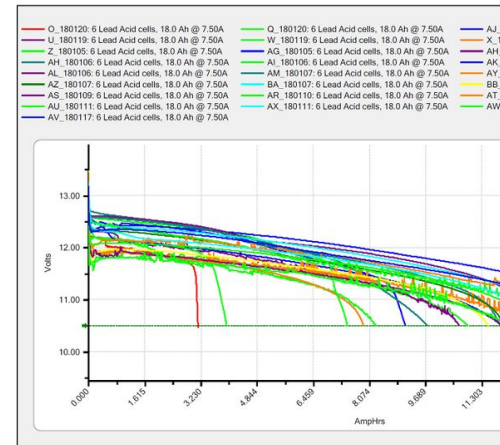
battery the flowing, is current of amount any and connected, is robot) a (like load a Once then and 13.2, reads it and Voltmeter, a with battery a check you if So drop. will voltage Station Driver the on 12.9 maybe lower, read will it on, power and robot your to it connect Characterization see robot, 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

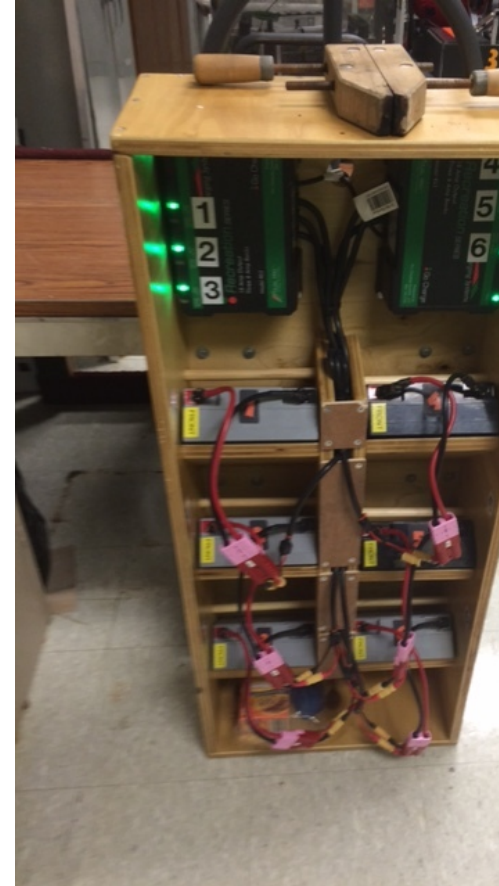
Practices Best Battery 36.7.5

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 •



הם: **מנועים ליישומים ברובוטיקה** הם המנועים המרכזיים של המערכת, המאפשרים את תנועת הרכב. הם יכולים להיות מנועים חשמליים או מנועים הידראוליים.

37.1 מנועים ליישומים ברובוטיקה

הם המנועים המרכזיים של המערכת, המאפשרים את תנועת הרכב. הם יכולים להיות מנועים חשמליים או מנועים הידראוליים. הם יכולים להיות מנועים חשמליים או מנועים הידראוליים. הם יכולים להיות מנועים חשמליים או מנועים הידראוליים. הם יכולים להיות מנועים חשמליים או מנועים הידראוליים.

37.2 חיישנים

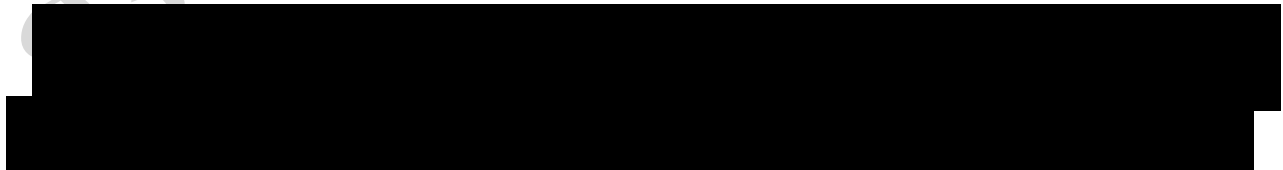
the allow Sensors vehicles. controlled radio really are robots sensing and sensors Without the as well as systems mechanical robots the of operation internal the understand to robots Professor WPI videos, these In robot. the around environment the with interact to ability provides and used, are they how sensors, of classes of number a describes Putnam Craig applications. your for best are sensors what on guidance

37.3 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

37.4 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.



Hardware - Overview Sensor 38.1

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,

38.1.1 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,

38.2 קלט אנלוגי - חומרה

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

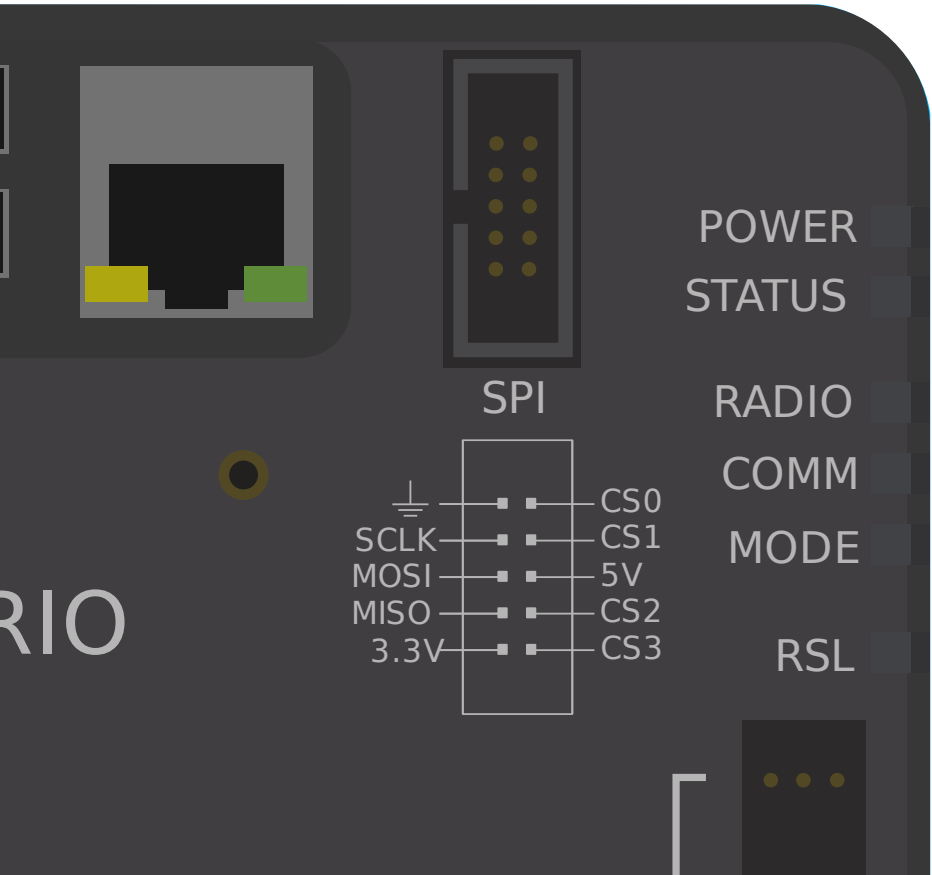
of resolution effective an that's range, 5V a For values. different 4096 or ,²¹² yields resolution bit12- A ¹
discretization the so 50mV, minusor-plus- is specification accuracy actual The .0012V. or mV, 1.2 approximately
accuracy. measurement the in factor limiting the not is

ports input analog roboRIO to Connecting 38.2.1

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

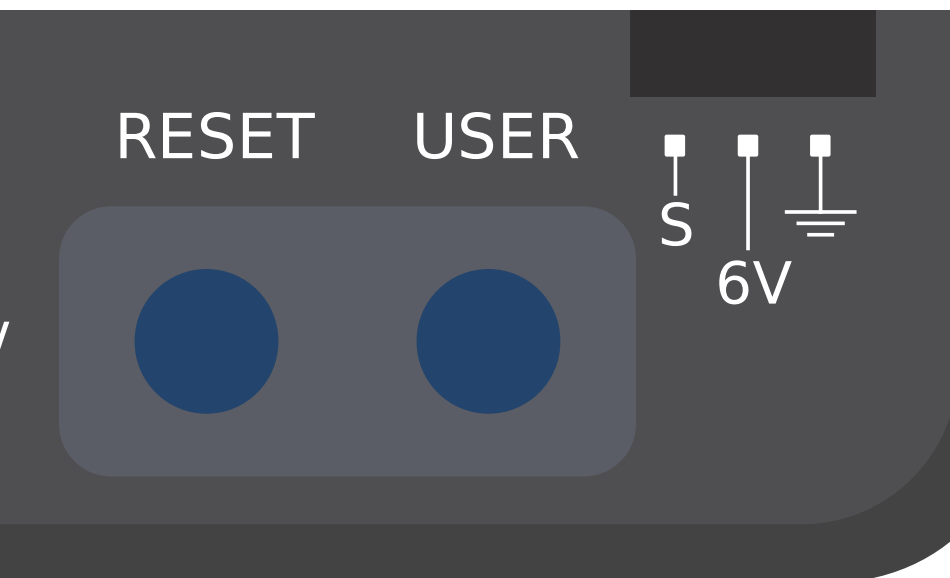
roboRIO! the on port any on pin ground the to pin power the connect directly **Never** :
behavior. unexpected in result may and roboRIO the on features protection trigger will This



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



Footnotes 38.2.2

Hardware - Potentiometers Analog 38.3

analog to guide software a For hardware. potentiometer analog covers section This :□□□□
.Software - Potentiometers Analog see potentiometers,

should Users range. travel limitedmechanically- a have generally Potentiometers :□□□□□
 maximum their past potentiometers their turn not do mechanisms their that careful be
 potentiometer. the destroy or damage will this as travel,

robots FRC® on rotation measuring of way common another ,*encoders quadrature* from Apart
 of shaft the as - resistor variable a simply is potentiometer A potentiometers. analog with is
 in resistor this Placing linearly). (usually changes resistance the turns, potentiometer the
 voltage the measuring by resistance the measure easily to user the allows divider voltage a
 the of position rotational the calculate to used be then can which potentiometer, the across
 shaft.

potentiometer analog an Wiring 38.3.1

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

orientation desired the in is it sure be to multimeter a with potentiometer your of directionality contacts. the to wires your soldering before

Footnotes 38.3.2

Hardware - Inputs Digital 38.4

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 .²¹0V of signal a to "low" and 5V, of signal a to corresponds

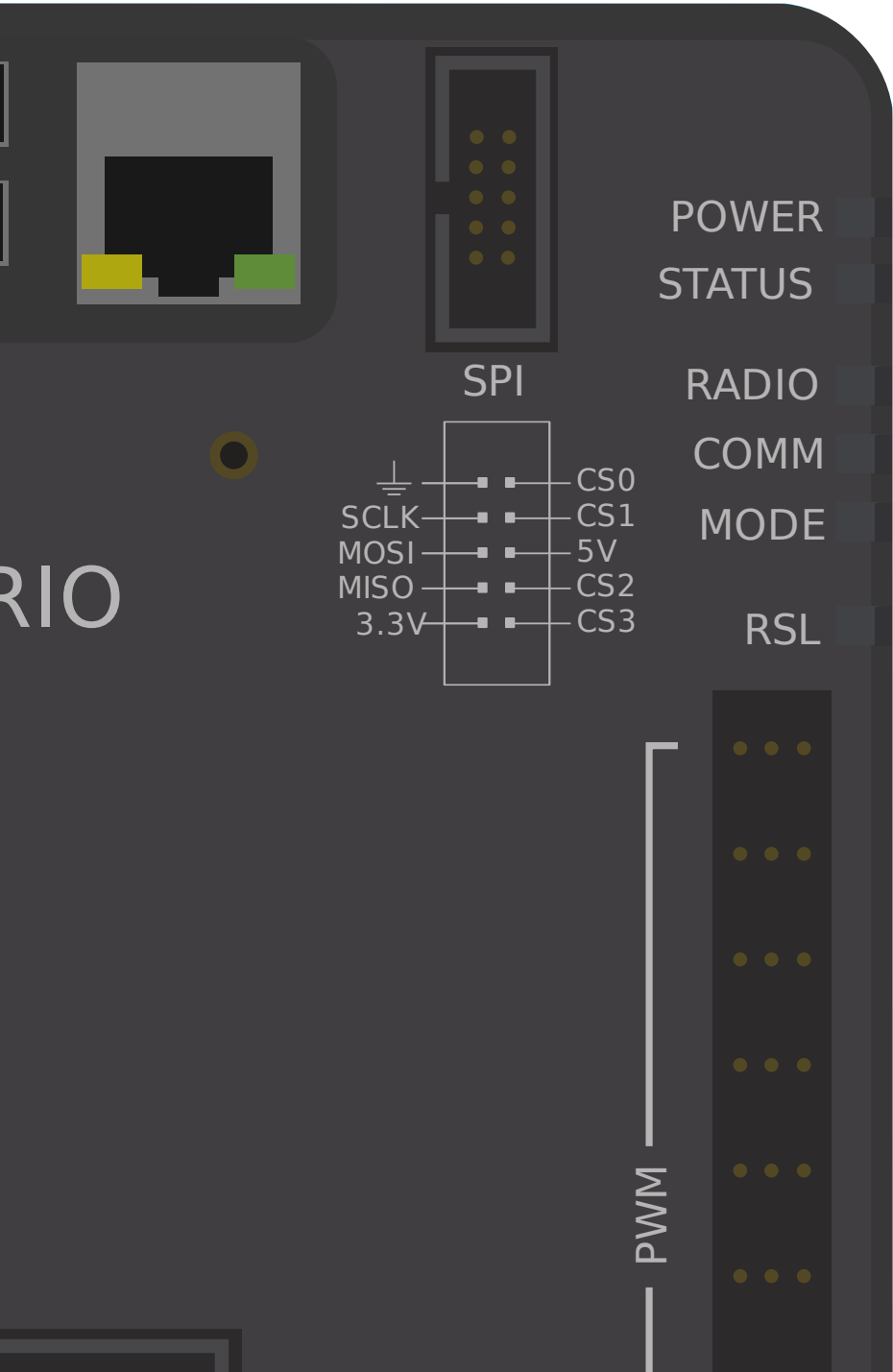
ports DIO roboRIO the to Connecting 38.4.1

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

0.8V below back falls it when "low" reads and 2.0V, above rises it when "high" reads signal the precisely, More ¹ consistent. be to guaranteed not is thresholds two these between behavior - common less far is this of use the however, port; expansion "MXP" the via logic 3.3V offers also roboRIO The ² 5V. the than





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



operation switch Proximity 38.5.1

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 38.5.2

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

actuating arm, switch the against pushes object an when activated is switch The travel. of switch. the

"throw" of amount the in and arm,switch- the of geometry the size, in vary switches Limit mechanical their cheap, quite are switches limit While switch. the activate to required also are they However, alternatives. contactno- than reliableless- sometimes is actuation the moving of capable object physical any by triggered be can they as versatile, extremely arm. switch

Switches. Limit for software the writing for [article this See](#)

Switches Proximity Magnetic

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



a turning by controlled (typically point activation adjustable an have sensors photoelectric also are sensors photoelectric hand, other the On body). sensor the on somewhere screw of types other the than objects of variety greater a detect can they as versatile, extremely switches. contactno-

the which in configuration, break“ ”beam a in used often also are sensors Photoelectric interposed is object an when activate typically These sensor. the from separate is emitter LED IR an with sensor break beam a is below Pictured sensor. the and emitter the between .receiver IR and transmitter



in found commonly not are and market the to newer are Switches Proximity flightof-Time-
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

38.6 אנקודרים - חומרה

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 38.6.1

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:

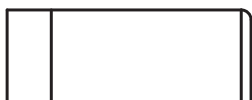
encoders Quadrature •

encoders Cycle Duty •

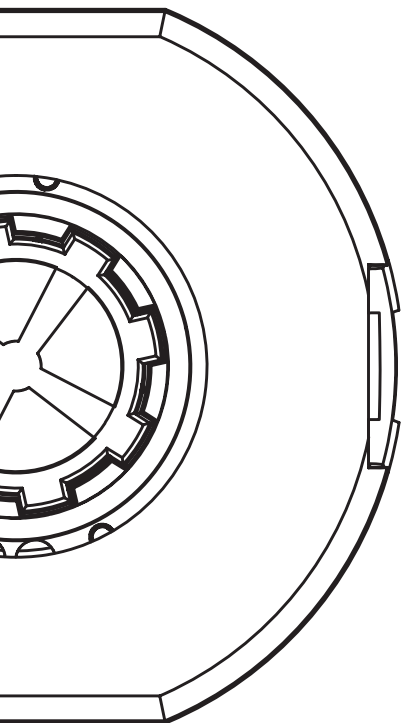
encoders Analog •

method communication one then more support may encoders Some :□□□□

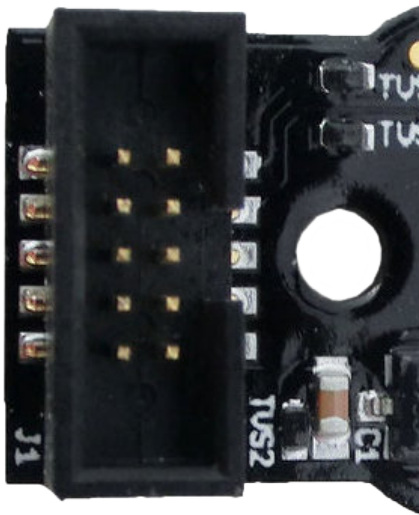
II 63R Optical Encoder



Incremental Encoder



Encoders Magnetic

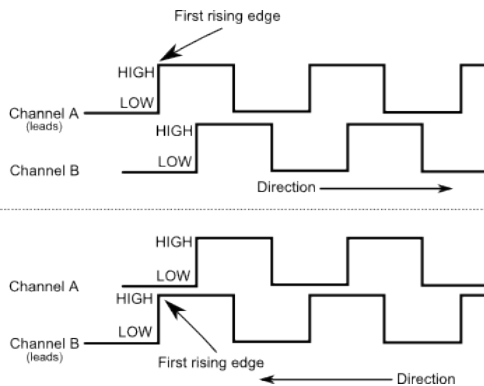


the track they rather, all; at shaft the to coupling mechanical no require encoders Magnetic encoders magnetic of nature contactno- the While shaft. the to fixed magnet a of orientation is magnet the that ensure to order in construction precise require often they handy, be can encoder. the to respect 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- •

