TALON SRX Software Reference Manual

Revision 1.26

Cross The Road Electronics

www.ctr-electronics.com

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TO OUR VALUED CUSTOMERS

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1. CAN bus Device Basics

Talon SRX, when used with CAN bus, has similar functional requirements with other FRC supported CAN devices. Specifically, every Talon SRX requires a unique device ID for typical FRC use (settings, control and status). The device ID is usually expressed as a number between ‘0’ and ‘62’, allowing use for up to 63 Talon SRXs at once. This range does not intercept with device IDs of other CAN device types. For example, there is no harm in having a Pneumatics Control Module (PCM) and a Talon SRX both with device ID ‘0’. However, having two Talon SRXs with device ID ‘0’ will be problematic.

Talon SRXs are field upgradable, and the firmware shipped with your Talon SRX will predate the “latest and greatest” tested firmware intended for FRC use. Firmware update can be done easily using the FRC roboRIO Web-based Configuration.

Talon SRX provides two pairs of twisted CANH (yellow) and CANL (green) allowing for daisy chaining. Unlike previous seasons, the CAN termination resistors are built into the FRC robot controller (roboRIO) and in the Power Distribution Panel (PDP) assuming the PDP’s termination jumper is in the ON position.

More information on wiring and hardware requirements can be found in the **Talon SRX User’s Guide**.

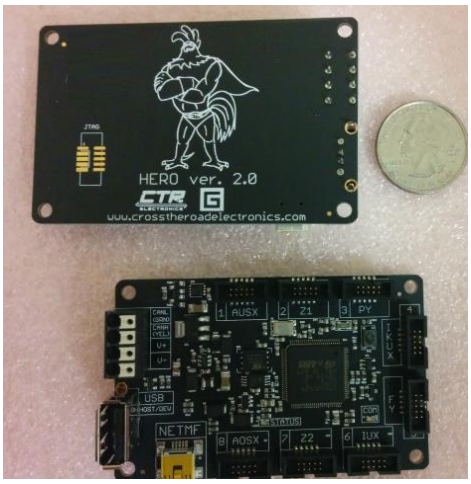
1.1. Supported Hardware Platforms

1.1.1. Cross The Road Electronics HERO Control System

The CTR HERO Control System board allows developers to utilize all features of the Talon SRX. It is meant for education, custom development, and integration of Talon SRX into existing applications.
The HERO also provides a method for field upgrading Talons to non-FRC firmware. It is the ideal development kit for learning and integrating the Talon into custom applications!

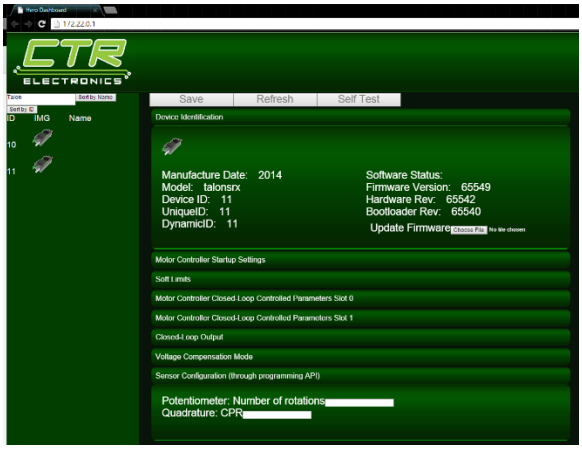
Applications are developed in Visual Studio 2015 (C#, VB, managed-C++) using .NETMF framework.

Be sure to look for the  for HERO related tips.



1.1.1.1. HERO Web-based Configuration (coming soon)

Hero supports an internal web-page with setting configuration and field-upgrade capability.



1.1.2. roboRIO FRC Control System

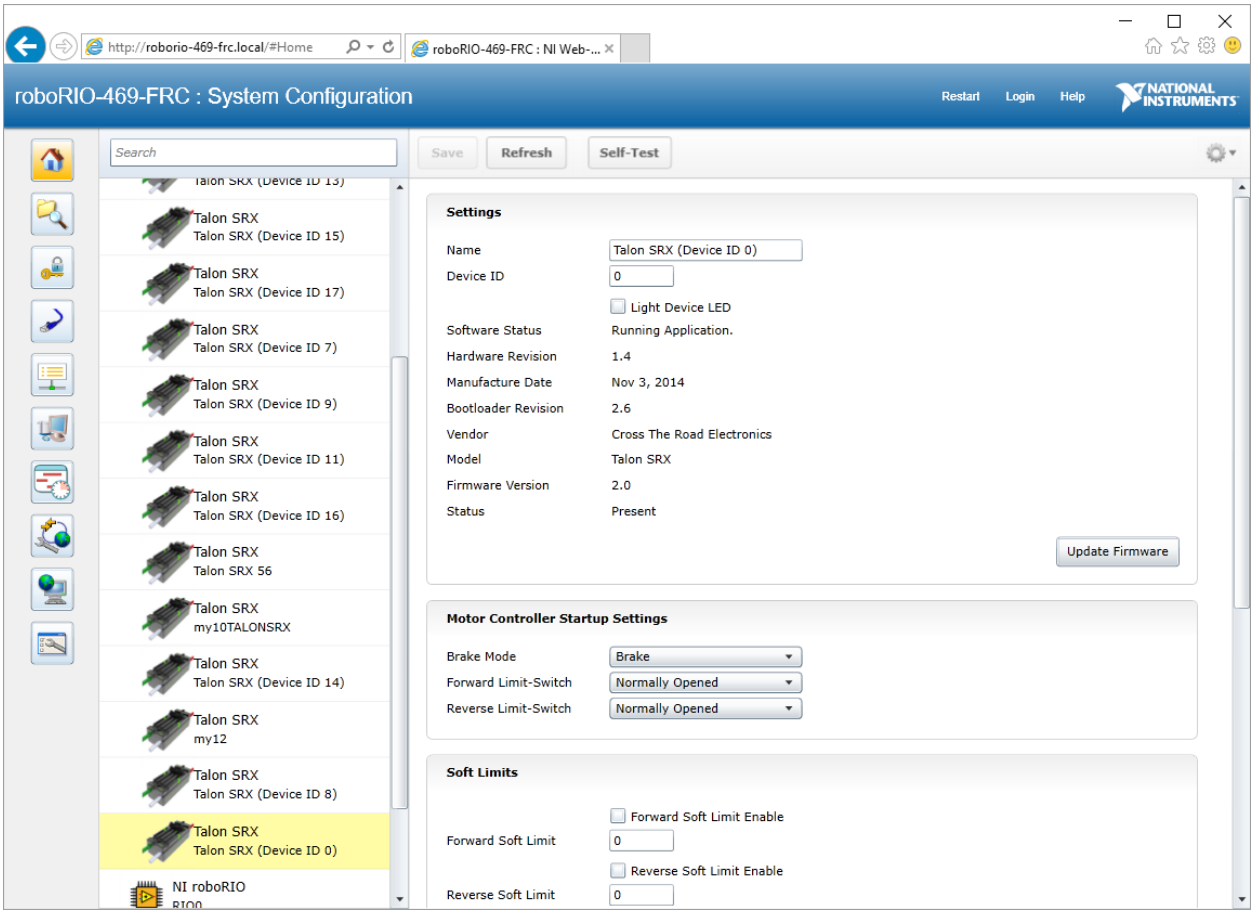
The only legal robot controller for FRC competition. This requires the FRC version of Talon SRX firmware. The roboRIO supports CAN bus and provides a Web-based configuration for re-flashing and diagnostics.

Be sure to look for the  for FRC related tips.

2. roboRIO Web-based Configuration: Firmware and diagnostics

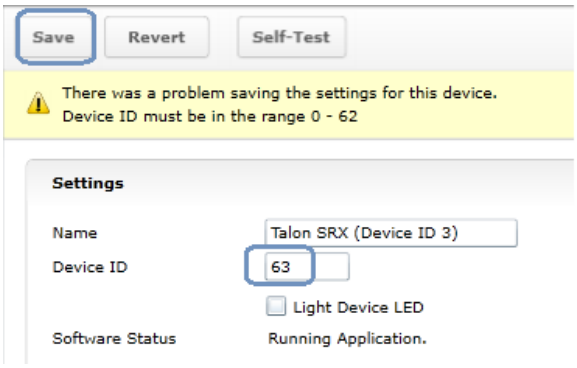
A useful diagnostic feature in the FRC Control system is the roboRIO's Web-based Configuration and Monitoring page. This provides diagnostic information on all discovered CAN devices, including Talon SRXs. Talon SRXs can also be field-upgraded using this interface. This feature is accessible by entering the mDNS name of your robot in a web browser, typically **roborio-XXXX-frc.local** where XXXX is the team number (no leading zeros for three digit team numbers).

Because **Chrome** no longer supports NPAPI, **Silverlight will not function**.
Internet Explorer functions adequately though refreshing the page (F5 or CNTRL+R) often leaves an empty page. The workaround is to simple create a new tab with the same URL.



2.1. Device ID ranges

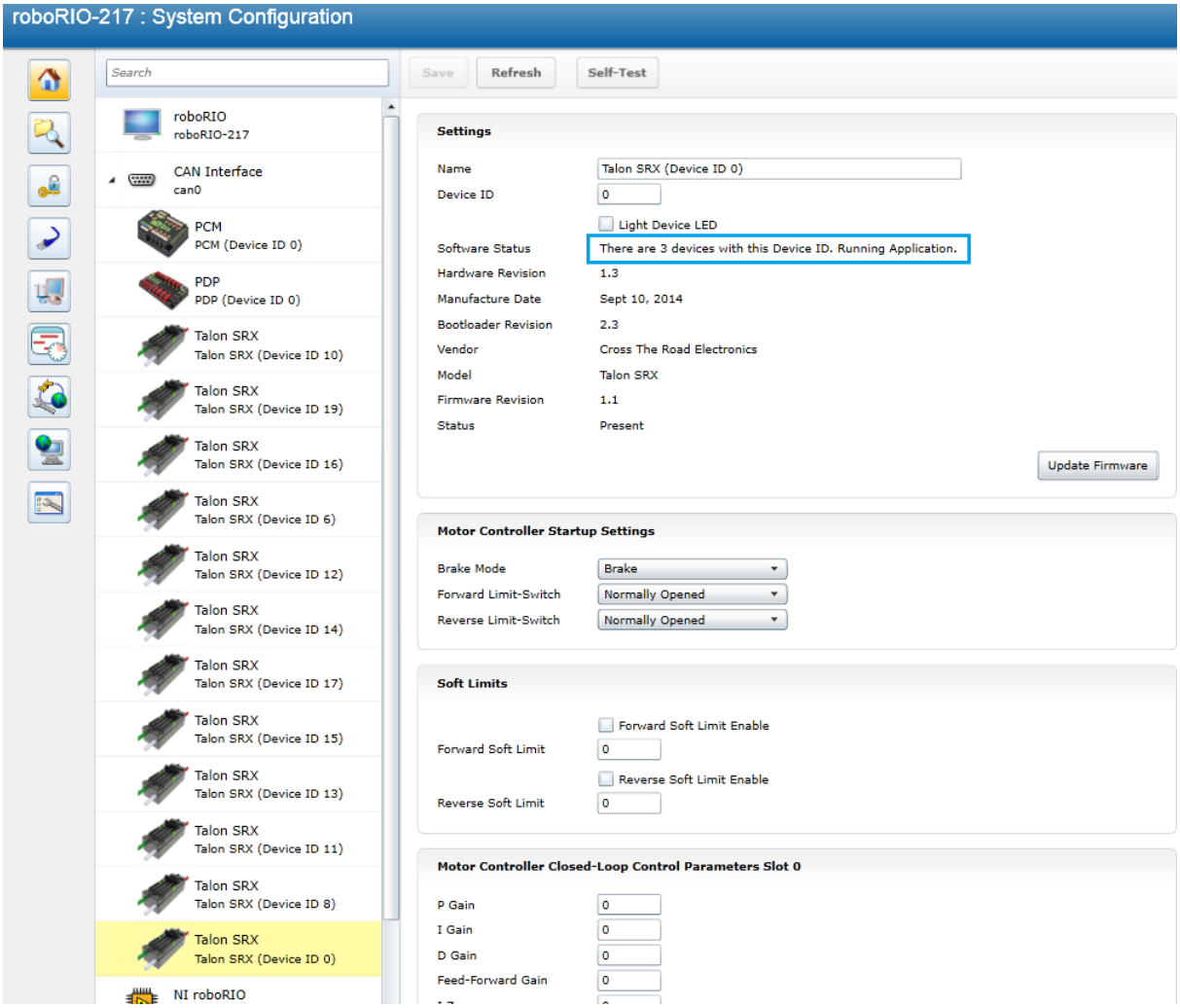
A Talon SRX can have a device ID from 0 to 62. 63 is reserved for broadcast.
If you select an invalid ID, you will get an immediate prompt.



2.2. Common ID Talons

During initial setup (and when making changes to your robot), there may be occasions where the CAN bus contains multiple running Talon SRXs with the same device ID. "Common ID" Talon SRXs are to be avoided since they prevent reliable communication and prevents your robot application from being able to distinguish one Talon SRX from another. However, the roboRIO's Web-based Configuration and Talon SRX firmware is designed to be tolerant of this problem condition to a degree.

In the event there are "common ID" Talons, they will reveal themselves as a single tree element (see image below). In this example, there is only one "Talon SRX (Device ID 0)" graphical element on the left, however the software status shows that there are three detected Talon SRXs with that device ID. If the number of "common ID" Talon SRXs is small (typically five or less) you will still be able to firmware update, modify settings, and change the device ID. This makes solving device ID contentions possible without having to isolate/disconnect "common ID" Talon SRXs.



When “common ID” Talon SRXs are present, correct this condition by changing the device ID to a “free” number, (one not already in use) before doing anything else. Then manually refresh the browser. This allows the web page to re-populate the left tree view with a new device ID.

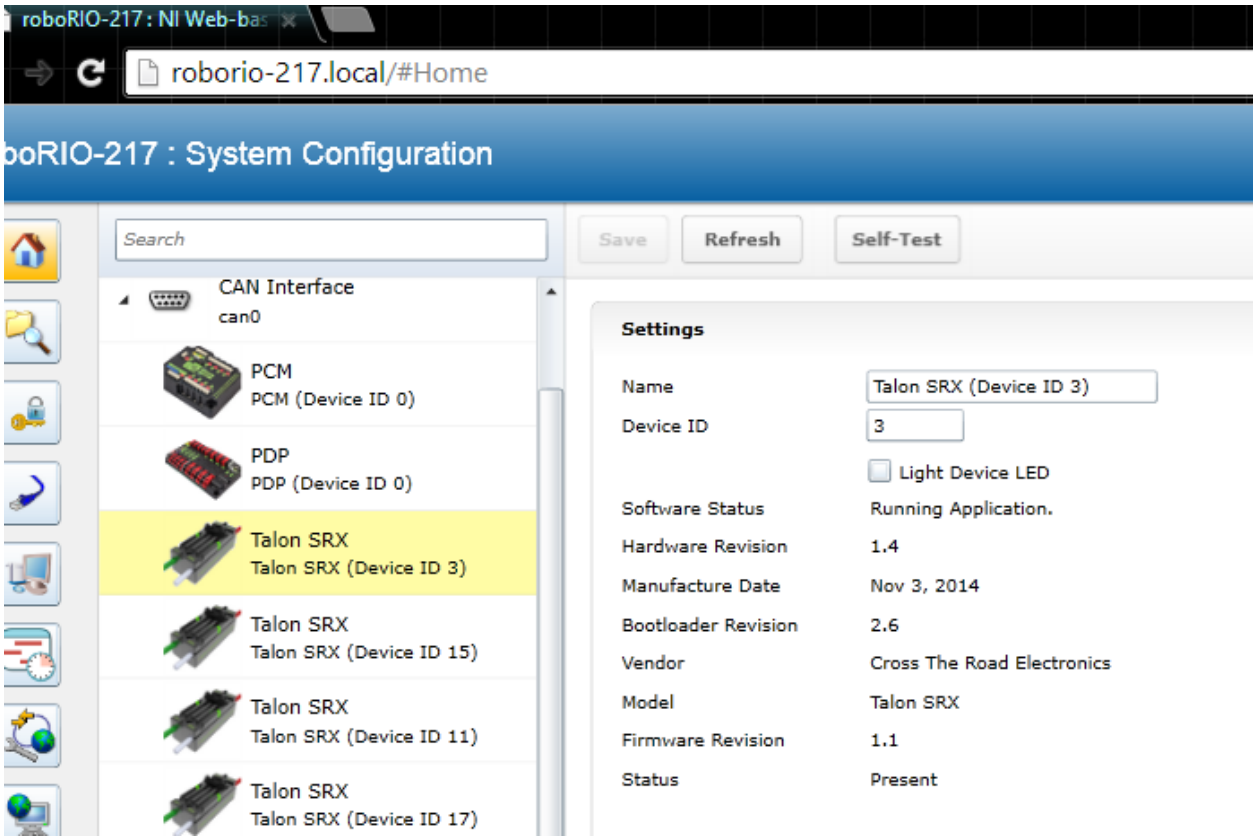
Since the web page allows control of one Talon SRX at a time, you may need to determine *which* “common ID” Talon SRX you are modifying. Checking the “Light Device LED” and pressing “Save” can be used to identify *which* physical Talon SRX is selected, and therefore which one will be modified. This will cause the selected Talon SRX to blink its LEDs uniquely (fast orange blink) for easy identification. In the unlikely event the device is in boot-loader (orange/green LED), it will still respond to this by increasing the blink rate of the orange/green pattern. The “Light Device LED” will uncheck itself after pressing “Save”.

Tip : Since the default device ID of an “out of the box” Talon SRX is device ID ‘0’, when you setup your robot for the first time, start assigning device IDs at ’1’. That way you can, at any time, add another default Talon to your bus and easily identify it.

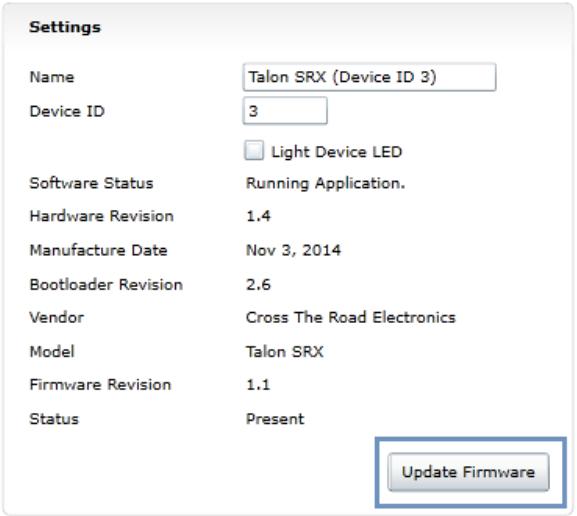
2.3. Firmware Field-upgrade a Talon SRX

Talon SRX uses a file format call CRF. To firmware flash a Talon SRX, navigate to the following page and select it in the left tree view.

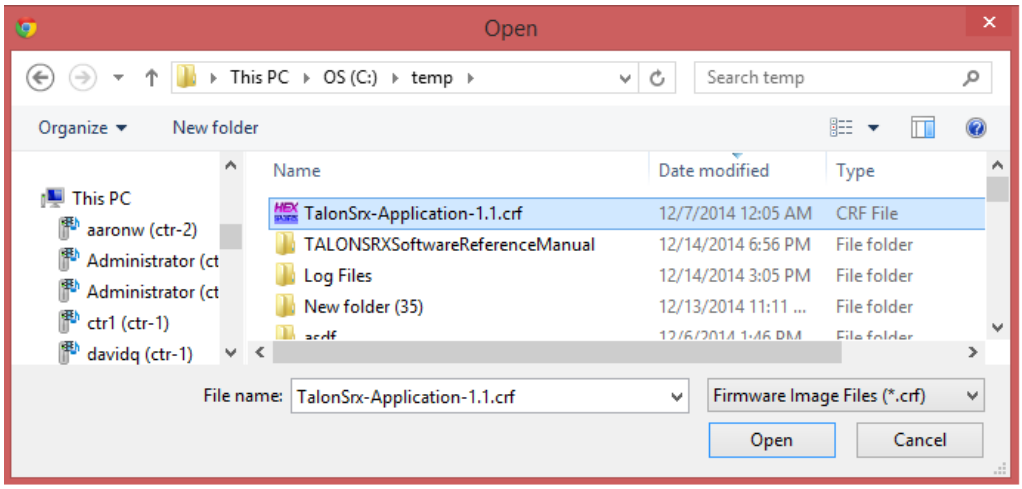
To get the latest firmware files see Section 2.3.4. Where to get CRF files?



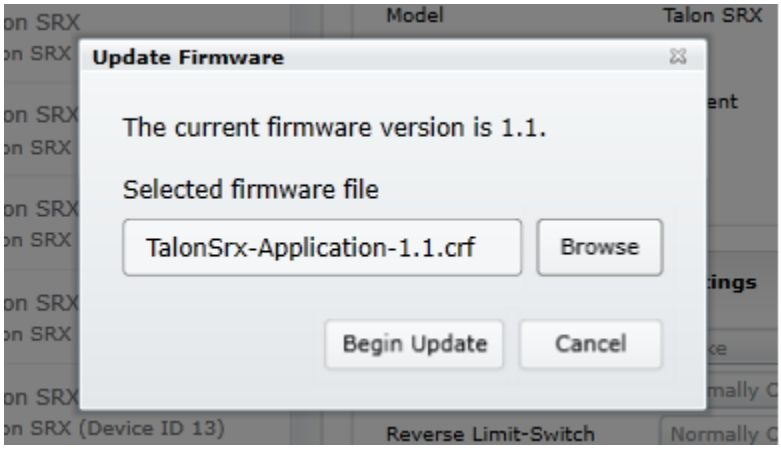
Press “Update Firmware”.



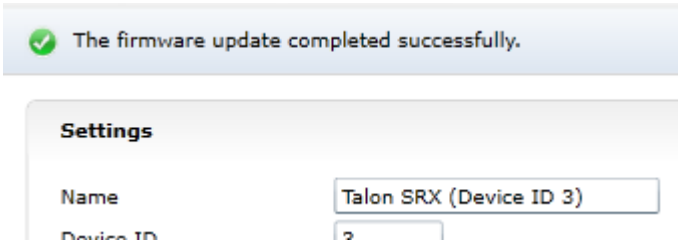
Select the firmware file (*.crf) to flash.



You will be prompted again, press “Begin Update”.



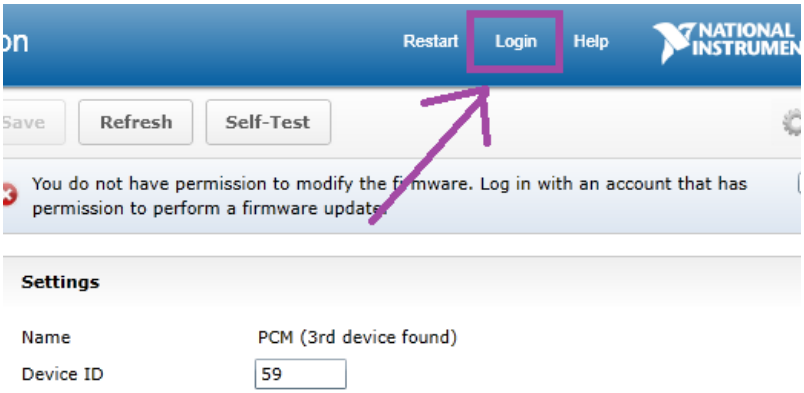
A progress bar will appear and finish with the following prompt. Total time to field-upgrade a Talon SRX is approximately ten seconds. The progress bar will fill quickly, then pause briefly at the near end, this is expected.



2.3.1. When I update firmware, I get “You do not have permissions…”

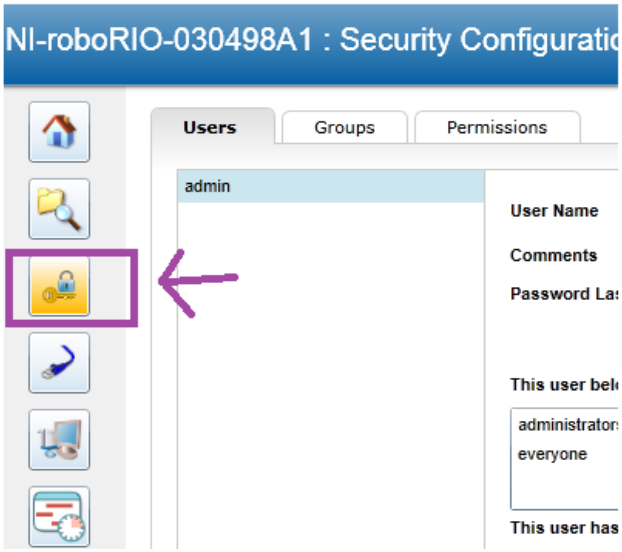
If you get the following error…

...then you have to log into the web interface using the username “admin”.

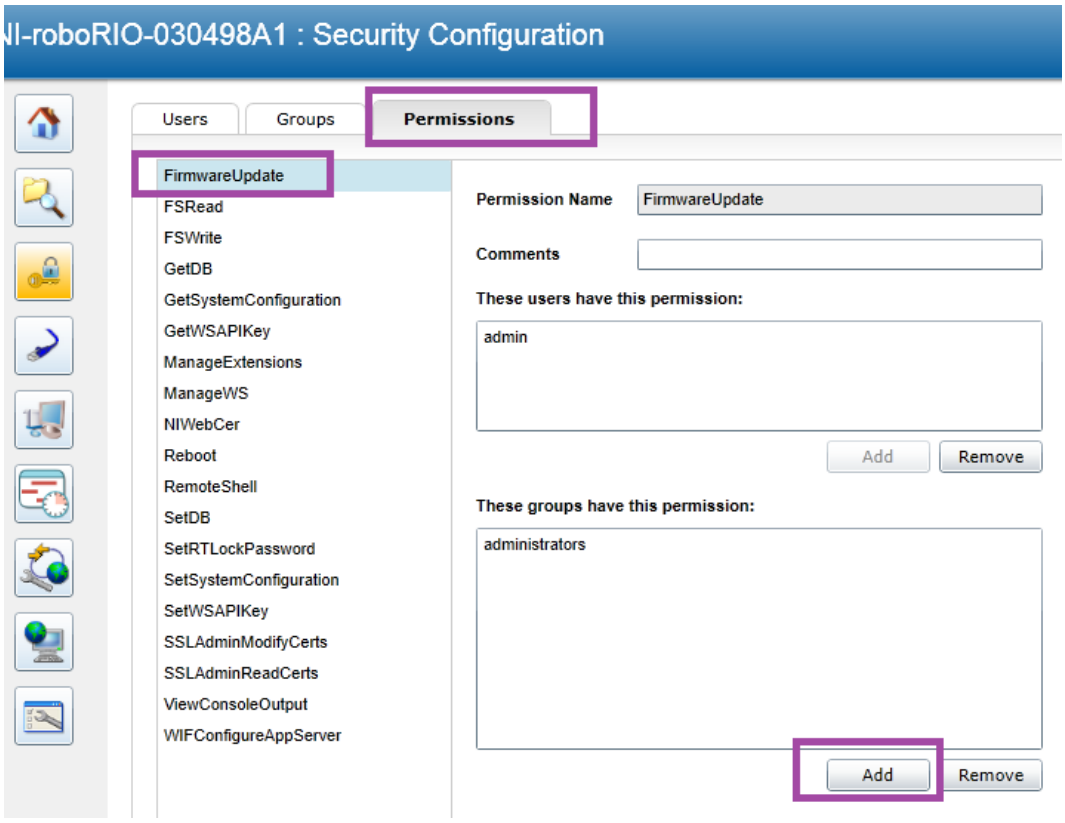


The user name is “admin” and the password is blank “”. Don’t enter any keys for password.

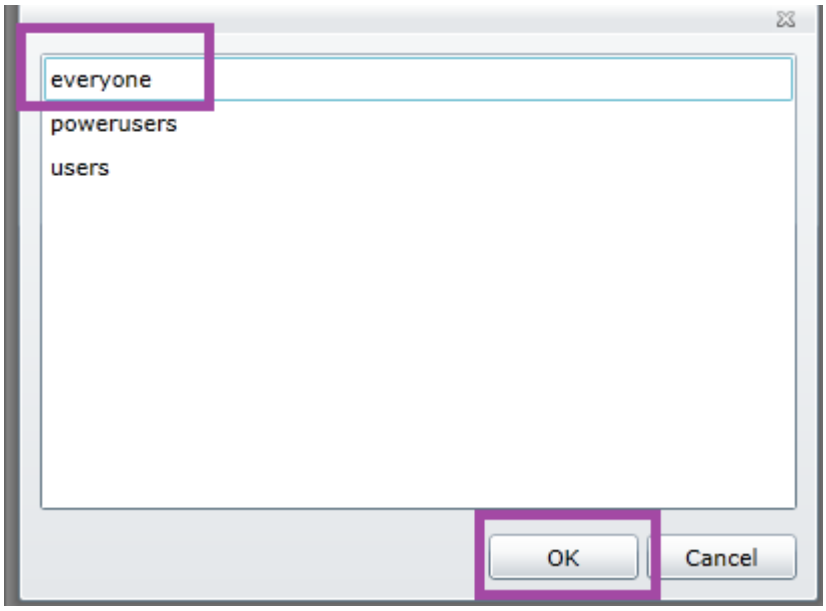
Additionally, you can modify permissions to allow field upgrade without being asked for login every single time. If security isn’t a concern then modify the permissions so that “anyone” can access “FirmwareUpdate” features.
Click on the key/lock icon in the left icon list.



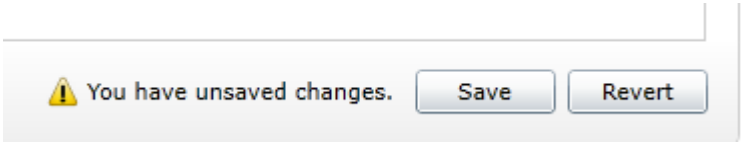
Then click on the “Permissions” tab. Select “FirmwareUpdate”, then press “Add” button.



Select everyone, then OK.



Click “Save” to save changes.

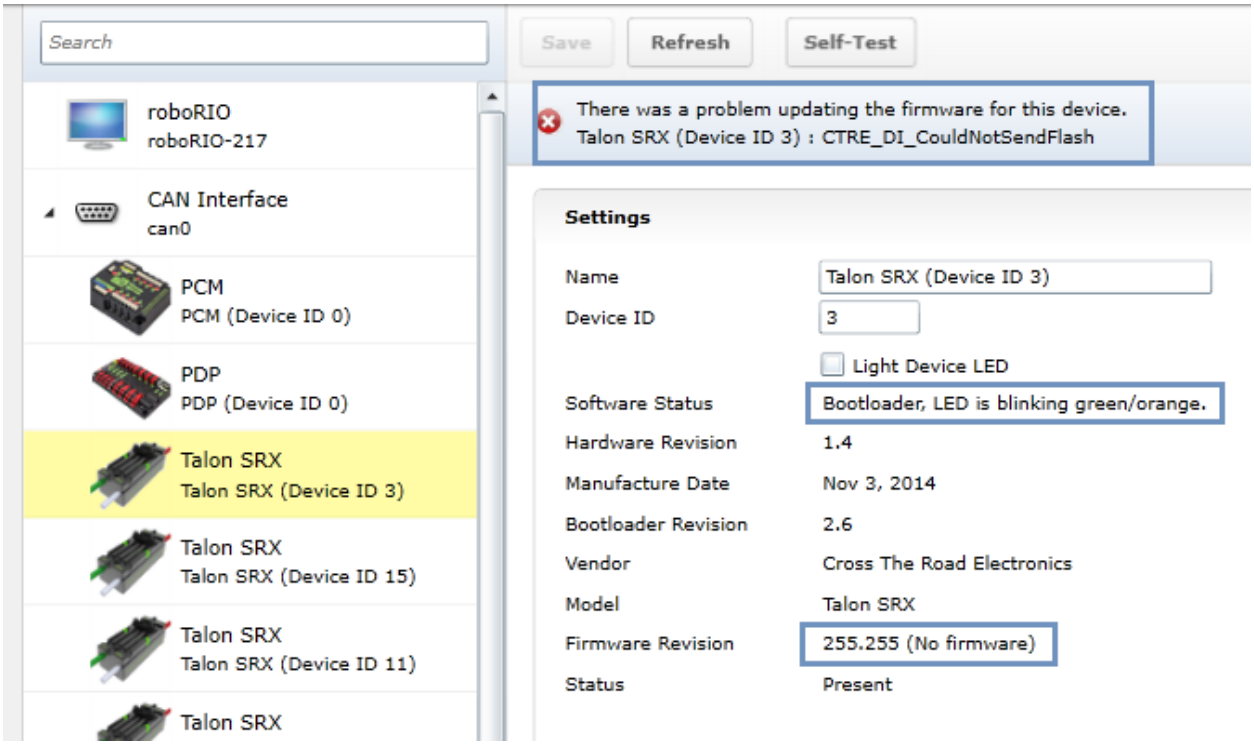


2.3.2. What if Firmware Field-upgrade is interrupted?

Since ten seconds is plenty of time for power or CAN bus to be disconnected, it is always possible for a field-update to be interrupted. An error code will be reported if the firmware field-update is interrupted or fails. Additionally, the Software Status will report “Bootloader” and Firmware Revision will be 255.255 (blank).

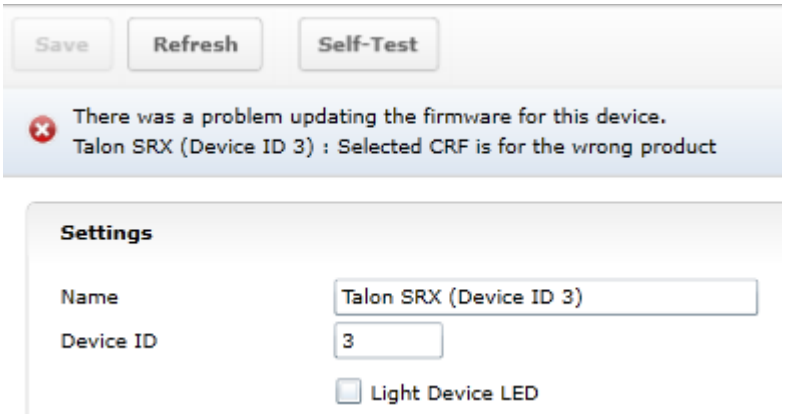
If a Talon SRX has no firmware, its boot-loader will take over and blink green/yellow on the device’s corresponding LED. It will also keep its device ID, so the roboRIO can still be used to change the device ID or (re)flash a new application firmware (crf). This means you can reattempt field-upgrade using the same web interface. There is no need for any sort of recovery steps, nor is it necessary to isolate no-firmware Talon SRXs.