CIMcoder •

Encoder Mag CTRE •

63r Grayhill •

Encoder Bore Through REV •

E4T Digital US •

Wiring Encoder Quadrature



Index

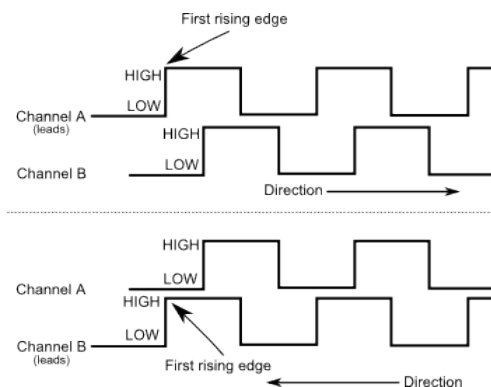
completes encoder the when pulses which pin index third a have encoders quadrature Some revolution. a

Resolution Encoder Quaderature

both denote to sources varying by used *both* are "PPR" and "CPR" acronyms The : tell to enough not is alone acronym the so revolution, per cycles *and* revolution per edges technical the consult doubt, in When value. given a by when meant is two the of is which encoder. specific your of manual

limited is measurement the of accuracy the pulses, digital with rotation measure encoders As the as known is This movement. rotational of amount given per pulses of number the by edges ways: different two of one in measured traditionally is and encoder, the of "resolution" revolution. per cycles or revolution, per highto-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 •

Encoders Analog



Gyros of Types 38.7.1

and gyros axis three- gyros, axis single- FRC: in used commonly- Gyros of types two are There gyro. axis 3- a include often which IMUs,

Gyros axis Single-

S
D



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 38.8

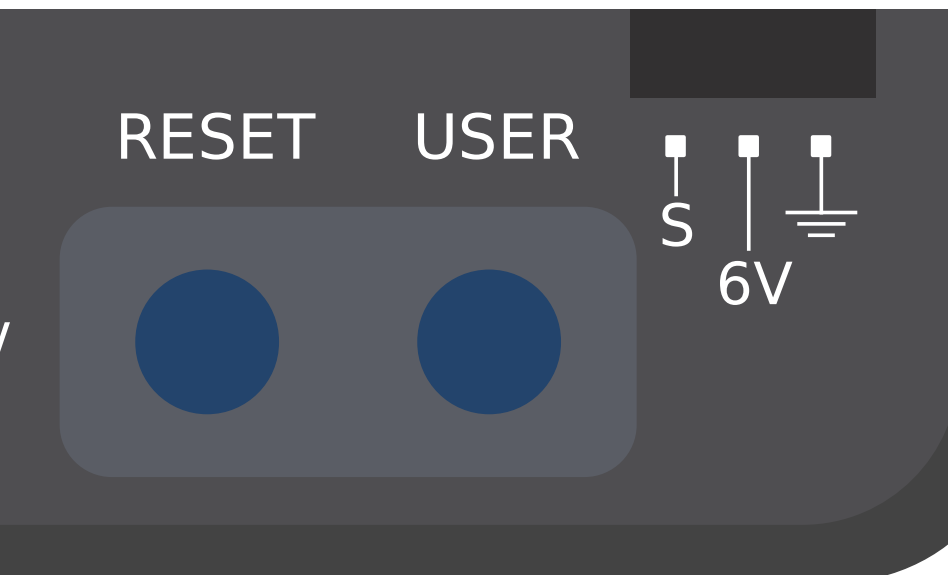
ultrasonics, to guide software a For hardware. sensor ultrasonic covers section This :□□□□
.Software - Ultrasonics see

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 38.8.1

above, outlined principle response""ping- the on operate rangefinders ultrasonic all While
 roboRIO. the with communicate they way the in vary may they

ultrasonics Analog



ultrasonics responsePing-



VEX Ultrasonic

חסרונות 38.8.2

As caveats, few 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

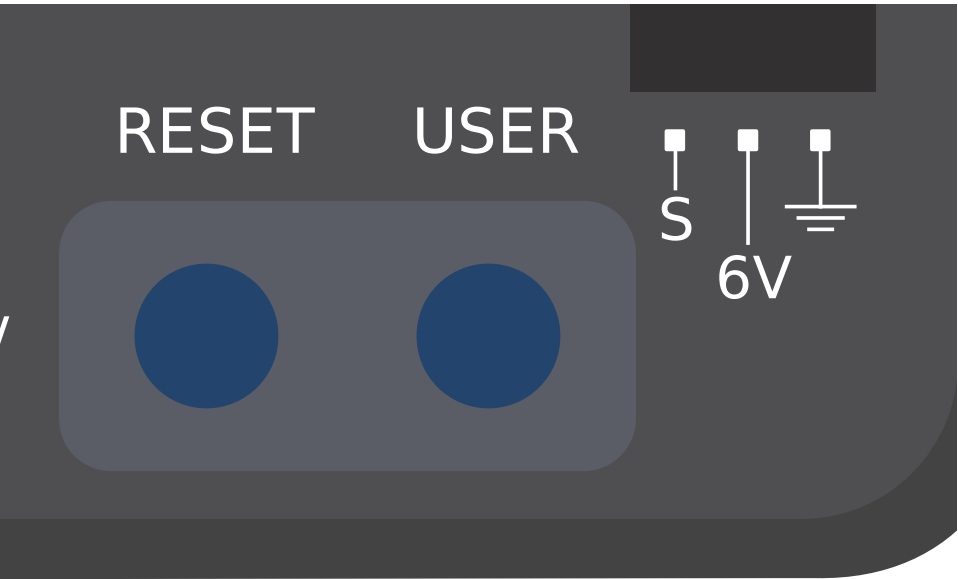
Hardware - Accelerometers 38.9

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

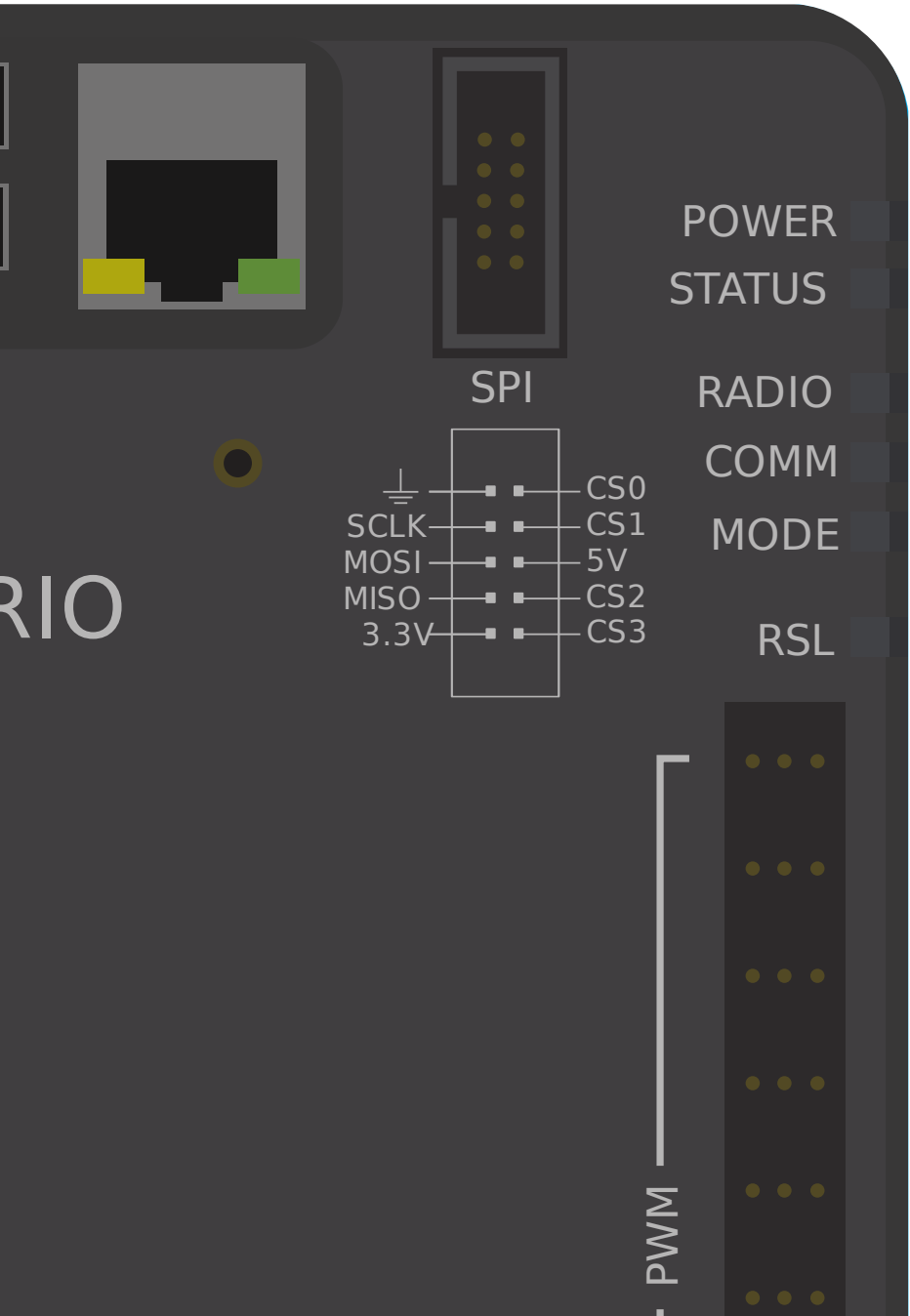
use, can teams all that *accelerometer axisthree- inbuilt-* a with comes roboRIO The peripheral a use and purchase may measurements precisemore- seeking teams however well. as accelerometer,

accelerometers of Types 38.9.1

accelerometers, axissingle- FRC: in usedcommonly- accelerometers of types three are There IMUs. and accelerometers, axismulti-



Fun Single Axis



IMUs 16470 ADIS and ADIS16448 Devices Analog •
IMU Pigeon CTRE •
NavX Labs Kauai •

Hardware - LIDAR 38.10

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 38.10.1

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

חסרונות 38.10.2

drawbacks: common few a from suffer do sensors LIDAR

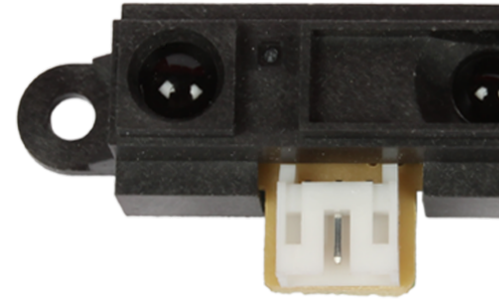
Thus, sensor. the to back pulse emitted the of reflection the on relies LIDAR ultrasonics, Like
 laser. the of wavelength the in material the of reflectivity the on depends critically LIDAR
 infrared the in transparent be to tends which polycarbonate, of made is wall field FRC The
 to struggle to tends 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

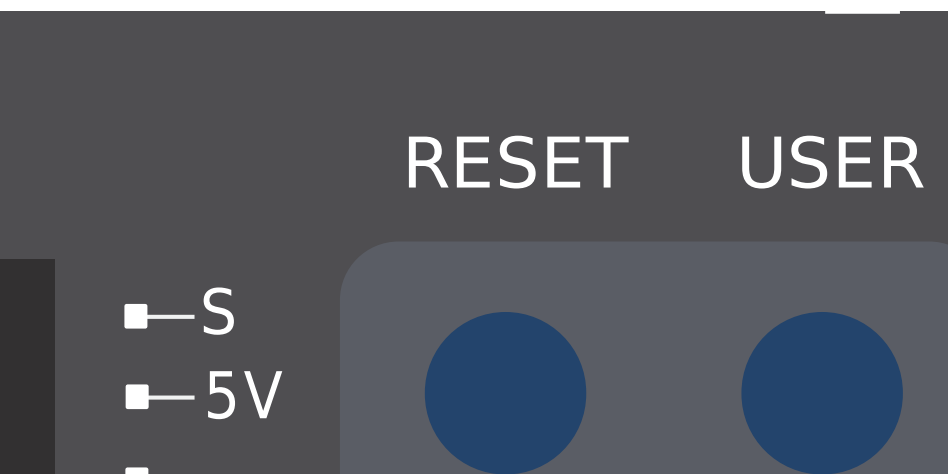
38.11 מדי טווח שפועלים בשיטת הטריאנגולציה



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 sensor. the to object the closer the emitter, the to beam reflected the of contact of point the

rangefinders IR Using 38.11.1



Buses Serial 38.12

serial of methods several offers also roboRIO the inputs, *analog* and *digital* the to addition In devices. peripheral with communication

sent be can that data of amount the in limited highly are inputs analog and digital the Both bandwidthhigher- and robustmore- far of use make to users allow buses Serial them. over inertial as such data, of amounts large collect that sensors with protocols communications sensors. LIDAR 2D or (IMUs) units measurement

buses serial supported of Types 38.12.1

communications: serial of types basic many supports roboRIO The

I2C •

SPI •

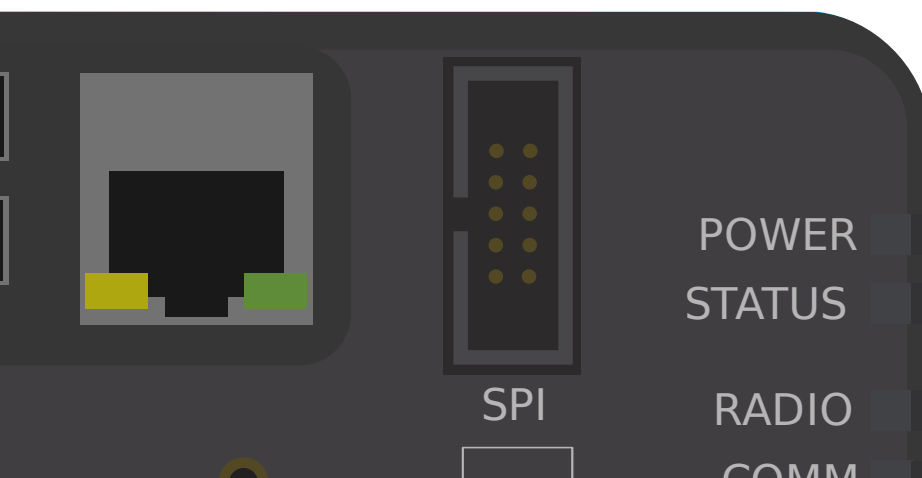
232RS- •

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

I2C 38.12.2



I²C Port

Figure 6 and Table 5 describe the I²C port pins and signals.

Figure 6. I²C Port Pinout

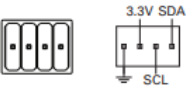


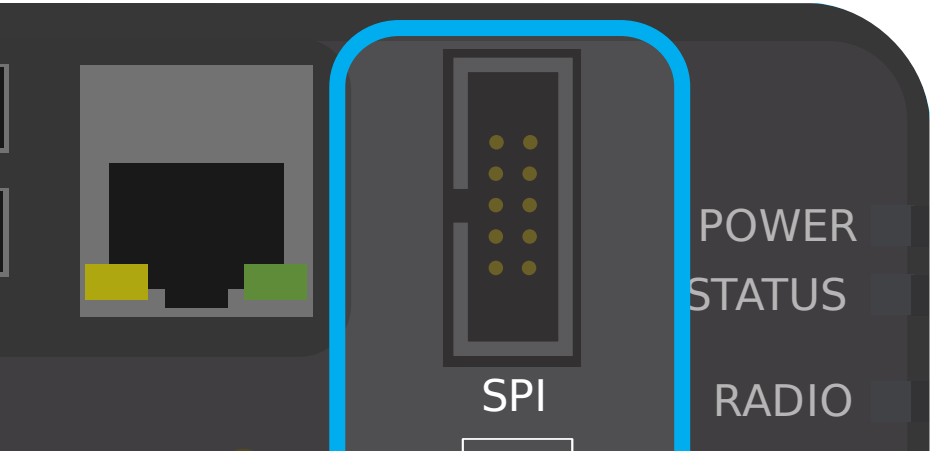
Table 5. I²C Port Signal Descriptions

Signal Name	Direction	Description
GND	—	Reference for digital line output.
3.3V	Output	+3.3 V power output.
SCL	Input or Output	I ² C lines with 3.3 V output, 5 V-compatible input. Refer to the section for more information.
SDA	Input or Output	I ² C lines with 3.3 V output, 5 V-compatible input. Refer to the section for more information.

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 38.12.3



SPI Port

Figure 13 and Table 12 describe the SPI port pins and signals.