Example capture of disconnecting the CAN bus in the middle of a firmware-upgrade…

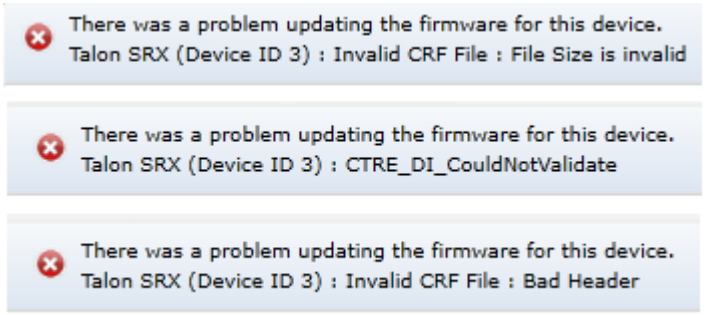


2.3.3. Other Field-upgrade Failure Modes

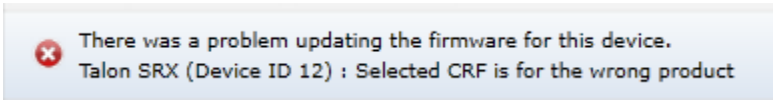
Here's an example error when trying to flash the wrong CRF into the wrong product.
The device will harmlessly stay in boot-loader, ready to be (re)flashed again.



Here's what to expect if your CRF file is corrupted (different errors depending on where the file is corrupted). The device will harmlessly stay in boot-loader, ready to be (re)flashed again. Re-downloading the CRF firmware file is recommended if this is occurring persistently.

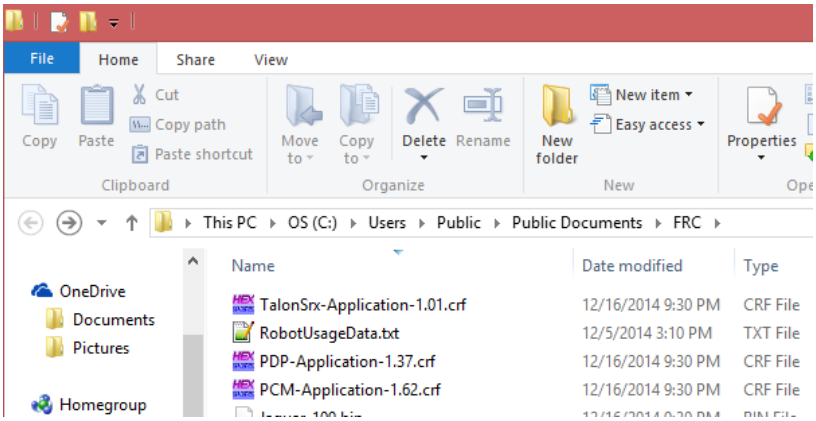


Here's what to expect if you flash the wrong product's CRF. For example, if you try to flash the CRF for the Power Distribution Panel (PDP) into a Talon SRX, you will get an error prompt.



2.3.4. Where to get CRF files?

The FRC Software installer will create a directory with various firmware files/tools for many control system components. Typically the path is "**C:\Users\Public\Documents\FRC**".



When the path is entered into a browser, the browser may fix-up the path into "**C:\Users\Public\Public Documents\FRC**".

In this directory are the initial release firmware CRF files for all CTRE CAN bus devices, including the Talon SRX.

The latest firmware to be used at time of writing is **version 2.0** (or newer).

TIP: Additionally newer updates may be provided online at http://www.ctr-electronics.com.

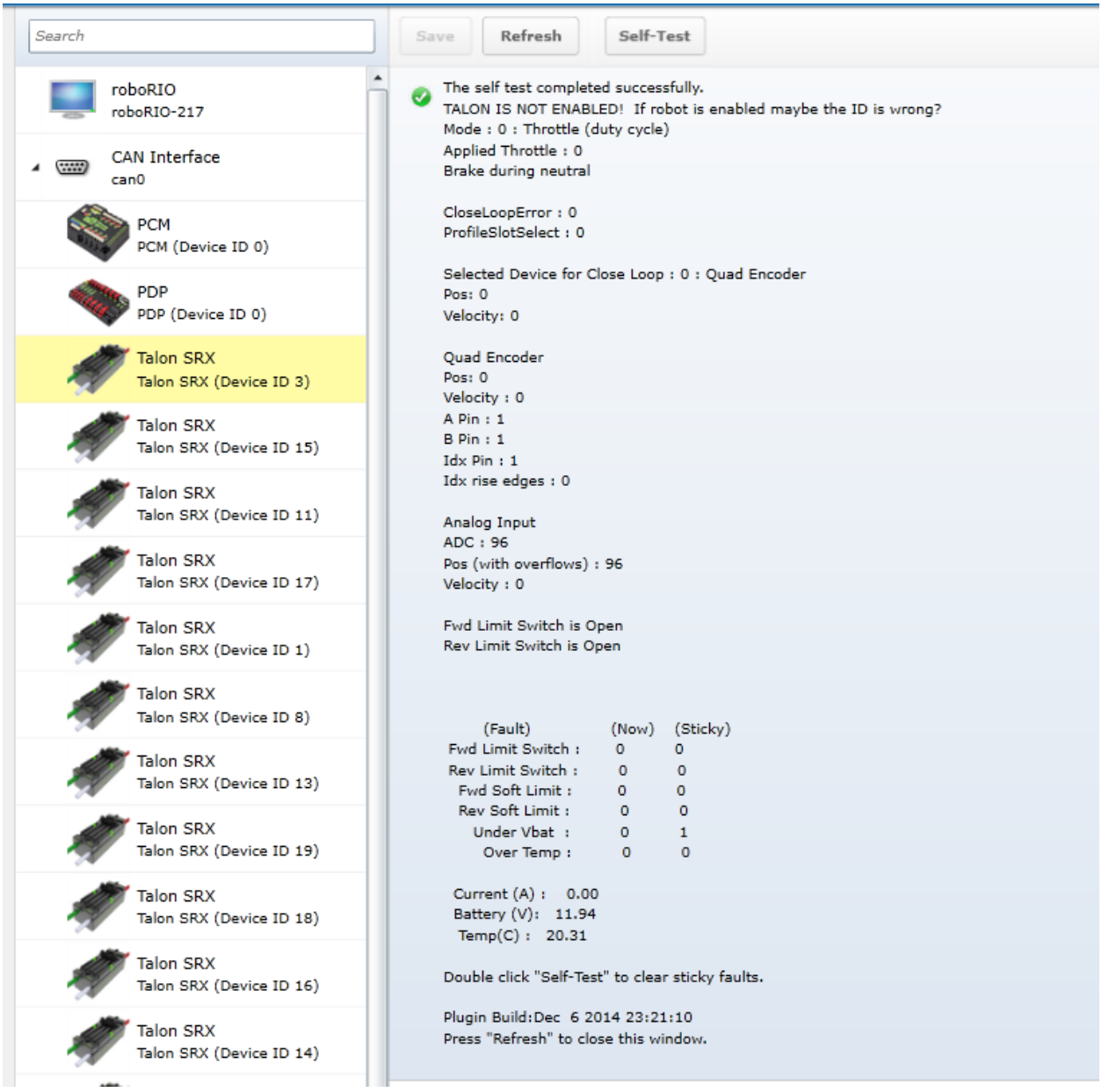
FRC: Be sure to watch for team updates for what is legal and required!

2.4. Self-Test

Pressing Self-Test will display data captured from CAN bus at the time of press. This can include fault states, sensor inputs, output states, measured battery voltage, etc.

At the bottom of the Self-Test results, the build time of the library that implements web-based CAN features is also present.

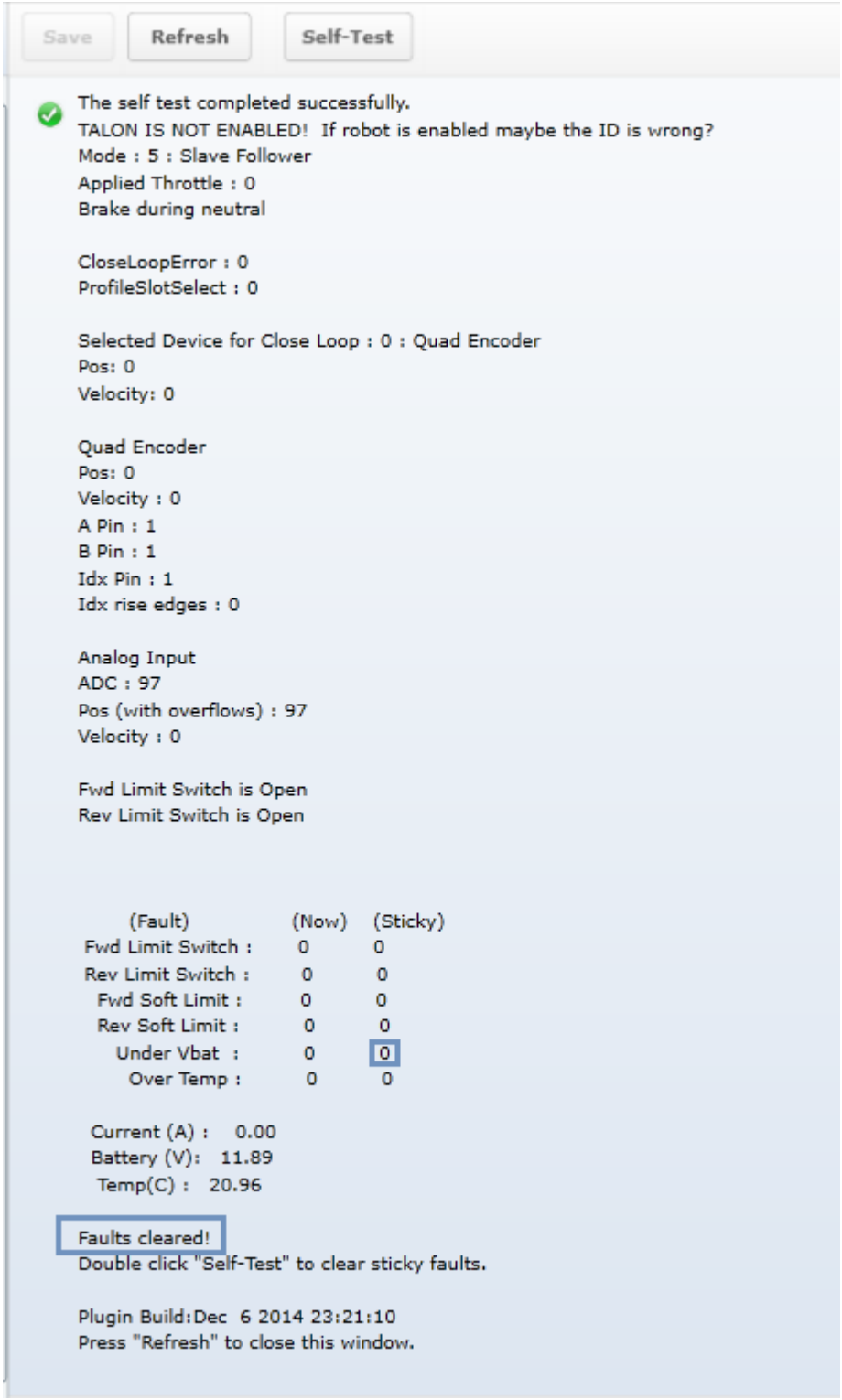
Here's an example of pressing "Self-Test" with Talon SRX. Be sure to check if Talon SRX is ENABLED or DISABLED. If Talon SRX is DISABLED then either the robot is disabled or the robot application has not yet created a Talon SRX object (see Section 3. Creating a Talon SRX Object (and basic drive)).



After enabling the robot and repressing “Self-Test” we see the Talon SRX is enabled.
Additionally we see there is a sticky fault asserted for low battery voltage.
Sticky faults persist across power cycles for identifying intermittent problems after they occur.

2.4.1. Clearing Sticky Faults

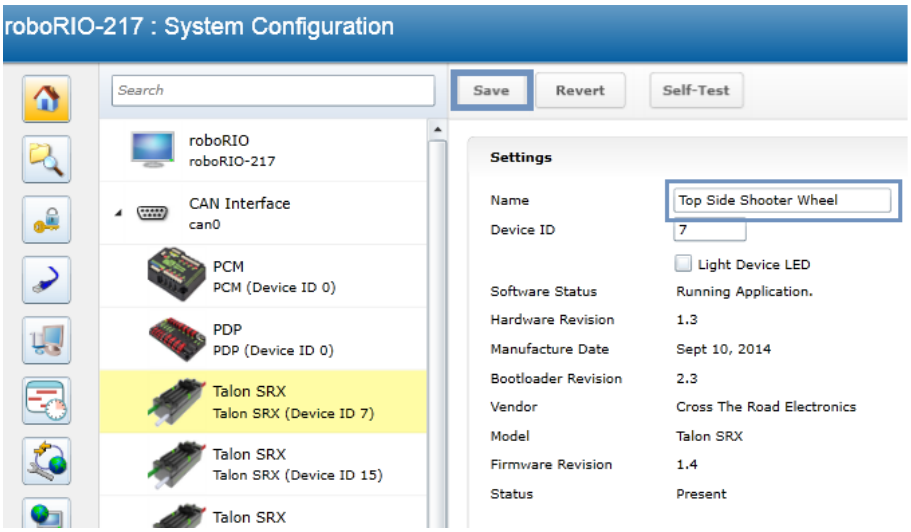
After double clicking Self-Test in a rapid fashion we see our fault gets cleared.



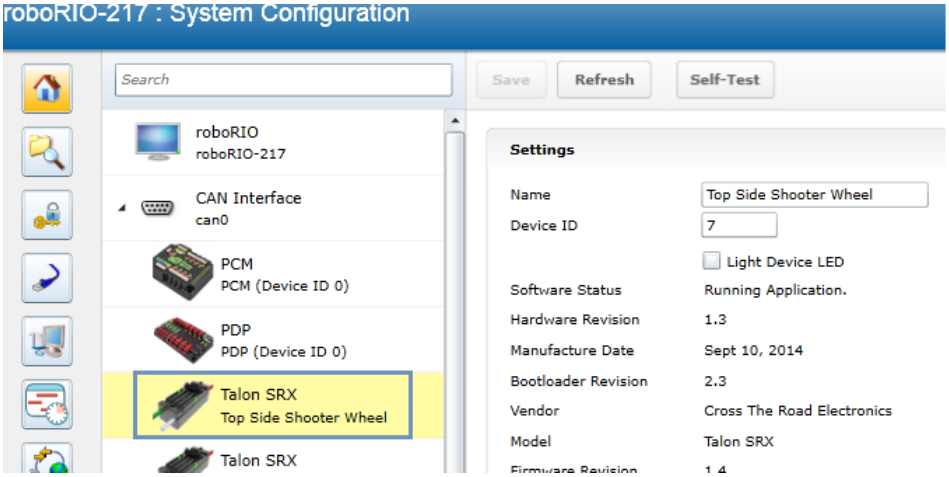
2.5. Custom Names

Another feature made available by the Web-based Configuration is the ability to rename Talon SRXs with custom string descriptions. A Talon SRX's custom name is saved persistently inside the Talon. To modify the default name highlight the contents of the "Name" text entry.

…then replace with a custom text description and press "Save".

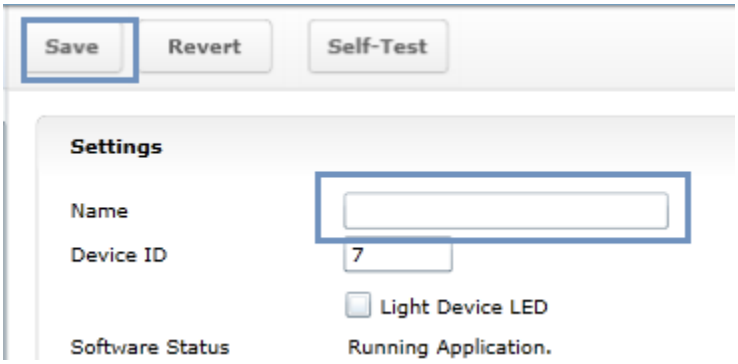


The new description will appear in the left tree view.

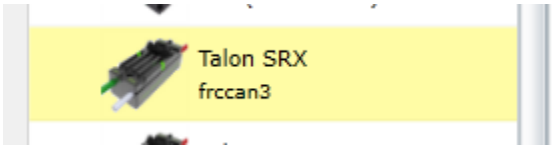


2.5.1. Re-default custom name

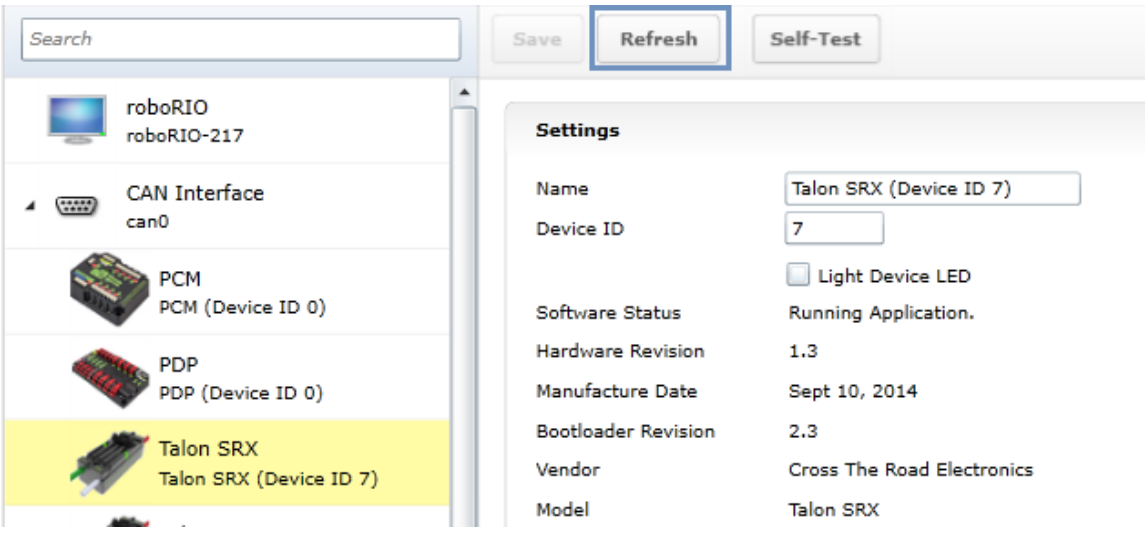
To re-default the custom name, clear the “Name” text entry and press “Save”.



Left tree view will update with a temporary name until the “Refresh” button is pressed.



After pressing “Refresh” the default name will appear.



3. Creating a Talon Object (and basic drive)

3.1. Programming API and Device ID

Regardless of what language you use on the FRC control system (LabVIEW/C++/Java), the method for specifying which Talon SRX you are programmatically controlling is the device ID. Although the roboRIO Web-based Configuration is tolerant of “common ID” Talon SRXs to a point, the robot programming API will not enable/control “common ID” Talons reliably. For the robot to function properly, there CANNOT BE “COMMON ID” Talon SRXs. See Section 2.2. Common ID Talons for more information.

TIP: Example projects for Talon SRX can also be found in the CTR GitHub account.
https://github.com/CrossTheRoadElec/FRC-Examples

3.1.1 Including Libraries (FRC)

To use Talon SRX libraries, FRC Teams need to download and install the CTRE Toolsuite, which can be found on the CTR Electronics website.

Once the libraries have been installed, users can simply add them to their project using standard import/include statements.

For Java, users should add an import statement as follows:

```
import com.ctre.CANTalon;
```

For C++, users should add an include for the CANTalon header file as follows:

```
#include "CANTalon.h"
```

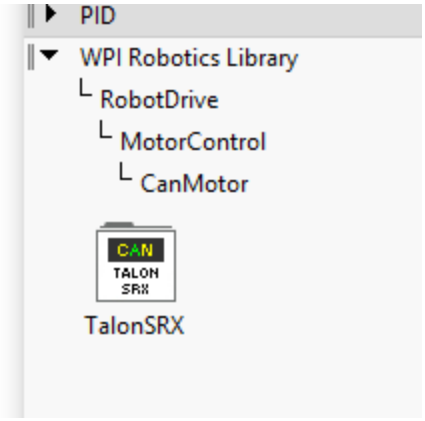
LabVIEW users will find the CAN Talon SRX VIs in a new subpalette in the WPI Robotics palette:

WPI Robotics -> Robot Drive -> MotorControl -> CANMotor -> TalonSRX

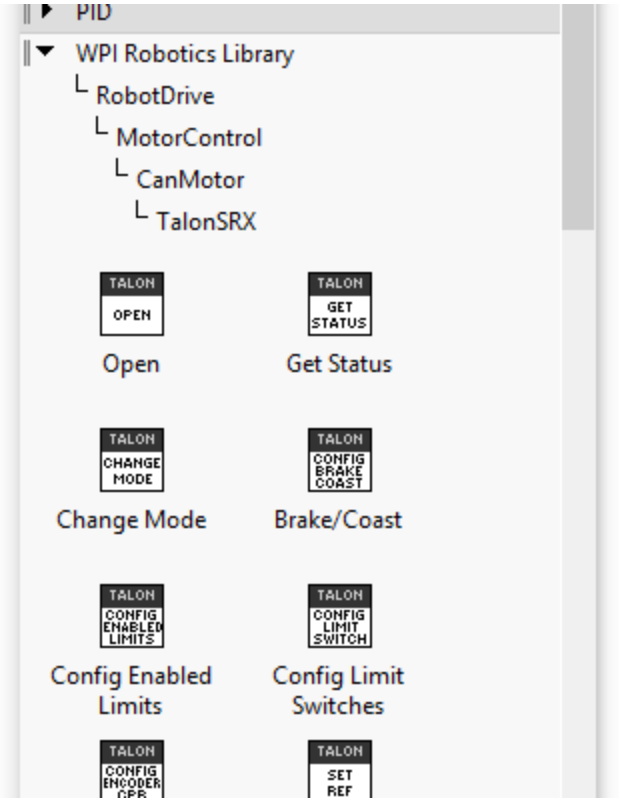
3.2. New Classes/Virtual Instruments

C++/Java now contains a new class **CANTalon** (.h/.cpp/.java).

LabVIEW contains three CTRE motor types for the FRC season: Talon SRX, Victor SP, CAN Talon SRX. When using Talon SRX on CAN bus, use the new Talon SRX Open VI. The other two modes are for PWM use and use the WPILib Motor Open VI. Additional VIs are available in the CAN Talon SRX palette.



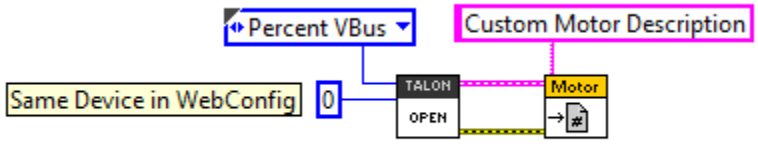
After selecting Talon SRX, the VIs are visible...



There are 24 current Vis, covering all new features of the Talon SRX, including the VIs relating to the motion profile and motion magic control modes.

3.2.1. LabVIEW

Creating a “bare-bones” Talon SRX object is similar to previously supported motor controllers. Start by creating a `WPI_CANTalonSRXOpen.vi` object (left) and a `WPI_MotorControlRefNum.vi` object (right).

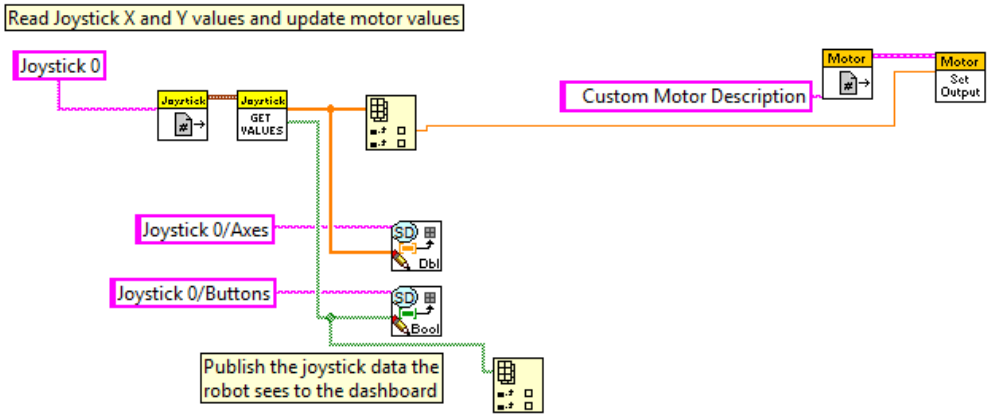


The `WPI_CANTalonSRXOpen.vi` is located in the Talon SRX palette, and the `WPI_MotorControlRefNum.vi` is accessible in the actuator palette (same VI as previous seasons).

Create two constants for the “Device Number” and “Control Mode” inputs. The control mode will default to “Percent VBus” and “0” for the Device ID. Enter the appropriate Device ID that was selected in the roboRIO Web-based Configuration.

Also similarly to other motor controllers, you may register a custom string reference using `WPI_MotorControlRefNum.vi` to reference the motor controller by description in other block diagrams. In this example we use “Custom Motor Description”.

Setting the output value of the Talon SRX is done similarly to other motor controllers.
In this example we directly control the motor output with a Joystick axis.
When using a closed-loop mode, the `Set Output VI` is also the method for specifying the set-point.



3.2.2. C++

When using a script language, the API class to support Talon SRX is called **CANTalon** (.cpp/.h/.java). When the object is constructed, the device ID is the first parameter. There may be an optional second parameter to change the frequency at which the Talon SRX is updated over CAN (default 10ms).

```
#include "WPILib.h"

class Robot: public IterativeRobot
{
    Joystick joy;
    CANTalon customMotorDescrip;

public:
    Robot() : joy(0),   /* gamepad at the first slot */
            customMotorDescrip(0)  /* device ID '0', match the RIO Web Config Page */
    {
    }

    void TeleopPeriodic()
    {
        double leftAxis = joy.GetY(Joystick::kLeftHand);

        customMotorDescrip.Set(leftAxis);
    }

};

START_ROBOT_CLASS(Robot);
```

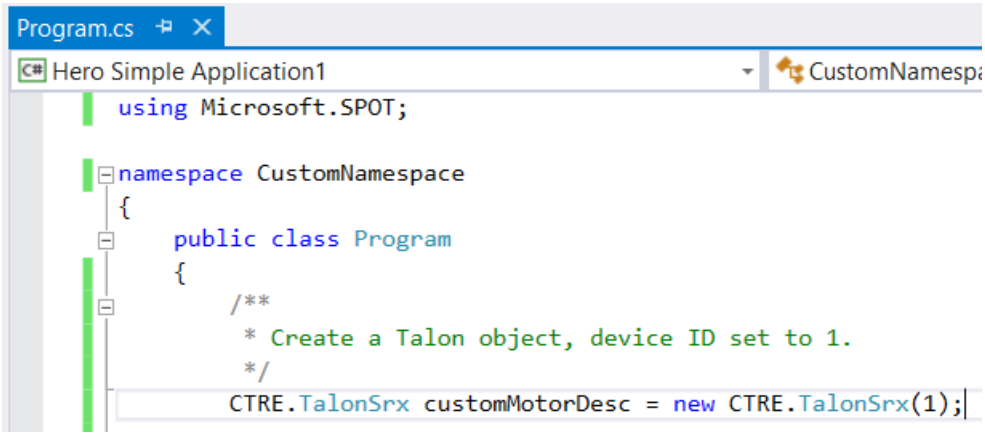
3.2.3. Java

When a **CANTalon** object is constructed in Java, the device ID is the first parameter. There may be an optional second parameter to change the frequency at which the Talon SRX is updated over CAN (default 10ms).

```
package org.usfirst.frc.team217.robot;
import edu.wpi.first.wpilibj.CANTalon;
import edu.wpi.first.wpilibj.IterativeRobot;
import edu.wpi.first.wpilibj.Joystick;
import org.usfirst.frc.team217.robot.subsystems.ExampleSubsystem;

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

    public static final ExampleSubsystem exampleSubsystem = new ExampleSubsystem();

    Joystick joy = new Joystick(0);                /* gamepad at the first slot */
    CANTalon customMotorDescrip = new CANTalon(0);  /* device ID '0', match the RIO Web Config Page */


    /**
     * This function is called periodically during operator control
     */
    public void teleopPeriodic() {

        double axis = joy.getY();

        customMotorDescrip.set(axis);
    }
}
```

3.2.4. Visual Studio .NETMF

A similar Talon SRX class is available using the HERO Control System. All CTRE classes are in the CTRE namespace. The member functions are comparable to the API available in the WPILIB languages available in the roboRIO.

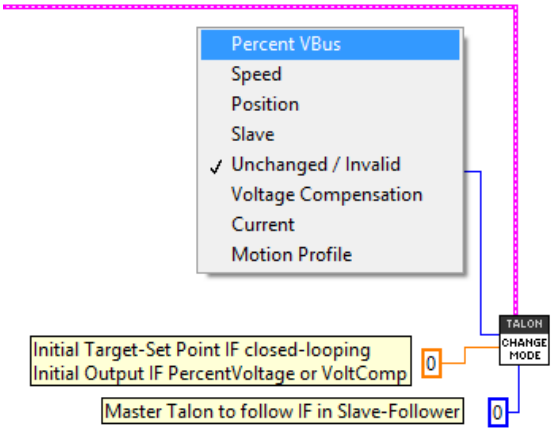


3.3. Changing Mode

After a Talon software object is created, the Talon SRX mode can be changed from the default Percent Vbus (open loop throttle) to the other supported modes programmatically. Additionally the LabVIEW `OPEN CAN TALON VI` also allows caller to select the initial control mode.

3.3.1. LabVIEW

The `CHANGE MODE VI` can be used to change the Talon SRX mode, and set the first target set point, throttle, or Talon Master ID to follow.



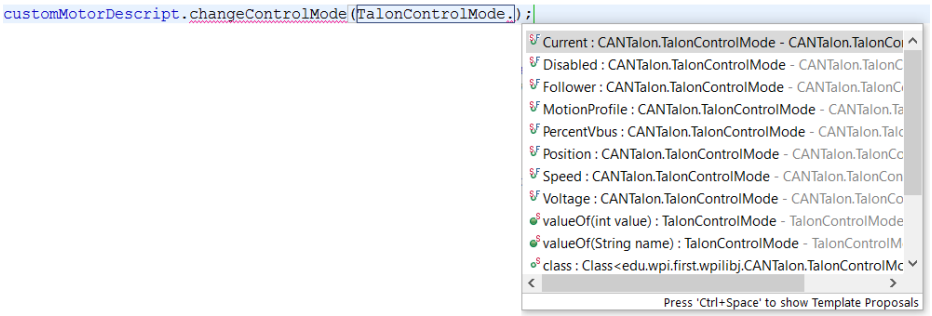
3.3.2. C++

The function `SetControlMode()` can be used to change the Talon SRX mode. Caller should ensure `Set()` is called immediately after to properly set the initial target set point, throttle, or Master ID to follow.

```
/* Possible modes to choose from.  Call Set() immediately after changing mode to set the target-set-point/throttle/ or Master Talon ID */
customMotorDescrip.SetControlMode(CANSpeedController::kPercentVbus);    /* direct throttle control, Set() controls drive */
customMotorDescrip.SetControlMode(CANSpeedController::kFollower);       /* follow another Talon, Set() determines Talon to follow. */
customMotorDescrip.SetControlMode(CANSpeedController::kSpeed);          /* Speed Closed-Loop, Set() controls set point */
customMotorDescrip.SetControlMode(CANSpeedController::kPosition);       /* Position Closed-Loop, Set() controls set point */
```

3.3.3. Java

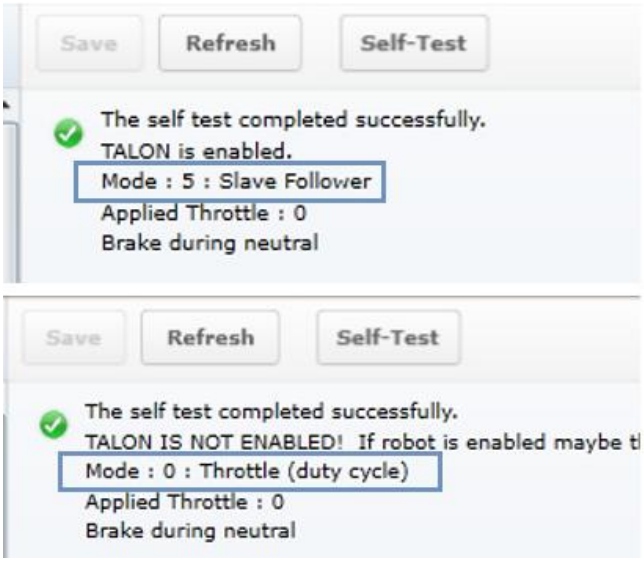
The function `changeControlMode()` can be used to change the Talon SRX mode. Caller should ensure `set()` is called immediately after to properly set the initial target set point, throttle, or Master ID to follow.



3.3.4. Check Control Mode with Self-Test

The Self-Test can be used to confirm the desired mode of the Talon SRX (Throttle, Slave, Position Closed-Loop, and Velocity Closed-Loop). However note that the Talon SRX mode will not update until robot is enabled.

Example Self-Test



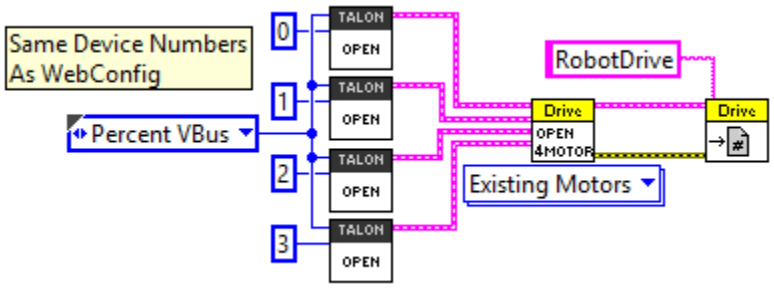
3.4. WPILib RobotDrive Class

The Robotdrive class is maintained by WPILib. CAN Talon SRX can be used with this class in LabVIEW, Java, and C++.

3.4.1. LabVIEW

The RoboDrive Vis are typically located in WPI Robotics Library -> RobotDrive.

To use CAN Talon SRX with either the 2 or 4 motor options, first use a Talon SRX Open Motor VI. The RefNum output is then wired to the input of the Open 2/4 Motor VI when the “Existing Motors” drop-down option is selected. The RobotDrive RefNum Set is then used as normal.



3.4.2. C++

RobotDrive is included in WPILib.h. Construct the appropriate CANTalon objects and pass them to the RobotDrive constructor.

```
FrontLeftMotor = new CANTalon(1);
FrontRightMotor = new CANTalon(2);
RearLeftMotor = new CANTalon(3);
RearRightMotor = new CANTalon(4);

drive = new RobotDrive(FrontLeftMotor, RearLeftMotor, FrontRightMotor,
      RearRightMotor);
```

3.4.3. Java

RobotDrive is included in WPILib. Construct the appropriate CANTalon objects and pass them to the RobotDrive constructor.

```
FrontLeftMotor = new CANTalon(1);
FrontRightMotor = new CANTalon(2);
RearLeftMotor = new CANTalon(3);
RearRightMotor = new CANTalon(4);

drive = new RobotDrive(FrontLeftMotor, RearLeftMotor, FrontRightMotor,
      RearRightMotor);
```

4. Limit Switch and Neutral Brake Mode

4.1. Default Settings

An “out of the box” Talon will default with the limit switch setting of “Normally Open” for both forward and reverse. This means that motor drive is allowed when a limit switch input is not closed (i.e. not connected to ground). When a limit switch input is closed (is connected to ground) the Talon SRX will disable motor drive and individually blink both LEDs red in the direction of the fault (red blink pattern will move towards the M+/white wire for positive limit fault, and towards M-/green wire for negative limit fault).

An “out of the box” Talon SRX will typically have a default brake setting of “Brake during neutral”. The B/C CALL button will be illuminated red (brake enabled).

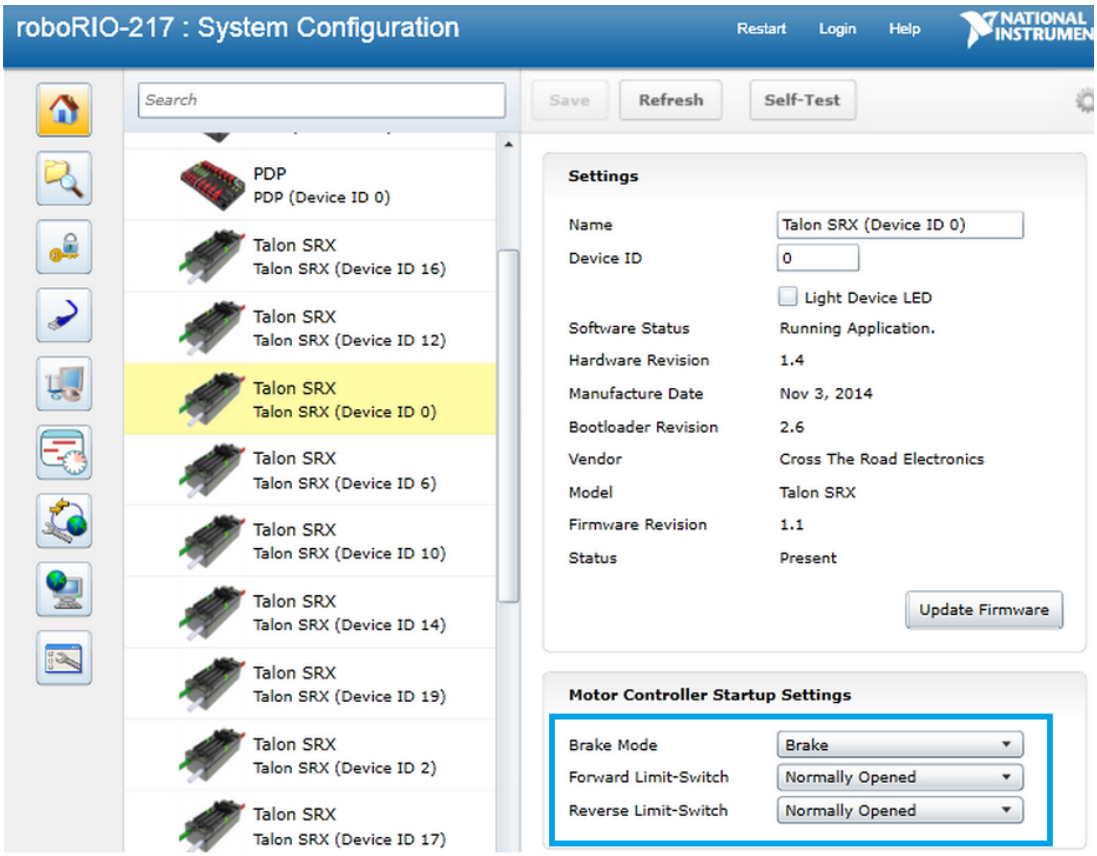
Since an “out of the box” Talon will likely not be connected to limit switches (at least not initially) and because limit switch inputs are internally pulled high (i.e. the switch is open), the limit switch feature is default to “normally open”. This ensures an “out of the box” Talon will drive even if no limit switches are connected.

For more information on Limit Switch wiring/setup, see the **Talon SRX User’s Guide**.

Forward Limit Switch Mode	Limit Switch NO pin	Limit Switch NC pin	Limit Switch COM pin	Motor Drive Switch open Fwd. throttle	Motor Drive Switch closed Fwd. throttle	*Voltage (Switch Open)	*Voltage (Switch Closed)
Normally Open	pin4	N.A.	pin10	Y	N	~2.5V	0 V
Normally Closed	N.A.	pin4	pin10	N	Y	0 V	~2.5V
Disabled	N.A.	N.A.	N.A.	Y	Y	N.A.	N.A.
Reverse Limit Switch Mode	Limit Switch NO pin	Limit Switch NC pin	Limit Switch COM pin	Motor Drive Switch open Rev. throttle	Motor Drive Switch closed Rev. throttle	*Voltage (Switch Open)	*Voltage (Switch Closed)
Normally Open	pin8	N.A.	pin10	Y	N	~2.5V	0 V
Normally Closed	N.A.	pin8	pin10	N	Y	0 V	~2.5V
Disabled	N.A.	N.A.	N.A.	Y	Y	N.A.	N.A.
	*Measured voltage at the Talon SRX Limit Switch Input pin.						
	Limit Switch Input Forward Input - pin4 on Talon SRX						
	Limit Switch Input Reverse Input - pin8 on Talon SRX						
	Limit Switch Ground - pin10 on Talon SRX						

4.2. roboRIO Web-based Configuration: Limit Switch and Brake

Limit switch features can be disabled or changed to “Normally Closed” in the roboRIO Web-based Configuration. Similarly the brake mode can be change through the same interface.



Changing the settings will take effect once the “Save” button is pressed. The settings are saved in persistent memory.

If the Brake or Limit Switch mode is changed in the roboRIO Web-based Configuration, the Talon SRX will momentarily disable then resume motor drive. All other settings can be changed without impacting the motor drive or enabled-state of the Talon SRX.

Additionally the brake mode can be modified by pressing the B/C CAL Button on the Talon SRX itself, just like with previous generation Talons.

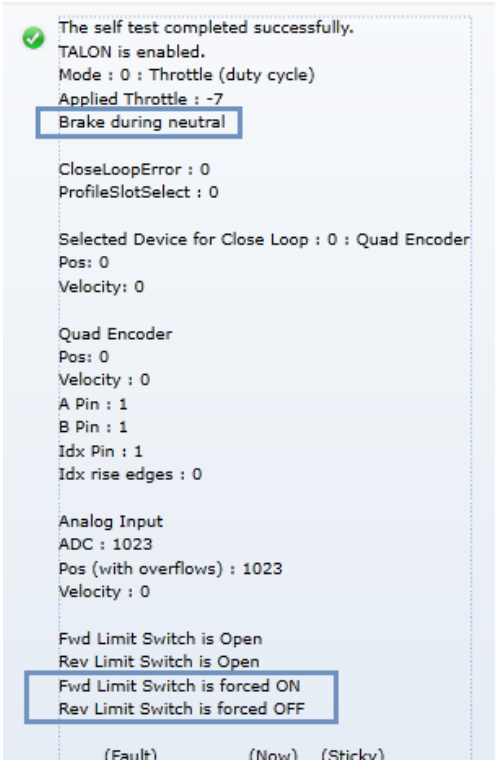
4.3. Overriding Brake and Limit Switch with API

The Brake and Limit Switch can, to a degree, be changed programmatically (during a match). A great example of this would be for dynamic braking.

The programming API allows for overriding the active neutral brake mode. When this is done the Brake/Coast LED will reflect the overridden value (illuminated red for brake, off for coast) regardless of the startup brake mode specified in the roboRIO Web-based Configuration (i.e. what's saved in persistent memory).

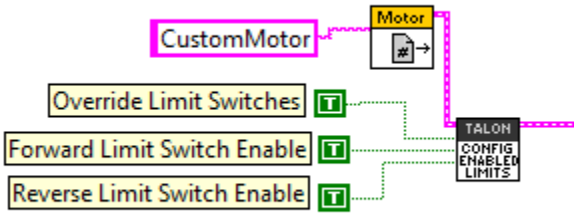
Similarly the enabled states of the limit switches (on/off) for the forward and reverse direction can be individually enabled/disabled by overriding them with programming API.

The brake and limit switch overrides can be confirmed in the Self-Test results. If limit switches are overridden by the robot application, the forced states are displayed as "forced ON" or "forced OFF". Also the currently active brake mode is in the Self-Test results.

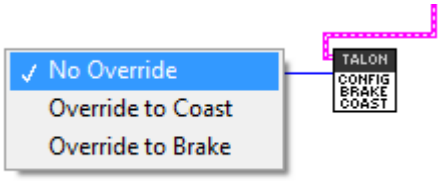


4.3.1. LabVIEW

The `CONFIG ENABLED LIMITS VI` can be used to override the limit switch enable states. When overriding the limit switch enable states, set the override signal to true, then pass true/false to the forward and reverse limit switch enable.



The neutral brake mode can also be overridden to Brake or Coast using the `CONFIG BRAKE COAST VI`. If “No Override” is selected then the Startup Brake Mode is used.



4.3.2. C++

Limit Switches can be forced on or off using `ConfigLimitMode()`, along with soft limits (see Section 8. Soft Limits).

```
customMotorDescrip.ConfigLimitMode(CANSpeedController::kLimitMode_SwitchInputsOnly);        /* limit switches only */
customMotorDescrip.ConfigLimitMode(CANSpeedController::kLimitMode_SoftPositionLimits);      /* limits switches and soft-limits */
customMotorDescrip.ConfigLimitMode(CANSpeedController::kLimitMode_DisableSwitchInputs); /* disabled limit switches and disable soft-limits */
```

`ConfigNeutralMode()` can be used to override the brake/coast mode. Also selecting the enumerated value of `kNeutralMode_Jumper` will signal the Talon SRX to use its default setting (controlled by roboRIO Web-based Configuration and B/C CAL button).

```
customMotorDescrip.ConfigNeutralMode(CANSpeedController::NeutralMode::kNeutralMode_Brake); /* override to brake during neutral */
customMotorDescrip.ConfigNeutralMode(CANSpeedController::NeutralMode::kNeutralMode_Coast); /* override to coast during neutral */
customMotorDescrip.ConfigNeutralMode(CANSpeedController::NeutralMode::kNeutralMode_Jumper);/* default to flash setting - No Override */
```

4.3.3. Java

`enableLimitSwitch()` can be used to override the enabled state for forward and reverse limit switch enable. `enableBrakeMode()` can be used to override the brake/coast setting.

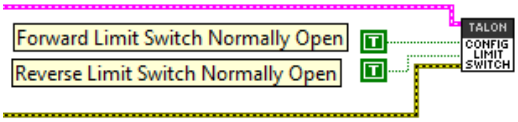
```
customMotorDescrip.enableLimitSwitch(true,true);    /* forward enable, reverse enable */
customMotorDescrip.enableBrakeMode(true);           /*when in neutral : true for brake, false for coast */
```

4.4. Changing limit switch mode between “Normally Open” or “Normally Closed”

The limit switch setting that determines “Normally Open” vs “Normally Closed” can also be set programmatically using the `CONFIG LIMIT SWITCH VI`. However care should be taken when this is done. When a Talon SRX’s limit switch mode is changed from its current setting to a different value, it briefly disables motor drive during the transition. This should not be a problem since the limit switches in the robot are typically not changed during a match.

However it may be convenient to ensure NO/NC settings at startup (particularly when using the non-default setting of Normally Closed) so as to avoid needing to use the roboRIO Web-based Configuration to select NC whenever a Talon SRX needs to be added/replaced.

4.4.1. LabVIEW



4.4.2. C++

`ConfigFwdLimitSwitchNormallyOpen()` and `ConfigRevLimitSwitchNormallyOpen()` can be used to change the NO/NC state of a limit switch input.

```
if(btn4){
    customMotorDescrip.ConfigFwdLimitSwitchNormallyOpen(true); /* forward limit set to Normally Open */
}else if(btn2){
    customMotorDescrip.ConfigFwdLimitSwitchNormallyOpen(false);/* forward limit set to Normally Closed */
}

if(btn1){
    customMotorDescrip.ConfigRevLimitSwitchNormallyOpen(true); /* reverse limit set to Normally Open */
}else if(btn3){
    customMotorDescrip.ConfigRevLimitSwitchNormallyOpen(false);/* reverse limit set to Normally Closed */
}
```

4.4.3. Java

`ConfigFwdLimitSwitchNormallyOpen()` and `ConfigRevLimitSwitchNormallyOpen()` can be used to change the NO/NC state of a limit switch input.

```
if(btn4){
    customMotorDescrip.ConfigFwdLimitSwitchNormallyOpen(true); /* forward limit set to Normally Open */
}else if(btn2){
    customMotorDescrip.ConfigFwdLimitSwitchNormallyOpen(false);/* forward limit set to Normally Closed */
}

if(btn1){
    customMotorDescrip.ConfigRevLimitSwitchNormallyOpen(true); /* reverse limit set to Normally Open */
}else if(btn3){
    customMotorDescrip.ConfigRevLimitSwitchNormallyOpen(false);/* reverse limit set to Normally Closed */
}
```

5. Getting Status and Signals

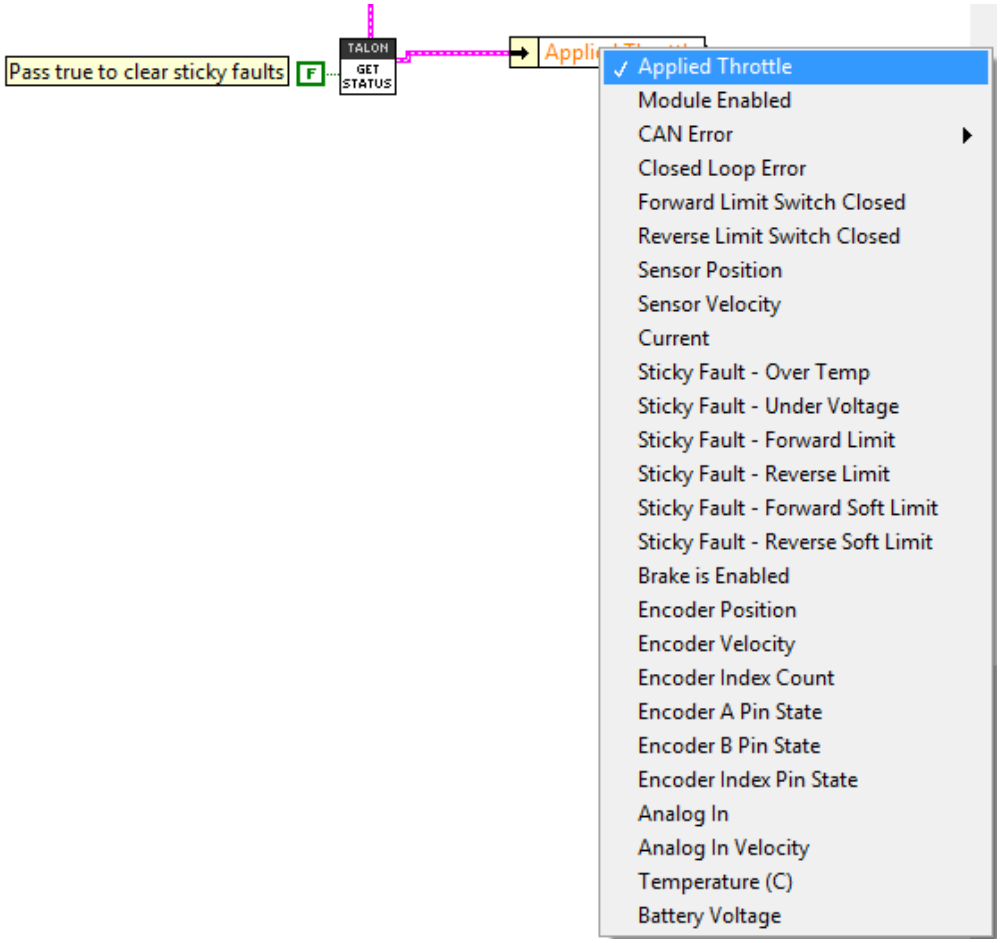
The Talon SRX transmits most of its status signals periodically, i.e. in an unsolicited fashion. This improves bus efficiency by removing the need for “request” frames, and guarantees the signals necessary for the wide range of use cases Talon supports, are available.

These signals are available in API regardless of what control mode the Talon SRX is in. Additionally the signals can be polled in the roboRIO Web-based Configuration (see Section 2.4. Self-Test).

Included in the list of signals are…
- Quadrature Encoder Position, Velocity, Index Rise Count, Pin States (A, B, Index)
- Analog-In Position, Analog-In Velocity, 10bit ADC Value,
- Battery Voltage, Current, Temperature
- Fault states, sticky fault states,
- Limit switch pin states
- Applied Throttle (duty cycle) regardless of control mode.
- Applied Control mode: Voltage % (duty-cycle), Position/Velocity closed-loop, or slave follower.
- Brake State (coast vs brake)
- Closed-Loop Error, the difference between closed-loop set point and actual position/velocity.
- Sensor Position and Velocity, the signed output of the selected Feedback device (robot must select a Feedback device, or rely on default setting of Quadrature Encoder).

5.1. LabVIEW

The `GET STATUS VI` can be used to retrieve the latest value for the signals Talon SRX periodically transmits. Additionally, sticky faults can be cleared if “true” is passed into the “Clear Sticky Fault” signal. To get a particular signal, unbundle-by-name the output of the `GET STATUS VI`. Then select the signal to get by right clicking the center of the unbundle object.



5.2. C++

All get functions are available in C++. Here are a few examples….

```
double currentAmps = customMotorDescrip.GetOutputCurrent();
double outputV = customMotorDescrip.GetOutputVoltage();
double busV = customMotorDescrip.GetBusVoltage();

int quadEncoderPos = customMotorDescrip.GetEncPosition();
int quadEncoderVelocity = customMotorDescrip.GetEncVel();

int analogPos = customMotorDescrip.GetAnalogIn();
int analogVelocity = customMotorDescrip.GetAnalogInVel();

int selectedSensorPos = customMotorDescrip.GetPosition();
int selectedSensorSpeed = customMotorDescrip.GetSpeed();

int closeLoopErr = customMotorDescrip.GetClosedLoopError();
if(bEverySecond){

    printf("currentAmps:%f\n",currentAmps);
    printf("outputV:%f\n",outputV);
    printf("busV:%f\n\n",busV);

    printf("quadEncoderPos:%i\n",quadEncoderPos);
    printf("quadEncoderVelocity:%i\n\n",quadEncoderVelocity);

    printf("analogPos:%i\n",analogPos);
    printf("analogVelocity:%i\n\n",analogVelocity);

    printf("selectedSensorPos:%i\n",selectedSensorPos);
    printf("selectedSensorSpeed:%i\n\n",selectedSensorSpeed);

    printf("closeLoopErr:%i\n",closeLoopErr);
}
```

5.3. Java

All get functions are available in java. Here are a few examples….

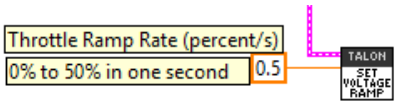
```
double currentAmps = _talons[masterId].getOutputCurrent();
double outputV = _talons[masterId].getOutputVoltage();
double busV = _talons[masterId].getBusVoltage();
double quadEncoderPos = _talons[masterId].getEncPosition();
double quadEncoderVelocity = _talons[masterId].getEncVelocity();
int analogPos = _talons[masterId].getAnalogInPosition();
int analogVelocity = _talons[masterId].getAnalogInVelocity();
double selectedSensorPos = _talons[masterId].getPosition();
double selectedSensorSpeed = _talons[masterId].getSpeed();
int closeLoopErr = _talons[masterId].getClosedLoopError();

if(bEverySecond){
    System.out.println("currentAmps" + currentAmps);
    System.out.println("outputV:" + outputV);
    System.out.println("output%:" + 100*(outputV / busV) );
    System.out.println("busV:" + busV);
    System.out.println("");
    System.out.println("quadEncoderPos:" + quadEncoderPos);
    System.out.println("quadEncoderVelocity:" + quadEncoderVelocity);
    System.out.println("");
    System.out.println("analogPos:" + analogPos);
    System.out.println("analogVelocity:" + analogVelocity);
    System.out.println("");
    System.out.println("selectedSensorPos:" + selectedSensorPos);
    System.out.println("selectedSensorSpeed:" + selectedSensorSpeed);
    System.out.println("");
    System.out.println("closeLoopErr:" + closeLoopErr);
}
```

6. Setting the Ramp Rate

The Talon SRX can be set to honor a ramp rate to prevent instantaneous changes in throttle. This ramp rate is in effect regardless of which mode is selected (throttle, slave, or closed-loop).

6.1. LabVIEW

Use the SET VOLTAGE RAMP to specify the ramp rate in percent per second.



6.2. C++

Ramp can be set in Volts per second using `SetVoltageRampRate()`.

```
customMotorDescrip.SetVoltageRampRate(6.0); /* 0V to 6V in one second */
```

6.3. Java

Ramp can be set in Volts per second using `setVoltageRampRate()`.

```
customMotorDescrip.setVoltageRampRate(6); /* 0V to 6V in one second */
```

6.4. What is the slowest ramp possible?

The Talon SRX internally expresses the (Voltage) Ramp Rate in throttle units per 10ms (see Section 17.6). As a result, at the minimum (slowest) ramp rate, the time from zero-to-full-throttle is 10.23 seconds. This is derived from 1 throttle unit per 10ms. In terms of voltage per second, this is equivalent to 1.173 V per second or 9.77% per second. When choosing an initial ramp rate avoid specifying a rate that is slower than this limitation. Choosing a slower rate than what's possible will cause the programming API to truncate the calculated result to zero throttle units per 10ms, leading to the effect of no ramp at all.

7. Feedback Device (Sensor Feedback)

Although the analog and quadrature signals are available all the time, the Talon SRX requires the robot application to “pick” a particular “Feedback Device” for soft limit and closed-loop features.

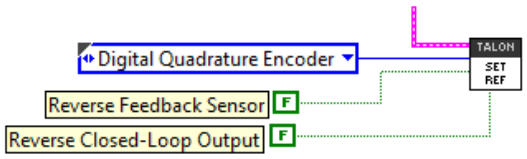
The selected “Feedback Device” defaults to Quadrature Encoder.

Once a “Feedback Device” is selected, the “Sensor Position” and “Sensor Velocity” signals will update with the output of the selected feedback device. It will also be multiplied by (-1) if “Reverse Feedback Sensor" is asserted programmatically.

Alternatively, the output of the closed loop logic can also be inverted if necessary.

7.1. LabVIEW

Use SET REF to select which Feedback Sensor to use for soft limits and closed-loop features. The supported selections include: Quadrature Encoder, Analog Encoder (or any continuous 3.3V analog sensor), Analog Potentiometer and more.



7.2. C++

`SetFeedbackDevice()` can be used to select Quadrature Encoder, Analog Encoder (or any continuous 3.3V analog sensor), Analog Potentiometer and more.

```
/* Quadrature Encoder CPR=1024 */
customMotorDescrip.SetFeedbackDevice(CANTalon::QuadEncoder);
customMotorDescrip.ConfigEncoderCodesPerRev(1024);
/* Analog signal with no wrap-around, 0-3.3V */
customMotorDescrip.SetFeedbackDevice(CANTalon::AnalogPot);
/* Analog signal with wrap-arounds tracked, 0-3.3V */
customMotorDescrip.SetFeedbackDevice(CANTalon::AnalogEncoder);
customMotorDescrip.ConfigPotentiometerTurns(10); /* multiple analog sweeps per mechanical rotation */
/* CTRE Magnetic Encoder: Absolute within one rotation */
customMotorDescrip.SetFeedbackDevice(CANTalon::CtreMagEncoder_Absolute);
/* CTRE Magnetic Encoder: Relative */
customMotorDescrip.SetFeedbackDevice(CANTalon::CtreMagEncoder_Relative);
/* Convert pulse width into a position. */
customMotorDescrip.SetFeedbackDevice(CANTalon::PulseWidth);
/* Counting falling edges on QuadA pin. */
customMotorDescrip.SetFeedbackDevice(CANTalon::EncFalling);
/* Counting rising edges on QuadA pin. */
customMotorDescrip.SetFeedbackDevice(CANTalon::EncRising);
```

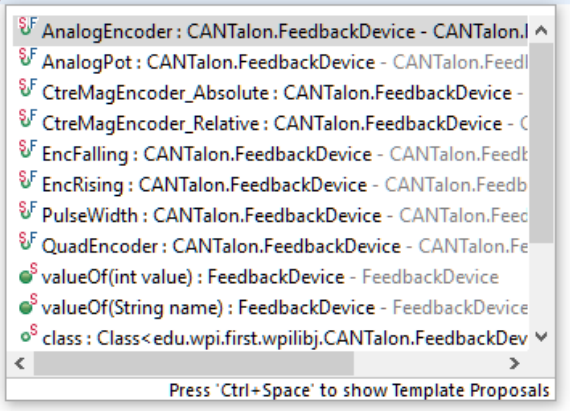
`SetSensorDirection()` can be used to keep the sensor and motor in phase for proper limit switch and closed loop features. This functions sets the "Reverse Feedback Sensor" signal.

```
/* pass true to reverse feedback sensor, false to leave it pure. */
customMotorDescrip.SetSensorDirection(true);
```

7.3. Java

`setFeedbackDevice()` can be used to select Quadrature Encoder, Analog Encoder (or any continuous 3.3V analog sensor) or Analog Potentiometer. Depending on software release EncRising may also be supported (increment position per rising edge on Quadrature-A).

```
customMotorDescrip.setFeedbackDevice(FeedbackDevice.);
```

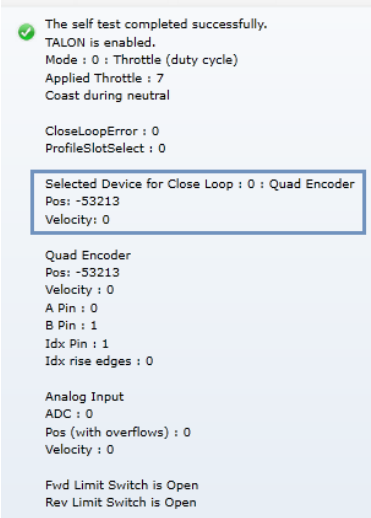


`reverseSensor()` and `reverseOutput()` are also available in java. `reverseSensor()` sets the "Reverse Feedback Sensor" signal. `reverseOutput()` sets the "Reverse Closed-Loop Output" signal.

```
/* pass true to reverse feedback sensor, false to leave it pure. */
customMotorDescrip.reverseSensor(true);
/* pass true to reverse the output of the closed loop math as an alternative method to flip motor direction.
 * Typically reverseSensor is sufficient to keep sensor and motor in
 * phase for proper limit switch and closed loop features. */
customMotorDescrip.reverseOutput(false);
```

7.4. Reversing sensor direction, best practices.

In order for limit switches and closed-loop features to function correctly the sensor and motor has to be “in-phase”. This means that the sensor position must move in a positive direction as the motor controller drives positive throttle. To test this, first drive the motor manually (using gamepad axis for example). Watch the sensor position either in the roboRIO Web-based Configuration Self-Test, or by calling `GetSensorPosition()` and printing it to console. If the “Sensor Position” moves in a negative direction while Talon SRX throttle is positive (blinking green), then use the “Reverse Feedback Sensor” signal to multiply the sensor position by (-1). Then retest to confirm “Sensor Position” moves in a positive direction with positive motor drive.



When using the Self-Test be sure to track the Selected Device Position which is **above** the Quadrature Encoder signals. These signals will reflect if "Reverse Feedback Sensor" is asserted.

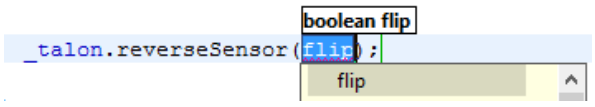
In the special case of using the EncRising feedback device, "Reverse Feedback Sensor" will need to be false. This Feedback Device is guaranteed to be positive since it increments per rising edge, and never decrements. "Reverse Closed-Loop Output" can then be used to output a negative motor duty-cycle. "Reverse Closed-Loop Output" can also be used to reverse a slave Talon SRX to be the signed opposite of the master Talon SRX.

“Reverse Feedback Sensor" can be changed with the following APIs.

7.4.1. Reversing Sensor – C++

```
_talon.SetSensorDirection(true);
```

7.4.2. Reversing Slave Motor Drive – Java



7.4.3. Reversing Feedback Sensor – LabVIEW

7.5. Supported Feedback Devices

Many feedback back interfaces are supported. The complete list is below.

7.5.1. Quadrature / Count Rising Edge / Count Falling Edge

The Talon directly supports Quadrature Encoders. If Quadrature is selected, the decoding is done in 4x mode. Additionally the Talon can be put into counter mode where edges on Quadrature A are counted, if the selected FeedbackDevice is changed to “Count Rising Edge” or “Count Falling Edge”.

7.5.2. Analog Potentiometer / Analog Encoder

Analog feedback sensors, or sensors that provide a variable voltage to represent position, are also supported. Some devices are continuous and wrap around from 3.3V back to 0V. For these sensors choose “Analog Encoder” so that these wrap arounds are detected and counted. For other sensors (like potentiometers) that do not wrap around the voltage signal, choose “Analog Potentiometer”.

7.5.3. Pulse Width Decoder

For sensors that encode position as a pulse width this mode can be used to decode the position. The pulse width decoder is 1us accurate and the maximum time between edges is 15ms.

7.5.4. Cross The Road Electronics Magnetic Encoder (Absolute and Relative)

The CTRE Magnetic Encoder is actually two sensor interfaces packaged into one (pulse width and quadrature encoder). Therefore the sensor provides two modes of use: absolute and relative.

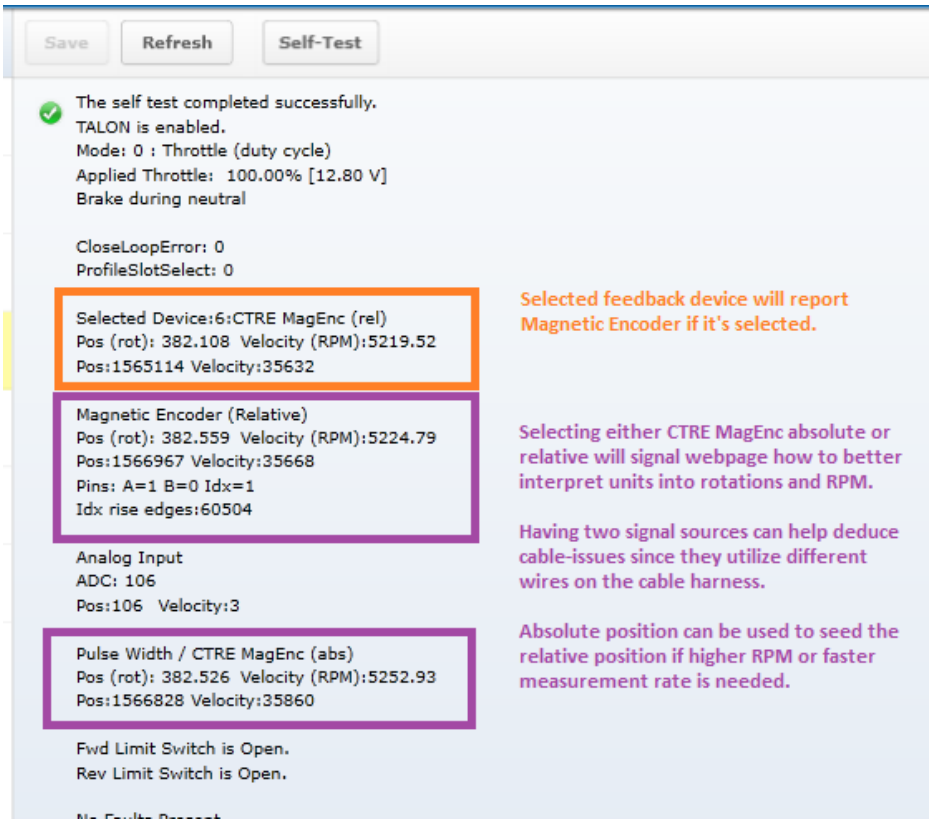
The advantage of absolute mode is having a solid reference to where a mechanism is without re-tare-ing or re-zero-ing the robot. The advantage of the relative mode is the faster update rate. However both values can be read/written at the same time. So a combined strategy of seeding the relative position based on the absolute position can be used to benefit from the higher sampling rate of the relative mode and still have an absolute sensor position.

Parameter	Absolute Mode	Relative Mode
Update rate (period)	4ms	100 us
Max RPM	7,500 RPM	15,000 RPM
Accuracy	12 bits per rotation (4096 steps per rotation)	12 bits per rotation (4096 steps per rotation)
Software API	Use Pulse Width API	Use Quadrature API

7.5.4.1. Selecting the Magnetic Encoder

Selecting the Magnetic Encoder for closed-loop / soft-limit features is no different than selecting other sensor feedback devices. There are two new feedback types: CTRE Magnetic Encoder (absolute) and CTRE Magnetic Encoder (relative). After selecting the Magnetic Encoder, no configuration calls are necessary to ensure proper scaling into rotations/RPMs.

Additionally the position and velocity can be retrieved without selecting the Magnetic Encoder as the selected feedback device. One method is to utilize the self-test in the roboRIO web-based configuration.



To programmatically read the absolute and relative position and velocities, the robot API provides get routines for pulse width decoding and quadrature, which can be read any time without sensor selection.