Figure 13. SPI Port Pinout

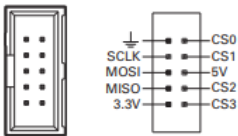
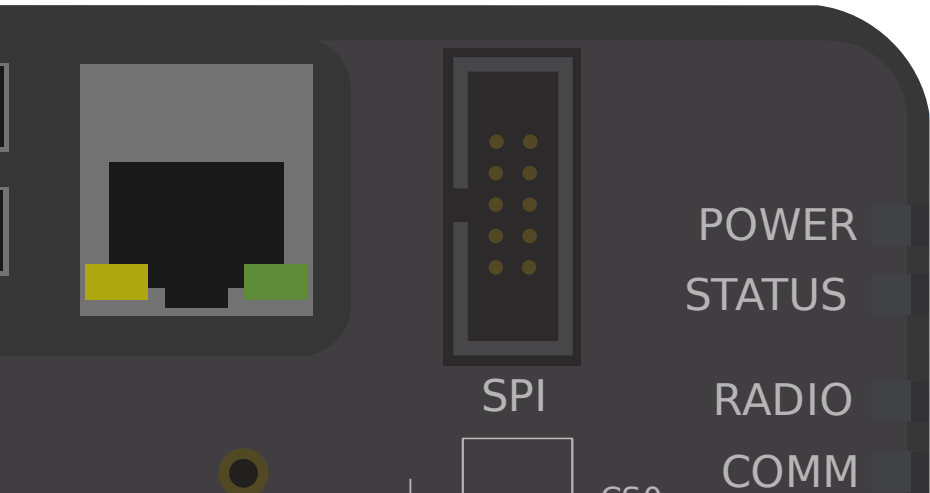


Table 12. SPI Port Signal Descriptions

Signal Name	Direction	Description
3.3V	Output	+3.3 V power output.
5V	Output	+5 V power output.
CS <0..3>	Output	SPI with 3.3 V output, 3 input. Refer to the SPI L information.
SCLK	Output	
MOSI	Output	
MISO	Input	
GND	—	Reference for digital lines +5.5 V power output.

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- 38.12.4



RS-232 Port

Figure 7 and Table 6 describe the RS-232 port pins and signals.

Figure 7. RS-232 Serial Port Pinout

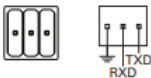


Table 6. RS-232 Serial Port Signal Description

Signal Name	Direction	Description
TXD	Output	Serial transmit output with levels. Refer to the UART section for more information.
RXD	Input	Serial receive input with range. Refer to the UART section for more information.
GND	—	Reference for digital lines.

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 38.12.5

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

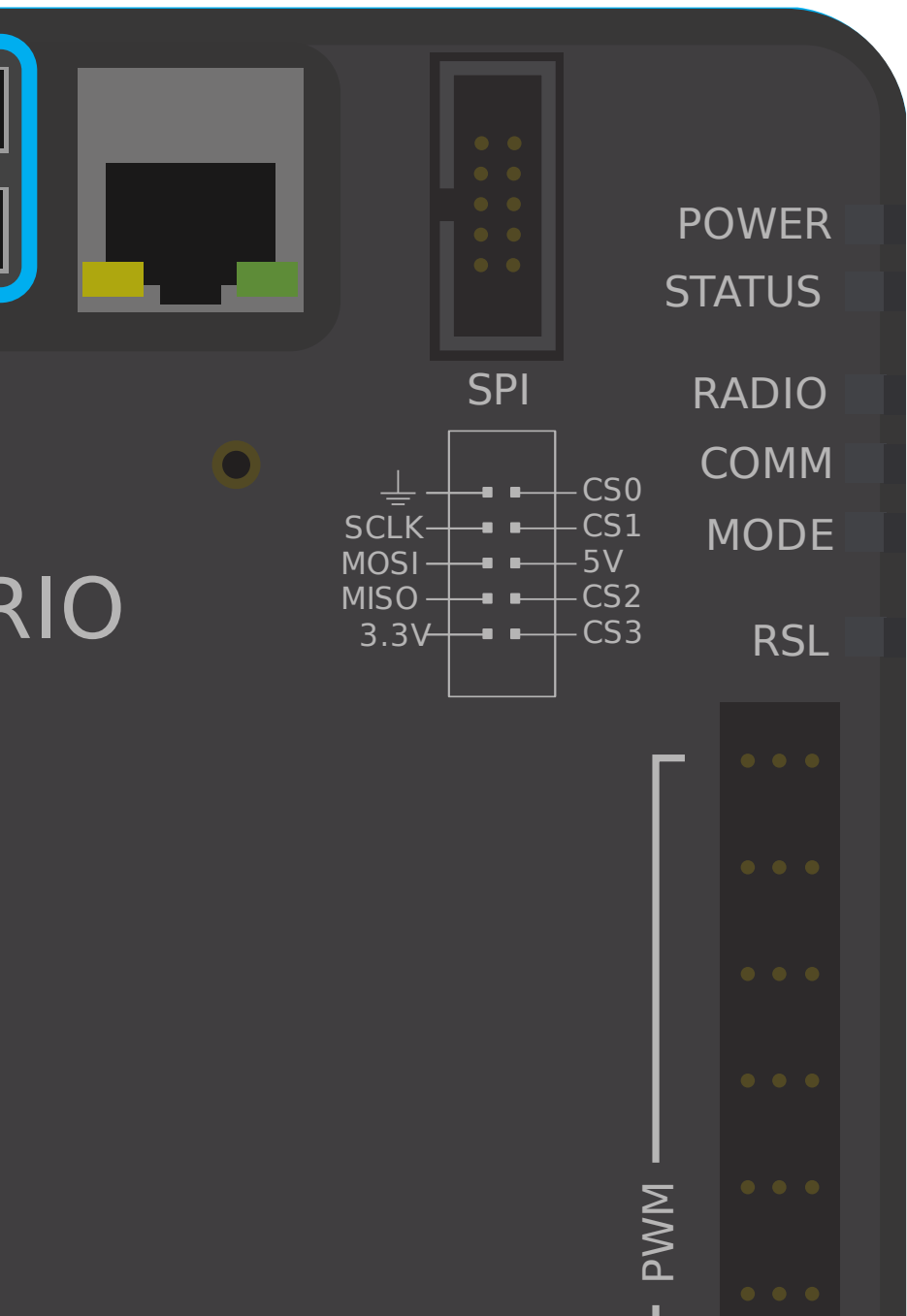
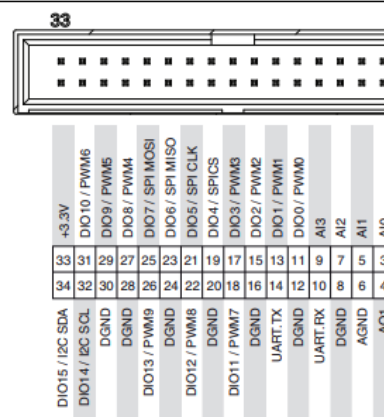
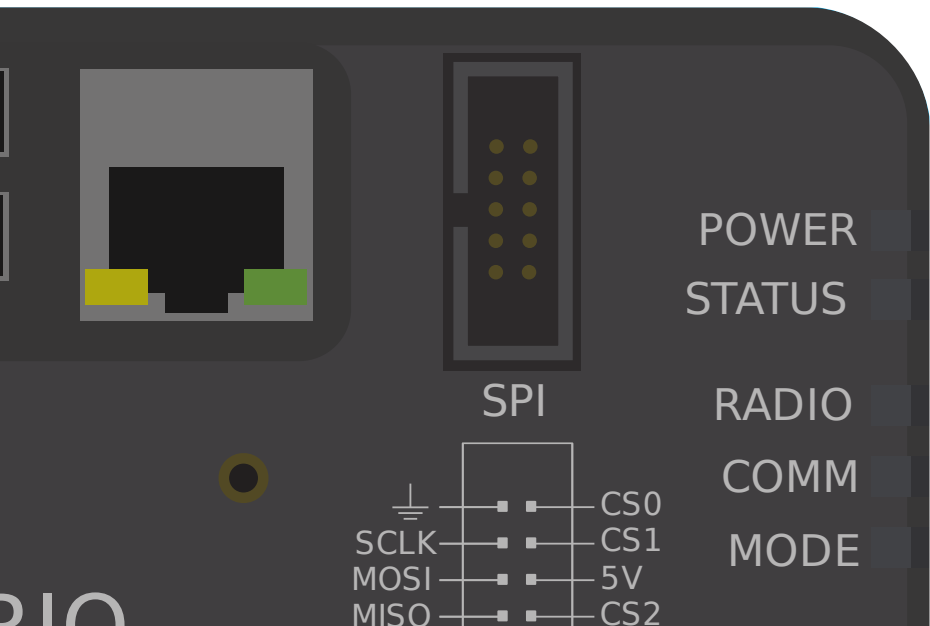


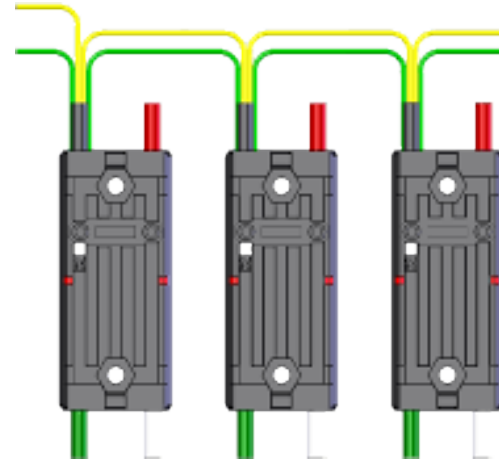
Figure 4. MXP Pinout



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

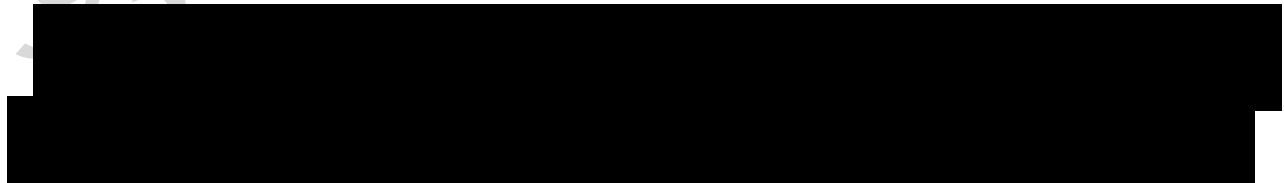
Bus CAN 38.12.8





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

93



FRC programming about learning for designed robot inexpensive and small a is Romi The program to used be can robots FRC sizedfull- programming for used tools same the All robots. also It encoders. wheel integrated with motors drive two with comes Romi The Romi. the it Using accelerations. and headings measuring for used be can that sensor *IMU* an includes command will It computer. your on it running and program, robot a writing as simple as is program. the in steps the follow to Romi the

Thinkscape. via available is Robot Romi the using programming teaches that course A :□□□
here available is course this on Information



39.1 חומרה והרכבה של Romi

הרכבת Romi, הרכבת Romi, הרכבת Romi, הרכבת Romi, הרכבת Romi.

1. Romi from Kit Pololu - free shipping for qualifies Order

2. Raspberry Pi - 3B+ 4

3. (or 8GB) Micro SD card larger

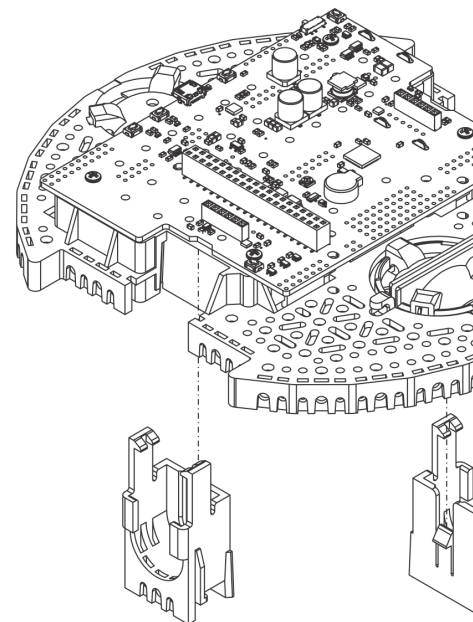
4. Micro SD card reader - if you don't already have one

5. 6 AA batteries (Rechargeable is best) - forget the charger

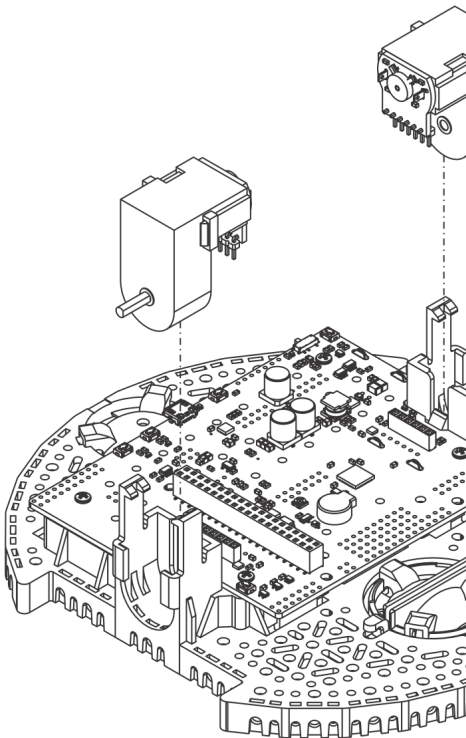
39.1.1 הרכבה

הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST. הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST.

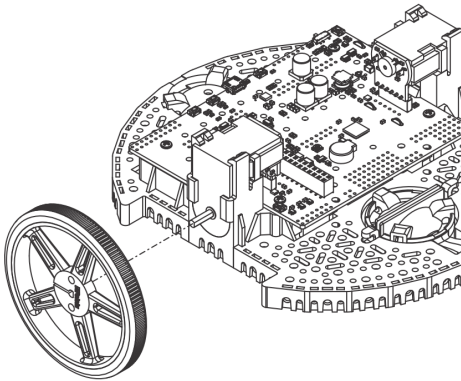
1. הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST. הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST.



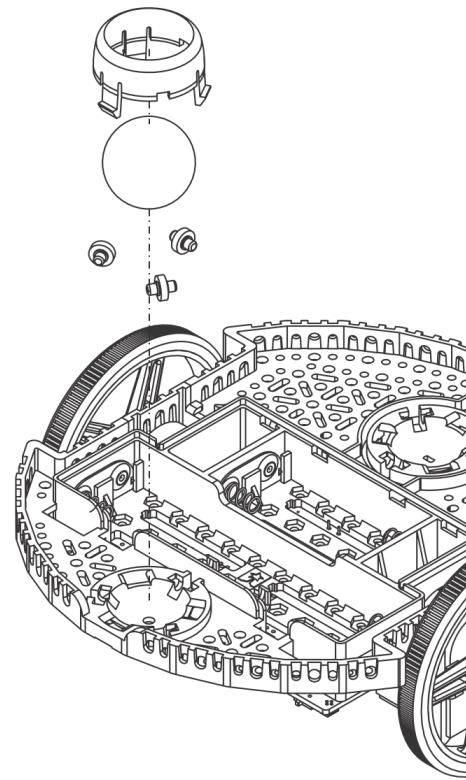
2. הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST. הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST, הרכבת Romi FIRST.



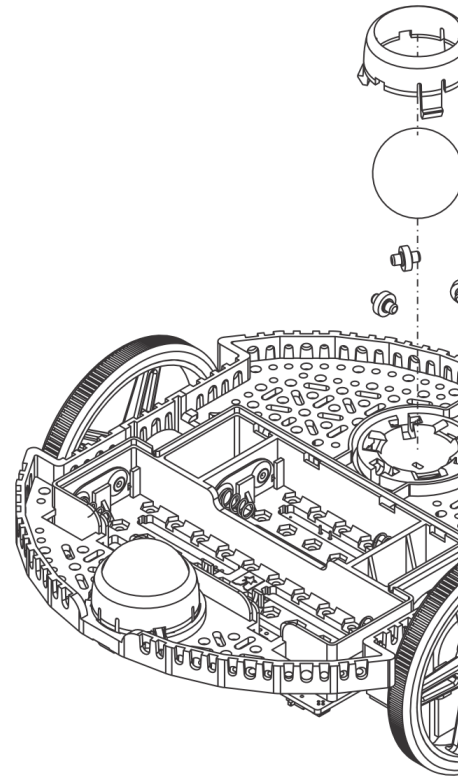
3. The motor and sensor are positioned above the chassis. The motor is connected to the power source and the sensor is connected to the control system. The motor is used to drive the wheels and the sensor is used to detect obstacles. The chassis is then assembled and the robot is ready for use.



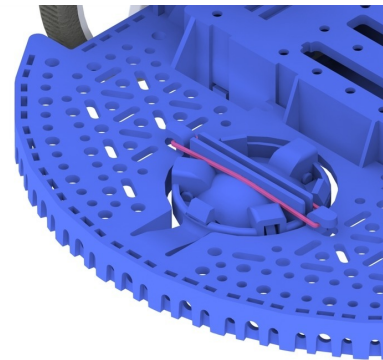
4. The wheel is positioned next to the chassis. The wheel is then pushed into the cutouts in the chassis. The wheel is then secured by the snap legs. The wheel is then pushed into the cutouts in the chassis. The wheel is then secured by the snap legs. The wheel is then pushed into the cutouts in the chassis. The wheel is then secured by the snap legs.



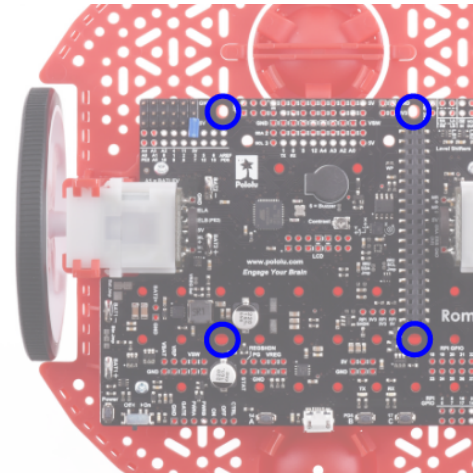
robot. the of back the and front the on caster a is there so caster ball front the for Repeat 5.