7.5.4.2. CTR Magnetic Encoder (absolute) – C++

```
int pulseWidthPos = _tal.GetPulseWidthPosition();     /* get the decoded pulse width encoder position */
int pulseWidthUs = _tal.GetPulseWidthRiseToFallUs();  /* get the pulse width in us, rise-to-fall */
int periodUs = _tal.GetPulseWidthRiseToRiseUs();      /* get the periodin us, rise-to-rise */
int pulseWidthVel = _tal.GetPulseWidthVelocity();    /* get the measured velocity */
/* is sensor plugged in to Talon */
CANTalon::FeedbackDeviceStatus sensorStatus = _tal.IsSensorPresent(CANTalon::CtreMagEncoder_Absolute);
bool sensorPluggedIn = (CANTalon::FeedbackStatusPresent == sensorStatus);
```

7.5.4.3. CTR Magnetic Encoder (absolute) – Java

```
int pulseWidthPos = _tal.getPulseWidthPosition();     /* get the decoded pulse width encoder position */
int pulseWidthUs = _tal.getPulseWidthRiseToFallUs();  /* get the pulse width in us, rise-to-fall */
int periodUs = _tal.getPulseWidthRiseToRiseUs();      /* get the periodin us, rise-to-rise */
int pulseWidthVel = _tal.getPulseWidthVelocity();    /* get the measured velocity */
/* is sensor plugged in to Talon */
FeedbackDeviceStatus sensorStatus = _tal.isSensorPresent(FeedbackDevice.CtreMagEncoder_Absolute);
boolean sensorPluggedIn = (FeedbackDeviceStatus.FeedbackStatusPresent == sensorStatus);
```

7.6. Multiple Talon SRXs and single sensor

There are many uses where a mechanism requires multiple Talon SRXs but a single sensor. For example, a single-side of a tank-drive or a shooter-wheel powered by two motors. The recommended strategy for these mechanisms is to…

- Connect the sensor to one of the Talons. This Talon will be referred to the “master” Talon.
- Set the supplemental Talon(s) to slave/follower mode and follow the device ID of the “master” Talon. See Section 9.1 for details.
- Select PercentVoltage Mode on the “master” Talon. Write a test robot application to drive the “master” Talon manually and confirm all slave Talon(s) correctly follow by watching the LEDs on all involved Talon SRXs. This can be done without motors connected. **Consult Talon User’s Guide to avoid damaging Talons by incorrectly wiring inputs/outputs**.
- Next, connect the motors to all involved Talons. **Consult Talon User’s Guide to avoid damaging Talons by incorrectly wiring inputs/outputs**. Test to make sure all motors drive in the correct directions. For example, when drive a shooter wheel, the motors may be oriented to require each motor to drive in opposite directions. If this is the case signal the slave Talon to reverse its output (Section 9.1.4). **Do not use excessive motor output.** Otherwise you may stall your motors if the slave and master Talon are driving against each other.
- Instrument the Sensor Position or Velocity using the roboRIO Web-based Configuration Page Self-Test, or print/plot the values. Ensure that sensor moves in a positive direction when master Talon is given positive forward throttle (green LEDs).
- Now that the motor(s) and sensor orientation has been confirmed, select the desired control mode of the master Talon. Any of the closed-loop/motion-profile control modes can be used.
- When using Velocity Closed-Loop, Current Closed-Loop, or MotionProfile Control Mode, be sure to calculate the F gain when all slave Talon/motors are connected and used.

7.7. Checking Sensor Health

Certain languages may have a routine for detecting if a sensor is plugged in. Not all sensor types support this as some interfaces do not provide a method to determine this reliably. But for the sensors that do, this provides a sanity check that the sensor is actually plugged in.

The supported sensor types are: CTRE Mag Encoder, Pulse-Width Encoded.
All other signals will return `FeedbackStatusUnknown`.

7.7.1. Checking Sensor Health – C++

```
CANTalon::FeedbackDeviceStatus status = _talon.IsSensorPresent(CANTalon::CtreMagEncoder_Absolute);
switch(status)
{
    case CANTalon::FeedbackStatusPresent:
        break;
    case CANTalon::FeedbackStatusNotPresent:
        break;
    case CANTalon::FeedbackStatusUnknown:
        break;
}
```

7.7.2. Checking Sensor Health – Java

```
FeedbackDeviceStatus status = _talon.isSensorPresent(FeedbackDevice.CtreMagEncoder_Absolute);
switch(status)
{
    case FeedbackStatusPresent:
        break;
    case FeedbackStatusNotPresent:
        break;
    case FeedbackStatusUnknown:
        break;
}
```

7.8. Velocity Measurement

The Talon SRX measures the velocity of all supported sensor types as well as the current position. Every 1ms a velocity sample is measured and inserted into a rolling average.

The velocity sample is measured as the change in position at the time-of-sample versus the position sampled 100ms-prior-to-time-of-sample. The rolling average is sized for 64 samples. Though these settings can be modified, the (100ms, 64 samples) parameters are default.

7.8.1. Changing Velocity Measurement Parameters.

The two characteristics for the Talon Velocity Measurement are…

- Sample Period (Default 100ms)
- Rolling Average Window Size (Default 64 samples).

These settings are also persistent across power cycles.

To change these values, the Talon SRX must be updated to…

- Greater or equal to 10.22 (HERO, non-FRC)
- Greater or equal to 2.22 (FRC)

Each can be modified through programming API, and through HERO LifeBoat (non-FRC).

NOTE – When the sample period is reduced, the **units** of the native velocity measurement is still change-in-position-per-100ms. In other words, the measurement is up-scaled to normalize the units. Additionally, a velocity sample is **always inserted every 1ms** regardless of setting selection.

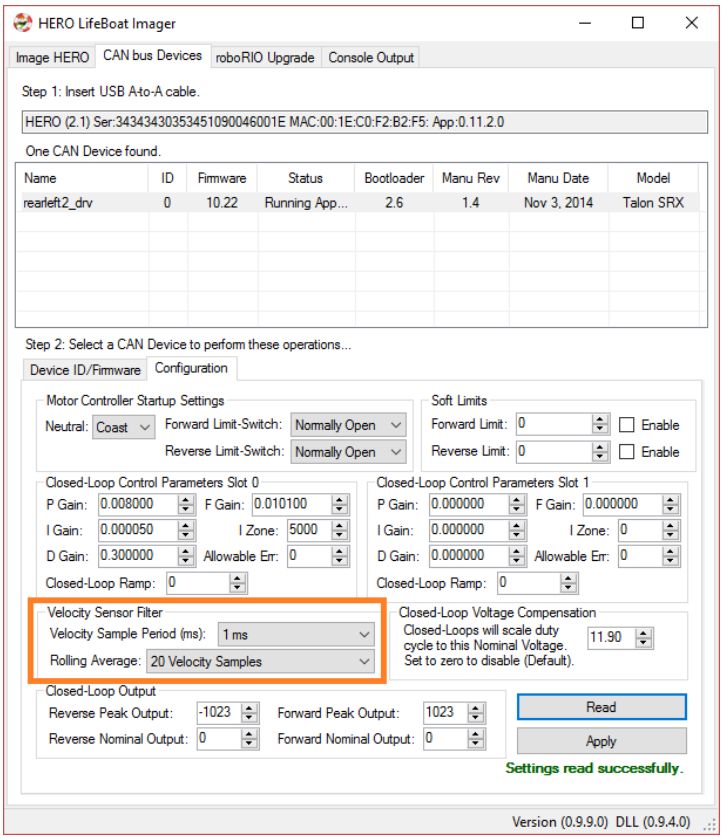
NOTE – The Velocity Measurement Sample Period is selected from a fixed list of pre-supported sampling periods [1, 5, 10, 20, 25, 50, 100(default)] milliseconds.

NOTE – The Velocity Measurement Rolling Average Window is selected from a fixed list of pre-supported sample counts: [1, 2, 4, 8, 16, 32, 64(default)]. If an alternative value is passed into the API, the firmware will **truncate** to the nearest supported value.

7.8.1.1. Changing Parameters – HERO C#

```
_talon.SetVelocityMeasurementPeriod(CTRE.TalonSrx.VelocityMeasurementPeriod.Period_10Ms);
_talon.SetVelocityMeasurementWindow(20);
```

7.8.1.2. Changing Parameters – Hero LifeBoat



When using the HERO Development Board, the Sample Period and Rolling Average can be modified through the graphical interface.

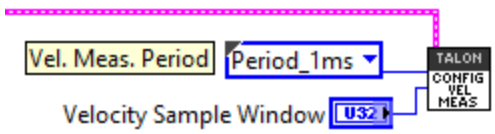
7.8.1.3. Changing Parameters – FRC Java

```
talon.SetVelocityMeasurementPeriod(VelocityMeasurementPeriod.Period_100Ms);
talon.SetVelocityMeasurementWindow(64);
```

7.8.1.4. Changing Parameters – FRC C++

```
_talon.SetVelocityMeasurementPeriod(CANTalon::Period_100Ms);
_talon.SetVelocityMeasurementWindow(64);
```

7.8.1.5. Changing Parameters – FRC LabVIEW



7.8.2. Recommended Procedure

The general recommended procedure is to first set these two parameters to the minimal value of ‘1’ (Measure change in position per 1ms, and no rolling average). Then plot the measured velocity while manually driving the Talon SRX(s) with a joystick/gamepad. Sweep the motor output to cover the expected range that the sensor will be expected to cover.

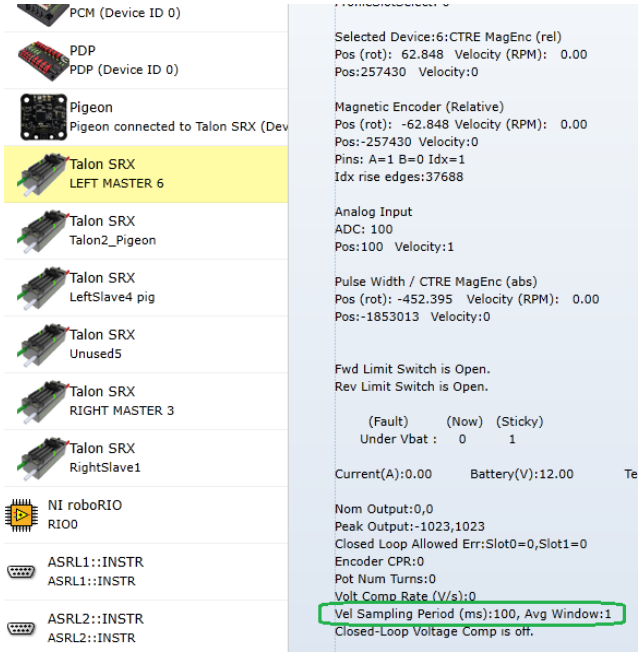
Unless the sensor velocity is considerably fast (hundreds of sensor units per sampling period) the measurement will be very coarse (visual stair-stepping as the motor output is increased). Increase the sampling period until the measured velocity is sufficiently granular.

At this point the sensor velocity will have minimal stair-stepping (good) but will be quite noisy. Increase the rolling average window until the velocity plot is sufficiently smooth, but still responsive enough to meet the timing requirements of the mechanism.

7.8.3. Self-Test Velocity Settings

The current Velocity Measurement Settings can be confirmed by performing the Self-Test in the roboRIO Web-based configuration page.

In this screenshot the Sampling Period is set to 100ms and the Rolling Average Window is set to 1 sample.



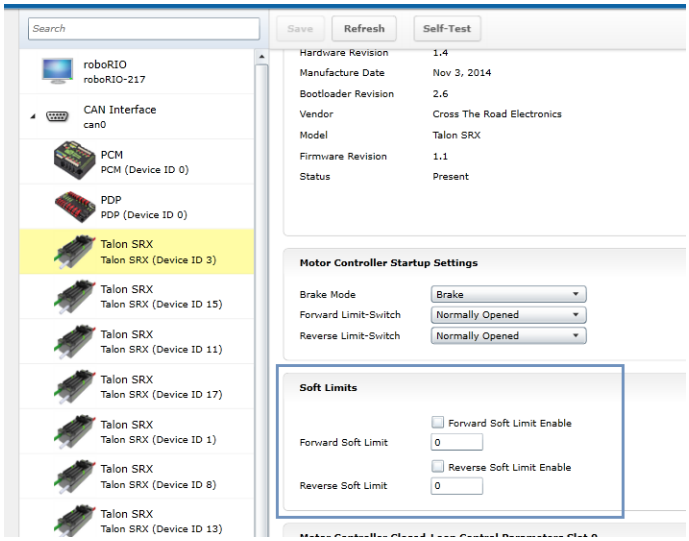
7.8.3.1. Self-Test reads 0 for Period and Window.

If the firmware is too old to allow configuration of the velocity measurement settings, then the self-test will report ‘0’ for both. In this configuration, the firmware is hardcoded to use 100ms and 64 samples.

8. Soft Limits

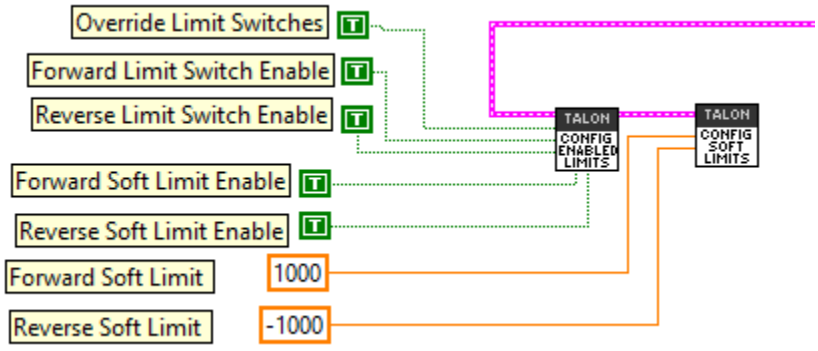
Soft limits can be used to disable motor drive when the “Sensor Position” is outside of a specified range. Forward throttle will be disabled if the “Sensor Position” is greater than the Forward Soft Limit. Reverse throttle will be disabled if the “Sensor Position” is less than the Reverse Soft Limit. The respective Soft Limit Enable must be enabled for this feature to take effect.

The settings can be set and confirmed in the roboRIO Web-based Configuration.



8.1. LabVIEW

The soft limits can also be set up programmatically. In LabVIEW, Soft Limit enables and thresholds can be set using both the `CONFIG ENABLED LIMITS VI` and `CONFIG SOFT LIMITS VI`.



8.2. C++

`ConfigLimitMode()` can be used to enable soft limits (and optionally limit switches if they are wired).

```
customMotorDescrip.ConfigLimitMode(CANSpeedController::kLimitMode_SoftPositionLimits);      /* limits switches and soft-limits */
customMotorDescrip.ConfigForwardLimit(20000);   /* set forward soft limit to 20,000 */
customMotorDescrip.ConfigReverseLimit(-20000);  /* set reverse soft limit to -20,000 */
```

8.3. Java

The limit threshold and enabled states can be individually specified using: `setForwardSoftLimit()`, `enableForwardSoftLimit()`, `setReverseSoftLimit()`, and `enablReverseSoftLimit()`.

```
customMotorDescrip.setForwardSoftLimit(10000);      /* set forward soft limit to 10,000 */
customMotorDescrip.enableForwardSoftLimit(true);    /* enable forward soft limit */
customMotorDescrip.setReverseSoftLimit(-10000);     /* set reverse soft limit to -10,000 */
customMotorDescrip.enableReverseSoftLimit(true);    /* enable reverse soft limit */
```

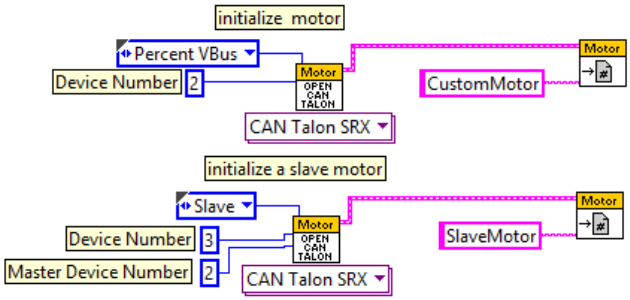
9. Special Control Modes

9.1. Follower Mode

Any given Talon SRX on CAN bus can be instructed to “follow” the drive output of another Talon SRX. This is done by putting a Talon SRX into “slave” mode and specifying the device ID of the “Master Talon” to follow. The “Slave Talon” will then mirror the output of the “Master Talon”. The “Master Talon” can be in any mode: closed-loop, voltage percent (duty-cycle), motion profile control mode, or even following yet another Talon SRX.

9.1.1. LabVIEW

When opening a Talon SRX, the Master Device Number determines which Talon to follow when in Slave Mode. The `CHANGE MODE VI` can also be used to enter Slave mode and specify the Master Device ID to follow.



9.1.2. C++

CANTalon objects can be constructed with the Follower mode, or can be changed afterwards. Pass the device ID of the Master Talon into `Set()`. The device ID should be between 0 and 62 (inclusive).

```
slaveMotor.SetControlMode(CANSpeedController::kFollower); /* set this motor to follow another TALON */
slaveMotor.Set(2); /* follow master TALON with device ID 2 */
```

9.1.3. Java

CANTalon objects can be constructed with the Follower mode, or can be changed afterwards. Pass the device ID, of the Master Talon into set(). The device ID should be between 0 and 62 (inclusive). Alternatively you can call the `getDeviceID()` routine of the Talon object created with the Master Talon SRX’s device ID.

```
slaveMotor.changeControlMode(CANTalon.ControlMode.Follower);
slaveMotor.set(customMotorDescrip.getDeviceID());
```

9.1.4. Reversing Slave Motor Drive

"Reverse Closed-Loop Output" can be used to invert the output of a slave Talon. This may be useful if a slave and master Talon are wired out of phase with each other.

9.1.4.1. Reversing Slave Motor Drive – C++

```
slaveMotor.SetClosedLoopOutputDirection(true);
```

9.1.4.2. Reversing Slave Motor Drive – Java

```
slaveMotor.reverseOutput(true);
```

9.1.4.3. Reversing Slave Motor Drive – LabVIEW

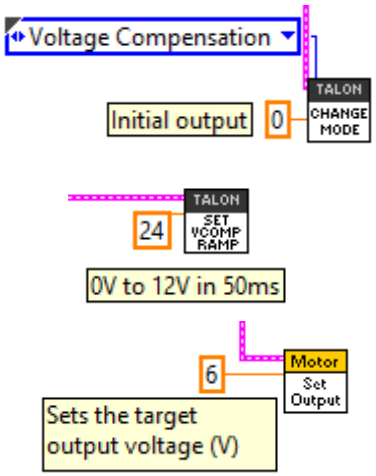
The 

VI explained in Section 7.1 can be used to set Reverse Closed-Loop output.

9.2. Voltage Compensation Mode

In Voltage Compensation Mode, the output duty cycle is calculated to meet the desired output voltage. This is done by sampling the battery voltage and scaling the output duty cycle to match the desired output voltage. If the desired output voltage exceeds battery voltage, then Talon will drive full available voltage.

9.2.1. LabVIEW



9.2.2. C++

```
customMotorDescrip.SetControlMode(CANTalon::kVoltage);  /* Voltage Compensation mode */
customMotorDescrip.SetVoltageCompensationRampRate(24.0);        /* 0V to 12V in 50ms */
customMotorDescrip.Set(6.0);  /* If battery voltage is say 12.6V, output will be 47.6% */
```

9.2.3. Java

```
customMotorDescrip.changeControlMode(TalonControlMode.Voltage); /* Voltage Compensation mode */
customMotorDescrip.setVoltageCompensationRampRate(24.0);        /* 0V to 12V in 50ms */
customMotorDescrip.set(6.0);  /* If battery voltage is say 12.6V, output will be 47.6% */
```

10. Closed-Loop Modes

Talon SRX supports position closed-loop, velocity closed-loop, current closed-loop, Motion Profiling, and Motion Magic. The actual implementation can be seen in Section 18. How is the closed-loop implemented?

All closed-loop modes update every 1ms (1000Hz).

TIP: While tuning the closed-loop, use the roboRIO web-based configuration to quickly change the gains “on the fly”. Once the PID is stable, set the gain values in code so that Talons can be swapped/replaced easily. Below is an example of tweaking the gains in the roboRIO Web-based configuration.

TIP: Example code of the parameters in C++ once initial tweaking is done. Parameters can also be tweaked “on the fly” using the roboRIO Web-based configuration or reading values from a file.

```
/* Closed-Loop Control Parameters */
_tal.SetPID(0.3,0,0,0.025);          /* P=0.3, F=0.025, rest is zero */
_tal.SetCloseLoopRampRate(0.0);      /* rest is zero */
_tal.SetIzone(0.0);                  /* rest is zero */
```

10.1. Position Closed-Loop

The Talon's Closed-Loop logic can be used to maintain a target position. Target and sampled position is passed into the equation in Section 18 in native units. However the robot API uses values expressed in decimal precision rotations if the requirements in Section 17.2.1 are met.

TIP: A simple strategy for setting up a closed loop is to zero out all Closed-Loop Control Parameters and start with the Proportional Gain.

For example if you want your mechanism to drive 50% throttle when the error is 4096 (one rotation when using CTRE Mag Encoder, see section 17.2.1), then the calculated Proportional Gain would be (0.50 X 1023) / 4096 = ~0.125.

To check our math, take an error (native units) of 4096 X 0.125 => 512 (50% throttle).

Tune this until the sensed value is close to the target under typical load. Many prefer to simply double the P-gain until oscillations occur, then reduce accordingly.

If the mechanism accelerates too abruptly, Derivative Gain can be used to smooth the motion. Typically start with 10x to 100x of your current Proportional Gain.

If the mechanism never quite reaches the target and increasing Integral Gain is viable, start with 1/100th of the Proportional Gain.

See Section 12.5 for HERO C# complete example of Position Closed-Loop. The functions used are comparable to the WPILIB C++/Java API.

10.2. Current Closed-Loop

The Talon's Closed-Loop logic can be used to approach a target current-draw. Target and sampled current is passed into the equation in Section 18 in milliamperes. However the robot API expresses the target current in amperes.

TIP: A simple strategy for setting up a current-draw closed loop is to zero out all Closed-Loop Control Parameters and start with the Feed-Forward Gain. Tune this until the current-draw is close to the target under typical load. Then start increasing P gain so that the closed-loop will make up for the remaining error. If necessary, reduce Feed-Forward gain and increase P Gain so that the closed-loop will react more strongly to the ClosedLoopError.

See Section 12.3 for a walk-through in LabVIEW. Though the example is written in LabVIEW, the procedure is the similar for all supported languages.

10.3. Velocity Closed-Loop

The Talon's Closed-Loop logic can be used to maintain a target velocity. Target and sampled velocity is passed into the equation in Section 18 in native units per 100ms. See Section 17.2.1 for information regarding native units.

TIP: A simple strategy for setting up a closed loop is to zero out all Closed-Loop Control Parameters and start with the Feed-Forward Gain. Tune this until the sensed value is close to the target under typical load. Then start increasing P gain so that the closed-loop will make up for the remaining error. If necessary, reduce Feed-Forward gain and increase P Gain so that the closed-loop will react more strongly to the ClosedLoopError.

TIP: Velocity Closed-Loop tuning is similar to Current Closed-Loop tuning in their use of feed-forward. Begin by measuring the sensor velocity while driving the Talon at a large throttle.

A complete Java example is available in Section 12.4.

10.4. Motion Profile Control Mode

A recent addition to the Talon SRX is the motion profile mode. With this, a savvy developer can actually stream motion profile trajectory points into the Talon's internal buffer (even while executing the profile). This allows fine control of position and speed throughout the entire movement. Since this is an advanced feature addition, a separate document will be provided shortly to cover this.

10.5. Peak/Nominal Closed-Loop Output

Since firmware 2.0, The Talon SRX supports bounding the output of the Closed-Loop modes. These settings are in effect during…

- Position Closed-Loop Control Mode
- Velocity Closed-Loop Control Mode
- Current Closed-Loop Control Mode
- Motion Profile Control Mode
- Motion Magic Control Mode

To clearly communicate what these parameters accomplish, the following terms are introduced.

- Peak Output- The “maximal” or “strongest” motor output allowed during closed-loop. These settings are useful to reduce the maximum velocity of the mechanism, and can make tuning the closed-loop simpler.

  The “Positive Peak Output” or “Forward Peak Output” refers to the “strongest” motor output when the Closed-Loop motor output is positive. If the Closed-Loop Output exceeds this setting, the motor output is capped.

  This value is typically positive or zero. The default value is +1023 as read in the web-based configuration Self-Test.

  The “Negative Peak Output” or “Reverse Peak Output” refers to the “strongest” motor output when the Closed-Loop motor output is negative. If the Closed-Loop Output exceeds this setting, the motor output is capped.

  This value is typically negative or zero. The default value is -1023 as read in the web-based configuration Self-Test.

- Nominal Output- The “minimal” or “weakest” motor output allowed during closed-loop if the “Closed-Loop Error” is nonzero and outside of the “Allowable Closed-Loop Error”.

  This is expressed using two signals: “Positive Nominal Output” and “Negative Nominal Output”, to uniquely describe a limit for each direction.

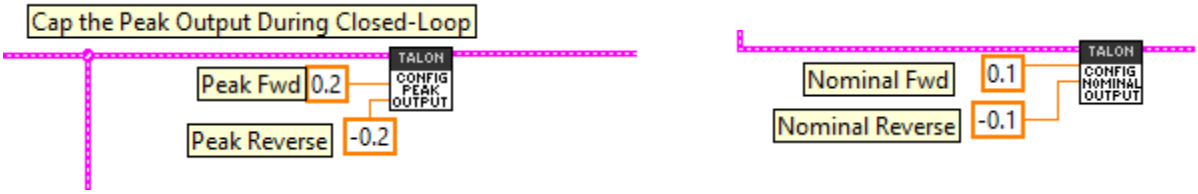
  If the Closed-Loop is calculating a motor-output that is too “weak”, the robot application can use these signals to promote the motor-output to a minimum limit. With this the robot application can ensure the motor-output is large enough to drive the mechanism. Typically this is accomplished with Integral gain, however this method may be a simpler alternative as there is no risk of Integral wind-up.

10.5.1. Peak/Nominal Closed-Loop Output – LabVIEW

These signals can be set using 

and 

.
Peak and nominal values range from -1.0 (full reverse) to +1.0 (full forward).



10.5.2. Peak/Nominal Closed-Loop Output – C++

The parameters are expressed in voltage where +12V represents full forward, and -12V represents full reverse.

```
/* set the peak and nominal outputs, 12V means full */
_talon.ConfigNominalOutputVoltage(+0, -0);
_talon.ConfigPeakOutputVoltage(+12, -12);
```

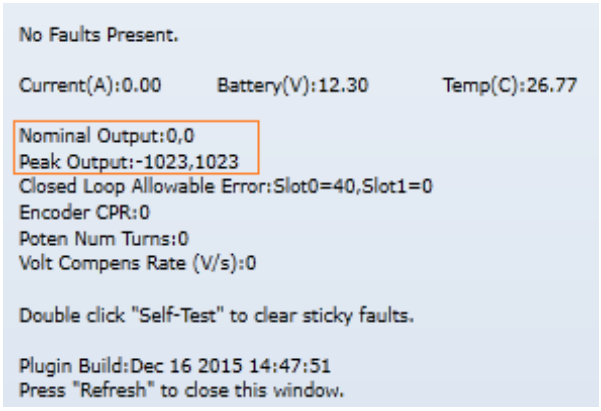
10.5.3. Peak/Nominal Closed-Loop Output – Java

The parameters are expressed in voltage where +12V represents full forward, and -12V represents full reverse.

```
/* set the peak and nominal outputs, 12V means full */
_talon.configNominalOutputVoltage(+0f, -0f);
_talon.configPeakOutputVoltage(+12f, -12f);
```

10.5.4. Peak/Nominal Closed-Loop Output – Web based Configuration Self-Test

The parameters are expressed in native units where +1023 represents full forward, and -1023 represents full reverse.



10.6. Allowable Closed-Loop Error

Since firmware 2.0, The Talon SRX supports specifying an Allowable Closed-Loop Error whereby the motor output is neutral regardless of the calculated result. This signal affects…

- Position Closed-Loop Control Mode
- Velocity Closed-Loop Control Mode
- Current Closed-Loop Control Mode
- Motion Profile Control Mode
- Motion Magic Control Mode

When the Closed-Loop Error is within the Allowable Closed-Loop Error

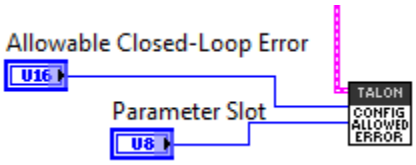
- P, I, D terms are zeroed. In other words, the math that uses P, I, and D gains is disabled. However, F term is still in effect.
- Integral Accumulator is cleared.

Allowable Closed-Loop Error defaults to zero, and is persistently saved.

10.6.1. Allowable Closed-Loop Error – LabVIEW

Use the 

VI to set this signal. The Allowable Closed-Loop error is in the same units as Closed-Loop Error. See Section 17.2.2 for more information. Each Closed-Loop Motor Profile slot has a unique Allowable Closed-Loop Error. Select ‘0’ or ‘1’ for slot 0 or slot 1 respectively.



10.6.2. Allowable Closed-Loop Error – C++

The Allowable Closed-Loop error is in the same units as Closed-Loop Error. See Section 17.2.2 for more information. Each Closed-Loop Motor Profile slot has a unique Allowable Closed-Loop Error. This function affects the currently selected slot/profile.

```
/* set the allowable closed-loop error,
 * Closed-Loop output will be neutral within this range.
 * See Table in Section 17.2.1 for native units per rotation.
 */
_talon.SetAllowableClosedLoopErr(409);
```

In this example, 409 corresponds to 9.985% of a rotation or 35.95 degrees (assuming 4096 units per rotation, such as 1024CPR encoder or CTRE Mag Encoder).

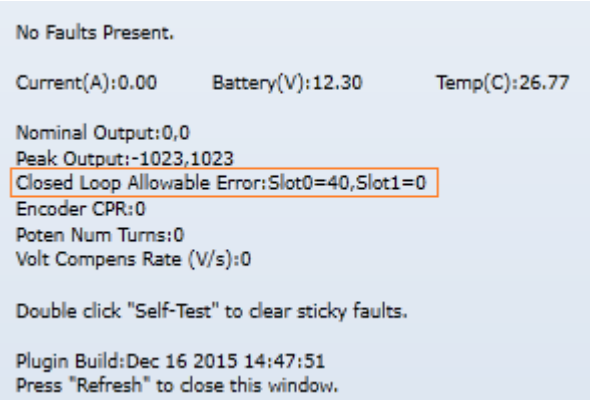
10.6.3. Allowable Closed-Loop Error – Java

The Allowable Closed-Loop error is in the same units as Closed-Loop Error. See Section 17.2.2 for more information. Each Closed-Loop Motor Profile slot has a unique Allowable Closed-Loop Error. This function affects the currently selected slot/profile.

```
/* set the allowable closed-loop error,
 * Closed-Loop output will be neutral within this range.
 * See Table in Section 17.2.1 for native units per rotation.
 */
_talon.setAllowableClosedLoopErr(409);
```

In this example, 409 corresponds to 9.985% of a rotation or 35.95 degrees (assuming 4096 units per rotation, such as 1024CPR encoder or CTRE Mag Encoder).

10.6.4. Allowable Closed-Loop Error – Web based Configuration Self-Test



The Allowable Closed-Loop Error for both slots can be read using the roboRIO Web based configuration Self-Test.

The values are in the same units as Closed-Loop Error.

In this example 40 corresponds to 0.9767% of a rotation or 3.52 degrees (assuming 4096 units per rotation, such as 1024CPR encoder or CTRE Mag Encoder).

10.7. Motion Magic Control Mode

Motion Magic is a control mode for Talon SRX that provides the benefits of Motion Profiling without needing to generate motion profile trajectory points. When using Motion Magic, Talon SRX will move to a set target position using a Trapezoidal Motion Profile, while honoring the user specified acceleration and maximum velocity (cruise velocity).

The benefits of this control mode over "simple" PID position closed-looping are…

- Control of the mechanism *throughout* the entire motion (as opposed to racing to the end target position).
- Control of the mechanism's inertia to ensure smooth transitions between set points.
- Improved repeatability despite changes in battery voltage.
- Improved repeatability despite changes in motor load.

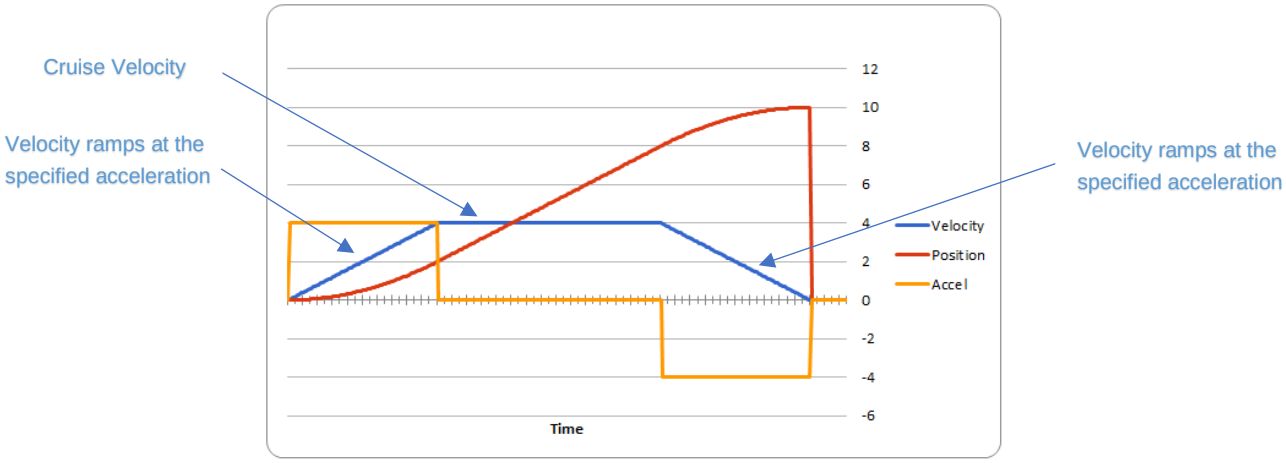
After gain/settings are determined, the robot-application only needs to periodically set the target position.

There is no general requirement to "wait for the profile to finish", however the robot application can poll the sensor position and determine when the motion is finished if need be.

A Trapezoidal Motion Profile generally ramps the output velocity at a specified acceleration until cruise velocity is reached. This cruise velocity is then maintained until the system needs to deaccelerate to reach the target position and stop motion. Talon determines when these critical points occur on-the-fly.