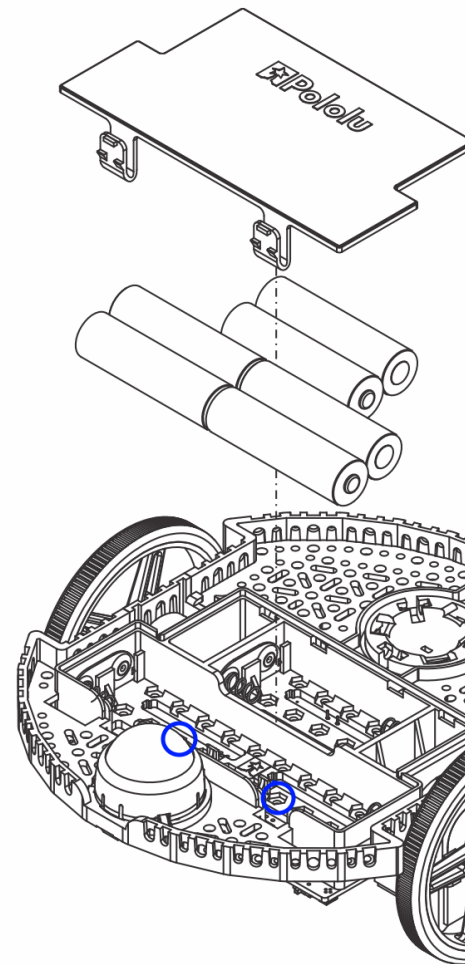
suspension a as acts that arm flexible a by supported is caster ball front The Optional: 6.
 hooks two the around band rubber a wrap can you stiffer, it make to want you If system.
 chassis. the of side top the on caster ball the of side either on located



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



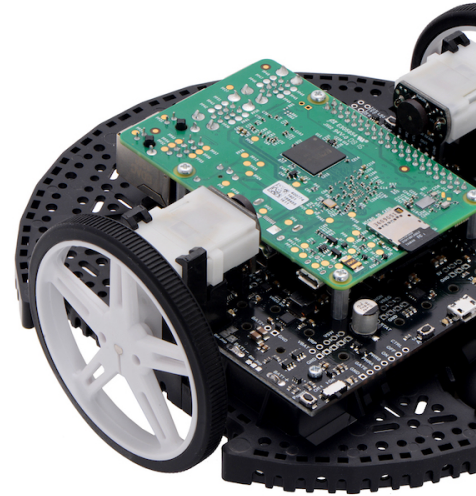
AA rechargeable using recommend (we batteries AA six or four with works chassis The 8.
shapedbattery- the by indicated is batteries the for orientation correct The cells). NiMH
itself. chassis the in indicators - and + the as well as chassis Romi the in holes



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 :
above. image the in circles blue the by shown are locations The compartment.



complete! now is chassis Romi your of assembly The

39.2 צריבת ה-Romi

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

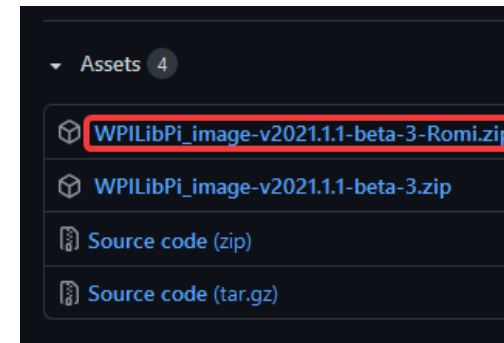
Pi Raspberry 39.2.1

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



צריכה

.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 position. on the to board 32U4 Romi the on switch power the sliding by on Romi the Turn 1. 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.

SSID the using network WiFi Romi the to connect computer, your Using 2. 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.

http://10. either at dashboard Pi Raspberry the to connect and browser web a Open 3. .http://wpilibpi.local/ or 0.0.2/

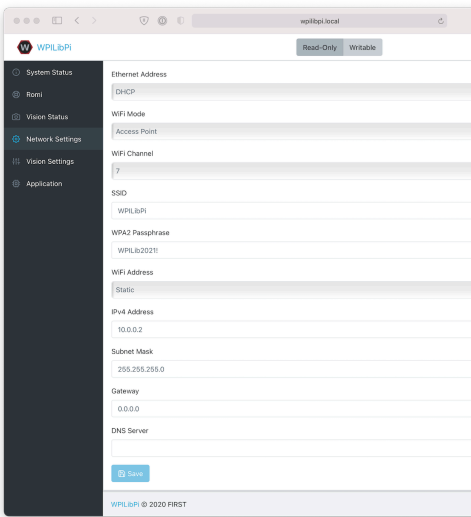
button Writable the click to necessary is it so default, by onlyread- up boots image The :□□□□ memory prevent to button Only-Read the click changes, making done Once changes. make to corruption.

page. web dashboard the of top the at Writable Select 4. WPA2 the in password new a setting by Romi your for password default the Change 5. field. Passphrase

changes. save to page the of bottom the at button Save the Press 6. a on Romi your operating on plan you if name unique a to SSID network the Change 7. Romis. other with network wireless

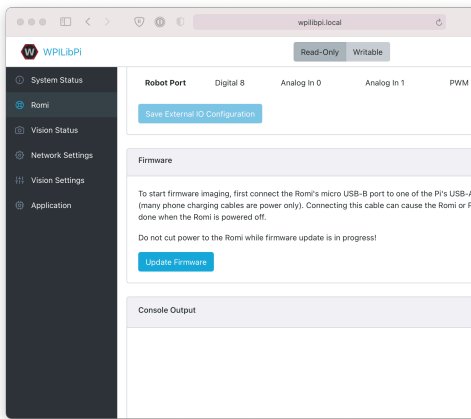
set. you password new the with network WiFi Romi's the to Reconnect 8.

completed. been have changes the all when only-Read to Dashboard the set to sure Be

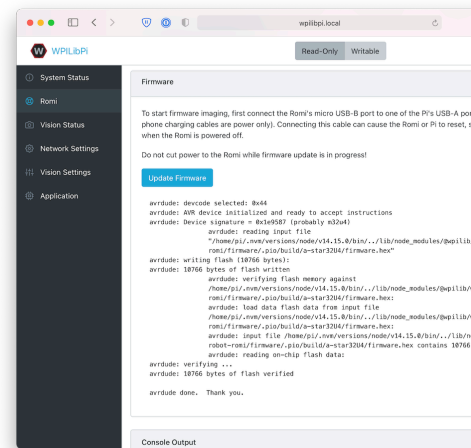


Board Control 32U4 39.2.2

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.



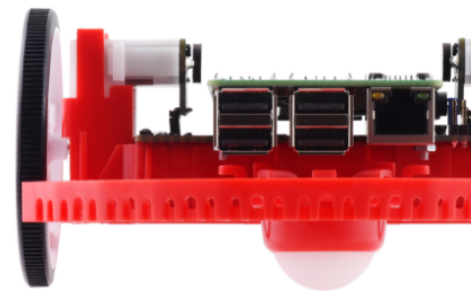
has firmware the Once process. deploy firmware the of log a showing appear will console A
will you. Thank done. avrdude message the Board, Control 32U4 the to deployed been
appear.



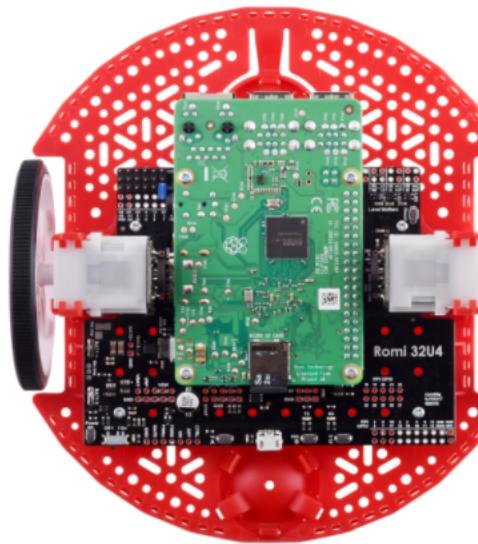
Romi your know to Getting 39.3

Conventions Directional 39.3.1

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, 39.3.2

- 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

Channel	רכיבי התוכנה של Romi
0 PWM	Motor Left
1 PWM	Motor Right

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

Channel	רכיבי התוכנה של Romi
4 DIO	A Channel Quadrature Encoder Left
5 DIO	B Channel Quadrature Encoder Left
6 DIO	A Channel Quadrature Encoder Right
7 DIO	B Channel Quadrature Encoder Right

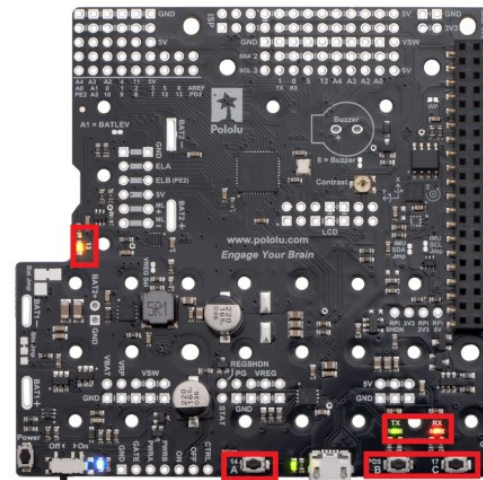
forward. moves Romi the when up count encoders the default, By :□□□□

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

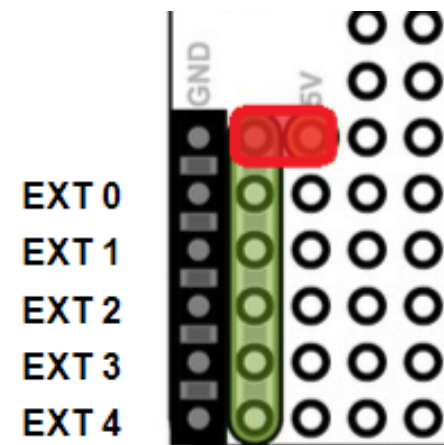


Channel DIO	רכיבי התוכנה של Romi
0 DIO	only) (input A Button
1 DIO	(output) LED Green (input), B Button
2 DIO	(output) LED Red (input), C Button
3 DIO	only) (output LED Yellow

.*opno*- a 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 use the pins. ground

Classes Compatible 39.4.3

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

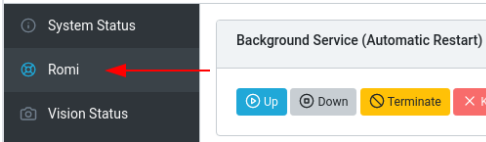
-)Spark (i.e. Controllers Motor PWM •
- Encoder •
- AnalogInput •
- DigitalInput •
- DigitalOutput •
- Servo •
- BuiltInAccelerometer •

.Vendordep Romi the by provided are classes following The

- RomiGyro •
- RomiMotor •
- OnboardIO •

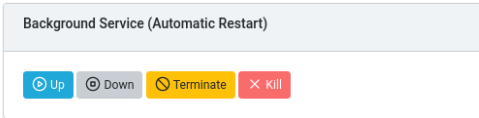
UI Web Romi The 39.5

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 39.5.1



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 39.5.2

Romi Status	
	Value
Romi Service Version	0.0.12
Firmware Compatible	Yes
Battery Voltage	7.65

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 39.5.3

Web Service Update

To perform an offline update of the Romi webservice, obtain an appropriate release page, and upload the .tgz file here.

Upload Romi Webservice Package

No file chosen

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 39.5.4

External IO Configuration

Each of the 5 external pins can be configured to perform one of three functions: Digital Input, Analog Input, or PWM Output (EXT 0 can only be set to DIO or PWM).

After saving the IO configuration, the *Robot Port* section will update with the use in robot code.

Romi Pin	EXT 0	EXT 1	EXT 2	EXT 3
Setting	DIO	Analog	Analog	PWM
Robot Port	Digital 8	Analog In 0	Analog In 1	PWM 2

Save External IO Configuration

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 39.5.5

IMU Calibration

Most gyros will have some sort of zero offset. In order to get more accurate gyro can be calibrated to calculate an appropriate zero offset.

To calibrate the gyro, place the Romi on a flat surface and click the "Calibrate Gyro" button. While calibration is running, please do not touch the Romi.

Current Gyro Offsets

X Offset

0.683

Y Offset

-4.305

Z Offset

-2.817

Calibrate Gyro

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 39.5.6

Romi your Imaging on section the See :□□□□

Output Console 39.5.7

Console Output

```
Version: 0.0.12
HardwareI2C(bus=1)
[CONFIG] External Pins: EXT0(dio), EXT1(ain), EXT2(ain), EXT3(pw
[CONFIG] Mode: Server, Port: 3300, URI: /wpilibws
WebSocket Interface Ready
[IMU] Identified as LSM6DS33
[IMU] Gyro Zero Offset at Init: {"x":0.6825000000000001,"y":-4.3
[IMU] Accelerometer Scale: SCALE_2G
[IMU] Gyro Scale: SCALE_1000_DPS
[ROMI] LSM6DS33 Initialized
Robot (WPILibWS Reference Robot (Romi)) is ready
[SERVICE] Endpoint (server) Started
[REST-INTERFACE] Endpoints:
[REST-INTERFACE] GET /status/service-version
[REST-INTERFACE] GET /status/firmware-status
[REST-INTERFACE] GET /status/external-io-config
[REST-INTERFACE] GET /status/battery-status
[REST-INTERFACE] GET /imu/status/calibration-state
[REST-INTERFACE] GET /imu/status/last-gyro-calib
[REST-INTERFACE] GET /imu/status/gyro-reading
[REST-INTERFACE] GET /imu/status/accel-reading
[REST-INTERFACE] GET /imu/status/gyro-offset
[REST-INTERFACE] POST /imu/calibrate
[REST-INTERFACE] Server listening on port 9999
```

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 39.5.8

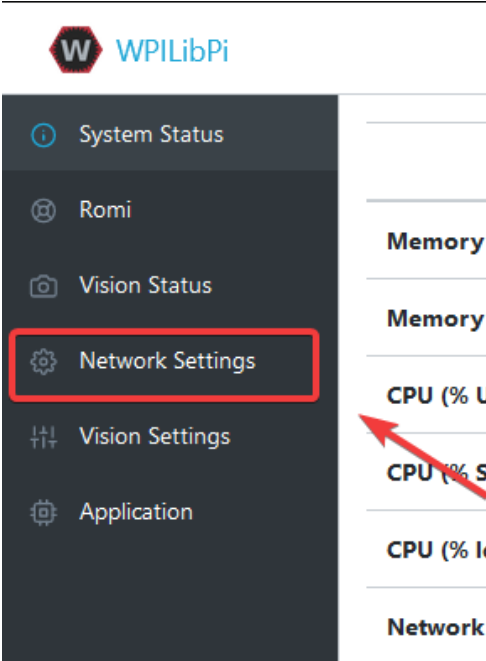
an as acting of instead network WiFi a to connect to robot Romi your allows mode Bridge use can you as environments, learning remote in useful especially is This (AP). Point Access hardware. extra without Romi the using while internet the

environments network restricted in properly work to likely not is mode Bridge :□□□□ Institutions). (Educational

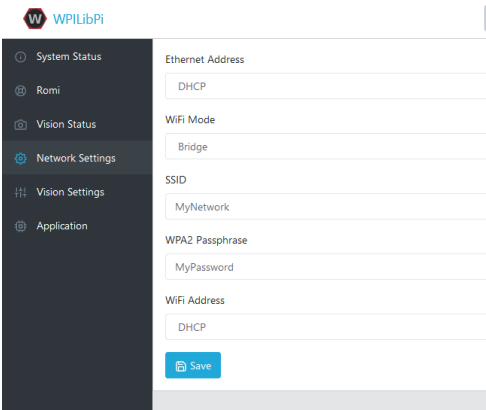
menu. top the in *Writable* Enable 1.



Settings Network on Click 2.



applied: he 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 39.6

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 39.6.1

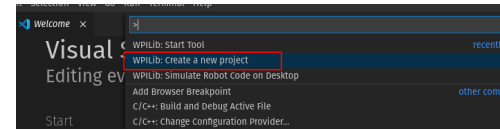
the to similar program, FRC normal a creating like is Romi a for program new a Creating steps. programming *Robot To Zero*

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

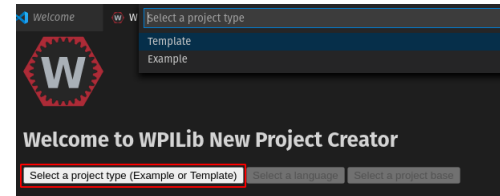
must compiler desktop C++ compatible a C++, using Romi the program to order In :!!!!
.Dependency C++ Additional - Simulation Robot See installed. be

Project Romi WPILib New a Creating

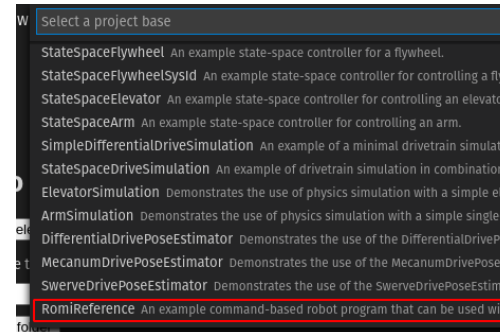
project" "New type and ,Ctrl+Shift+P with palette command Code Studio Visual the up Bring command: project" new a "Create the Select prompt. the into



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

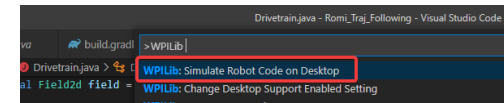
builtpre- a has project The run. to ready essentially is it generated, is project robot the Once using around Romi the drive you lets that command default associated and class Drivetrain joystick. a

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.

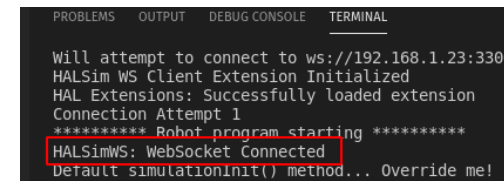
the to connect Next, on. powered is Romi your that ensure first, program, Romi a run To network Romi the changed you If Romi. the by broadcast network WiFi ><number-WPILibPi address IP the change may you network) WiFi own your to it connect to example, (for settings and file build.gradle the open this, 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// 43
true = defaultEnabled.)(addWebsocketsServer.sim.wpi 45
true = defaultEnabled.)(addWebsocketsClient.sim.wpi 46
```

)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“:



running! now is code Romi Your

(LabVIEW) Romi the Programming 39.7

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 39.7.1

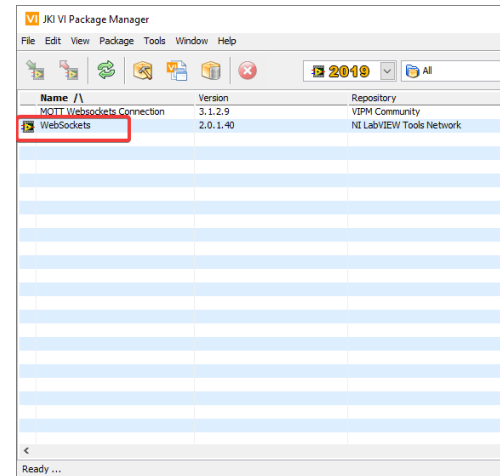
program, [reg] FRC normal a creating than different no is Romi a for program new a Creating separate a create to wish may you Initially, steps. programming *Robot To Zero* the to similar ports different to connected be may hardware Romi the as Romi the just on use for project robot. roboRIO your on than

respectively. side right and left for 1 and 0 ports *PWM* used Robot Romi The

VI WebSockets the Installing

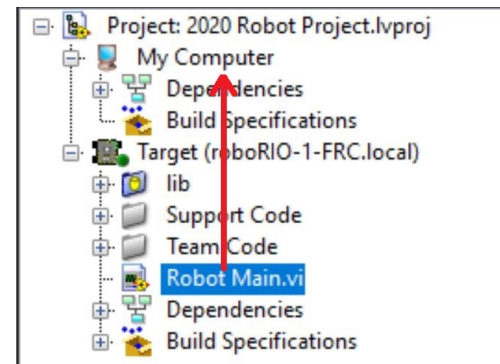
the that is project robot [reg] FRC regular a from differs project Romi a where aspect One development your on runs project Romi a Instead, Romi. the to directly deployed not is code Romi the with communicate to framework simulation WPILib the leverages and computer, Romi. the with converse to uses LabVIEW 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.



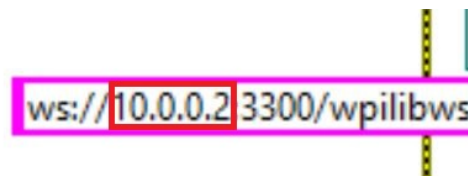
Target Project the Changing

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



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* while 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

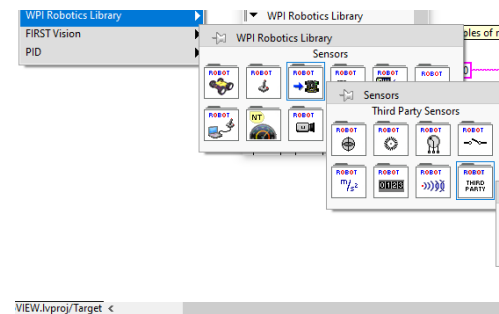
LabVIEW the as computer same the on software Station Driver the run to recommended is It automatically will it Station, Driver the to connects successfully program your Once code. Station Driver the allowing Desktop, the on running is code the that Station Driver the notify need you'll Next, Station. 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

show also will Station Driver the Romi, the to connect to unable is code robot your If :□□□□ connectivity. no

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 -



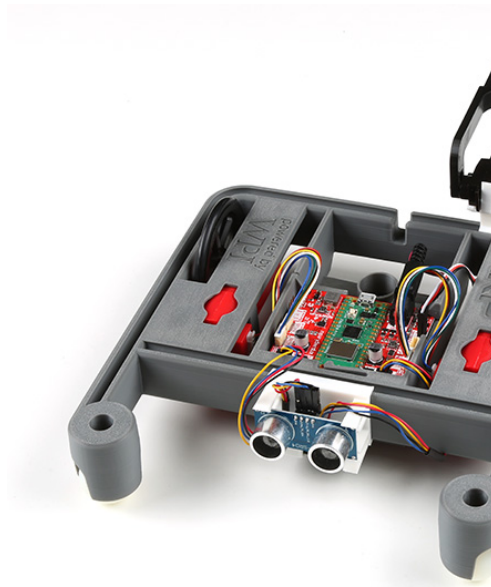
are: ports DIO The function. encoder standard the using used be can encoders The

5) (4, Left •

7) (6, Right •

04

FRC programming about learning for designed robot inexpensive and small a is XRP The program to used be can robots FRC sizedfull- programming for used tools same the All robots. also It encoders. wheel integrated with motors drive two with comes XRP The XRP. the it Using accelerations. and headings measuring for used be can that sensor *IMU* an includes command will It computer. your on it running and program, robot a writing as simple as is program. the in steps the follow to XRP the a using albeit functionality, similar with *Romi* the as case use similar a provides XRP The cost. in lower overall is and processor power lower



Imaging and Assembly Hardware, XRP 40.1

hardware. necessary the have to need will you XRP, the with started get To educational for discount a at Available - DigiKey from or SparkFun from Kit XRP 1. details. for vendors individual See teams. FIRST or institutions
cable data a is this that Ensure - cable USBMicro- 2.
charger) the forget (don't best is)example(Rechargeable - batteries AA 4 3.

הרכבה 40.1.1

.Guide User XRP the on instructions assembly the See :□□□□
mounted is arm XRP the where point the including and to up instructions the follow should You servo. the to

XRP your Imaging 40.1.2

to need will firmware special A processor. main its as W Pico Pi Raspberry a uses XRP The properly. operates robot the that so installed be

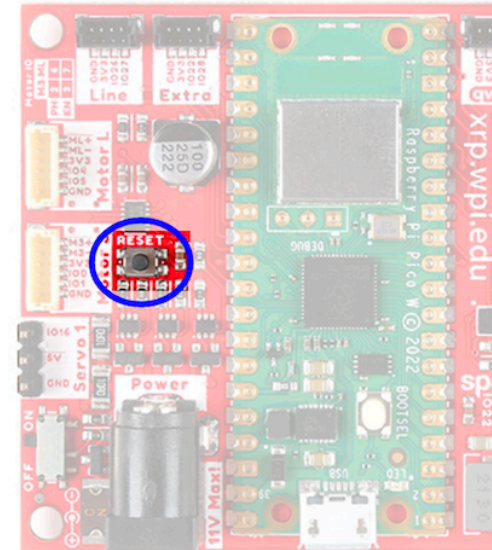
הורדה

the at Assets on Click W. Pico the to written and downloaded be must firmware XRP The files: image available the see to description the of bottom

Firmware WPILibXRP-

צריבה

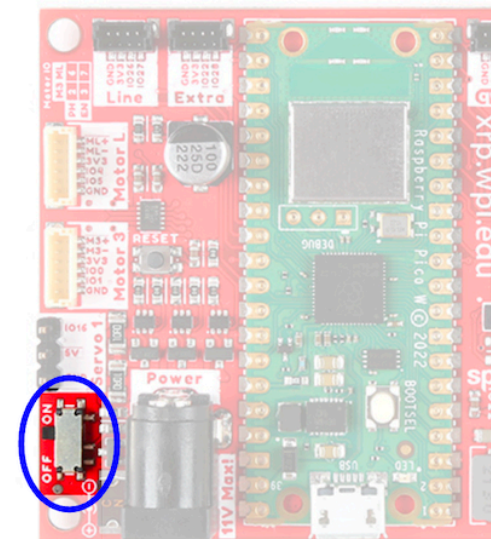
steps: following the perform XRP, the image To
file. uf2. a with up end should You file. ZIP firmware the of contents the Extract 1.
power red a see should You cable. USBMicro- a with computer your into XRP the Plug 2.
up. lights that LED
USB the near W, Pico green the on button white (the button B00TSEL the holding While 3.
B00TSEL the release then and below), (circled button reset the press quickly connector),
button.



4. The board will temporarily disconnect from the computer and then reconnect as a USB device named 'RP2-RPI'.
 5. The firmware file 'uf2' will be automatically updated to the latest version.
 6. Once the update is complete, disconnect the USB from the computer and the board will run on battery power.

Boot First

Perform the following steps to get ready for XRP:
 1. Ensure you have 4 AA batteries installed.
 2. Turn the sliding switch on the bottom of the board (circled in red) to the 'ON' position. The red LED will turn on.



><IDENT-XRP SSID the using network WiFi XRP the to connect computer, your Using 3.
passphrase WPA2 the with W) Pico the of ID unique the on based is ><IDENT (where
.wpilib-xrp

can SSID the XRP's, other multiple with environment an in XRP the on powering If :□□□□
device storage USB the to navigating computer, a to XRP the connecting by found be also
file. status.txt-xrp the opening and appears that)PICODISK(

the If .http://192.168.42.1:5000 at UI web the to connect and browser web a Open 4.
XRP. the with connectivity established have you loads, page

UI Web the in found be can configuration and UI Web the about information More :□□□□
.section

XRP your know to Getting 40.2

XRP the up Booting 40.2.1

will following the USB), or battery via either XRP the to applied is power (when up start Upon
happen:

indicated be will and seconds, 53- approximately lasts This itself. calibrate will IMU The 1.
surface flat a on placed be should XRP the Ideally, rapidly. blinking LED green the by
firmware the restart to button reset the hit can users necessary, if and up, power to prior
process. calibration IMU and

section the See settings. configuration the on depending configured, be will network The 2.
default By settings. network the configure to how on information more for *UI Web the on*
Point. Access WiFi own its broadcast will XRP the
use. for ready is XRP the this, After 3.

GPIO and Sensors Hardware, 40.2.2

hardware/peripherals: inbuilt- following the has XRP The

- encoders with motors drive geared 2x •
- and Motor3 (marked support encoder with connectors motor geared additional 2x •
Motor4)
- Servo2) and Servo1 (marked connectors Servo 2x •
- (IMU) Unit Measurement Inertial 1x •
- (green) LED 1x •
- USER) (marked pushbutton 1x •
- inputs) Analog 2 as (exposed sensor following Line 1x •
- input) analog an as exposed pins, IO digital 2 (uses rangefinder style PING Ultrasonic 1x •

Encoders and Wheels, Motors,

90 of speed output loadno- a and reduction gear 48.75:1 a have XRP the on used motors The 4.5V. at RPM

(6.1"). 155mm of trackwidth a have They (2.3622"). 60mm 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 585 nets this ratio, gear provided the With (CPR). Revolution below. table the in listed are channels motor The

use the requires XRP the as channels" "PWM of instead here channels" "motor use We :□□□□ hardware. the with interact to code WPILib in object XRPMotor special a of

Channel	Component Hardware XRP
0 XRPMotor	Motor Left
1 XRPMotor	Motor Right
2 XRPMotor	3 Motor
3 XRPMotor	4 Motor

Thus 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

below. table the in listed are channels servo The

use the requires XRP the as channels" "PWM of instead here channels" "servo use We :□□□□ hardware. the with interact to code WPILib in object XRPServo special a of

Channel	Component Hardware XRP
4 XRPServo	1 Servo
5 XRPServo	2 Servo

below. table the in listed are channels encoder The

Channel	Component Hardware XRP
4 DIO	A Channel Quadrature Encoder Left
5 DIO	B Channel Quadrature Encoder Left
6 DIO	A Channel Quadrature Encoder Right
7 DIO	B Channel Quadrature Encoder Right
8 DIO	A Channel Quadrature Encoder Motor3
9 DIO	B Channel Quadrature Encoder Motor3
10 DIO	A Channel Quadrature Encoder Motor4
11 DIO	B Channel Quadrature Encoder Motor4

forward. moves XRP the when up count encoders the default, By :□□□□

Unit Measurement Inertial

which (IMU) Unit Measurement Inertial LSM6DSOX STMicroelectronics an includes XRP The accelerometer. axis3- a and gyro axis3- a contains will LED onboard (the boot each upon accelerometer and gyro the calibrate will XRP The time). startup at seconds 53- about for flash quickly

Button Push and LED Onboard

as exposed are that onboard LED green a and USER) (labeled button push a has XRP The code. robot to channels (DIO) IO Digital

Channel DIO	Component Hardware XRP
0 DIO	Button USER
1 DIO	LED Green

use. system future for reserved are 3 and 2 DIO :□□□□

Sensor (Reflectance) Following Line

2 with sensor following line a supports XRP the instructions, the to according assembled When AnalogInput as these exposes reflectance measures element sensing Each elements. sensing black). (pure 5V to white) (pure 0V from range values returned The code. robot to channels

Channel AnalogInput	Component Hardware XRP
0 AnalogInput	Sensor Reflectance Left
1 AnalogInput	Sensor Reflectance Right

Rangefinder Ultrasonic

style, PING ultrasonic, an supports XRP the instructions, the to according assembled When values returned The code. robot to channel AnalogInput an as exposed is This rangefinder. (4000mm). 5V to (20mm) 0V from range

Channel AnalogInput	Component Hardware XRP
2 AnalogInput	Rangefinder Ultrasonic

Support Hardware XRP 40.3

with compatible is roboRIO, a than architecture hardware different a having robot, XRP The components. system control FRC used commonly of subset a

Hardware Compatible 40.3.1

following: the with compatible is XRP the general, In
connector) pin(6- encoders inbuilt- with motors DC Hobby •
controllers) motor based PWM servos, (e.g. devices output *PWM* styleRC- Standard •
port) RANGE the to connected when (only sensors ultrasonic style "Ping" •

Hardware Incompatible 40.3.2

following: the with compatible not is XRP the limitations, hardware to Due
motors hobby into integrated already those than other Encoders •
sensors based Timing •
devices based CAN •

Classes Compatible 40.3.3

is it that assume here, listed not is class a If XRP. the by supported are here listed classes All
work. *not will* and supported not

Encoder •
AnalogInput •
DigitalInput •
DigitalOutput •
BuiltInAccelerometer •

XRP The supported. not are Servo and)Spark (e.g. classes controller motor PWM The :□□□□
classes. XRPServo and XRPMotor specialized of use requires

WPILib). to in(built- Vendordep XRP the by provided are classes following The

XRPGyro •
XRPMotor •
XRPServo •
XRPOnBoardIO •

UI Web XRP The 40.4

Address <IPhttp:// at accessible is It configuration. for UI Web simple a provides XRP The .http://192.168.42.1:5000 is this default, By .>:5000XRP of network the configure to user a allows that object JSON simple a is configuration XRP The XRP. the of settings

XRP Configuration

Edit the JSON below as necessary

Configuration JSON