NOTE: If the remaining sensor distance to travel is small, the velocity may not reach cruise velocity as this would overshoot the target position. This is often refered to as a "triangle profile".

Example Trapezoidal Motion Profile



Motion Magic utilizes the same PIDF parameters as Motion Profiling.

The F parameter should be tuned using the process outlined in Section 12.8.3. Note that while the F parameter is not normally used for Position Closed-Loop control, Motion Magic requires this parameter to be properly tuned.

See Section 12.7 for a HERO C# complete example of Motion Magic. The functions used are comparable to the WPILIB C++/Java API.

See Section 12.8 for complete FRC JAVA walkthrough on tuning.

Two additional parameters need to be set in the Talon SRX– Acceleration and Cruise Velocity.

The Acceleration parameter controls acceleration and deacceleration rates during the beginning and end of the trapezoidal motion. The Cruise Velocity parameter controls the cruising velocity of the motion. Both parameters follow the API Unit Scaling in Section 17.2.2.

This feature is further enhanced when used with Closed-Loop Voltage Compensation (Section 10.8).

10.8. Closed-Loop Nominal Battery Voltage

Since firmware 2.22, The Talon SRX supports an additional signal called Closed-Loop Nominal Battery Voltage. When set, the output of the Closed Loop mode is compensated for the measured battery voltage.
This signal affects…

- Position Closed-Loop Control Mode
- Velocity Closed-Loop Control Mode
- Current Closed-Loop Control Mode
- Motion Profile Control Mode
- Motion Magic Control Mode

As an example, if the Position Closed-Loop Control Mode calculates an output of 512 units (50% motor output), then instead of applying 50% of max voltage, the Talon will apply 50% of the specified Nominal Battery Voltage. This is accomplished by scaling the motor output against the measured battery voltage.

If the measured battery voltage is below the necessary voltage to reach the calculated output of the compensated closed-loop control mode, 100% motor output is applied (unless capped by the peak motor output setting, see Section 10.5).

This is done every 1ms synchronous with the closed-loop controller.

Two functions are available to enable/disable this feature. Additionally, this signal can be set in HERO Lifeboat utility.

The setting is persistent across power cycles and has a default value of 0.0 (disabled).

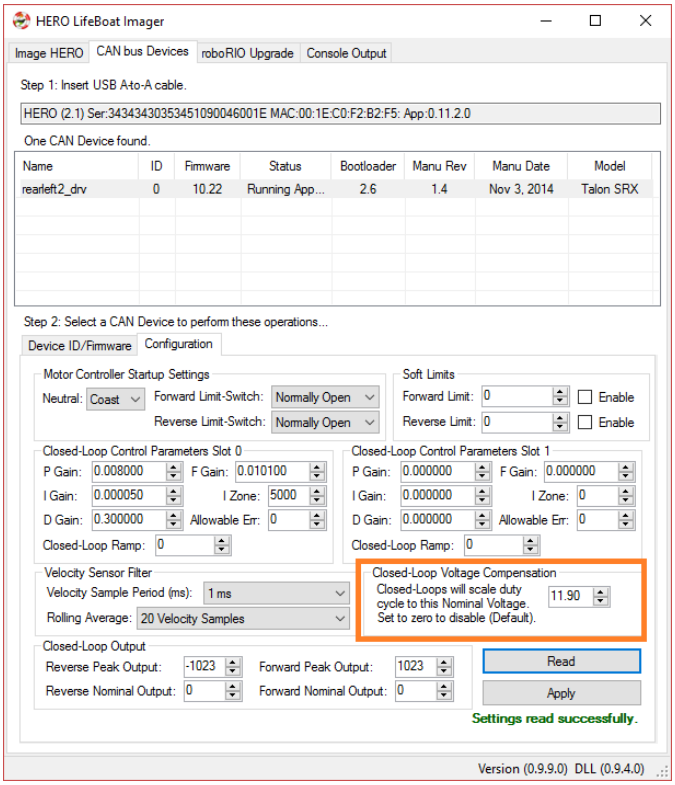
To leverage this feature, the Talon SRX must be updated to…

- Greater or equal to 10.22 (HERO, non-FRC)
- Greater or equal to 2.22 (FRC)

10.8.1. HERO C#

```
/* disables nominal battery voltage so that closed-loop output is purely the % of
available source voltage */
_talon.DisableNominalClosedLoopVoltage();
/* set nominal battery voltage to 12.0.  When closed loop output 100%, output 12.0V */
_talon.SetNominalClosedLoopVoltage(12.0f);
```

10.8.2. HERO LifeBoat



When using the HERO Development board, the Closed-Loop Nominal Voltage can be set using HERO LifeBoat.

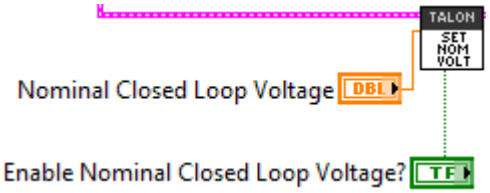
10.8.3. FRC Java

```
talon.disableNominalClosedLoopVoltage();
talon.setNominalClosedLoopVoltage(12.0);
```

10.8.4. FRC C++

```
_talon.DisableNominalClosedLoopVoltage();
_talon.SetNominalClosedLoopVoltage(12.0);
```

10.8.5. FRC LabVIEW



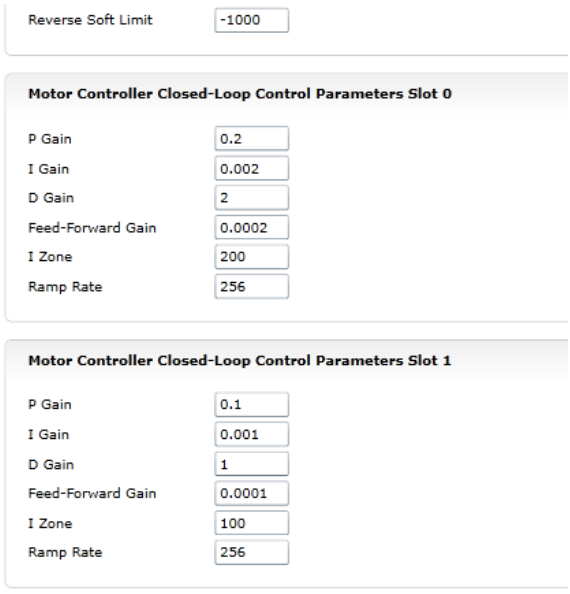
11. Motor Control Profile Parameters

The Talon persistently saves two unique Motor Control Profiles.
Each Motor Control Profile contains…

P Gain: K_p constant to use when control mode is a closed-loop mode.
I Gain: K_I constant to use when control mode is a closed-loop mode.
D Gain: K_D constant to use when control mode is a closed-loop mode.
F Gain: K_F constant to use when control mode is a closed-loop mode.
I Zone: Integral Zone. When nonzero, Integral Accumulator is automatically cleared when the absolute value of Closed-Loop Error exceeds it.
(Closed-Loop) **Ramp Rate**: Ramp rate to apply when control mode is a closed-loop mode.
Allowable Closed-Loop Error: When Closed-Loop Error's magnitude is less than this signal, Integral Accum and motor output are auto-zeroed during closed-loop.
Peak Closed-Loop Output: Caps the maximal or peak motor-output during closed-loop.
Nominal Closed-Loop Output: Promotes the minimal or weakest motor-output during closed-loop.

One unique feature of the Talon SRX is that gain values specified in a Motor Control Profile are not dedicated to just one type of closed-loop. When selecting a closed-loop mode (for example position or velocity) the robot application can select either of the two Motor Control Profiles to select *which* set of values to use. This can be useful for gain scheduling (changing gain values on-the-fly) or for persistently saving two sets of gains for two entirely different closed loop modes.

The settings can be set and read in the web control page.



11.1. Persistent storage and Reset/Startup behavior

The Talon SRX was designed to reduce the “setup” necessary for a Talon SRX to be functional, particularly with closed-loop features. This is accomplished with efficient CAN framing and persistent storage.

All settings in the Motor Control Profile (MCP) are saved persistently in flash. Additionally there are two complete Motor Control Profiles. Teams that use a constant set of values can simply set them using the roboRIO Web-based Configuration, and they will “stick” until they are changed again.

Additionally Motor Control Profile (MCP) Parameters can be changed though programming API. When they are changed, the values are ultimately copied to persistent memory using a wear leveled strategy that ensures Flash longevity, but also meets the requirements for teams.
-Changing MCP values programmatically always take effect immediately (necessary for gain tuning).
-If the MCP Parameters have remained unchanged for fifteen seconds, and an MCP Parameter value is then changed using programming API, they are copied to persistent memory immediately.
-If the persistent memory has been updated within the last fifteen seconds due to a previous value change, and an MCP Parameter value is changed again, it will be applied to persistent memory once fifteen seconds has passed since the last persistent memory update. However the closed-loop will react immediately to the latest values sent over CAN bus.
-If power loss occurs during the period of time when MCP Parameters are being saved to persistent storage, the previous values for all MCP Parameters prior to last value-change is loaded. This is possible because the Talon SRX keeps a small history of all value changes.

These features fit well with the two common strategies that FRC teams utilize when programmatically changing closed-loop parameters...

(1) Teams use programming API at startup to apply previous tested constants.
(2) Teams use programming API to periodically set/change the constants because they are “gain scheduled” or action specific.

For use case (1), the constants are eventually saved in Talon SRX persistent memory (worst case fifteen seconds after robot startup). Once this is done the Talon SRX will have the values in persistent storage, so even after Talons are power cycled, they will load the constants that were previous set. This frees the robot controller from needing to re-set the values during a power cycle, reset, brownout, etc…. On subsequent robot startups, when the robot controller sends the same values again, and Talon SRX will still react by updating its variables, and comparing against what’s saved in persistent storage to see if it needs to be updated again. In the event the robot code changes to use new constants, the Talon will again update the persistent storage shortly after getting the new values.

For use case (2) teams, there are two “best” solutions depending on what’s being accomplished. If a team needs to switch between two sets of gains, they can leverage both MCP slots by setting one set of constants in slot 0, and another unique set of constants in slot 1. Then during the match, teams can switch between the two with a single API. This means that as far as the Talon is concerned, the values in each slot never changes so the contents of the Talon’s persistent storage never changes. Instead the robot controller just changes *which* slot to use. So this use case regresses to use case (1), and a freshly booted Talon already has all the MCP parameters it needs to function.

For use case(2) teams that requires more than two gain sets likely are changing gain values so frequently (as a function of autonomous, or state machine driven logic) that they would prefer not to rely on the previous set of gains sent to the Talon (despite it being available at startup). In which case they likely will periodically set the MCP parameters continuously (every number of loops or fixed period of time). Talon SRX always honors whatever parameters are requested over CAN bus, overriding what was loaded at startup or mirrored in persistent storage. And since the persistent storage is wear-leveled and mirrored at fifteen second intervals, this has no harmful impact on Flash longevity. So this use case is also supported well.

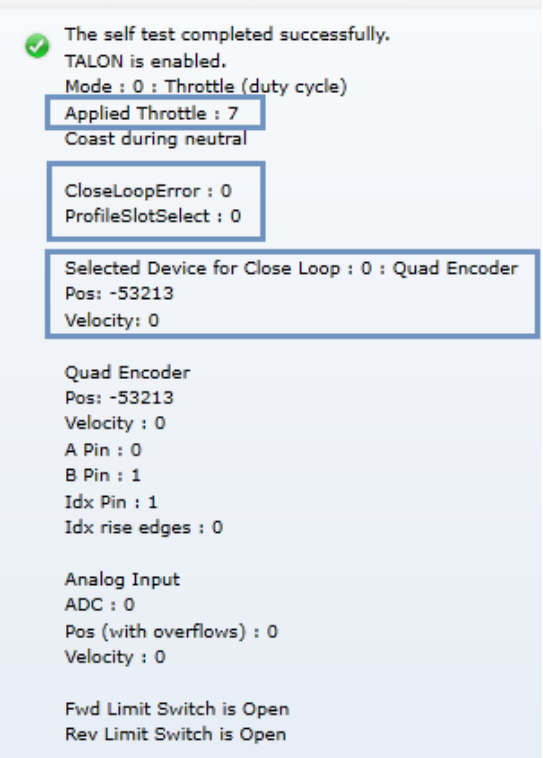
Beyond the Motor Control Profile Parameters, closed-loop modes requires selecting
-which control mode (position or velocity)
-which feedback sensor to use
-if the feedback sensor should be reversed
-if the closed-loop output should be reversed
-what is the latest target or set point
-the global ramp rate (if specified)
-which Motor Control Profile Slot to use.

The programming API provides set functions for all of these, but what’s noteworthy is that all of these signals are saved in the robot controller, and periodically sent inside *one complete* CAN frame. This means that if a Talon SRX loses power and is booted back up again (due to cable disconnect, battery brownout, etc…) the Talon receives all of the necessary signals after *getting one single control frame*. This is far more robust than requiring the robot application to re-set and re-acknowledge each parameter individually in the event of a reset.

11.2. Inspecting Signals

When testing/calibrating closed-loops it is helpful to plot/check…
-Closed-Loop Error
-Output (Applied) Throttle
-Profile Slot Select (which profile slot the closed-loop math is using).
-Position and Velocity depending control mode.

The Self-Test can provide these values for quick sanity checking. These values are also available with programming API for custom plotting, smart dashboard, LabVIEW front panels, etc...

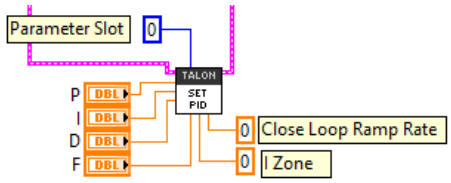


12. Closed-Loop Code Excerpts/Walkthroughs

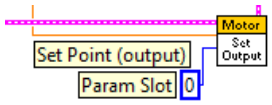
12.1. Setting Motor Control Profile Parameters

12.1.1. LabVIEW

Setting the Motor Controller Profile parameters can be done with the SET PID VI.
This allows filling all parameters for a given Parameter Slot.



Specifying the set point is also done with the Set Output VI. Additionally you can select the Parameter Slot to use for the selected closed-loop.



12.1.2. C++

Closed-loop parameters for a given profile slot can be modified with several different functions.

```
double p = 0.3;         /*Kp */
double i = 0.003;       /*Ki */
double d = 3;           /*Kd */
double f = 0.0003;      /*Kf */
int izone = 300;        /* encoder ticks / analog units */
double ramprate = 48;   /* volts per second, => 0% to 100% in 250ms */
int profile = 1;    /* can be 0 or 1 */
customMotorDescrip.SelectProfileSlot(profile);
customMotorDescrip.SetPID(p, i, d, f);
customMotorDescrip.SetIzone(izone);
customMotorDescrip.SetCloseLoopRampRate(ramprate);
```

Setting the target position or velocity is also done with `Set()`.

```
customMotorDescrip.Set(targetPosOrVel); /* use Set() to servo to target position or velocity */
```

12.1.3. Java

Closed-loop parameters for a given profile slot can be modified using `setPID()`. This also sets the “Profile Slot Select” to the slot being modified. There are also individual Set functions for each signal.

```
double p = 0.1;         /*Kp */
double i = 0.001;       /*Ki */
double d = 1;           /*Kd */
double f = 0.0001;      /*Kf */
int izone = 100;        /* encoder ticks / analog units */
double ramprate = 36;   /* volts per second */
int profile = 0;    /* can be 0 or 1 */
customMotorDescrip.setPID(p, i, d, f, izone, ramprate, profile);
```

Setting the target position or velocity is also done with `set()`.

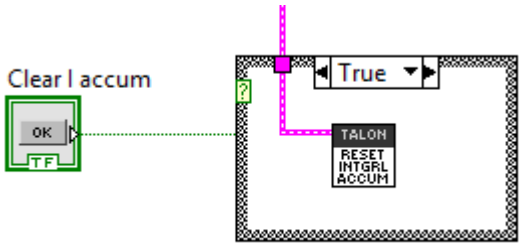
```
customMotorDescrip.set(targetPosOrVel); /* use set() to servo to target position or velocity */
```

12.2. Clearing Integral Accumulator (I Accum)

Clearing the integral accumulator ("I Accum") may be necessary to prevent integral windup. When using "I Zone" this is done automatically when the Closed-Loop Error is outside the "I Zone". However there may be other situations when manually clearing the integral accumulator is necessary. For example, if the mechanism that's being closed-looped is "close enough" and its desirable to reduce occasional spurts of movement caused by a slowly incrementing integral term, then the robot logic can periodically clear the "I Accum" to prevent this.

12.2.1. LabVIEW

In this example a case structure is leveraged to conditionally clear the Integral Accumulator when the case structure conditional evaluates true (this example uses a system button on the front panel).



12.2.2. C++/Java

The `ClearIaccum()` function is available in C++/Java.

```
customMotorDescrip.ClearIaccum();
```

12.2.3. Is Integral Accum cleared any other time?

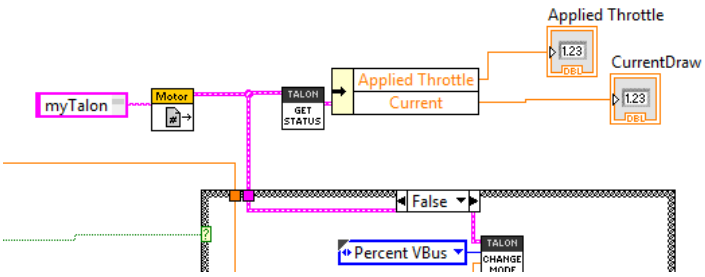
In addition to the "I Zone" feature and manual clear, there are certain cases where the integral accumulator is automatically cleared for more predicable motor response…
-Whenever the control mode of a Talon is changed.
-When a Talon is in the disabled state.
-When the motor control profile slot has changed.
-When the Closed Loop Error's magnitude is smaller than the "Allowable Closed Loop Error".

12.3. Current Closed-Loop Walkthrough – LabVIEW

This example can be found on the CTR GitHub account. https://github.com/CrossTheRoadElec/FRC-Examples

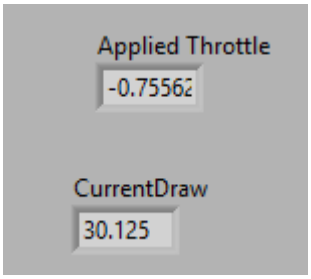
12.3.1. Current Closed-Loop Walkthrough – Collect Sensor Data – LabVIEW

The first step is to confirm that the sensor is functional and in-phase with the motor. Additionally data can be collected to be used later to determine a decent Feed-forward gain.



Create a Talon and instrument its current draw and throttle output. Also provide a method to directly control the Talon to servo (Percent Voltage). In this example Talon is in Percent Voltage mode when button is off, and in current closed-loop when button is on.

Enable the Robot and drive the motor to a reasonable output. Take note of what the throttle output in percent. This will gives us a basic relationship between current and motor-output.



Shown to the left is the LabVIEW front panel, however these values can also be retrieved in the roboRIO web-based configuration (works for all FRC languages). Print statements can also be used for C++, JAVA, and HERO C#.

This example was taken by using a Talon SRX and CIM to back drive a secondary CIM motor with leads connected together. At full throttle this setup will exceed the 40A breaker rating so less-the-full throttle was used. However in a typical mechanism full throttle may be used to acquire a more accurate measurement.

12.3.2. Current Closed-Loop Walkthrough – Calculating Feed Forward– LabVIEW

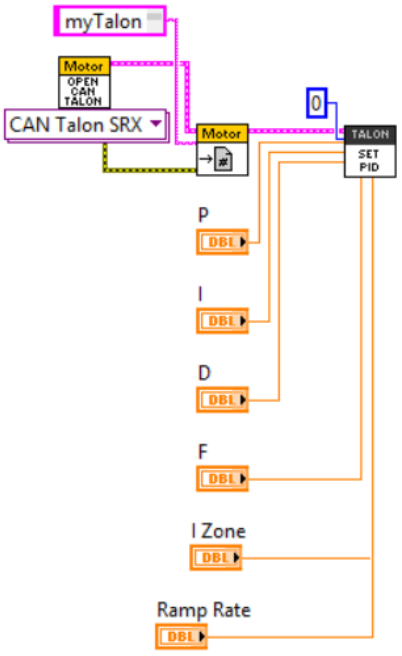
From this we can calculate our initial Feed-Forward gain. Since measured current is always positive, we ignore the negative sign of applied throttle.

According to Section 17.2.2, the Talon SRX closed loop takes the desired current in milliamps and outputs a throttle value (-1023 to +1023). Knowing this we calculate a Feedforward that will gives us 75% throttle when the Target currentDraw is 30125 mA.

(0.7556 X 1023) / 30125 mA => **~0.02566**

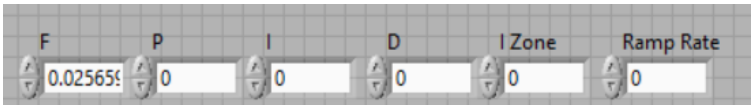
As a math check, when the set point is 30125mA, the feedforward term will be 30125 X **0.02566** gives us 773 throttle units (~75%).

Next we will set the F gain to **0.02566**, while zeroing the PID gains. This can be done in the web-based configuration or programmatically using the robot API.



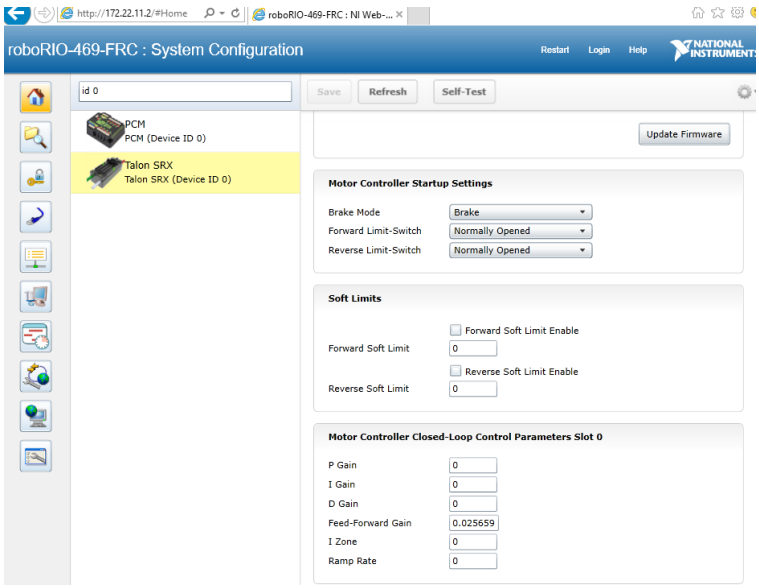
On the left we have an example in LabVIEW, setting the closed-loop parameters in Begin.vi.

The values are entered below in the front panel, though they could also be constants if need be.

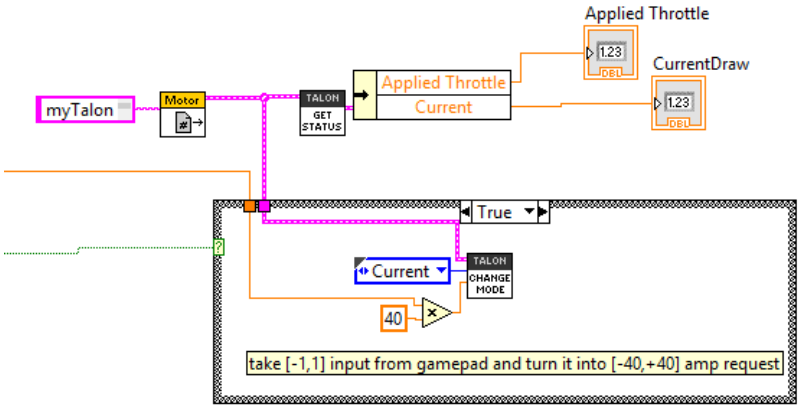


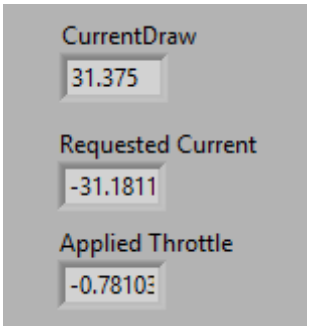
Additionally, the other languages have comparable APIs for gain-setting, or the gains can be set using the roboRIO web-based configuration.

Web-based configuration can also be used to double check that the settings are what you expect.



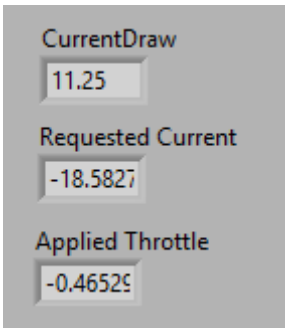
Now rerun the test setup, but now we will press and hold our button to conditionally enable Current-closed loop mode.





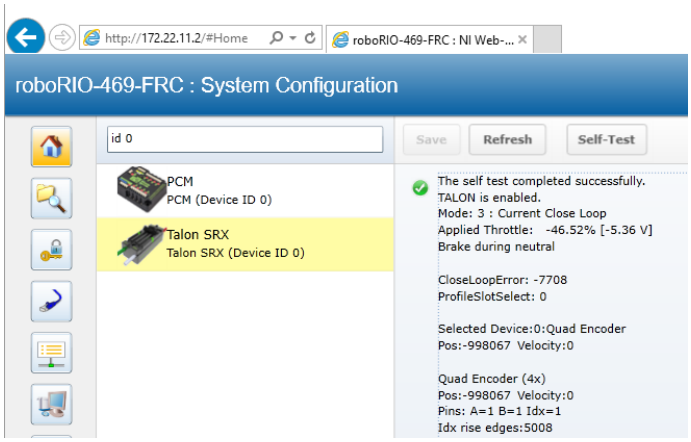
Not surprisingly the desired and measured current draw are nearly identical.

Of course there is no guarantee this will be the case at all request current draws under differing battery conditions. Remember this is just Feed-forward, we're not close-looping yet! For example, as we deviate away from our tuned point, we see error between our desired and measured current.



Next we will tune P gain so that the closed-loop actually responds to error.

12.3.3. Current Closed-Loop Walkthrough – Dialing Proportional Gain – LabVIEW



In this example the Closed-Loop Err was ~7000 (mA).

Perhaps we want to start with adding another 10% motor output to help approach our target current.

10% throttle X 1023 = 102 throttle units

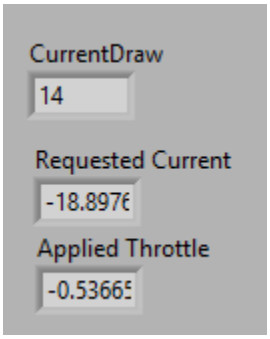
Since we want 102 throttle units when the error is 7700, calculate P gain by dividing the two…

102.3 / 7700 = **0.01329**

To check our math, let's take our P-gain of 0.01329 and multiply by Closed Loop Err (7700mA)

0.01329 X 7700 = 102 (10% of 1023 full throttle).

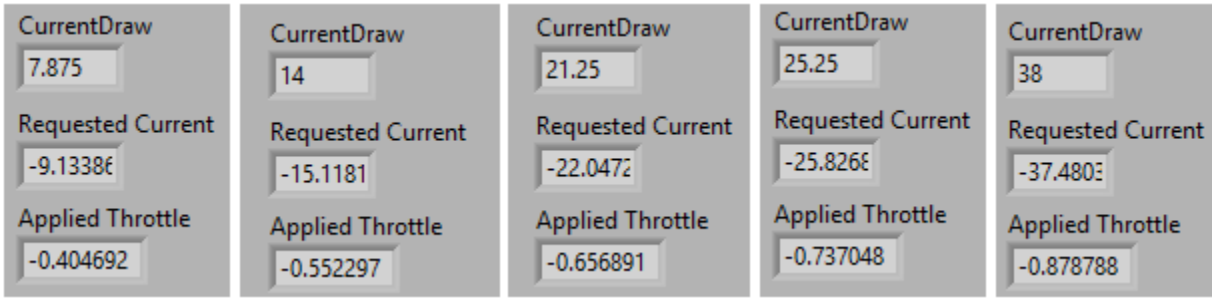
Now we can expect approximately 10% more motor output when our error is ~7 amps.



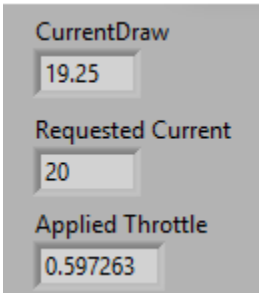
Here we attempt to reproduce the same target point. We see our throttle output has increased as a result of the stronger P-gain and our current draw is closer to our target.

Keep increasing the P-gain until the desired response is achieved. To save time, many will double the P-gain until oscillation is observed (overshooting the target and then returning to target. This can also be observed by plotting, or watching the color change on the Talon SRX LEDs).

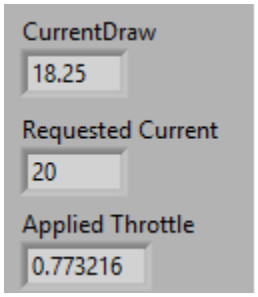
After further increasing P-gain, we see our desired and measured current-draw to follow closely.



We can also observe how the closed-loop responds to a change in load. Disconnecting the back driven CIM motor's connected leads and connecting them to a 0.2 ohm power resistor reveals how the Closed-Loop increases its motor output to target the desired 20 amps.



Closed Loop driving 59.7% when back-driven CIM has leads connected.



Closed Loop driving 77.7% when back-driven CIM has power resistor in series with leads.

With additional tweaking and leveraging the remaining gains (I and D), the closed-loop can be further improved, though many will find that a simple FP loop will be sufficient for many applications.

12.4. Velocity Closed-Loop Walkthrough – Java

This example can be found on the CTR GitHub account. https://github.com/CrossTheRoadElec/FRC-Examples

12.4.1. Velocity Closed-Loop Walkthrough – Collect Sensor Data – Java

The first step is to drive the Talon SRX manually to check that the selected sensor is functioning and in phase with the motor. The following example below will accomplish this. Deploy and drive the Talon forward by pulling the gamepad's y-axis.

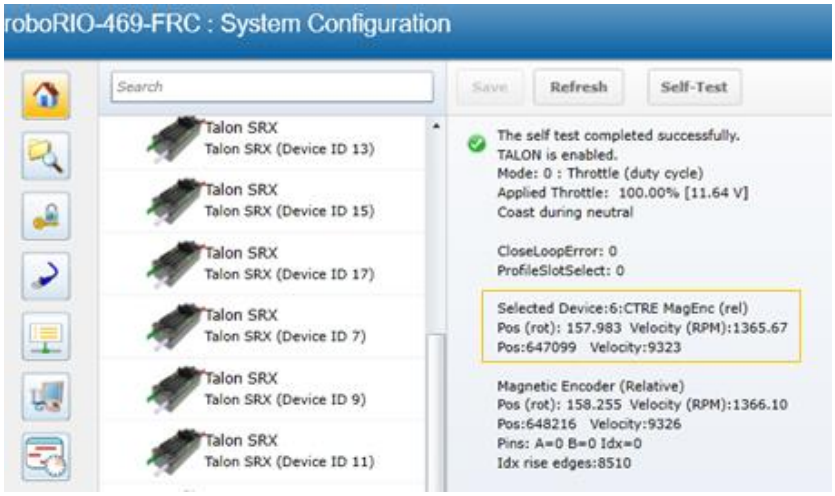
```
public void robotInit() {
    /* first choose the sensor */
    _talon.setFeedbackDevice(FeedbackDevice.CtreMagEncoder_Relative);
    _talon.reverseSensor(false);
    //_talon.configEncoderCodesPerRev(XXX), // if using FeedbackDevice.QuadEncoder
    //_talon.configPotentiometerTurns(XXX), // if using FeedbackDevice.AnalogEncoder or AnalogPot

    /* set the peak and nominal outputs, 12V means full */
    _talon.configNominalOutputVoltage(+0.0f, -0.0f);
    _talon.configPeakOutputVoltage(+12.0f, -12.0f);
    /* set closed loop gains in slot0 */
    _talon.setProfile(0);
    _talon.setF(0);
    _talon.setP(0);
    _talon.setI(0);
    _talon.setD(0);
}
public void teleopPeriodic() {
    /* get gamepad axis */
    double leftYstick = _joy.getAxis(AxisType.kY);
    double motorOutput = _talon.getOutputVoltage() / _talon.getBusVoltage();
    /* prepare line to print */
    _sb.append("\tout:");
    _sb.append(motorOutput);
    _sb.append("\tspd:");
    _sb.append(_talon.getSpeed() );

    if(_joy.getRawButton(1)){
        /* Speed mode */
        double targetSpeed = leftYstick * 1500.0; /* 1500 RPM in either direction */
        _talon.changeControlMode(TalonControlMode.Speed);
        _talon.set(targetSpeed); /* 1500 RPM in either direction */

        /* append more signals to print when in speed mode. */
        _sb.append("\terr:");
        _sb.append(_talon.getClosedLoopError());
        _sb.append("\ttrg:");
        _sb.append(targetSpeed);
    } else {
        /* Percent voltage mode */
        _talon.changeControlMode(TalonControlMode.PercentVbus);
        _talon.set(leftYstick);
    }

    if(++_loops >= 10) {
        _loops = 0;
        System.out.println(_sb.toString());
    }
    _sb.setLength(0);
}
```

```
out:0.9708333333333333 spd:1372.265625
out:0.975 spd:1370.947265625
out:0.975 spd:1372.119140625
out:0.975 spd:1371.826171875
out:0.975 spd:1369.04296875
out:0.975 spd:1372.265625
out:0.975 spd:1365.8203125
out:0.9708333333333333 spd:1370.654296875
out:0.975 spd:1366.259765625
out:0.9708333333333333 spd:1368.310546875
out:0.975 spd:1368.896484375
out:0.975 spd:1366.552734375
out:0.975 spd:1370.654296875
out:0.975 spd:1366.69921875
```

While throttling the Talon in the positive direction, make sure the sensor speed is also positive.

Additionally note the approximate sensor speed while the Talon is driven. getSpeed() will return the speed in RPM since the requirements in Section 17.2.1 are met.

The same values can be read in the roboRIO web-based configuration under Self-Tests.



12.4.2. Velocity Closed-Loop Walkthrough – Calculating Feed Forward– Java

Now that we've confirmed that the position/speed moves in the positive direction with forward (green throttle), we can calculate our Feed-forward gain. According to Section 17.2.1, our selected sensor uses 4096 native units per rotation. That means our measurement of **1366RPM** scales to **9326** native units per 100ms. This is also calculated for you in the Self-Test.

Velocity is measured in change in native units per $T_{velMeas}$= 100ms.