```
{
  "configVersion": 1,
  "network": {
    "defaultAP": {
      "ssid": "XRP-6361-7c28",
      "password": "xrp-wpillib"
    },
    "networkList": [
      {
        "ssid": "Test Network",
        "password": "Test Password"
      }
    ],
    "mode": "AP"
  }
}
```

RESET TO DEFAULT SAVE

Modes Network Switching 40.4.1

the switch to order in changed be to needs that field the shows above image the in 3 Box will XRP the mode,)AP(Point Access In mode. Station to/from mode Point Access from XRP WiFi existing an to connect will XRP the mode,)STA(Station In network. WiFi a broadcast).STA/AP(value appropriate the with field mode the Update network.

(AP) Point Access default a up Setting 40.4.2

network. WiFi a broadcasts it where mode, Point Access in operate will XRP the default, By and SSID AP the for settings the control fields which shows above image the in 1 Box passphrase.

WiFi the create to used be will information point access the ,AP to set is mode operating the If the of any to connect to unable is XRP the and (station) STA to set is mode the If Point. Access specified information the using again, mode, AP to back fall will it then networks, WiFi listed 1. box in

network WiFi existing an to Connecting 40.4.3

XRP the want you that network WiFi a listing of example an shows above image the in 2 Box as networks preferred many as with populated be can array networkList the to. connect to will XRP the mode, STA to set When 2). Box as format same the (following like would you the available, are networks the of none If order. in network listed each to connect to attempt mode. AP into fallback will XRP

is it network WiFi which or in, operating is XRP the mode what about unsure are you If :□□□□ device storage USB A cable. USB a via computer a to XRP the connect can you to, connected appropriate the list will it within file status.txt-xrp the and appear, will PICODISK named information. network

XRP the Programming 40.5

robot. FRC regular a for program a writing to similar very is XRP the for program a Writing be can etc) SmartDashboard, Station, Driver Code, Studio (Visual tools same the all fact, In XRP. the with used

Program XRP an Creating 40.5.1

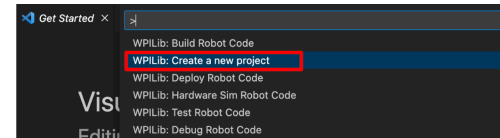
the to similar program, FRC normal a creating like is XRP an for program new a Creating steps. programming *Robot To Zero*

TimedRobot, on based one including projects, XRP for templates two with comes WPILib which provided is project example an Additionally, template. project BasedCommand- a and vendordep the use to how shows and XRP, the of functionality inbuilt- the of some showcases example. this from project a creating through walk will article This classes. XRP exposed

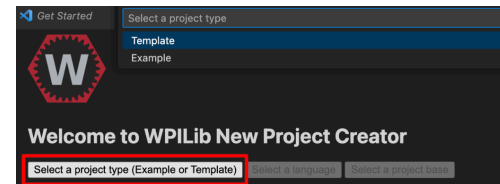
be must compiler desktop C++ compatible a C++, using XRP the program to order In :□□□□
.Dependency C++ Additional - Simulation Robot See installed.

Project XRP WPILib New a Creating

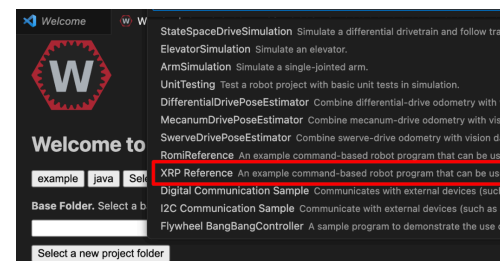
project" "New type and ,Ctrl+Shift+P with palette command Code Studio Visual the up Bring
command: project" new a "Create the Select prompt. the into



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



Reference" "XRP 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 XRP an Running

builtpre- a has project The run. to ready essentially is it generated, is project robot the Once
using around XRP the drive you lets that command default associated and class Drivetrain
joystick. a

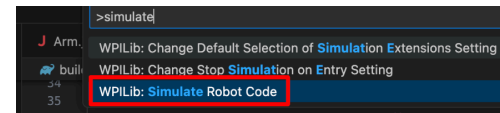
is code the that is project robot FRC regular a from differs project XRP an where aspect One
computer development your on runs project XRP an Instead, XRP. the to directly deployed not
XRP. the with communicate to framework simulation WPILib the leverages and

to connect Next, on. powered is XRP your that ensure first, program, XRP an run To
settings network XRP the changed you If XRP. the by broadcast network WiFi ><IDENT-XRP
your that address IP the change may you network), own your to it connect to example, (for
the update and file build.gradle the open this, do To XRP. the to connect to uses program
address. IP appropriate the to line wpi.sim.envVar

Host Client XRP the Sets//

true = defaultEnabled.)(addXRPClient.sim.wpi

)Ctrl+Shift+P (type Palette Command WPILib the open code, robot XRP your start to Now
.F5 press or Code", Robot "Simulate select and



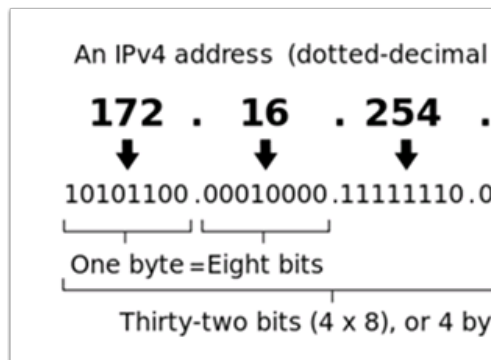
accelerometer and gyro the see and up pop GUI simulation the see should you well, goes all If
updating. values
running! now is code XRP Your

roboRIO Station Driver

41.1 יסודות הרשתות

41.1.1 מהי כתובת IP?

כתובת IP היא סדרת 4-ספרות (הנקראות "אוקטטים") המיושבות ב-255.0-0.0.0.0. כל כתובת IP יכולה להיות כתובת של שרת, כתובת של מחשב, כתובת של רשת, וכו'.



As shown above, each IP address means this, 32-bit address. However, nearly all of these addresses are used by publicly accessible web servers.

This brings up our **first key point** of IP Addressing: Each device on the network must have a unique IP address. No two devices can have the same IP address, otherwise collisions will occur.

כל כתובת IP יכולה להיות כתובת של שרת, כתובת של מחשב, כתובת של רשת, וכו'. כתובת IP היא סדרת 4-ספרות (הנקראות "אוקטטים") המיושבות ב-255.0-0.0.0.0. כל כתובת IP יכולה להיות כתובת של שרת, כתובת של מחשב, כתובת של רשת, וכו'.

41.1.2 כתובות IP ציבוריות לעומת פרטיות

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	ביטים	כתובת התחלה	כתובת סיום	מספר כתובות
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.

assigned? addresses these are How 41.1.3

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

DHCP? מהו שרת

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

localLink- is What 41.1.4

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-ב IP כתובות 41.1.5

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:

Ports Network Available

ports. network available regarding information for Manual Game 2024 the of R704 see Please

mDNS 41.1.6

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? זה מה

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-א 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 41.1.7

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 41.1.8

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

סיכום 41.1.9

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

41.2 קונפיגורציות IP

הערה: כל המידע בדף זה מיועד למטרת לימודית בלבד. אין להשתמש בו לצורכי תשלום, פרסום או כל מטרה אחרת. כל הזכויות שמורות.

41.2.1 הסימון TE.AM עבור IP

הסימון TE.AM מיועד לסימון כתובות IP של המכשירים. הסימון מורכב מ-10, TE, AM, 2. הסימון מיועד לסימון כתובות IP של המכשירים.

10.TE.AM.2 :הסימון

10.0.12.2 - 12 הסימון

10.1.22.2 - 122 הסימון

10.12.12.2 - 1212 הסימון

10.12.2.2 - 1202 הסימון

10.12.20.2 - 1220 הסימון

10.34.56.2 - 3456 הסימון

41.2.2 על המגרש

המגרש מיועד לסימון כתובות IP של המכשירים. המגרש מיועד לסימון כתובות IP של המכשירים.

קונפיגורציות DHCP במגרש

10.TE. AM.20 gateway default- 255.255.255.0 mask subnet 10.TE.AM.199 10.TE.AM.4 .10.TE.AM.200 gateway- 255.255.0 mask subnet 10.TE.AM.219 10.TE.AM.200 .10.TE.AM.1

- radio ACOM5P- ANOM5P- OpenMesh 10.TE.AM.1 - Kiosk
- roboRIO - Radio Robot- 10.TE.AM.2
- DHCP - Station Driver 10.TE.AM.X ("IP address")
- DHCP - (IP address) 10.TE.AM.Y` `` Radio Robot-
- DHCP - (IP address) 10.TE.AM.Z Radio Robot-

- 100% 100% 100%**

- _____

Troubleshooting Network roboRIO 41.3

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 41.3.1

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

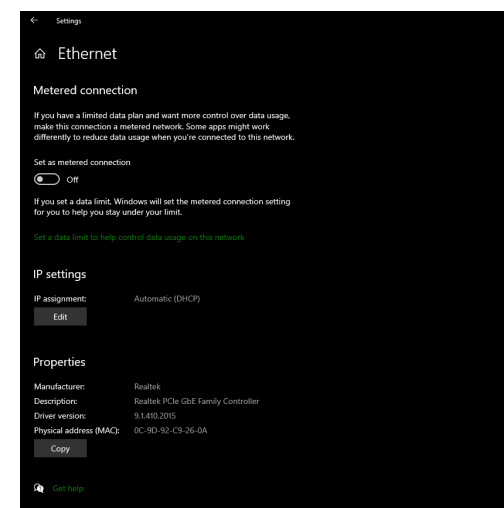
Address IP roboRIO the Ping 41.3.2

command the using)*Notation IP TE.AM*(10.TE.AM.2 ping ping 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 41.3.3



network the with issue an have may you fails, directly address IP the pingging 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