(**1366** Rotations / min) X (1 min / 60 sec) X (1 sec / 10 $T_{velMeas}$) X (4096 native units / rotation)
= **9326** native units per 100ms

Now let's calculate a Feed-forward gain so that 100% motor output is calculated when the requested speed is 9328 native units per 100ms.

F-gain = (100% X 1023) / **9326**
F-gain = 0.1097

Let's check our math, if the target speed is **9326** native units per 100ms, Closed-loop output will be (**0.1097** X **9326**) => 1023 (full forward).

```
_talon.setF(0.1097);
_talon.setP(0);
_talon.setI(0);
_talon.setD(0);
```

Next we will set the calculated gain. This can also be done in the roboRIO web-based configuration or programmatically.

After applying the new gain, rerun the test but hold down button1 to put Talon into Speed Control Mode. Now review the target and measured speed to see how close we are.

A few DS console samples are shown below, which contain the print statements. Looking at "spd" and "trg" we see that we're within ~100RPM for most of the speed-sweep. Remember "err" is in native units per 100ms. So an error of 900 units per 100ms equals an error of 131RPM since each rotation is 4096 units.

```
out:-84.375 spd:-84.375 err:-224 trg:-117.1875
out:-89.6484375 spd:-89.6484375 err:-184 trg:-117.1875
out:-91.259765625 spd:-91.259765625 err:-177 trg:-117.1875
out:-85.693359375 spd:-85.693359375 err:-216 trg:-117.1875
out:-86.42578125 spd:-86.42578125 err:-207 trg:-117.1875
out:-93.45703125 spd:-93.45703125 err:-163 trg:-117.1875
out:-87.01171875 spd:-87.01171875 err:-208 trg:-117.1875
out:-84.814453125 spd:-84.814453125 err:-221 trg:-117.1875
```

```
out:-869.091796875 spd:-869.091796875 err:-466 trg:-937.5
out:-869.82421875 spd:-869.82421875 err:-463 trg:-937.5
out:-868.798828125 spd:-868.798828125 err:-469 trg:-937.5
out:-869.677734375 spd:-869.677734375 err:-463 trg:-937.5
out:-868.505859375 spd:-868.505859375 err:-470 trg:-937.5
out:-866.015625 spd:-866.015625 err:-488 trg:-937.5
out:-866.748046875 spd:-866.748046875 err:-484 trg:-937.5
out:-868.798828125 spd:-868.798828125 err:-469 trg:-937.5
out:-867.919921875 spd:-868.359375 err:-472 trg:-937.5
```

```
out:-916.9921874999999 spd:-916.9921874999999 err:-538 trg:-996.09375
out:-920.9472656249999 spd:-920.9472656249999 err:-513 trg:-996.09375
out:-924.0234374999999 spd:-924.0234374999999 err:-491 trg:-996.09375
out:-920.2148437499999 spd:-920.2148437499999 err:-517 trg:-996.09375
out:-917.2851562499999 spd:-917.2851562499999 err:-538 trg:-996.09375
out:-916.5527343749999 spd:-916.5527343749999 err:-543 trg:-996.09375
out:-920.9472656249999 spd:-920.9472656249999 err:-512 trg:-996.09375
out:-920.5078124999999 spd:-920.5078124999999 err:-516 trg:-996.09375
out:-920.3613281249999 spd:-920.3613281249999 err:-437 trg:-972.65625
```

```
out:-1135.107421875 spd:-1135.107421875 err:-889 trg:-1265.625
out:-1129.541015625 spd:-1129.541015625 err:-930 trg:-1265.625
out:-1134.228515625 spd:-1134.228515625 err:-904 trg:-1265.625
out:-1131.005859375 spd:-1131.005859375 err:-922 trg:-1265.625
out:-1127.34375 spd:-1127.34375 err:-944 trg:-1265.625
out:-1136.279296875 spd:-1136.279296875 err:-882 trg:-1265.625
out:-1132.177734375 spd:-1132.177734375 err:-912 trg:-1265.625
out:-1126.7578125 spd:-1126.7578125 err:-948 trg:-1265.625
```

Additionally, since we have no feedback, you will find changes in load will impact the error considerably.

12.4.3. Velocity Closed-Loop Walkthrough – Dialing Proportional Gain – Java

Next we will add in P-gain so that the closed-loop can react to error. Suppose given our worst error so far (900 native units per 100ms), we want to respond with another 10% of throttle. Then our starting p-gain would be….

(10% X 1023) / (900) **= 0.113333**

Now let's check our math, if the Talon SRX sees an error of 900 the P-term will be

900 X **0.113333** = 102 (which is about 10% of 1023)

P-gain = **0.113333**

```
/* set closed loop gains in slot0 */
_talon.setProfile(0);
_talon.setF(0.1097);
_talon.setP(0.113333);
_talon.setI(0);
_talon.setD(0);
```

Apply the P -gain programmatically using your preferred method. Now retest to see how well the closed-loop responds to varying loads. Double the P -gain until the system oscillates (too much) or until the system responds adequately.

If the mechanism is moving to swiftly, you can add D-gain to smooth the motion. Start with 10x the p-gain.

If the mechanism is not quite reaching the final target position (and P -gain cannot be increased further without hurting overall performance) begin adding I-gain. Start with 1/100th of the P-gain.

Some mechanisms may require that the closed-loop can never spin in reverse of the desired direction (due to closed-loop wanting to slow down). This behavior can be achieve by reducing the Closed-Loop peak output voltage as show below (second parameter changed from -12V to 0).

```
/* set the peak and nominal outputs, 12V means full */
_talon.configNominalOutputVoltage(+0.0f, -0.0f);
_talon.configPeakOutputVoltage(+12.0f, 0.0f); /* only positive throttle */
/* set closed loop gains in slot0 */
_talon.setProfile(0);
_talon.setF(0.1097);
_talon.setP(0.22);
_talon.setI(0);
_talon.setD(0);
```

12.5. Position Closed-Loop – HERO C# (non-FRC)

Below is a full example for Position Closed-Looping using the HERO development board. These functions are also available in FRC C++/Java, and comparable VIs are available in LabVIEW.

This example also demonstrates switching between Position Closed-Loop and PercentVoltage mode.

This example can be found on the CTR GitHub account.
https://github.com/CrossTheRoadElec/HERO-Examples

```
/**
 * Example demonstrating the position closed-loop servo.
 * Tested with Logitech F350 USB Gamepad inserted into HERO.
 *
 * Use the mini-USB cable to deploy/debug.
 *
 * Be sure to select the correct feedback sensor using SetFeedbackDevice() below.
 *
 * After deploying/debugging this to your HERO, first use the left Y-stick
 * to throttle the Talon manually.  This will confirm your hardware setup.
 * Be sure to confirm that when the Talon is driving forward (green) the
 * position sensor is moving in a positive direction.  If this is not the cause
 * flip the boolean input to the SetSensorDirection() call below.
 *
 * Once you've ensured your feedback device is in-phase with the motor,
 * use the button shortcuts to servo to target positions.
 *
 * Tweak the PID gains accordingly.
 */
using System.Threading;
using Microsoft.SPOT;
using System.Text;

namespace Hero_Position_Servo_Example
{
    /** Simple stub to start our project */
    public class Program
    {
        static RobotApplication _robotApp = new RobotApplication();
        public static void Main()
        {
            while(true)
            {
                _robotApp.Run();
            }
        }
    }
    /**
     * The custom robot application.
     */
    public class RobotApplication
    {
        /** scalor to max throttle in manual mode. negative to make forward joystick positive */
        const float kJoystickScaler = -0.3f;

        /** hold bottom left shoulder button to enable motors */
        const uint kEnableButton = 7;

        /** make a talon with deviceId 0 */
        CTRE.TalonSrx _talon = new CTRE.TalonSrx(0,true);

        /** Use a USB gamepad plugged into the HERO */
        CTRE.Gamepad _gamepad = new CTRE.Gamepad(CTRE.UsbHostDevice.GetInstance());
```

```
/** hold the current button values from gamepad*/
bool[] _btns = new bool[10];

/** hold the last button values from gamepad, this makes detecting on-press events trivial */
bool[] _btnsLast = new bool[10];

/** some objects used for printing to the console */
StringBuilder _sb = new StringBuilder();
int _timeToPrint = 0;

float _targetPosition = 0;

uint [] _debLeftY = { 0, 0 };    // _debLeftY[0] is how many times its zero,
                                 // _debLeftY[1] is how many times nonzero.

public void Run()
{
    /* first choose the sensor */
    _talon.SetFeedbackDevice(CTRE.TalonSrx.FeedbackDevice.CtreMagEncoder_Relative);
    _talon.SetSensorDirection(false);
    //_talon.ConfigEncoderCodesPerRev(XXX), // if using CTRE.TalonSrx.FeedbackDevice.QuadEncoder
    //_talon.ConfigPotentiometerTurns(XXX), // if using AnalogEncoder or AnalogPot

    /* set closed loop gains in slot0 */
    _talon.SetP(0, 0.2f); /* tweak this first, a little bit of overshoot is okay */
    _talon.SetI(0, 0f);
    _talon.SetD(0, 0f);
    _talon.SetF(0, 0f); /* For position servo kF is rarely used. Leave zero */

    /* use slot0 for closed-looping */
    _talon.SelectProfileSlot(0);

    /* set the peak and nominal outputs, 12V means full */
    _talon.ConfigNominalOutputVoltage(+0.0f, -0.0f);
    _talon.ConfigPeakOutputVoltage(+3.0f, -3.0f);

    /* how much error is allowed?  This defaults to 0. */
    _talon.SetAllowableClosedLoopErr(0,0);

    /* zero the sensor and throttle */
    ZeroSensorAndThrottle();

    /* loop forever */
    while (true)
    {
        Loop10Ms();

        if(_gamepad.GetButton(kEnableButton)) // check if bottom left shoulder btn is held down.
        {
            /* then enable motor outputs*/
            CTRE.Watchdog.Feed();
        }

        /* print signals to Output window */
        Instrument();

        /* 10ms loop */
        Thread.Sleep(10);
    }
}
/**
 * Zero the sensor and zero the throttle.
 */
void ZeroSensorAndThrottle()
{
    _talon.SetPosition(0); /* start our position at zero, this example uses relative positions */
    _targetPosition = 0;
    /* zero throttle */
```

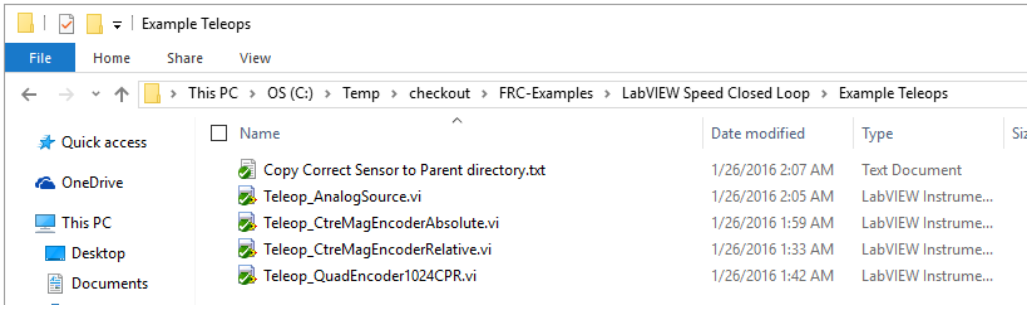
```
        _talon.SetControlMode(CTRE.TalonSrx.ControlMode.kPercentVbus);
        _talon.Set(0);
        Thread.Sleep(100); /* wait a bit to make sure the Setposition() above takes effect */
    }
    void EnableClosedLoop()
    {
        /* user has let go of the stick, lets closed-loop whereever we happen to be */
        _talon.SetVoltageRampRate(0); /* V per sec */
        _talon.SetControlMode(CTRE.TalonSrx.ControlMode.kPosition);
        _talon.Set(_targetPosition);
    }
    void GetJoystickValues (out float y, ref bool[] btns)
    {
        /* get all the buttons */
        FillBtns(ref btns);

        /* get the left y stick, invert so forward is positive */
        float leftY = kJoystickScaler * _gamepad.GetAxis(1);
        Deadband(ref leftY);

        /* debounce the transition from nonzero => zero axis */
        y = leftY;
    }
    void Loop10Ms()
    {
        float filteredY;
        GetJoystickValues (out filteredY, ref _btns);

        if (filteredY != 0)
        {
            /* put in a ramp to prevent the user from flipping their mechanism */
            _talon.SetVoltageRampRate(12.0f); /* V per sec */
            /* directly control the output */
            _talon.SetControlMode(CTRE.TalonSrx.ControlMode.kPercentVbus);
            _talon.Set(filteredY);
        }
        else if (_talon.GetControlMode() == CTRE.TalonSrx.ControlMode.kPercentVbus)
        {
            _targetPosition = _talon.GetPosition();

            /* user has let go of the stick, lets closed-loop whereever we happen to be */
            EnableClosedLoop();
        }

        /* if a button is pressed while stick is let go, servo position */
        if (filteredY == 0)
        {
            if (_btns[1])
            {
                _targetPosition = _talon.GetPosition() ; /* twenty rotations forward */
                EnableClosedLoop();
            }
            else if(_btns[4])
            {
                _targetPosition = +10.0f; /* twenty rotations forward */
                EnableClosedLoop();
            }
            else if (_btns[2])
            {
                _targetPosition = -10.0f; /* twenty rotations reverese */
                EnableClosedLoop();
            }
        }

        /* copy btns => btnsLast */
        System.Array.Copy(_btns, _btnsLast, _btns.Length);
    }
    /**
     * @return a filter value for the y-axis.
```

```
         *  Don't return zero unless we've been in deadband for a number of loops.
         *  This is only done because this example will throttle the motor with
         */
        float FilterLeftY(float y, uint numLoop)
        {
            /* get the left y stick */
            float leftY = -1 * _gamepad.GetAxis(1);
            Deadband(ref leftY);
            if (leftY == 0)
            {
                _debLeftY[1] = 0;
                ++_debLeftY[0];
            }
            else
            {
                _debLeftY[0] = 0;
                ++_debLeftY[1];
            }

            if (_debLeftY[0] > numLoop)
                return 0;
            return y;
        }
        /**
         * If value is within 10% of center, clear it.
         */
        void Deadband(ref float value)
        {
            if (value < -0.10)
            {
                /* outside of deadband */
            }
            else if (value > +0.10)
            {
                /* outside of deadband */
            }
            else
            {
                /* within 10% so zero it */
                value = 0;
            }
        }
        /** throw all the gamepad buttons into an array */
        void FillBtns(ref bool[] btns)
        {
            for (uint i = 1; i < btns.Length; ++i)
                btns[i] = _gamepad.GetButton(i);
        }
        /** occasionally builds a line and prints to output window */
        void Instrument()
        {
            if (--_timeToPrint <= 0)
            {
                _timeToPrint = 20;
                _sb.Clear();
                _sb.Append( "pos=");
                _sb.Append(_talon.GetPosition());
                _sb.Append(" vel=");
                _sb.Append(_talon.GetSpeed());
                _sb.Append(" err=");
                _sb.Append(_talon.GetClosedLoopError());
                _sb.Append(" out%=");
                _sb.Append(_talon.GetOutputVoltage()*100.0f/12.0f);
                Debug.Print(_sb.ToString());
            }
        }
    }
}
```

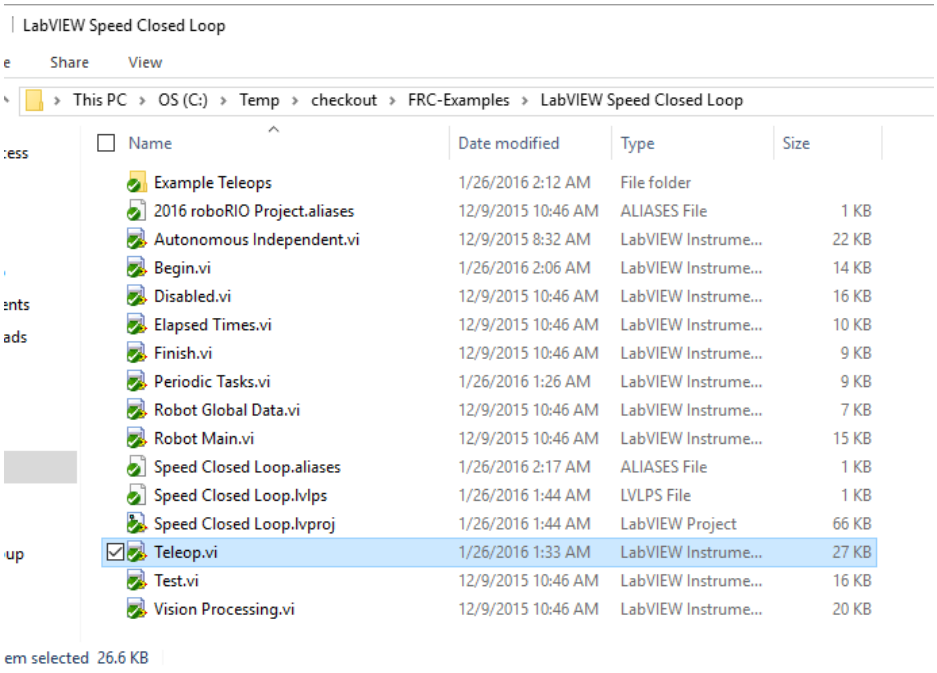
12.6. Velocity Closed-Loop Example – LabVIEW

This example can be found on the CTR GitHub account. https://github.com/CrossTheRoadElec/FRC-Examples

Supplemental Teleop_XXXX VIs can be found for various sensor types.
These can be copied over Teleop.vi.



Then replace the active Telep.vi file in “LabVIEW Speed Closed Loop” directory.



Look at the sensor-specific teleop VIs to confirm how the Feed Forward gain is calculated.
There will be a text label similar to the following…

```
Press and Hold Button1 to enable Speed-Closed-Loop., otherwise Talon is in PercentVoltage Mode.
Use the Left Y-axis on Logitech Gamepad.

VelocityNativeUnits = Change In Sensor / 100mS
also
VelocityNativeUnits = RPM / 600 * SensorUnitsPerRotation

Fgain = 100% X 1023 / VelocityNativeUnits ,
    where VelocityNativeUnits  is measured at 100% throttle

Mag Encoder has 4096 units per rotation.

Example: VelocityRPM is 10198 at 100% throttle
          => VelocityNativeUnits = (10198 / 600 * 4096) = 69618
          => Fgain = (1023 / 69618)  = 0.01469
```

12.7. Motion Magic Closed-Loop HERO C# (non-FRC)

Below is a full example for Motion Magic using the HERO development board. These functions are also available in FRC C++/Java, and comparable VIs are available in LabVIEW.

The latest example can be found on the CTR GitHub account.
https://github.com/CrossTheRoadElec/HERO-Examples

```
/**
 * Example using the Motion Magic Control Mode of Talon SRX and the Magnetic Encoder.
Other sensors can be used by
 * changing the selected sensor type below.

 * MotionMagic control mode requires Talon firmware 10.10 or greater.

 * The test setup is ...
 *      A single Talon SRX (Device ID 0) http://www.ctr-electronics.com/talon-srx.html
 *      A VEX VersaPlanetary Gearbox http://www.vexrobotics.com/versaplanetary.html
 *      Gearbox uses the CTRE Magnetic Encoder http://www.vexrobotics.com/vexpro/all/new-
for-2016/217-5046.html
 *      Ribbon cable http://www.ctr-electronics.com/talon-srx-data-cable-4-pack.html
 *
 *      Talon SRX ribbon cable is connected to the Magnetic Encoder.  This provies the
Talon with rotar position.
 *      See Talon SRX Software Reference Manual for gain-tuning suggestions.
 *
 * Press the top left shoulder button for direct-control of Talon's motor output using
the left-y-axis.
 * Press the bottom left shoulder button to set the target position of the Talon's closed
loop servo
 * using the left-y-axis.  Notice the geared output will ramp up initiallly then ramp
down as it approaches
 * the target position.
 */
using System.Threading;
using System;
using Microsoft.SPOT;

namespace HERO_Motion_Magic_Example
{
    public class Program
    {
        /** talon to control */
        private CTRE.TalonSrx _talon = new CTRE.TalonSrx(0);
        /** desired mode to put talon in */
        private CTRE.TalonSrx.ControlMode _mode = CTRE.TalonSrx.ControlMode.kPercentVbus;
        /** attached gamepad to HERO, tested with Logitech F710 */
        private CTRE.Gamepad _gamepad = new CTRE.Gamepad(new CTRE.UsbHostDevice());
        /** constant slot to use */
        const uint kSlotIdx = 0;
        /** How long to wait for receipt when setting a param.  Many setters take an
optional timeout that API will wait for.
```

```
            This is benefical for initial setup (before movement), though typically not
desired when changing parameters concurrently with robot operation (gain scheduling for
example).*/
        const uint kTimeoutMs = 1;

        /**
         * Setup all of the configuration parameters.
         */
        public int SetupConfig()
        {
            /* binary OR all the return values so we can make a quick decision if our
init was successful */
            int status = 0;
            /* specify sensor characteristics */

_talon.SetFeedbackDevice(CTRE.TalonSrx.FeedbackDevice.CtreMagEncoder_Relative);
            _talon.SetSensorDirection(false); /* make sure positive motor output means
sensor moves in position direction */
            // call ConfigEncoderCodesPerRev or ConfigPotentiometerTurns for Quadrature
or Analog sensor types.

            /* brake or coast during neutral */
            status |= _talon.ConfigNeutralMode(CTRE.TalonSrx.NeutralMode.Brake);

            /* closed-loop and motion-magic parameters */
            status |= _talon.SetF(kSlotIdx, 0.1153f, kTimeoutMs); // 1300RPM (8874 native
sensor units per 100ms) at full motor output (+1023)
            status |= _talon.SetP(kSlotIdx, 2.00f, kTimeoutMs);
            status |= _talon.SetI(kSlotIdx, 0f, kTimeoutMs);
            status |= _talon.SetD(kSlotIdx, 20f, kTimeoutMs);
            status |= _talon.SetIzone(kSlotIdx, 0, kTimeoutMs);
            status |= _talon.SelectProfileSlot(kSlotIdx); /* select this slot */
            status |= _talon.ConfigNominalOutputVoltage(0f, 0f, kTimeoutMs);
            status |= _talon.ConfigPeakOutputVoltage(+12f, -12f, kTimeoutMs);
            status |= _talon.SetMotionMagicCruiseVelocity(1000f, kTimeoutMs); // 1000 RPM
            status |= _talon.SetMotionMagicAcceleration(2000f, kTimeoutMs); // 2000 RPM
per sec, (0.5s to reach cruise velocity).

            /* Home the relative sensor,
                alternatively you can throttle until limit switch,
                use an absolute signal like CtreMagEncoder_Absolute or analog sensor.
                */
            status |= _talon.SetPosition(0, kTimeoutMs);

            return status;
        }
        /** spin in this routine forever */
        public void RunForever()
        {
            /* config our talon, don't continue until it's successful */
            int initStatus = SetupConfig(); /* configuration */
            while (initStatus != 0)
            {
                Instrument.PrintConfigError();
                initStatus = SetupConfig(); /* (re)config*/
            }
            /* robot loop */
            while (true)
```

```
            {
                /* get joystick params */
                float leftY = -1f * _gamepad.GetAxis(1);
                bool btnTopLeftShoulder = _gamepad.GetButton(5);
                bool btnBtmLeftShoulder = _gamepad.GetButton(7);
                Deadband(ref leftY);

                /* keep robot enabled if gamepad is connected and in 'D' mode */
                if (_gamepad.GetConnectionStatus() == CTRE.UsbDeviceConnection.Connected)
                    CTRE.Watchdog.Feed();

                /* set the control mode based on button pressed */
                if (btnTopLeftShoulder)
                    _mode = CTRE.TalonSrx.ControlMode.kPercentVbus;
                if (btnBtmLeftShoulder)
                    _mode = CTRE.TalonSrx.ControlMode.kMotionMagic;

                /* calc the Talon output based on mode */
                if (_mode == CTRE.TalonSrx.ControlMode.kPercentVbus)
                {
                    float output = leftY; // [-1, +1] percent duty cycle
                    _talon.SetControlMode(_mode);
                    _talon.Set(output);
                }
                else if (_mode == CTRE.TalonSrx.ControlMode.kMotionMagic)
                {
                    float servoToRotation = leftY * 10;// [-10, +10] rotations
                    _talon.SetControlMode(_mode);
                    _talon.Set(servoToRotation);
                }
                /* instrumentation */
                Instrument.Process(_talon);

                /* wait a bit */
                System.Threading.Thread.Sleep(5);
            }
        }
        /** @param [in,out] value to zero if within plus/minus 10% */
        public static void Deadband(ref float val)
        {
            if (val > 0.10f) { /* do nothing */ }
            else if (val < -0.10f) { /* do nothing */ }
            else { val = 0; } /* clear val since its within deadband */
        }
        /** singleton instance and entry point into program */
        public static void Main()
        {
            Program program = new Program();
            program.RunForever();
        }
    }
}
```

12.8. Motion Magic Closed-Loop Walkthrough – Java

This latest example should be downloaded from the CTR GitHub account.

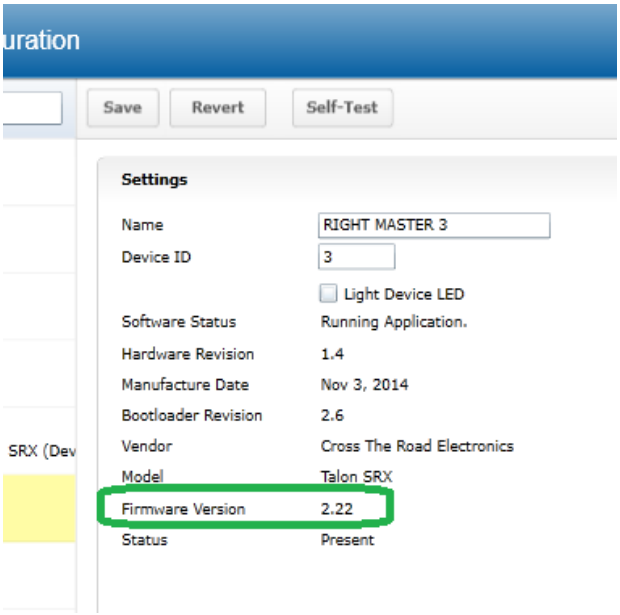
https://github.com/CrossTheRoadElec/FRC-Examples

The example will appear similar to the snippet below..

```
public class Robot extends IterativeRobot {
	CANTalon _talon = new CANTalon(3);
	Joystick _joy = new Joystick(0);
	StringBuilder _sb = new StringBuilder();

	public void robotInit() {
		/* first choose the sensor */
		_talon.setFeedbackDevice(FeedbackDevice.CtreMagEncoder_Relative);
		_talon.reverseSensor(false);
		// _talon.configEncoderCodesPerRev(XXX)
		// _talon.configPotentiometerTurns(XXX)

		/* set the peak and nominal outputs, 12V means full */
		_talon.configNominalOutputVoltage(+0.0f, -0.0f);
		_talon.configPeakOutputVoltage(+12.0f, -12.0f);
		/* set closed loop gains in slot0 - see documentation */
		_talon.setProfile(0);
		_talon.setF(0);
		_talon.setP(0);
		_talon.setI(0);
		_talon.setD(0);
		_talon.setMotionMagicCruiseVelocity(0);
		_talon.setMotionMagicAcceleration(0);
	}
	/**
	 * This function is called periodically during operator control
	 */
	public void teleopPeriodic() {
		/* get gamepad axis - forward stick is positive */
		double leftYstick = -1.0 * _joy.getAxis(AxisType.kY);
		double motorOutput = _talon.getOutputVoltage() / _talon.getBusVoltage();
		/* prepare line to print */
		_sb.append("\tout:");
		_sb.append(motorOutput);
		_sb.append("\tspd:");
		_sb.append(_talon.getSpeed());

		if (_joy.getRawButton(1)) {
			/* Motion Magic */
			double targetPos = leftYstick
					* 10.0; /* 10 Rotations in either direction */
			_talon.changeControlMode(TalonControlMode.MotionMagic);
			_talon.set(targetPos);

			/* append more signals to print when in speed mode. */
			_sb.append("\terr:");
			_sb.append(_talon.getClosedLoopError());
			_sb.append("\ttrg:");
			_sb.append(targetPos);
		} else {
			/* Percent voltage mode */
			_talon.changeControlMode(TalonControlMode.PercentVbus);
			_talon.set(leftYstick);
		}
		/* instrumentation */
		Instrum.Process(_talon, _sb);
	}
}
```

12.8.1. Motion Magic Closed-Loop Walkthrough – General Requirements

Be sure to check that the firmware is up to date. See CRF release notes for when motion magic was added.



Additionally, a reliable signal plotter is helpful for tuning parameters.
The signals of interest are the…

- Sensor Position
- Sensor Velocity
- Active Trajectory Position(1,2)
- Active Trajectory Velocity(1,2)
- Motor Output (AppliedThrottle)
- ClosedLoopErr

(1): These signals are calculated by the Talon SRX Motion Magic controller. These represent the target position and velocity at a given moment in time.

(2): API will be added in future HERO/FRC release to retrieve these signals.

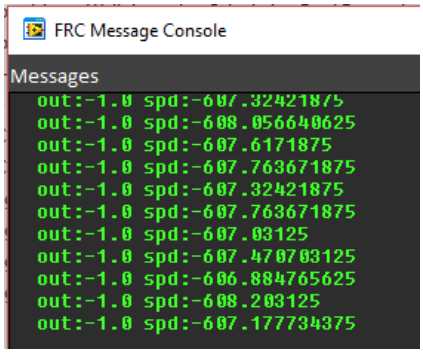
12.8.2. Motion Magic Closed-Loop Walkthrough – Collect Sensor Data – Java

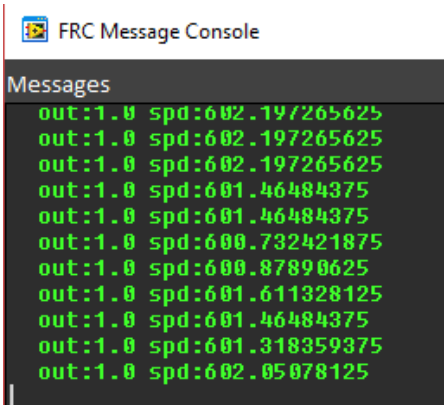
The first step is to drive the Talon SRX manually to check that the selected sensor is functioning and in phase with the motor. Deploy the GitHub example (or similar drive code) and drive the Talon by pulling the gamepad's y-axis.

Checking the sensor means…

- Confirming the sensor direction matches Talon motor output.
- Confirm position and speed measurement is accurate throughout entire position/speed range.
- Confirming the speed is approximately correct given the mechanical setup.
- Noting the measured speed at a given motor output for calculating f-gain
- Noting the measured max speed for initial selection of velocity cruise and acceleration.

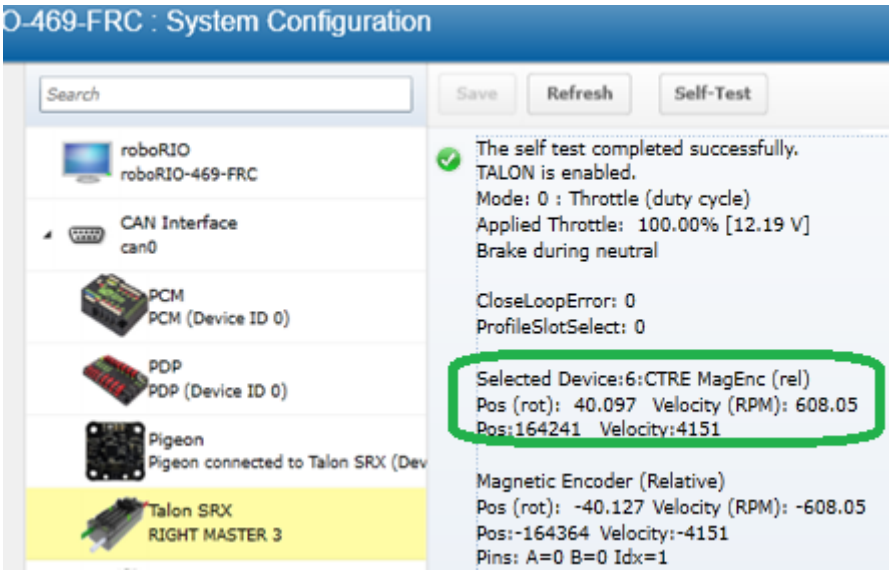
While throttling the Talon in the **positive** direction, make sure the sensor speed is also **positive**. Talon should be illuminating green when doing this. If this is not the cause, change the parameter in `reverseSensor()` and retest.





Additionally, note the approximate sensor speed while the Talon is driven. getSpeed() will return the speed in RPM if the requirements in Section 17.2.1 are met.

The same values can be read in the roboRIO web-based configuration under Self-Tests.



It's important to note the speed for calculating the f-gain and for picking cruise velocity and acceleration.