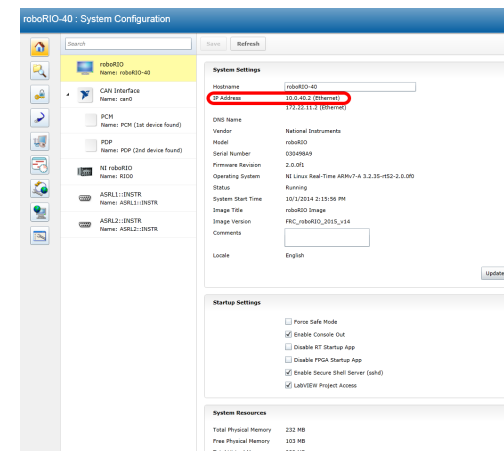
Troubleshooting Connection USB 41.3.4

IP roboRIO's the pingging 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 connection. USB the for needed

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 •

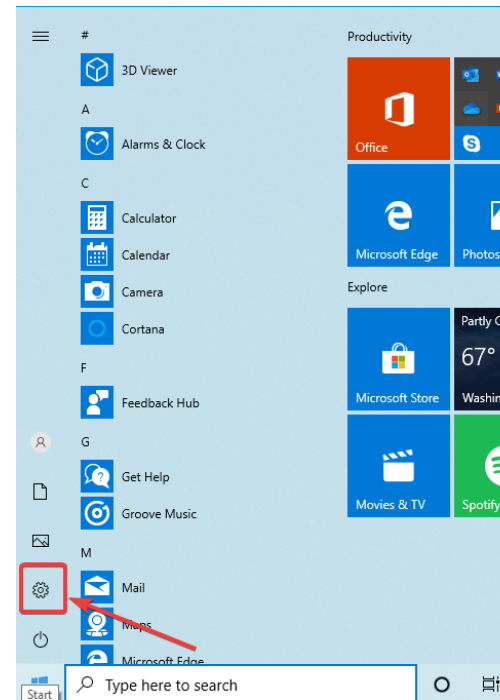
Connection Ethernet 41.3.5



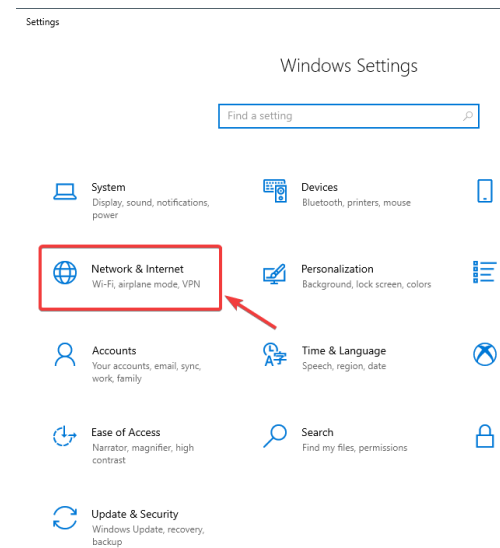
that sure make first to helpful be may it connection, Ethernet an troubleshooting are you If open connection, USB the Using connection. USB the using roboRIO the to connect can you ethernet the on address IP an has roboRIO the that verify and *webdashboard roboRIO* the 169.*. assignedself- a be should 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 41.3.6

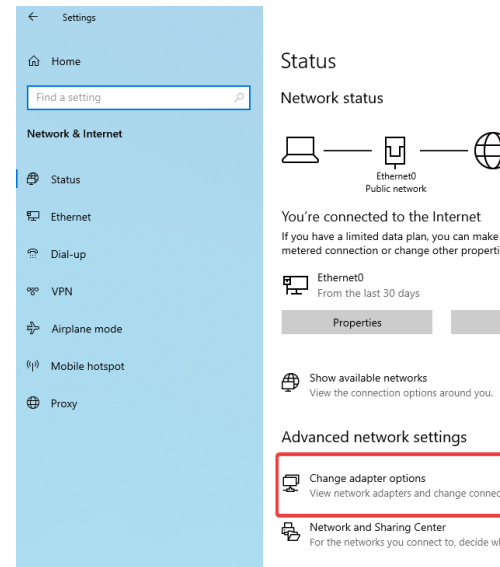
the putting or button physical a with off adapters the turning as same the always not is This
adapters. disable to how on detail more provide steps following The mode. airplane into PC



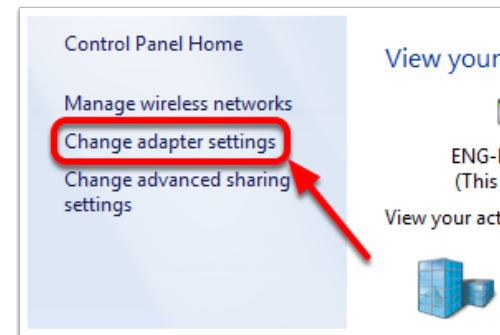
icon. settings the on clicking by application Settings the Open



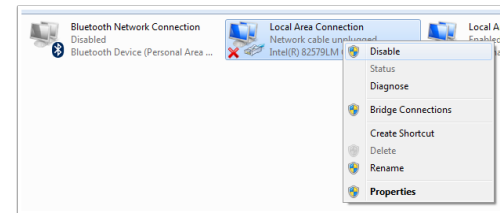
category. *Internet & Network* the Choose



Click on Change adapter options



On the left pane, click Change Adapter Settings.



For each adapter other than the one connected to, click the radio button on the right to turn it off. Select *Disable* from the menu.

Proxies 41.3.7

• Having Proxies. proxy enabled may cause issues with the roboRIO networking.

Configuration Firewall Windows 41.4

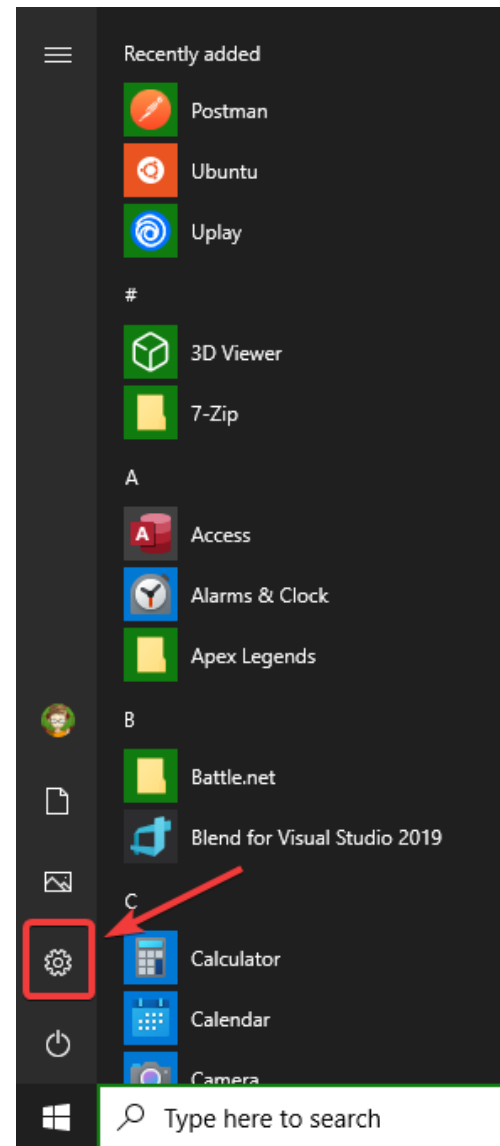
reasons. various for access network need FRC® in used tools programming the of Many with interfere potentially may Firewall Windows the configuration, exact the on Depending programs. these of more or one for access this

Firewall Windows Disabling 41.4.1

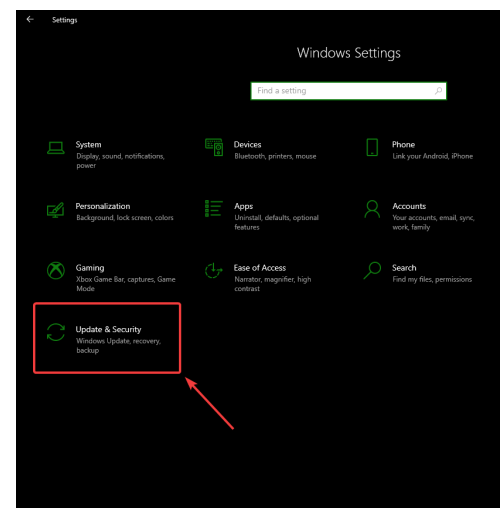
note Additionally PC. the to privileges administrator requires firewall your Disabling :□□□□ internet. the to connect that computers for recommended not is firewall the disabling that

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

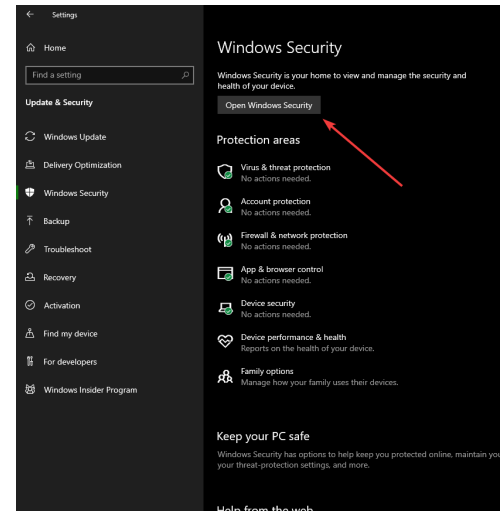
Settings >- Start Click



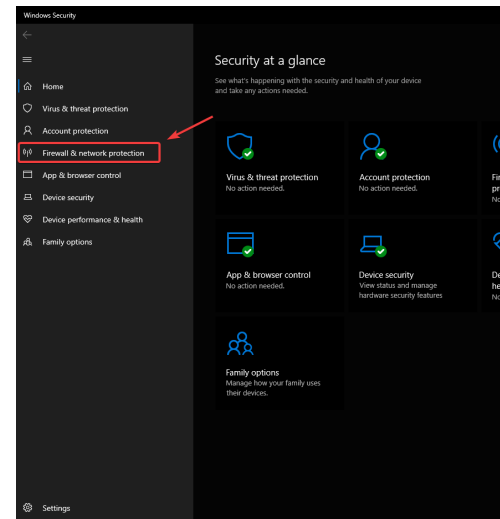
Security & Update Click



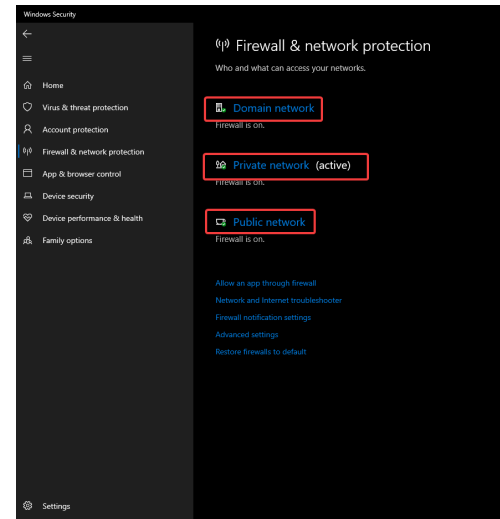
Security Windows Open select pane, right the In



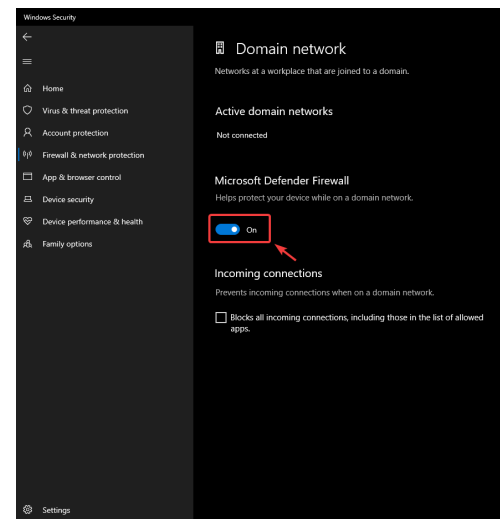
protection network and Firewall select pane, left the In



options highlighted the of **each** on Click



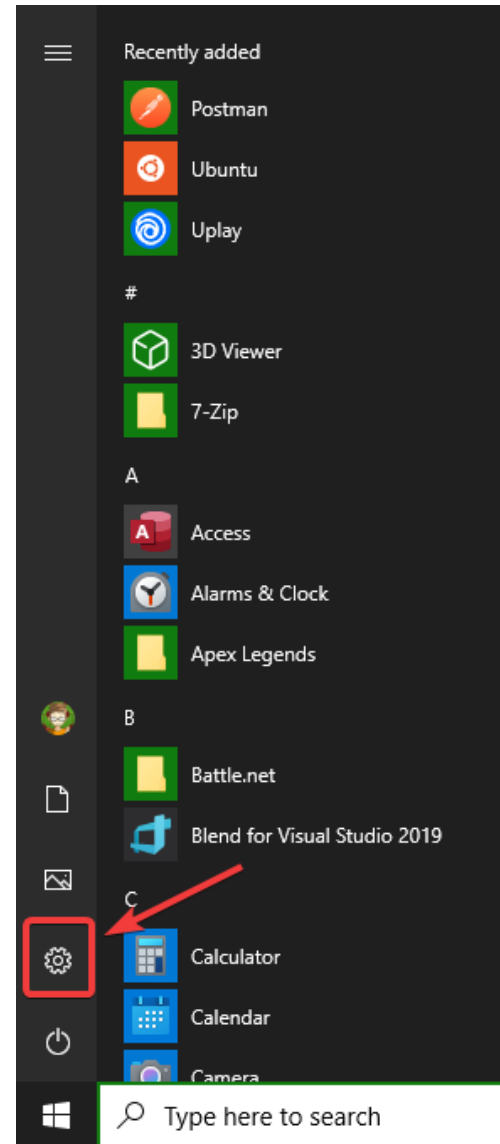
off. it turn to toggle **On** the on click Then



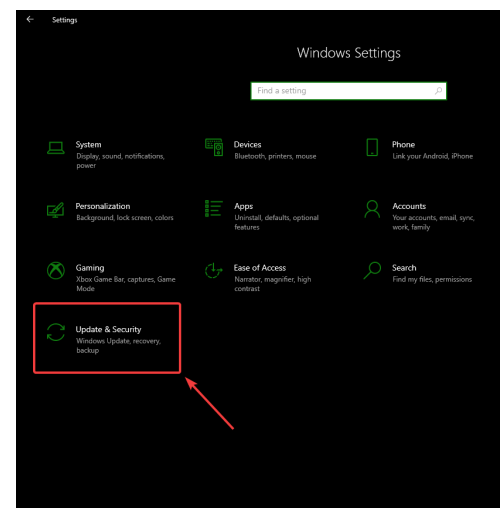
Apps Whitelisting 41.4.2

having are you programs FRC any for Firewall the to exceptions add can you Alternatively, with. issues

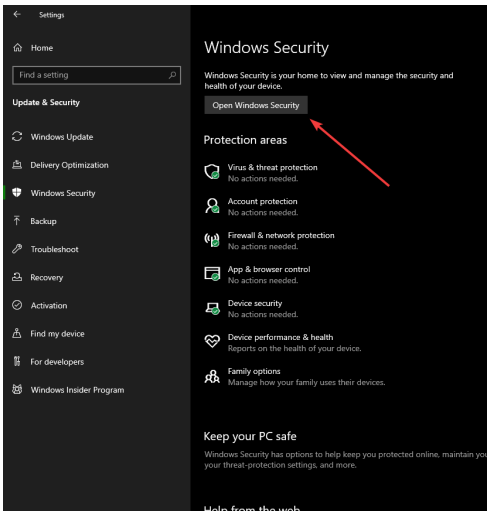
Settings >- Start Click



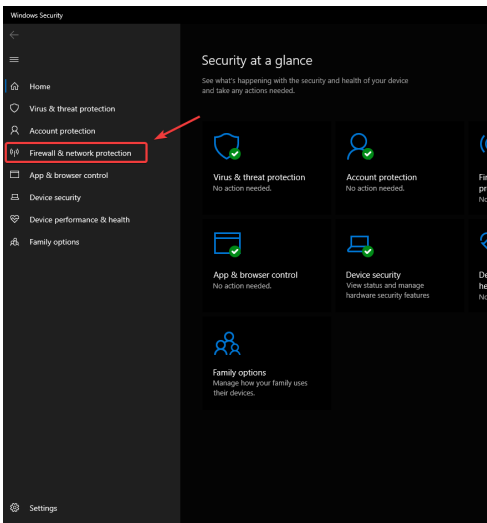
Security & Update Click



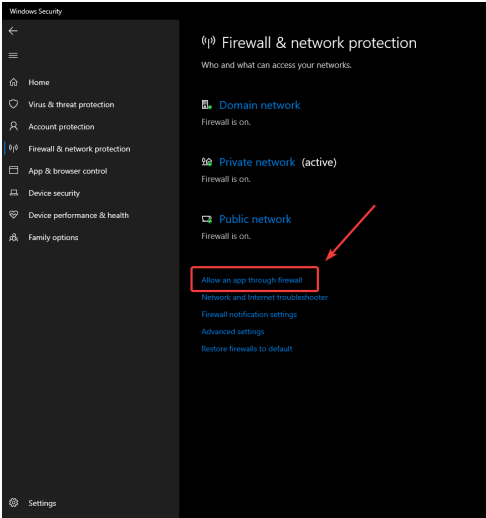
Security Windows Open select pane, right the In



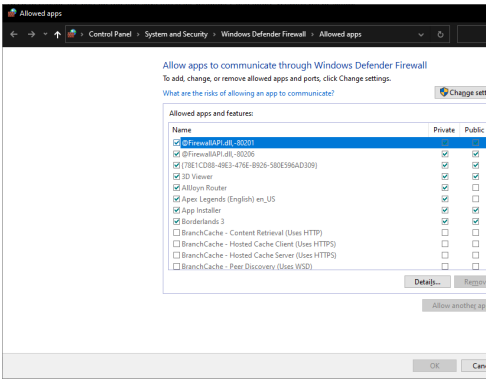
protection network and Firewall select pane, left the In



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 41.5

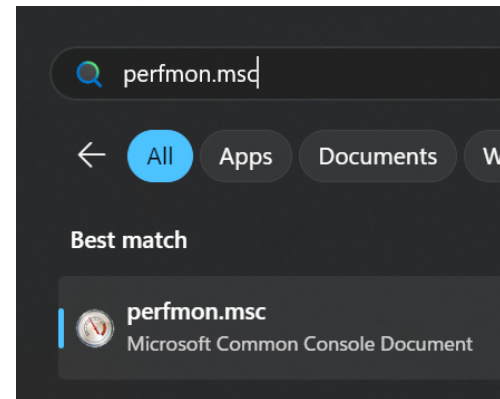
2024 the in R704 (see bandwidth network limited allocated is team each Field FRC® the On bandwidth the determining on information more provides *Whitepaper FMS The manual*). bandwidth overall their measure to wish may teams some but camera, Axis the of usage measurement. that make to how details document 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 41.5.1 (7/10

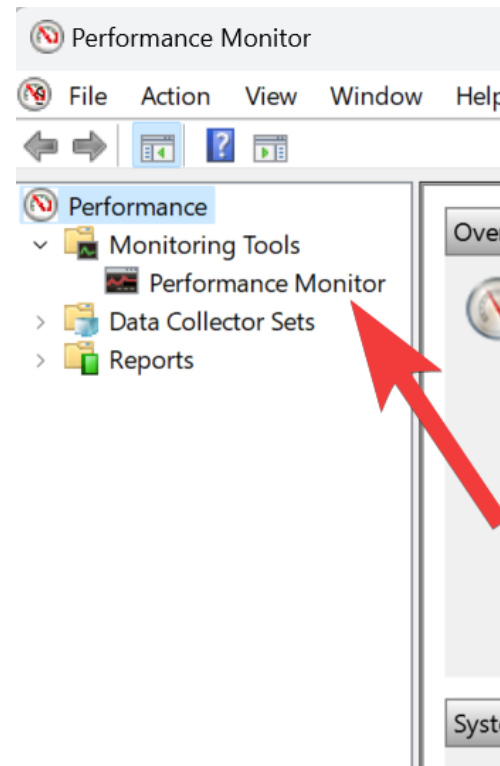
monitor to used be can that Monitor Performance the called tool inbuilt- a contains Windows interface. network a over usage bandwidth the

Monitor Performance the Launching



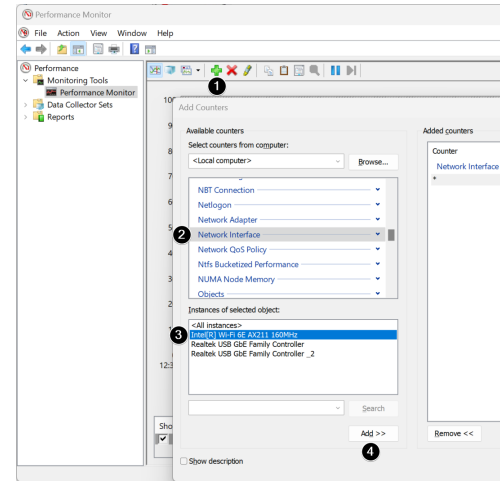
Enter. press and perfmon.msc type box, search the in and menu Start the Open

Monitor TimeReal- Open



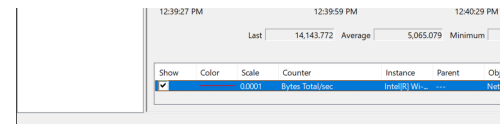
monitor. timereal- the display to *Monitor Performance* click pane, left the In

Counter Network Add



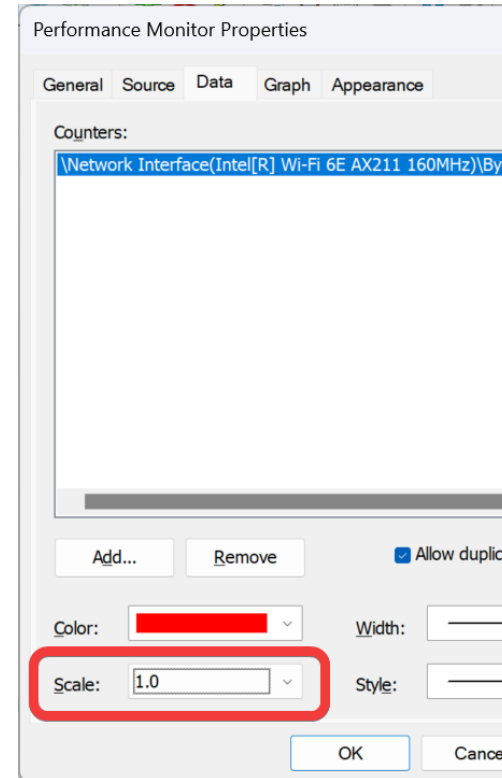
Click the green plus sign near the top of the screen to add a counter. 1.
 In the left pane, locate and click on 'Network Interface' to select it. 2.
 In the left pane, locate and click on 'All instances' (or the desired network interface) to select it. 3.
 Click the '>> Add' button in the bottom right pane. 4.
 Click the 'OK' button in the bottom right pane to add the counter to the graph. 5.

Counters Extra Remove



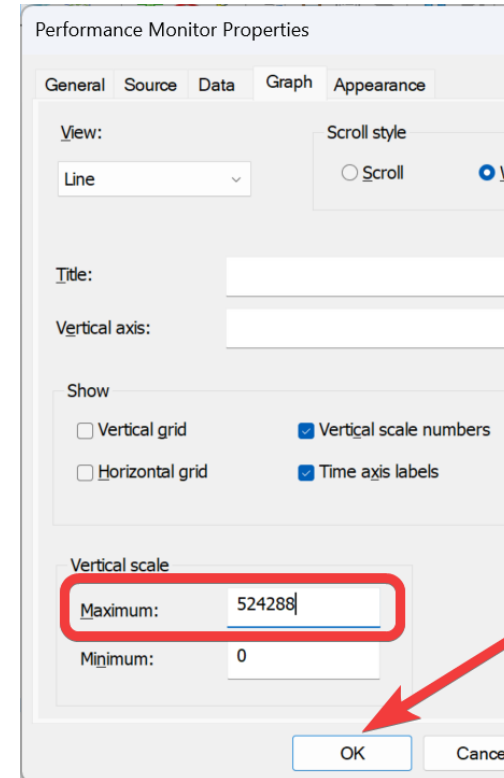
In the bottom pane, select each counter other than 'Total/sec Bytes'. Press the delete key. The only entry remaining in the pane should be 'Total/sec Bytes'.

Properties Data Configure



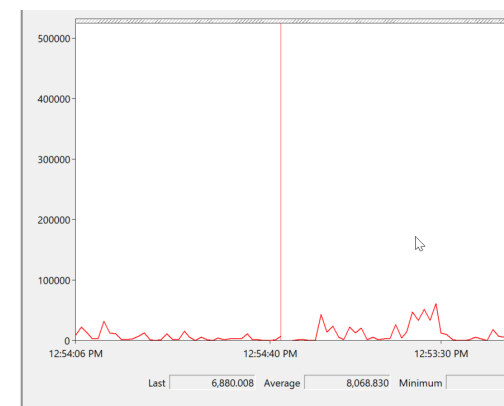
and Scale to next dropdown the on Click window. Properties the up bring to Ctrl+Q Press
tab. *Graph* the on click Then .1.0 select

Properties Graph Configure



to converted Megabits 4 is (this 524288 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

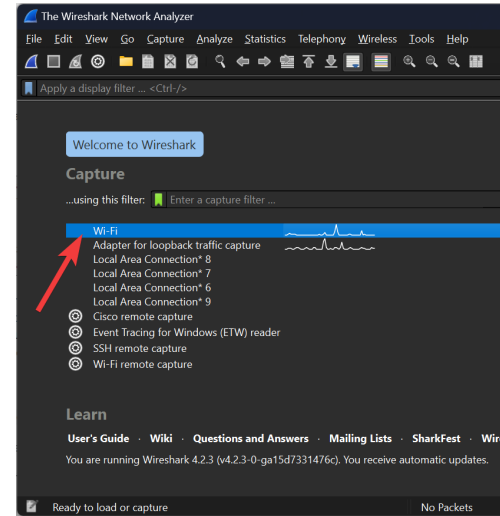


haven't you (if interface selected the over normal as robot your to connect now may You with connection, the of usage bandwidth total the show will graph The already). so done also are values Max and Min Average, Last, The graph. the of top the at cap bandwidth the meaning Bytes/Second in are values these that Note graph. the of bottom the at displayed ~100000 at line flat a see should you open Station Driver the just With 524,288. is cap the Bytes/Second.

Wireshark using Usage Bandwidth Measuring 41.5.2

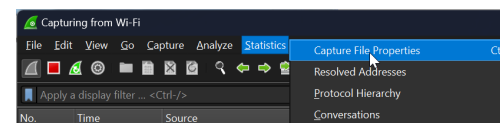
monitor to program party 3rd a install to need will you monitor, performance use not can you If Download Wireshark. is purpose this for used be can that program One usage. bandwidth After .page this from Windows of version your for Wireshark of version latest the install and robot, your to computer your Connect Wireshark. open and locate complete, is installation using. be may you programs custom or Dashboard any and Station Driver the open

capture Start and interface the Select



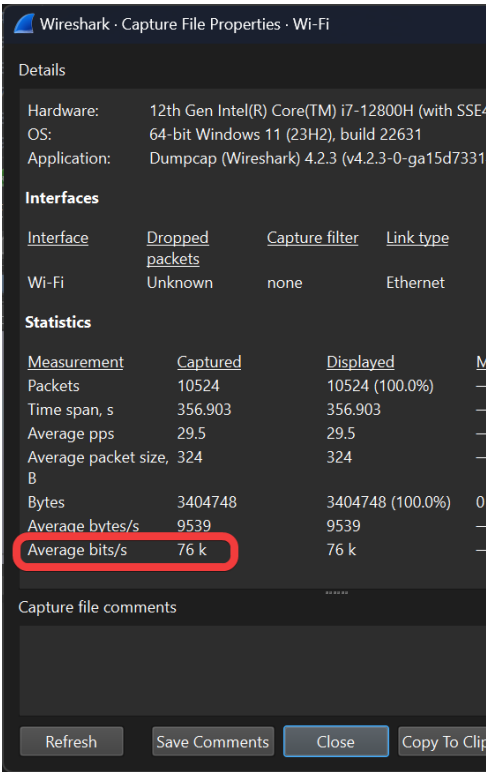
connect to using are you interface the click double side, left the on program Wireshark the In robot. the to

Properties File Capture Open



.Properties File Capture then Statistics click then minute, 1 least at for run capture the Let

Usage Bandwidth View



window. the of bottom the near displayed is bits/second in usage, bandwidth Average

Modification Radio ACOM5P- 41.6

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 41.6.1

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

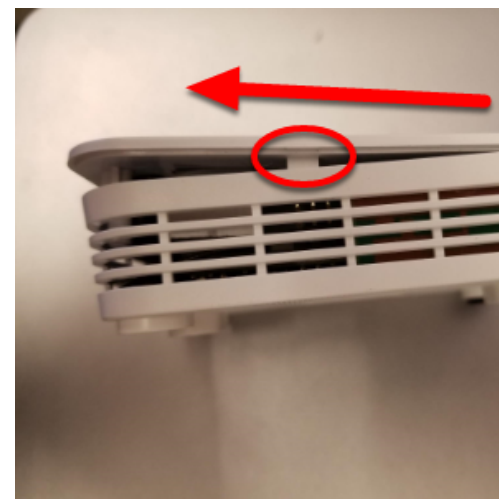
Latches Side



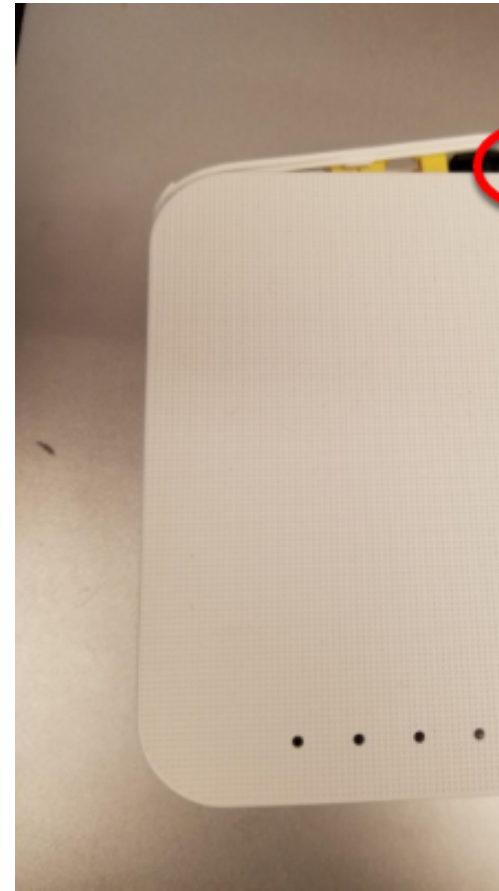
see can (you edge long each of middle the near radio the of lid the on latch small a is There slide tool, thin very or fingernail a Using picture). next the in clearly more latches these radio, the of middle the towards back to front from case and lid the between gap the along (note: side other the on 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

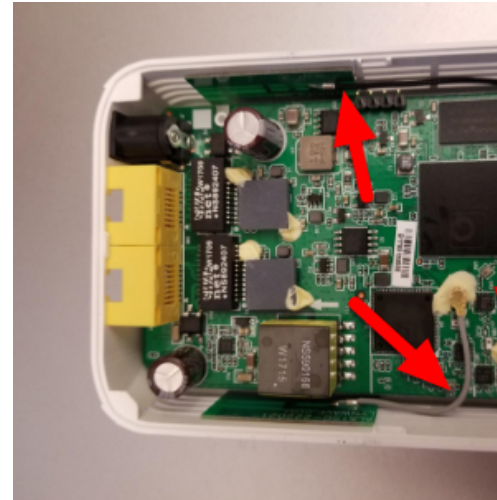


case the hit holders screw the until slightly) (lifting forward it slide lid, the removing begin To
this. doing while areas latch the on pressure apply to need may (you front



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
body. the from away completely lid the lift

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 41.6.2



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- 41.6.3

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 •



Forwarding Port 42.1

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 42.1.1

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 wpinet
```