The self-test confirms ~608 RPM (or **4151 native units per 100ms**)

12.8.2.1. Is speed magnitude correct?

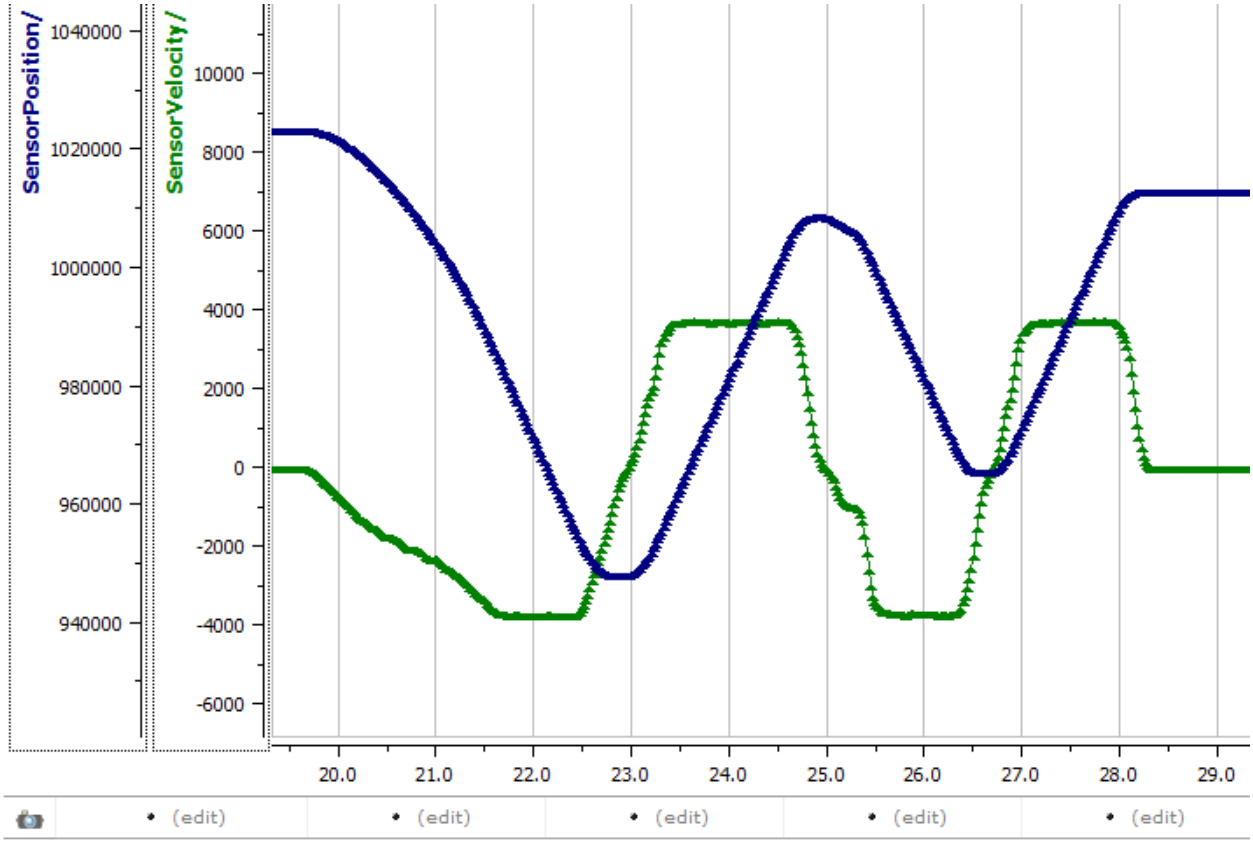
In this example, we measure **~604 RPM** at full motor output (averaged of peak in both directions). This setup involves 1 X CIM Motor motor (free speed 5330 RPM). The selected gear ratio is ~9:1. The CTRE magnetic encoder is on the geared output. So, a measurement of ~604 RPM is reasonable.

12.8.2.2. Is direction correct?

Looking at the screenshots above, positive motor output yielded a positive speed.

12.8.2.3. Sweep motor output and plots signals

While sweeping position and velocity, look for any discontinuities or unexplained behavior. In the capture below, the sensor velocity and position appear to follow with no discontinuities or plateaus.



12.8.2.4. Measurements

For the calculations done in the next section, the measurement of **~604 RPM** at full motor output is observed.

12.8.3. Motion Magic Closed-Loop Walkthrough – Calculate F-Gain – Java

The Motion-Magic Closed-Loop mode operates by closed-loop servoing to a calculated position with a fed-forward calculated velocity. The calculations are based on the set-point, cruise velocity, acceleration parameter, and time. This requires the use of the Feed-Forward gain. Per Section 17.2.1, our selected sensor uses 4096 native units per rotation. That means the measurement of **604 RPM** scales to **4123** native units per 100ms. This is also calculated/displayed in the Self-Test.

Velocity is measured in change in native units per $T_{velMeas}$= 100ms.

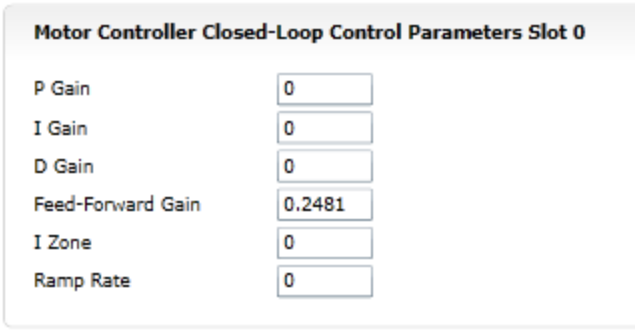
(**600** Rotations / min) X (1 min / 60 sec) X (1 sec / 10 $T_{velMeas}$) X (4096 native units / rotation)
= **4123** native units per 100ms

Now let's calculate a Feed-forward gain so that 100% motor output is calculated when the requested speed is 4123 native units per 100ms.

F-gain = (100% X 1023) / **4123**
F-gain = 0.2481

Let's check our math, if the target speed is **4123** native units per 100ms, Closed-loop output will be (**0.2481** X **4123**) => 1023 (full forward).

Next we will set the calculated gain. This can also be done in the roboRIO web-based configuration or programmatically.




```
/* set closed loop gains in slot0 */
_talon.setProfile(0);
_talon.setF(0.2481);
_talon.setP(0);
_talon.setI(0);
_talon.setD(0);
_talon.setMotionMagicCruiseVelocity(0);
_talon.setMotionMagicAcceleration(0);
```

12.8.4. Motion Magic Closed-Loop Walkthrough – Initial Cruise-Velocity/Acceleration – Java

Since our peak measured velocity was **604 RPM**, the initial cruise velocity should be set to a smaller value to ensure the speed can be reached. In this example, we will arbitrarily take 75% of the top speed. Depending on the mechanism type, how safe the mechanism is, and what is trying to be accomplished, a lower or higher cruise velocity could be specified. Also remember that this setting can be changed easily and at any time.

75% X **604 RPM** = **~453 RPM**

For the initial acceleration value, we will arbitrarily choose a value so that it takes an entire second to reach our cruise velocity. This will ensure the acceleration is slow enough to be observable. If this is too fast/slow, adjust accordingly. Since the acceleration is in terms of change in velocity per second, an acceleration of **453 RPM per sec** will achieve our 1 second accel time.

```
/* set closed loop gains in slot0 */
_talon.setProfile(0);
_talon.setF(0.2481);
_talon.setP(0);
_talon.setI(0);
_talon.setD(0);
_talon.setMotionMagicCruiseVelocity(453);     /* 453 RPM */
_talon.setMotionMagicAcceleration(453);       /* 453 RPM per second */
```

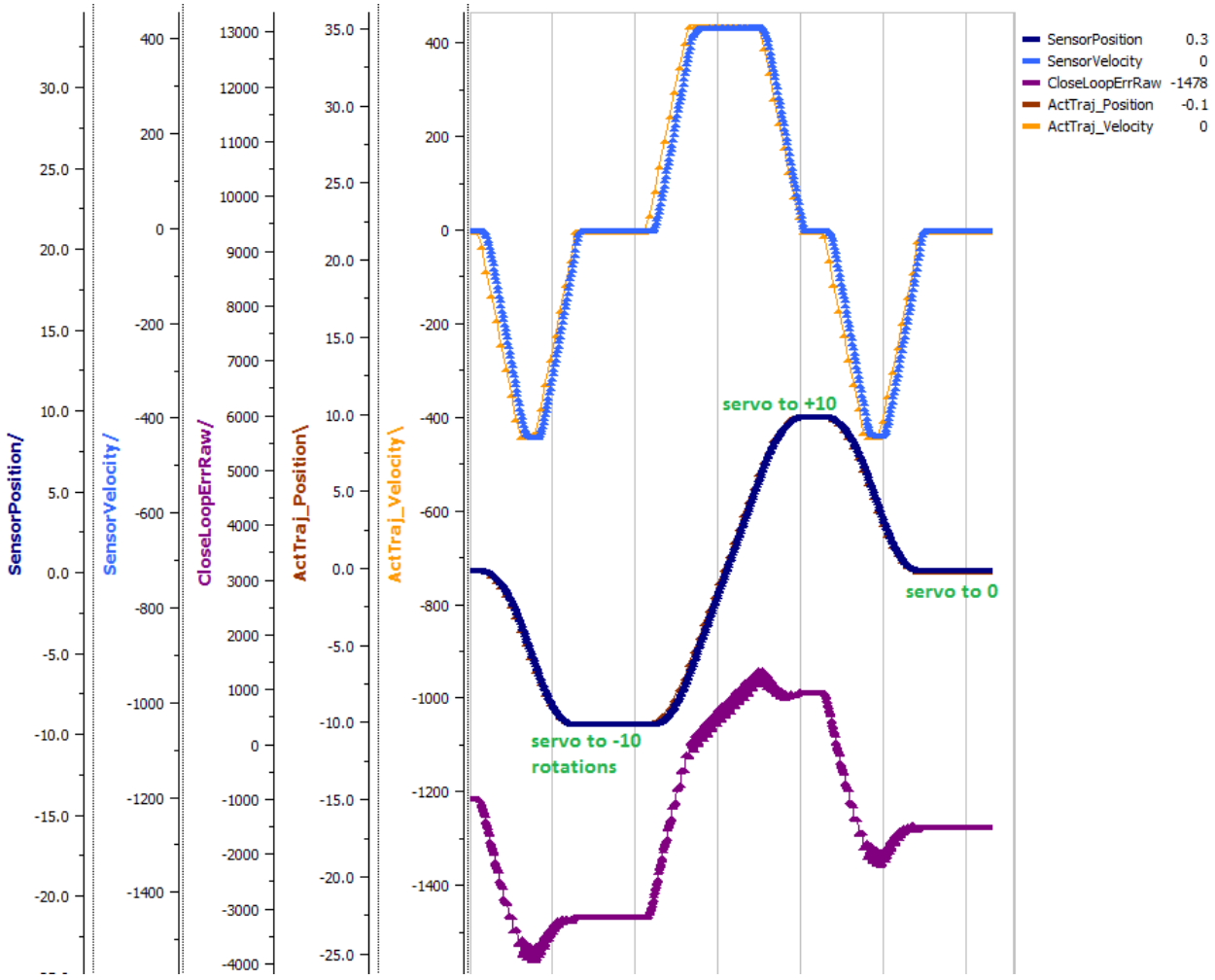
With the F gain and initial cruise velocity/acceleration configured, potentially you may start the servo by holding down button 1 and manipulating the gamepad stick.
Before doing this be aware of the following…

- The servo range is programmed for ±10 rotations (see code snippet below).

```
if (_joy.getRawButton(1)) {
    /* Motion Magic */
    double targetPos = leftYstick
            * 10.0; /* 10 Rotations in either direction */
    _talon.changeControlMode(TalonControlMode.MotionMagic);
    _talon.set(targetPos);
```

  If that is beyond the mechanism's range, reduce this and/or setup soft-limits/limit-switches so that there is no risk in reaching the mechanism's hard limits (potentially damaging mechanism).
- Consider that the current sensor position may be far from '0' because of manual-driving the motor when collecting sensor values in the previous sections. If needed, reset the sensor by calling `setPosition()`.
- Since PID gains are zero, the movement may coast past the target position, particularly if the Talon's neutral mode is in coast. But the motor output will reach neutral near the final target position passed into `set()`.

In this example the mechanism is the left-side of a robot's drivetrain. The robot is elevated such that the wheels spin free. In the capture below we see the sensor position/velocity (blue) and the Active Trajectory position/velocity (brown/orange). At the end of the movement the closed-loop error (which is in raw units) is sitting at **~1400**.units. Given the resolution of the sensor this is approximately 0.34 rotations (4096 units per rotation). Another note is that when the movement is finished, you can freely back-drive the mechanism without motor-response (because PID gains are zero).



12.8.5. Motion Magic Closed-Loop Walkthrough – P-Gain – Java

Next we will add in P-gain so that the closed-loop can react to error. In the previous section, after running the mechanism with just F-gain, the servo appears to settle with an error or **~1400**.

Given an error of (**~1400**.), suppose we want to respond with another 10% of throttle. Then our starting p-gain would be….

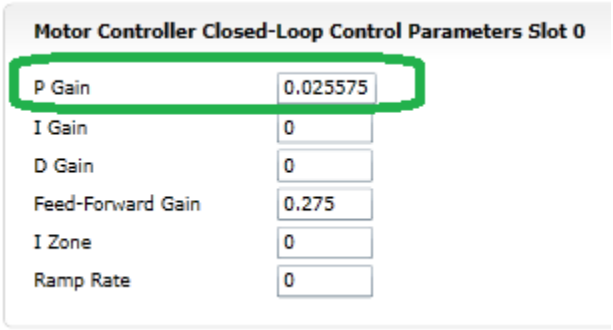
(10% X 1023) / (**1400**) **= 0.0731**

Now let's check our math, if the Talon SRX sees an error of 1400 the P-term will be

1400 X **0.0731**= 102 (which is about 10% of 1023)

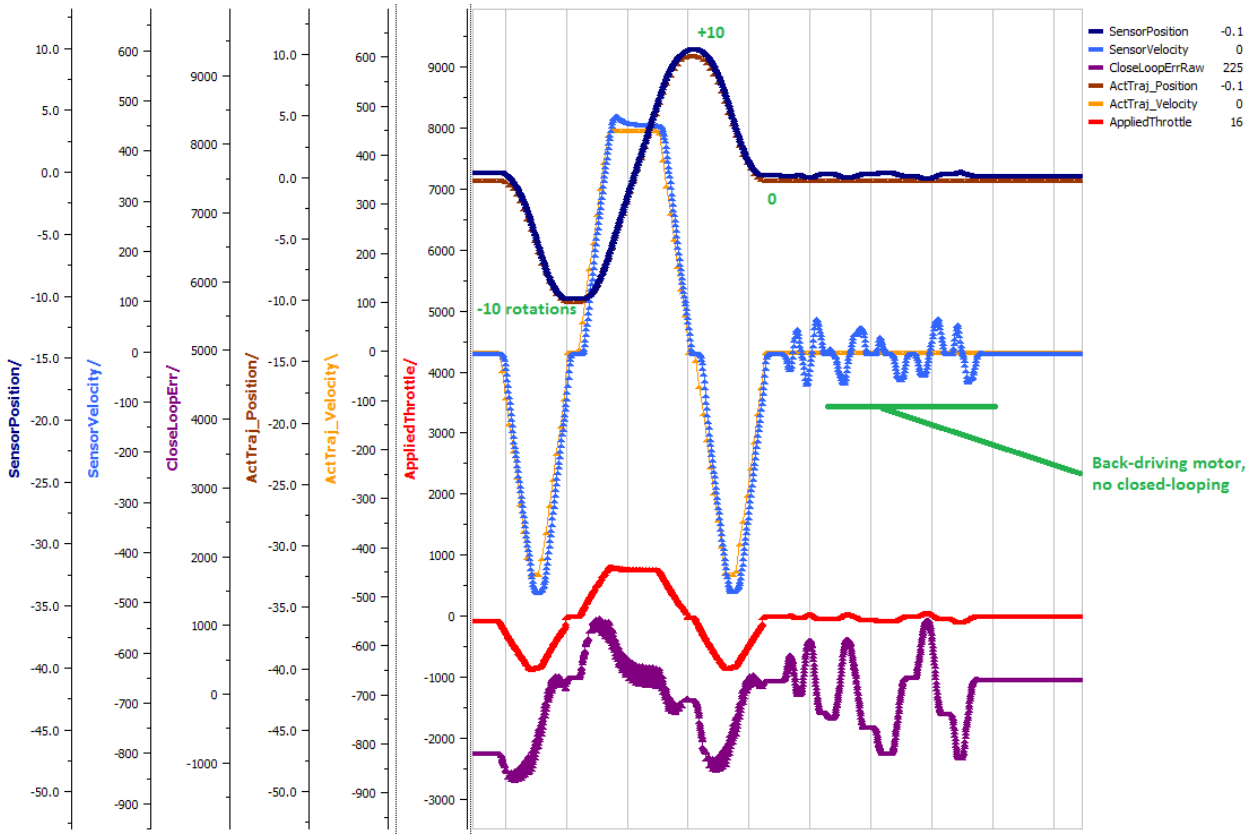
P-gain = **0.0731**

Apply the P -gain programmatically using your preferred method. Now retest to see how well the closed-loop responds to varying loads.




```
/* set closed loop gains in slot0 */
_talon.setProfile(0);
_talon.setF(0.2481);
_talon.setP(0.0731);
_talon.setI(0);
_talon.setD(0);
_talon.setMotionMagicCruiseVelocity(453);/* 453 RPM */
_talon.setMotionMagicAcceleration(453);/* 453 RPM per sec */
```

Retest the maneuver by holding button 1 and sweeping the gamepad stick.
At the end of this capture, the wheels were hand-spun to demonstrate how aggressive the position servo responds. Because the wheel still backdrives considerably before motor holds position, the P-gain still needs to be increased.



Double the P-gain until the system oscillates (by a small amount) or until the system responds adequately.

After a few rounds the P gain is at 0.6.

Scope captures below show the sensor position and target position follows visually, but back-driving the motor still shows a minimal motor response.

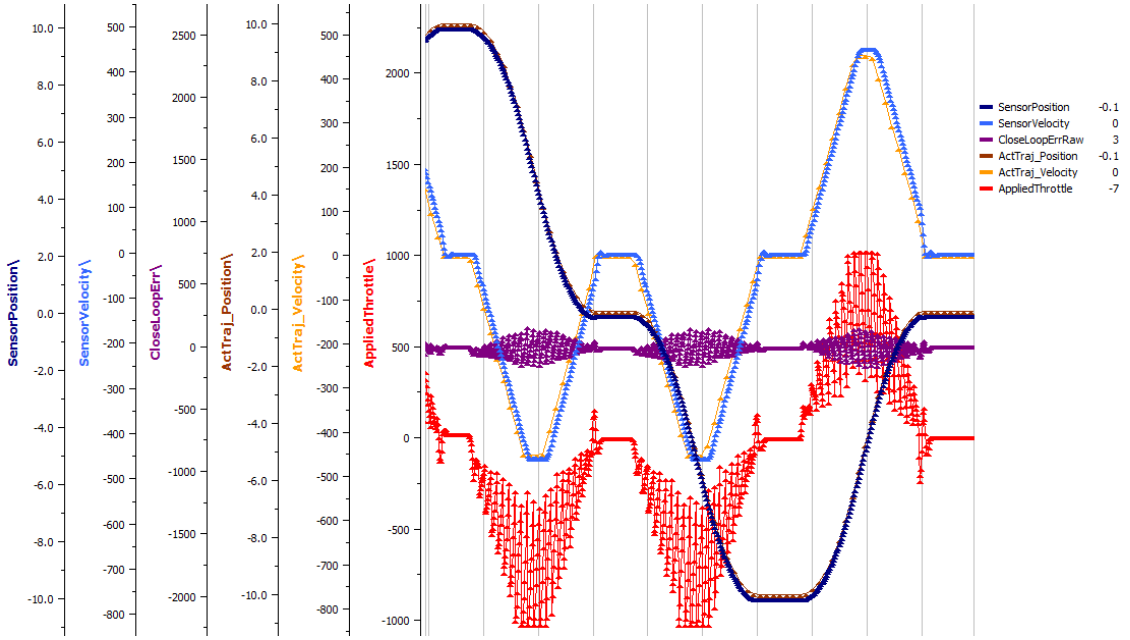
Motor Controller Closed-Loop Control Parameters Slot 0

P Gain	0.6
I Gain	0
D Gain	0
Feed-Forward Gain	0.275
I Zone	0
Ramp Rate	0

After several rounds, we've landed on a P gain value of 3. The mechanism overshoots a bit at the end of the maneuver. Additionally, back-driving the wheel is very difficult as the motor-response is immediate (good).

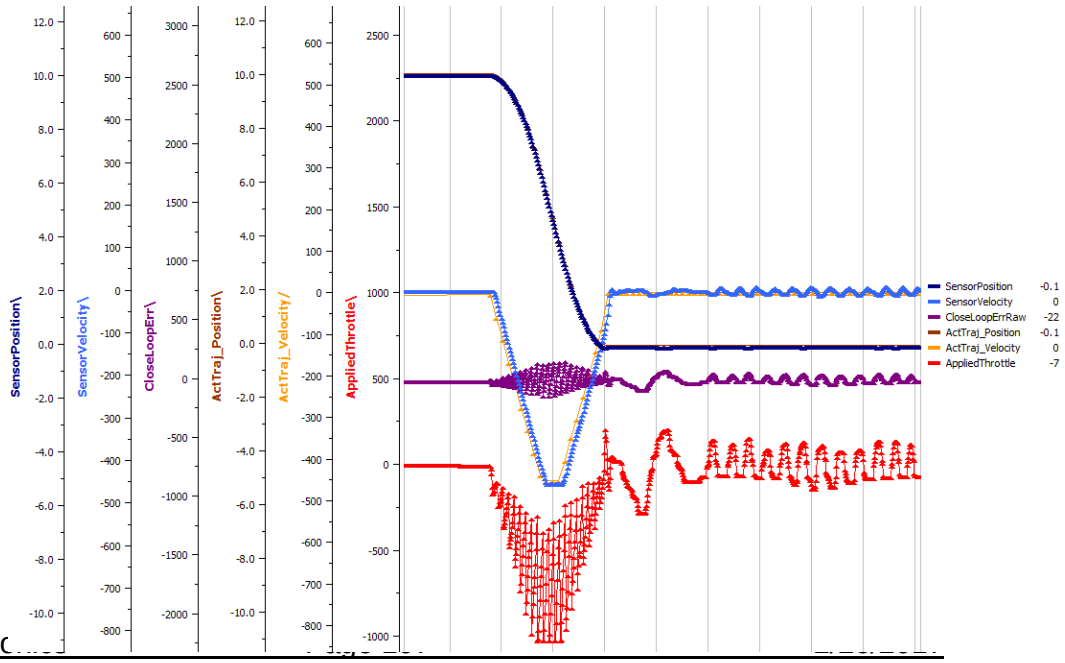
Motor Controller Closed-Loop Control Parameters Slot 0

P Gain	3
I Gain	0
D Gain	0
Feed-Forward Gain	0.2481
I Zone	0
Ramp Rate	0



Once settles, the motor is back-driven to assess how firm the motor holds position.

The wheel is held by the motor firmly.



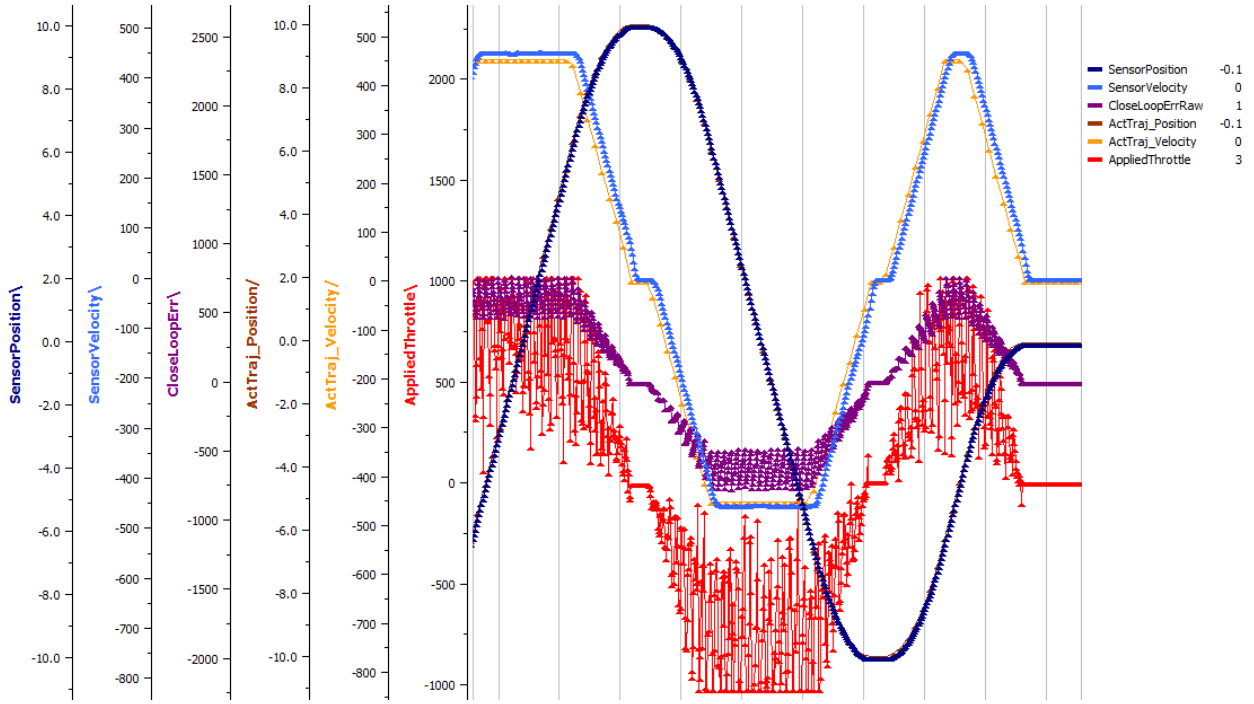
12.8.6. Motion Magic Closed-Loop Walkthrough – D-Gain – Java

To resolve the overshoot at the end of the maneuver, D-gain is added. D-gain can start typically at 10 X P-gain.

Motor Controller Closed-Loop Control Parameters Slot 0

P Gain	3
I Gain	0
D Gain	30
Feed-Forward Gain	0.2481
I Zone	0
Ramp Rate	0

With this change the visual overshoot of the wheel is gone. The plots also reveal reduced overshoot at the end of the maneuver.



12.8.7. Motion Magic Closed-Loop Walkthrough – I-Gain – Java

Typically, the final step is to confirm the sensor settles **very close** to the target position. If the final closed-loop error is not quite close enough to zero, consider adding I-gain and I-zone to ensure the Closed-Loop Error ultimately lands at zero (or close enough).

In testing the closed-loop error settles around 20 units, so we'll set the Izone to 50 units (large enough to cover the typical error), and start the I-gain at something small (0.001).

Motor Controller Closed-Loop Control Parameters Slot 0

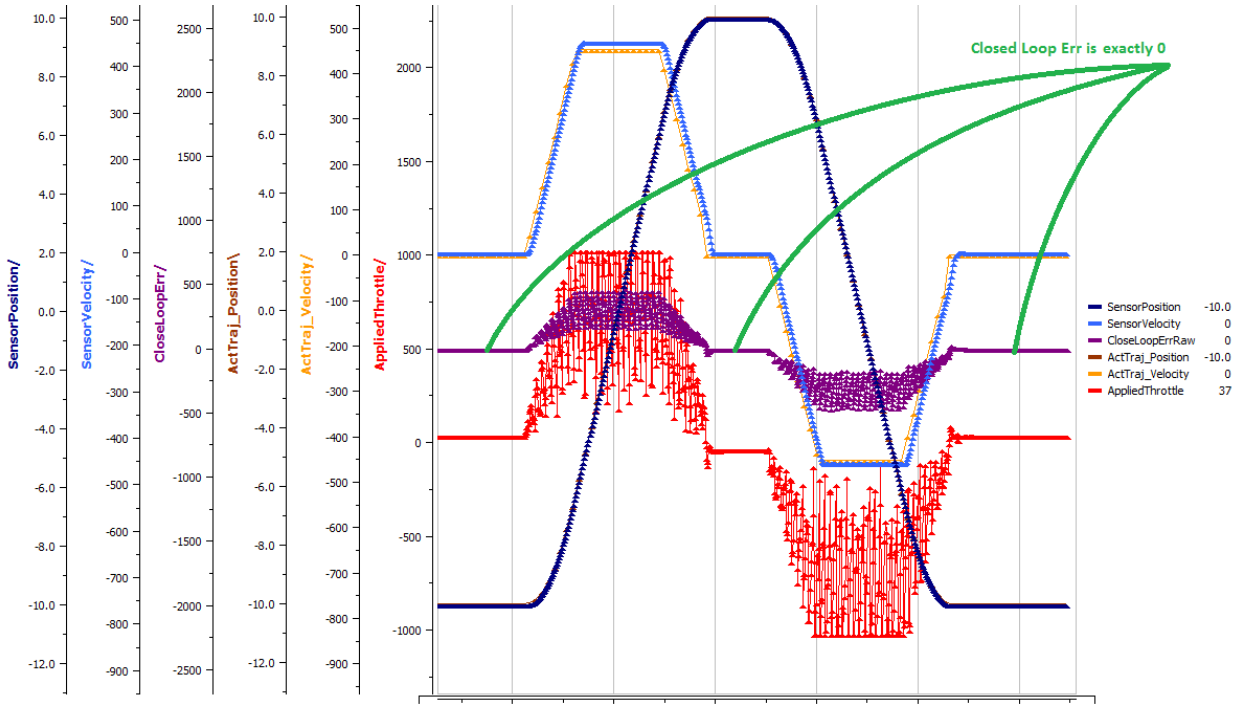
P Gain	3
I Gain	0.001
D Gain	30
Feed-Forward Gain	0.2481
I Zone	50
Ramp Rate	0

Keep doubling I-gain until the error reliably settles to zero.

Motor Controller Closed-Loop Control Parameters Slot 0

P Gain	3
I Gain	0.02
D Gain	30
Feed-Forward Gain	0.2481
I Zone	50
Ramp Rate	0

With some tweaking, we find an I-gain that ensures maneuver settles with an error of 0.



At this point the acceleration and cruise-velocity can be modified to hasten/dampen the maneuver as the application requires.

13. Setting Sensor Position

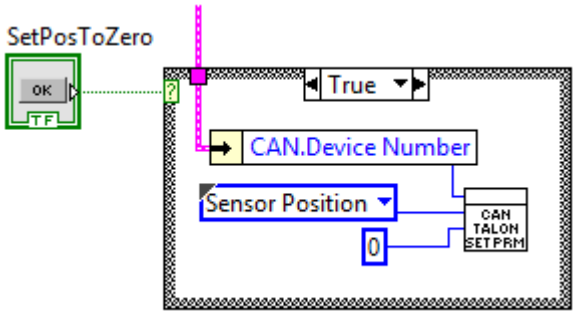
Depending on the sensor selected, the user can modify the “Sensor Position”. This is particularly useful when using a Quadrature Encoder (or any relative sensor) which needs to be “zeroed” or “home-ed” when the robot is in a known position.

Firmware 1.1: When using an “Analog Encoder”, setting the “Sensor Position” updates the top 14 bits of the 24bit Sensor Position value (which is the overflow/underflow portion). The bottom 10 bits will still reflect the analog voltage scaled over 3.3V (read only). With version 1.4 and on the full Sensor Position can be set.

Setting this signal when “Analog Potentiometer” is selected has no effect.

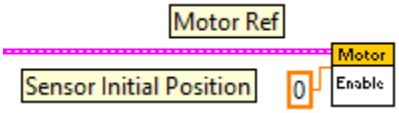
13.1. Setting Sensor Position – LabVIEW

In order to modify the “Sensor Position”, user will likely have to leverage the `WPI_CANTalonSRX_SetParameter.vi`. This can be drag dropped after locating the LabVIEW installer directory and searching for the VI file location. Select “Sensor Position” for the “Parameter” signal and the desired constant for the “Value” signal. In this example “0” is selected to re-zero the sensor when a front panel button is pressed.



13.1.1. Motor Enable

Alternatively the `Motor Enable VI` can be used to change the Sensor Position. If the Robot Application needs to turn on/off motor control in a periodic fashion, change the control mode instead (see Section 3.6) since this VI has the side effect of modifying Sensor Position.



13.2. Setting Sensor Position – C++

`SetPosition()` can be used to change the current sensor position, if a relative sensor is used.

```
customMotorDescrip.SetPosition(0); /* set the sensor position to zero */
```

13.3. Setting Sensor Position – Java

`setPosition()` can be used to change the current sensor position, if a relative sensor is used.

```
customMotorDescrip.setPosition(0); /* set the sensor position to zero */
```

13.4. Auto Clear Position using Index Pin

In addition to manually changing the sensor position, the Talon SRX supports automatically resetting the Selected Sensor Position to zero whenever a digital edge is detected on the Quadrature Index Pin.

This feature can be enabled regardless of which sensor is selected. This allows a means of resetting the position using a digital sensor, switch, or any external event that can drive a 3.3V digital signal. Since the Quadrature Index Pin has an internal pullup, the signal source can be an open-drain signal that provides ground when asserted, and high-impedance when not asserted (or vice versa).

This feature is useful for minimizing the latency of resetting the Sensor Position after the external event since the robot controller is not involved. The maximum delay is <1ms. Additionally this feature functions even if the Talon is disabled.

The feature uses the Quadrature Index Pin, which is convenient if the selected sensor is a Quadrature encoder and the application requires syncing the position to the sensor's index signal.

The polarity of the trigger edge can be set to rising or falling.

13.4.1. Setting Sensor Position – LabVIEW

13.4.2. Setting Sensor Position – Java

```
_tal.enableZeroSensorPositionOnIndex(true,false);
```

void edu.wpi.first.wpilibj.CANTalon.enableZeroSensorPositionOnIndex(boolean enable, boolean risingEdge)

13.4.3. Setting Sensor Position – C++

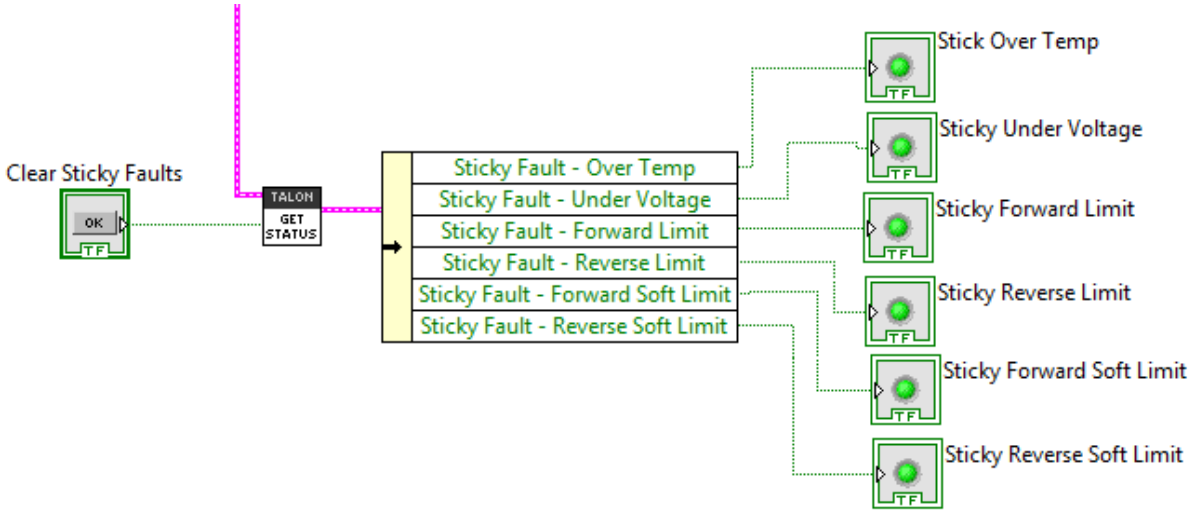
```
talon.EnableZeroSensorPositionOnIndex(true,false);
```

```
/**
 * Enables Talon SRX to automatically zero the Sensor Position whenever an
 * edge is detected on the index signal.
 * @param enable      boolean input, pass true to enable feature or false to disable.
 * @param risingEdge  boolean input, pass true to clear the position on rising edge,
 *                    pass false to clear the position on falling edge.
 */
void EnableZeroSensorPositionOnIndex(bool enable, bool risingEdge);
```

14. Fault Flags

The `GET STATUS VI` can be used to retrieve sticky flags, and clear them.