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 42.1.2

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 wpinet
```


Process Release 43.1.2

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 43.1.3

branch main the to point should They GitHub. on repo docsfrc- the to made be should PRs
.stable not and

Content New Creating 43.1.4

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

Repository.- Repository. FIRST WPILib. .

Tabs 43.2.8

use can You directive. code:: -set-tab .. the use can you article, an in tabs code create To
is: format The inside. directives rli and block-code

```

::tab-set-code ..
https://raw.githubusercontent.com/wpilibsuite/allwpilib/v2024.3.2/ ::rli ..
wpilibjExamples/src/main/java/edu/wpi/first/wpilibj/examples/ramsetecontroller/ ↪
Robot.java ↪
java :language:
44-61 :lines:
:linenos:
44 :lineno-start:

c++ ::code-block ..
timer. the Start //
m_timer.Start();

SmartDashboard. to Field2d Send //
frc::SmartDashboard::PutData(&m_field);

trajectory. the of pose starting the to odometry s'drivetrain the Reset //
m_drive.ResetOdometry(m_trajectory.InitialPose());

Field2d. to trajectory generated our Send //
m_field.GetObject("traj")->SetTrajectory(m_trajectory);

```

tabs, text or language, per RLI multiple language, per tab one than more use to need you If
is: format The directive. item:: -tab .. and set:: -tab .. the use can you

```

::tab-set ..

Title ::tab-item ..
sync-id :sync:

Content

```

synced be to key same the with tabs the of all allow to argument sync the uses example This
open. will key same the with tabs the of all tab, a on click you when that means This together.

by them sync can you page, a on directives code-set-tab and set-tab of mix a have you If
tab java a example, For .LANGUAGE-tabcode to directives item-tab the on id sync the setting
.java-tabcode of id sync a have would

אזהרות 43.2.9

There itself. admonition the as line same the on text their have should)here (list Admonitions
an of inside content of sections multiple having when however, rule, this to exceptions are
not is admonition an of inside content of sections multiple having Generally admonition.
recommended.

```
:[] [] [] [] []
```

```
warning! a is This ::warning ..
```

43.2.10 קישורים

Links Internal

section and filename ReStructuredText the on based generatedauto- be will Links Internal title.

documents. and sections to link to ways several are here example, For 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``

paths relative use can You document. a of leveltop- the reference to format this Use
a put paths, absolute use to Or `../../../../` to renders `instructions-build`:doc:
`apis/sensors/-docs/software/hardware/` :doc:` path the of beginning the at slash forward
the is rendered text the that Note `.Software - Ultrasonics` to renders `software-ultrasonics`
filename. target the of regardless page target the of title section main

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

```
cool! pretty s'it and `https://example.com>< link a is this` there, Hi |
```

. 000000 000000 000000 , 000000 0000 000000 000000 000000 00 0000 00000000 000000 , 000 00

```
cool! pretty s'it and `link a is this` there, Hi
```

https://example.com link: a is this ..

43.2.15 הערה חשובה!

התהליך של בניית הדפים מתבצע באופן אוטומטי. אם אתם רוצים לבדוק את התהליך, אתם יכולים להשתמש ב-`docsfrc` כדי לבדוק את התהליך.

43.3 הנחיות בנייה

התהליך של בניית הדפים מתבצע באופן אוטומטי. אם אתם רוצים לבדוק את התהליך, אתם יכולים להשתמש ב-`docsfrc` כדי לבדוק את התהליך.

43.3.1 דרישות מקדימות

התהליך של בניית הדפים מתבצע באופן אוטומטי. אם אתם רוצים לבדוק את התהליך, אתם יכולים להשתמש ב-`docsfrc` כדי לבדוק את התהליך.

IDE / Editors Text

reStructuredText the with along Code VS use you that recommend we development, For work. will editor text any However, .extension

As enabled. features doc8 all with linting enables extension reStructuredText the default, By settings. json Code VS your to following the add lint, length line the follow not does docsfrc-linting. length line disable to

```
[ :restructuredtext.linter.doc8.extraArgs""
    "D001" ignore--"
]
```

Windows

required only are they HTML, building for required not are convert - rsvg and MiKTeX :התהליך builds. PDF Windows for

3.9 Python •

Perl •

PDF) (התהליך של בניית הדפים מתבצע באופן אוטומטי) MiKTeX •

builds) PDF for needed (Only convert rsvg- •

Python. התהליך של בניית הדפים מתבצע באופן אוטומטי. אם אתם רוצים לבדוק את התהליך, אתם יכולים להשתמש ב-`docsfrc` כדי לבדוק את התהליך.



docs.frc- Powershell. Python, source/requirements.txt r- install pip : running then directory, docsfrc- the to navigating by packages MikTeX missing the Install require packages verbose-- miktex Powershell: from command following the packages.txt-miktex file-id-package--

(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 →
```

בנייה 43.3.2

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:
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
```


עדכון תלות נסתר

.lock poetry command: following the Run

43.4 הנחיות שמירת Draw.io

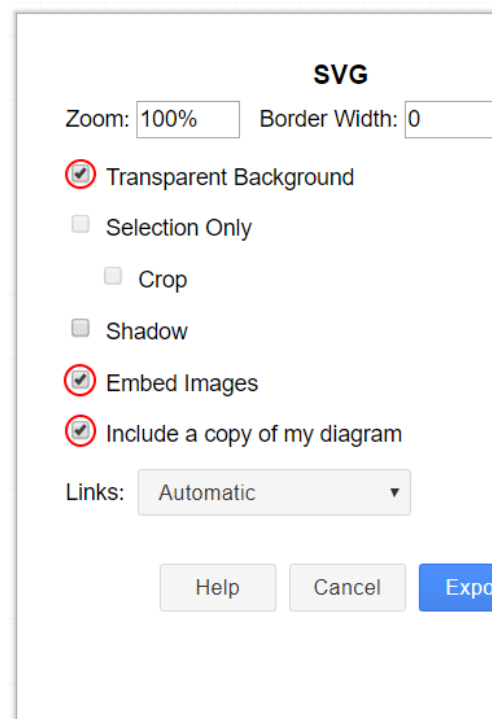
Make sure you don't modify any file in that folder, or ends in .svg; otherwise you might risk breaking the metadata of the file, making it uneditable. In draw.io, any other program than draw.io might risk breaking the metadata of the file, making it uneditable.

Draw.io (https://draw.io) is a free online diagram tool. It allows you to create and edit diagrams in a web browser. You can also download your diagrams as SVG files. However, there are some limitations when using the desktop version of Draw.io. For example, the desktop version does not support the 'Export as SVG' option. This is because the desktop version uses a different rendering engine than the web version. As a result, the desktop version cannot export diagrams as SVG files with all the features and metadata that the web version can. Therefore, if you want to export your diagrams as SVG files, you should use the web version of Draw.io.

There are a few methods to save a diagram with metadata, but using the 'Export as SVG' option in the web version is the preferred method. This is because it allows you to embed the diagram in an image, which is a more reliable way to preserve the metadata. The desktop version does not support this method, so you cannot export your diagrams as SVG files with all the features and metadata that the web version can.

draw.io desktop version does not support the 'Export as SVG' option. This is because the desktop version uses a different rendering engine than the web version. As a result, the desktop version cannot export diagrams as SVG files with all the features and metadata that the web version can. Therefore, if you want to export your diagrams as SVG files, you should use the web version of Draw.io. The web version allows you to export your diagrams as SVG files with all the features and metadata that the web version can. This is because the web version uses the same rendering engine as the desktop version, but it also supports the 'Export as SVG' option. Therefore, if you want to export your diagrams as SVG files, you should use the web version of Draw.io.

draw.io desktop version does not support the 'Export as SVG' option.



draw.io desktop version does not support the 'Export as SVG' option.

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 文档 - 文档 (zh_CN), 文档 - 文档 文档 文档文档 (tr_TR). 文档 - 文档 (fr_CA) 文档 -
 文档文档 文档 文档文档 文档 文档 .葡萄牙 文档 (pt_BR) 文档 - 文档文档 (he_IL),
 文档 文档 文档 文档 ,葡萄牙 文档 文档 文档 .葡萄牙 文档 文档 文档 文档 文档 文档 文档 文档
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43.5.4 דיוק

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 .000000 0000 0000 000000 0000 000 0000 **.docsfr-** 00 Repository-0 Issue 00 PR

43.6 מתרגמים מובילים

43.6.1 סינית

- Dhc 8192 •
Zhang Atlas •
Gong Jiangshan •
Kesetery •
Zhao Michael •
Huang Ningxi •
Xin Ran •
5308 Team •
Wu Tianrui •
Zhang Tianshuang •
Sun Xun •
Zhao Yitong •
Li Yuhao •
田 田 •
田 田 •
田 田 •
田 田 •
田 田 •
田 田 •
Sherry 田 •

43.6.2 צרפתית

Schneider Alexandra •
Theberge Andre •
Chang Andy •
Shalit Austin •
Smith Dalton •
Renaud Daniel •
Beaulac Étienne •
Giffard Félix •
Kenwell Kaitlyn •
Bedard Luna Laura •
Lalonde Marc •
Regimbald Martin •
Rioux Martin •
Bekale Regis •
D.G.- Sami •
Lavoie Sidney •
Marcellus Youdlain •

43.6.3 פורטוגזית

Wilmsen Carolina Amanda •
Oliveira Bibiana •
Osio Bruno •
Toso Bruno •
Silveira Gabriel •
Ribeiro Amaral Do Tomaz Gabriela •
Steinmeier Günther •
Carvalho Luca •
Francisco Fontes Lucas •
Gisse Grabin Eduarda Maria •
Chanan Timm Heitor Matheus •
Ramos Miguel •
Ramos S. Miguel •
Tristão Feijó Natan •
Santiago Nathany •

Pellicioli Dias Henrique Pedro •
Novo Anholon Rodrigo •
Silva Almeida De Dias Tales •
Castro Vinícius •
Silva Da Gabriel Vinícius •

ספרדית 43.6.4

Shalit Austin •
Ernesto Cesar •
Ramos Diana •
Rangel Lozano Diego •
Reveles Fernanda •
Soltero Fernando •
Verástegui Gibrán •
Sepúlveda Heber •
Gutierrez Heriberto •
Espino Hugo •
Luis_Hernández •
Mariano •
Adame León De Angel Miguel •
Gutiérrez Ariel Óscar •
Maynez Paulina •
Cote Pierre •
Acosta Rodrigo •
Sosa Hernandez Román •
Fernandez Sofia •
Moreno Zara •

טורקית 43.6.5

Bilgin Hasan •
Alkaya Müfit •
Özemre Esra •
Oktemer Ceren •
T Demet •
Tumkaya Demet •

Serdaroğlu Lal •
Aldeniz Melis •
Uslu Çağan •
Ünlü Duru •
Ünay Arhan •
Zagyapan Ada •
Akdoğan Doruk •
Alkaya_3390 Müfit •
Şengel Mayra •
Özer Tuna •
Hatipoğlu Duru •
Akın Elif •
Yiğit Ece •
Köşkeroğlu Serra Nesrin •

עברית 43.6.6

Radzin Aric •
Smith Dalton •
Ziv Itay •
Ashery Ofek •
Grossman Shai •
Starlight220 •
Shlomi Yotam •



WPILib. FRC® :
: WPILib. FRC®

allwpilib Repository-
allwpilib Repository-

44.1 התחלה מהירה

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 •

44.2 Repository ליבה

44.3 NetworkTables

577 ,entry
577 ,enumeration
577 ,EPA
1210 ,error
577 ,programming drivenevent-
1210 ,search exponential
1210 ,smoothing exponential

F

577 ,FIRST
577 ,FLL
577 ,point floating
577 ,FMS
577 ,FPGA
578 ,FRC
578 ,FTA
578 ,FTC

G

1210 ,gain
1210 ,distribution Gaussian
578 ,GDC
578 ,GP
1210 ,gradient
578 ,GradleRIO

H

1210 ,state hidden

I

578 ,I2C
578 ,programming imperative
578 ,IMU
1211 ,input

J

578 ,Java
578 ,JSON

K

578 ,KOP

A

575 ,AM
575 ,AprilTags

B

575 ,EMFback-
1209 ,control bangbang-
575 ,boolean

C

576 ,C++
575 ,CAD
575 ,stack call
575 ,CAM
575 ,CAN
1209 ,system coordinate Cartesian
69 ,CC
576 ,CD
576 ,theorem limit central
1209 ,losses churning
576 ,CIM
576 ,Mechanics Classical
576 ,composition
1209 ,effort control
1209 ,law control
1209 ,signal control
1210 ,controller
1210 ,convolution
1210 ,force electromotivecounter-
576 ,CRTP
576 ,CSA
576 ,CTRE
1210 ,current
69 ,CXX

D

576 ,programming declarative
576 ,injection dependency
1210 ,derivative
577 ,pattern design
577 ,DHCP
1210 ,dynamics

E

577 ,encapsulation

581 ,valve solenoid
 581 ,SPI
 1212 ,state
 581 ,machine state
 1213 ,robust statistically
 1213 ,error statesteady-
 1213 ,input step
 1213 ,response step
 581 ,subscriber
 1213 ,system
 1213 ,identification system
 1213 ,response system

T

581 ,TBA
 581 ,telemetry
 582 ,topic
 582 ,torque
 582 ,transitory

V

1213 ,drag viscous
 1213 ,voltage
 582 ,VRM

W

582 ,WCP
 582 ,WFA

X

1213 ,dotx-
 1213 ,hatx-



575 ,□□□□□□□□
 578 ,□□□□'□
 576 ,□□□□□□ □□□□
 582 ,□□□□□□
 578 ,□□□□□□
 575 ,□□□□□□ □□
 576 ,COTS □□□□□□
 582 ,□□□□□□
 578 ,KOP □□□□□□
 □□□□□□ □□□□□□
 69 ,CC
 69 ,CXX
 581 ,□□□□□□□□□□

L

579 ,LabVIEW
 1211 ,regression squaresleast-
 579 ,LED
 1211 ,LQR

M

579 ,mass
 1211 ,measurement
 1211 ,model
 579 ,inertia of moment
 579 ,mutable
 579 ,MXP

N

579 ,NetworkTables
 579 ,opno-

O

1211 ,observer
 579 ,odometry
 579 ,OPR
 1211 ,orthogonal
 1211 ,output

P

579 ,PCM
 579 ,PDH
 579 ,PDP
 579 ,motor DC magnetpermanent-
 580 ,persistent
 580 ,PH
 1211 ,portrait phase
 1212 ,PID
 1212 ,plant
 580 ,pose
 580 ,estimation pose
 1212 ,variable process
 580 ,property
 580 ,publisher
 580 ,PWM
 580 ,Python
 Proposals Enhancement Python
 69 ,600 PEP

R

1212 ,squaredr-
 580 ,RAII
 580 ,composition recursive
 1212 ,reference
 580 ,retained
 580 ,reflectionretro-
 580 ,REV
 1212 ,time rise
 1212 ,RMSE
 581 ,RPM
 581 ,RSL

S

581 ,serialized
 1212 ,setpoint
 1212 ,time settling
 1212 ,function signum
 581 ,library software