14.1. LabVIEW



14.2. C++

Use `GetFaults()` and `GetStickyFaults()` to get integral bit fields that can be masked against the constants available in the `CANSpeedController` header.

`ClearStickyFaults()` can be used to clear all sticky fault flags.

```
if(btn5){
    customMotorDescrip.ClearStickyFaults();            /* clear sticky faults */
}
if(bEverySecond){
    int faults = customMotorDescrip.GetFaults();           /* get bitfield of all faults */
    int stickyFaults = customMotorDescrip.GetStickyFaults();/* get bitfield of all sticky faults */

    if(faults & CANSpeedController::kTemperatureFault)
        printf("kTemperatureFault\r\n");
    if(faults & CANSpeedController::kBusVoltageFault)
        printf("kBusVoltageFault\r\n");
    if(faults & CANSpeedController::kFwdLimitSwitch)
        printf("kFwdLimitSwitch\r\n");
    if(faults & CANSpeedController::kRevLimitSwitch)
        printf("kRevLimitSwitch\r\n");
    if(faults & CANSpeedController::kFwdSoftLimit)
        printf("kFwdSoftLimit\r\n");
    if(faults & CANSpeedController::kRevSoftLimit)
        printf("kRevSoftLimit\r\n");

    if(stickyFaults & CANSpeedController::kTemperatureFault)
        printf("Sticky - kTemperatureFault\r\n");
    if(stickyFaults & CANSpeedController::kBusVoltageFault)
        printf("Sticky - kBusVoltageFault\r\n");
    if(stickyFaults & CANSpeedController::kFwdLimitSwitch)
        printf("Sticky - kFwdLimitSwitch\r\n");
    if(stickyFaults & CANSpeedController::kRevLimitSwitch)
        printf("Sticky - kRevLimitSwitch\r\n");
    if(stickyFaults & CANSpeedController::kFwdSoftLimit)
        printf("Sticky - kFwdSoftLimit\r\n");
    if(stickyFaults & CANSpeedController::kRevSoftLimit)
        printf("Sticky - kRevSoftLimit\r\n");
}
```

14.3. Java

Use the various `getFault<name>` and `getStickyFault<name>` functions to individually detect the various fault conditions.

```
getFaultOverTemp()
getFaultUnderVoltage()
getFaultForLim()
getFaultRevLim()
getFaultForSoftLim()
getFaultRevSoftLim()
getStickyFaultOverTemp()
getStickyFaultUnderVoltage()
getStickyFaultForLim()
getStickyFaultRevLim()
getStickyFaultForSoftLim()
getStickyFaultRevSoftLim()
```

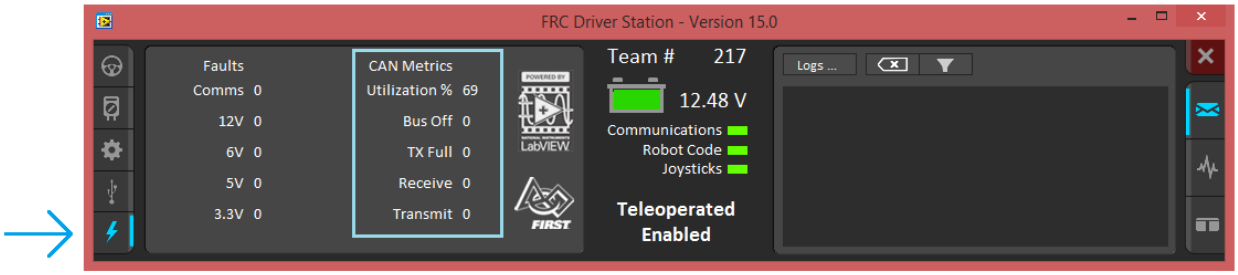
`clearStickyFaults()` can be used to clear all sticky fault flags.

```
if(btn5){
    customMotorDescrip.clearStickyFaults();            /* clear sticky faults */
}
if(bEverySecond){

    if(customMotorDescrip.getFaultOverTemp() != 0)
        System.out.println("FaultOverTemp");
    if(customMotorDescrip.getFaultUnderVoltage() != 0)
        System.out.println("FaultUnderVoltage");
    if(customMotorDescrip.getFaultForLim() != 0)
        System.out.println("FaultForLim");
    if(customMotorDescrip.getFaultRevLim() != 0)
        System.out.println("FaultRevLim");
    if(customMotorDescrip.getFaultForSoftLim() != 0)
        System.out.println("FaultForSoftLim");
    if(customMotorDescrip.getFaultRevSoftLim() != 0)
        System.out.println("FaultRevSoftLim");

    if(customMotorDescrip.getStickyFaultOverTemp() != 0)
        System.out.println("StickyFaultOverTemp");
    if(customMotorDescrip.getStickyFaultUnderVoltage() != 0)
        System.out.println("StickyFaultUnderVoltage");
    if(customMotorDescrip.getStickyFaultForLim() != 0)
        System.out.println("StickyFaultForLim");
    if(customMotorDescrip.getStickyFaultRevLim() != 0)
        System.out.println("StickyFaultRevLim");
    if(customMotorDescrip.getStickyFaultForSoftLim() != 0)
        System.out.println("StickyFaultForSoftLim");
    if(customMotorDescrip.getStickyFaultRevSoftLim() != 0)
        System.out.println("StickyFaultRevSoftLim");
}
```

15. CAN bus Utilization/Error metrics

The driver station provides various CAN bus metrics under the “lightning bolt” tab.
Utilization is the percent of bus time that is in use relative to the total bandwidth available of the 1Mbps Dual Wire CAN bus. So at 100% there is no idle bus time (no time between frames on the CAN bus).

Demonstrated here is 69% bus use when controlling 16 Talon SRXs, along with 1 Pneumatics Control Module (PCM) and the Power Distribution Panel (PDP).



The “Bus Off” counter increments every time the CAN Controller in the roboRIO enters “bus-off”, a state where the controller “backs off” transmitting until the CAN bus is deemed “healthy” again. A good method for watching it increment is to short/release the CAN bus High and Low lines together to watch it enter and leave “Bus Off” (counter increments per short).

The “TX Full” counter tracks how often the buffer holding outgoing CAN frames (RIO to CAN device) drops a transmit request. This is another common symptom when the roboRIO no longer is connected to the CAN bus.

The “Receive” and “Transmit” signal is shorthand for “Receive Error Counter” and “Transmit Error Counter”. These signals are straight from the CAN bus spec, and track the error instances occurred “on the wire” during reception and transmission respectively. These counts should always be zero. Attempt to short the CAN bus and you can confirm that the error counts rise sharply, then decrement back down to zero when the bus is restored (remove short, reconnect daisy chain).

When starting out with the FRC control system and Talon SRXs, it is recommend to watch how these CAN metrics change when CAN bus is disconnected from the roboRIO and other CAN devices to learn what to expect when there is a harness or a termination resistor issue. Determining hardware related vs software related issues is key to being successful when using a large number of CAN devices.

15.1. How many Talons can we use?

Generally speaking a maximum of 16 Motor controllers can be powered at once using a single PDP (sixteen breaker slots). However FRC game rules should always be checked as it determines what it considered legal. This is typically the bottleneck for how many Talon SRXs can be used despite having CAN device ID space for 63 device IDs. Release software is always tested to support 16 Talon SRXs, 1 PCM, and 1 PDP with guaranteed control of each Talon at a rate of 10ms. However this is not the limit. There is still additional bandwidth for more nodes. Additionally, if faster response time is desired, control frame periods can be decreased from the default 10ms, but keep a watchful eye of the CAN bus utilization to ensure reliable communication.

16. Troubleshooting Tips and Common Questions

- 2016 season refers to Kickoff January 2016 (FIRST Stronghold).
- 2015 season refers to Kickoff January 2015 (Recycle Rush). Issues that have been resolved since then are grayed out.
- Just because a firmware issue has been resolved does not mean your out-of-the-box hardware doesn't have old firmware. **Immediately** update your CAN devices to ensure your development time is not wasted chasing down an issue that has already been solved.

16.1. When I press the B/C CAL button, the brake LED does not change, neutral behavior does not change.

This is the expected behavior if the robot application is overriding the brake mode. The B/C CAL button press does toggle the brake mode in persistent memory, however the LED and selected neutral behavior will honor the override sent over CAN bus. Check if the override API is being used in the robot application logic.

16.2. Changing certain settings in Disabled Loop doesn't take effect until the robot is enabled.

This has been improved in FRC2016 Talon SRX Firmware by sending control parameters during disable. The motor controllers are still disabled, but the control signals are updated and can be confirmed in the roboRIO-web-based configuration Self-Test.

This is the expected behavior, the control frame that updates the Talon SRX with the latest brake/limit switch override, control mode, and set-point does not get transmitted in robot-disable mode. However the values are saved so that when the robot is enabled, the first control frame sent will have up to date values.

For example, the B/C CAL LED will not reflect changes in the overridden brake mode if `SetBrake()` is called in the disabled loop until **after** the robot has been enabled. Once the robot is enabled, the control frame sent to the Talon will enable the motor controller and contain the latest settings that were cached during disabled loop (including the brake override).

Similarly Self-Test results also won't reflect parameters that are changed programmatically until the robot is enabled, specifically the brake/limit switch overrides.

The startup values for limit switch and brake mode can be specified in the roboRIO's Web-based Configuration if they must be configured prior to robot enable.

16.3. The robot is TeleOperated/Autonomous enabled, but the Talon SRX continues to blink orange (disabled).

Most likely the device ID of that Talon is not being used. In other words there is no Open Motor (LabVIEW) or constructed CANTalon (C++/Java) with that device ID. This can be confirmed by doing a Self-Test in the roboRIO Web-based Configuration, and confirm the "TALON IS NOT ENABLED!" message at the top.

16.4. When I attach/power a particular Talon SRX to CAN bus, The LEDs on every Talon SRX occasionally blink red. Motor drive seems normal.

If there is a single CAN error frame, you can expect all Talon SRXs on the bus to synchronously blink red. This is a great feature for detecting intermittent issues that normally would go unnoticed. If attaching a particular Talon brings this behavior out, most likely its device ID is common with another Talon already on the bus. This means two or more "common ID" Talon SRXs are periodically attempting to transmit using the same CAN arbitration ID, and are stepping on each other's frame. This causes an intermittent error frame which then reveals itself when all Talon SRXs blink red. Check the roboRIO Web-based Configuration for the "There are X devices with this Device ID" explained in Section 2.2. Common ID Talons.

16.5. If I have a slave Talon SRX following a master Talon SRX, and the master Talon SRX is disconnected/unpowered, what will the slave Talon SRX do?

The slave Talon SRX monitors for throttle updates from the master. If the slave Talon doesn't see an update after 100ms, it will disable its drive. The LEDs will reflect robot-enable but with zero throttle (solid orange LEDs).

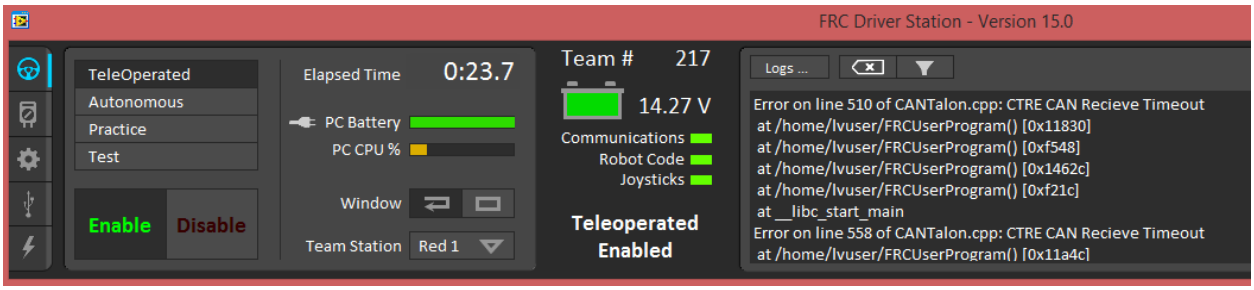
16.6. Is there any harm in creating a software Talon SRX for a device ID that's not on the CAN bus? Will removing a Talon SRX from the CAN bus adversely affect other CAN devices?

No! Attempting to communicate with a Talon SRX that is not present will not harm the communication with other CAN nodes. The communication strategy is very different than previously support CAN devices, and this use case was in mind when it was designed.

Creating more Talon software objects (LabVIEW Motor Open, or C++/Java class instances) will increase the bus utilization since it means sending more frames, however this should not adversely affect robot behavior so long as the bus utilization is reasonable.

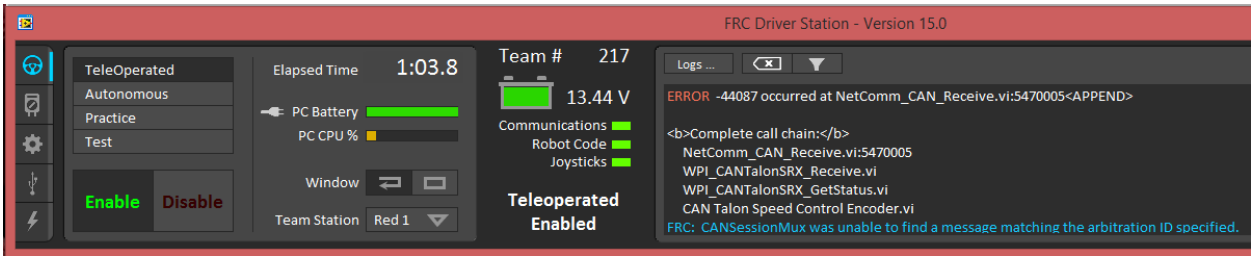
However the resulted error messages in the DS may be a distraction so when permanently removing a Talon SRX from the CAN bus, it is helpful to synchronously remove it from the robot software.

16.7. Driver Station log says Error on line XXX of CANTalon.cpp



This is to be expected when constructing a CANTalon with a device ID that is not present on CAN bus in C++/Java. These are caused by asserts in the programming API meant to signal the developer that some expected CAN frame was not detected on the bus. Although it should not impact other CAN nodes, it can be a distraction since it may mask other unrelated errors reported in the driver station that are no longer visible.

16.8. Driver Station log says -44087 occurred at NetComm...



This is to be expected when referencing a “CAN Talon SRX” with a device ID that is not present on CAN bus in LabVIEW. Although it should not impact other CAN nodes, it can be a distraction since it may mask other unrelated errors reported in the driver station that are no longer visible.

16.9. Why are there multiple ways to get the same sensor data? GetEncoder() versus GetSensor()?

The API that fetches latest values for Encoder (Quadrature) and Analog-In (potentiometer or a continuous analog sensor) reflect the pure decoded values sent over CAN bus (every 100ms). They are available all the time, regardless of which control mode is applied or whether the sensor type has been selected for soft limits and closed-loop mode. These signals are ideal for instrumenting/logging/plotting sensor values to confirm the sensors are wired and functional. Additionally they can be read at the same time (you can wire a potentiometer AND a quadrature encoder and get both position and velocities programmatically). Furthermore the robot application could actually use this method to process sensor information directly. If the 100ms update rate is not sufficient, it can be overridden to a faster rate.

For the purpose of using soft limits and/or closed-loop modes, the robot application must select which sensor to use for position/velocity. Selecting a sensor will cause the Talon SRX to mux the appropriate sensor to the closed-loop logic, the soft limit logic, to the “Sensor Position” and “Sensor Velocity” signals (update 20ms). These signals also can be inverted using the "Reverse Feedback Sensor" signal in order to keep the sensor in phase with the motor.

Since “Sensor Position” and “Sensory Velocity” are updated faster (20ms) they can also be used for processing sensor information instead of overriding the frame rates.

16.10. So there are two types of ramp rate?

There are two ways to “ramp” or acceleration cap the motor drive.
The “Voltage Ramp” API in all three languages are functional, and takes effect regardless of which mode the Talon SRX is in (duty cycle, slave, Position, Speed).

The selected Motor Control Profile also has a “Closed-Loop Ramp Rate” which can be used to apply a unique ramp rate only when the motor controller is closed-looping and the Profile Slot has been selected.

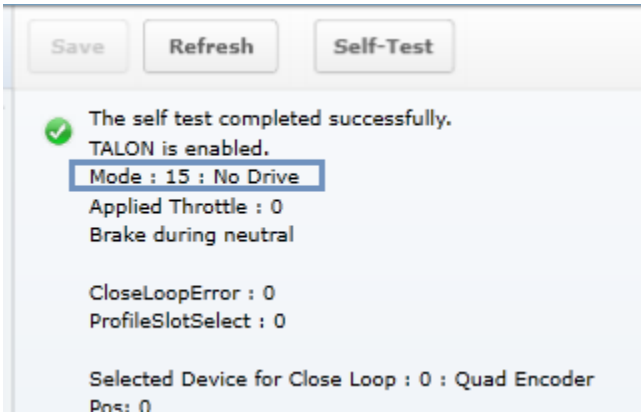
By having two options, a robot can have mode specific ramping with minimal effort in the robot controller. For example, a team may require a “weak” ramp to slightly dampen motor drive to prevent driver error (flipping the robot), or to reduce impulse stress (snapping chains). But when closed-looping, an additional ramp might be necessary to smooth the closed-loop maneuver.

16.11. Why are there two feedback “analog” device types: Analog Encoder and Analog Potentiometer?

When Analog Potentiometer is selected, the 10 bit Analog to Digital Converter (ADC) converts the 0 to 3.3V signal present on the analog input pin to a value between 0 and 1023.

When Analog Encoder is selected, the same conversion takes place, but rollovers to and from the min/max voltage are tracked so that analog sensors can be used as relative sensors. If an overflow is detected (1023 => 0), the position signal transitions (1023 => 1024). Likewise an underflow (0=>1023) is interpreted as (0 => -1). This is useful when using an analog encoder and allowing it to exceed the max turn count. This way an analog encoder can be used as a continuous relative sensor.

16.12. After changing the mode in C++/Java, motor drive no longer works. Self-Test says “No Drive” mode?



After calling a Talon SRX object's `changeMode()` function, the Talon SRX mode is set to disabled until the `Set()/set()` routine is called. This is to ensure the robot application has a chance to pass a new target set point before the new control mode is applied. Any call to `changeMode()` should be immediately followed with a `Set()` so that motor drive is not set to neutral.

This ensures that when the robot application changes a Talon's mode, it also specifies the throttle/set-point/or slave ID for the new mode to ensure all the necessary information is set for the mode switch.

16.13. All CAN devices have red LEDs. Recommended Preliminary checks for CAN bus.

Some basic checks for the CAN harness are…

Turn off robot, measure resistance between CANH and CANL.

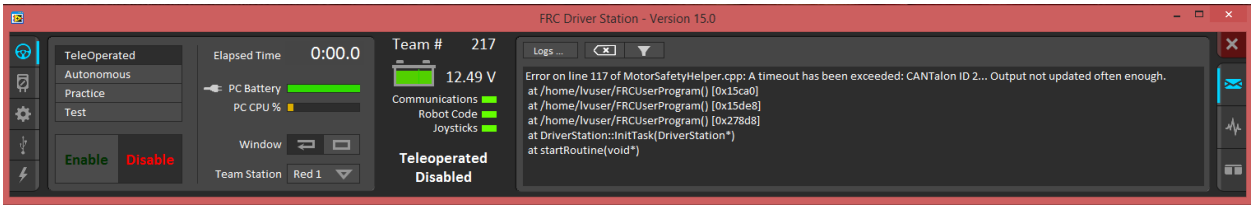
- ~60 ohm is typical (120ohm at each end of the cable).
- ~120 ohm suggests that one end is missing termination resistor. Terminate the end using PDP jumper or explicit 120 ohm resistor.
- ~0 ohm suggests a short between CANH and CANL.
- INF or large resistances, missing termination resistor at each side.

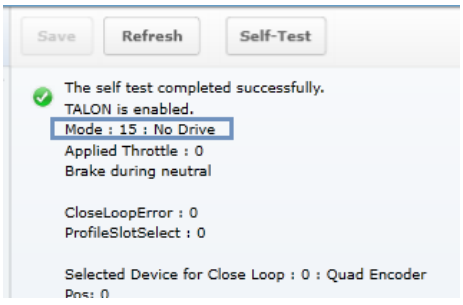
More information can be found in **Talon SRX User's Guide**.

Check the roboRIO's Web-based Configuration to see if any devices appear, and ensure there are no Talon SRX's sharing the same device ID.

16.14. Driver Station reports "MotorSafetyHelper.cpp: A timeout…", motor drive no longer works. roboRIO Web-based Configuration says "No Drive" mode? Driver Station reports error -44075?

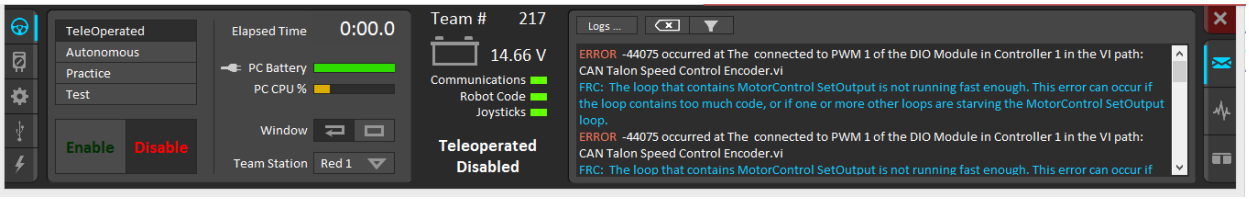
This can happen after enabling Motor Safety Enable and not calling `Set()/set()` often enough to meet the expiration timeout.





Another symptom of this is seeing "No Drive" has the control mode in the Self-Test.

When the safety timeout expires in LabVIEW, the error message will be different…



See section 19 for more information.

16.15. Motor drive stutters, misbehaves? Intermittent enable/disable?

Check the CAN Utilization to ensure it's not near 100%. An abnormally high percent may be a symptom of "common ID" Talons. This also can occur when selecting custom frame rates that are too fast.

Ensure robot application calls Set() on each Talon at least once per loop. Avoid strategies that attempt to write the Talon set-output "only when it changes". There is no cost to updating the set-output of the Talon SRX using the robot API, and often such strategies trip the motor-safety features (section 19). If using LabVIEW avoid using tunnels/shift-registers to only call 

when the input parameter has changed.

Check the roboRIO's Web-based Configuration to confirm all expected Talons are populated and are enabled according to the Self-Test.

Check the "Under Vbat" sticky flag in the Self-Test. This will rule out power/voltage related issues.

If the issues occur only during rapid changes in direction and magnitude, the power cables/crimps may not be efficient enough to deliver power during the stall-period when a loaded motor changes direction. This can be confirmed if increasing the voltage ramp rate removes/fixes this symptom.

Be sure to check the Driver Station Logs for packet loss since that can cause intermittent robot disables.

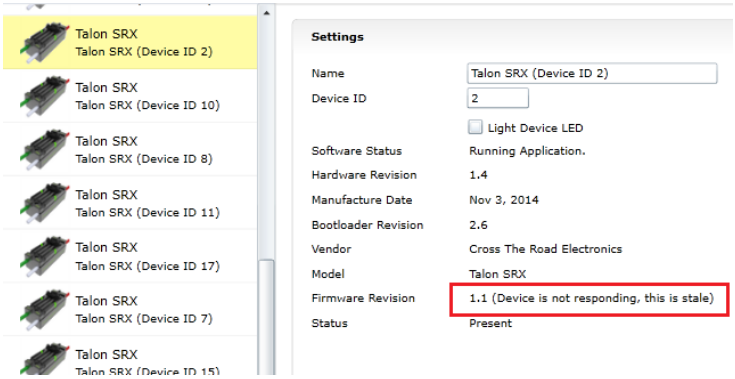
If the Driver Station has 3rd party software that uses network communication, or if the Driver Station

When using the DAP-1522 (or similar radio) be sure to use latest stable firmware. For example, rev-A DAP1522s (with production ship firmware) will not reliably enable the robot. Additionally consult FRC rules and documentation for which hardware rev is legal for competition and how to properly setup the radio.

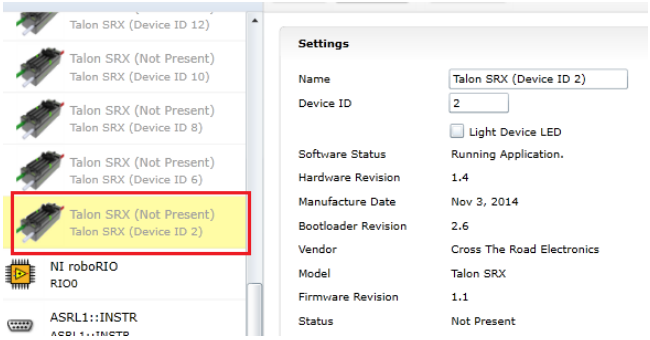
16.16. What to expect when devices are disconnected in roboRIO's Web-based Configuration. Failed Self-Test?

Depending what version of software is released, a discovered Talon will display loss of connection one of two ways.

The Firmware Version may report (Device is not responding).

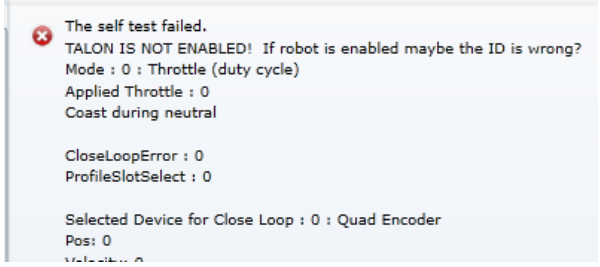


Alternatively the tree element will gray out to indicate loss of communication….



The roboRIO internals rechecks the CAN bus once every five seconds so when connecting/disconnecting Talons to/from the bus, be sure to wait at least five seconds and refresh the webpage to detect changes in connection state.

Doing a Self-Test when the Talon SRX is not present on the CAN bus will report a red 'X' in the top left portion of the Self-Test report. Depending on what robot controller image is release you may see the stale values of all signals when the red "X" is present.



16.17. When I programmatically change the "Normally Open" vs "Normally Closed" state of a limit switch, the Talon SRX blinks orange momentarily.

Changing the "Normally Open" versus "Normally Closed" setting of a motor controller will cause it to disable motor drive momentarily. If the goal is to enable/disable the limit switch feature, this can be done without affecting motor drive using the Limit Switch overrides.

Typically the only time a Talon SRX NO/NC setting won't match what is specified programmatically will be when a new Talon SRX is installed for the first time. Once the programming API has changed the setting once, the Talon SRX's persistent limit switch mode will match what the programming API requests, and therefore will not impact robot performance.

16.18. How do I get the raw ADC value (or voltage) on the Analog Input pin?

The bottom ten bits of Analog-In Position is equal to the converted ADC value. The range of [0, 1023] scales to [0V, 3.3V]. Additionally, if "Analog Potentiometer" is selected as the Feedback Device, the signal "Sensor Position" will exactly equal the bottom ten bits of Analog-In Position.

16.19. Recommendation for using relative sensors.

When using relative sensors for closed-loop control, it's always good practice to design in a way to re-zero your robot. Regardless of how/where relative sensors are connected (robot controller IO, Talon SRX, etc…), there is always the potential for sensors to "walk" or "drift" due to…

-Mechanical slip issues
-Skipped gear teeth in chain
-Intermittent electrical connections (harness gets damaged in middle of a match)
-Power cycle robot when armatures are not in their "home" position.
-Remote resets of robot controller when armatures are not in their "home" position.

A common solution to this is to design a way in the gamepad logic to force your robot into a "manual mode" where the driver/arm operator can manually servo motors to a home position and press a button (or button combination) to re-zero (or set to the "home" position values) all involved sensors.

Teams that do this already can continue to use this method with Talon SRX since there is are set functions to modify "Sensor Position".

16.20. Does anything get reset or lost after firmware updates?

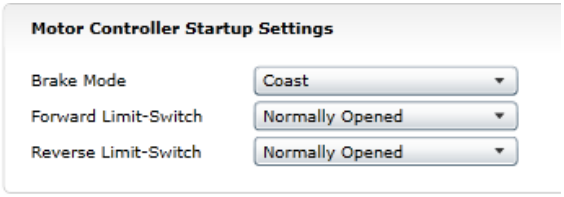
The device ID, limit switch startup settings, brake startup settings, Motor Control Profile Parameters, and sticky flags are all unaffected by the act of field-upgrading. If a particular firmware release has a "back-breaking" change, it will be explicitly documented.

16.21. Analog Position seems to be stuck around ~100 units?

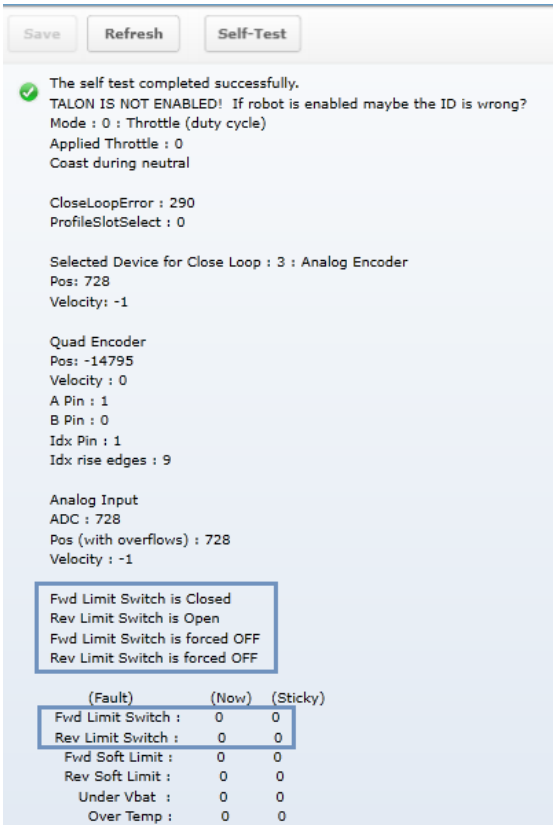
When the analog input is left unconnected, it will hover around 100 units. If an analog sensor has been wired, most likely it's connected to the wrong pin. Recheck wiring against the **Talon SRX User's Guide**.

16.22. Limit switch behavior doesn't match expected settings.

First check the Startup Settings in the roboRIO Web-based Configuration to determine that the "Normally Open"/ "Normally Closed" settings are correct. They can be changed programmatically and in the web page so it's worth confirming. Here we see both directions use NO limit switches...



Then press the "Self-Test" button to check…
-The open/closed state of the limit switch input pin on the Talon SRX.
-If enable/disable state of the limit-switch logic is overridden programmatically.
-Check the fault and sticky faults to see if limit fault conditions are detected.



In this example the Fwd. Limit Switch fault is not set despite the Fwd. Limit Switch being closed. This is because the Limit Switch logic forced OFF, because the feature is disable programmatically. As a result closing the forward limit switch will not disable motor drive.

16.23. How fast can I control just ONE Talon SRX?

The fastest control frame rate that can be specified is 1ms. That means that the average period at which the throttle/set point can be updates is 1ms. This will increase bus utilization by approximately 15%, which is acceptable if the number of Talon SRXs is few. Always check the CAN bus performance metrics in the Driver Station when doing this.

16.24. Expected symptoms when there is excessive signal reflection.

If the CAN bus harness has excessive signal reflection due to improper wiring or missing termination resistors, the following symptoms may be seen…

-Driver Station will show Rx and Tx CAN errors intermittently (see Section 15), particularly with higher bus utilization.

-CAN bus utilization will be higher than normal. This is because CAN devices transmit error frames in response to detecting improper frames. This is helpful if you are in the habit of checking your bus utilization every once in a while and knowing what is typical for your robot. See Section 15 for more details.

-The LED of every CAN device on the bus will blink red intermittently during normal use (the same symptom as Section 16.4). Both common-ID Talons and excessive signal reflection can cause error frames to appear, which trigger every CTRE CAN device to intermittently blink red during normal use.

One reliable way to observe this LED behavior is to deliberately leave a couple common-ID Talon SRXs on your CAN Bus. Then, power up your robot and leave it disabled. All Talon SRXs will rail-road orange (healthy CAN bus and disabled). Now watch any particular Talon SRX for a minute or so. It will blink red intermittently as the two (or more) common-ID Talon SRXs inevitably disrupt each other's frame transmission.

-Measured DC resistance between CANH and CANL (when robot is unpowered) should be approximately 60 Ω. If this is not the case then recheck the CAN wiring and termination resistors (see Talon SRX User's Guide).

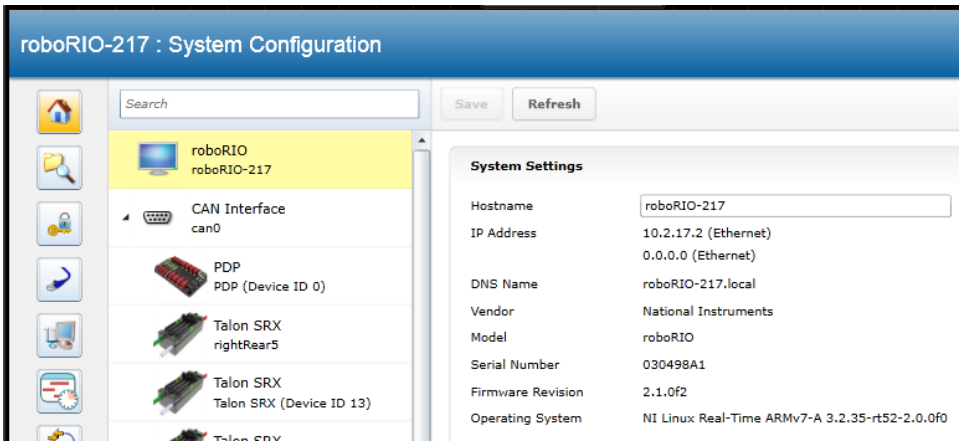
16.25. LabVIEW application reads incorrect Sensor Position. Sensor Position jumps to zero or is missing counts.

This is a common symptom if the LabVIEW application is calling the Motor Enable VI periodically. This VI has the side-effect of modifying the Sensor Position *every time it's invoked*. Additionally wiring the current Sensor Position to this signal also will prevent proper signal decoding since the RIO will send stale positions to the Talon SRX, overwriting valid signal changes in the Talon. See Section 13.1.1 for more information.

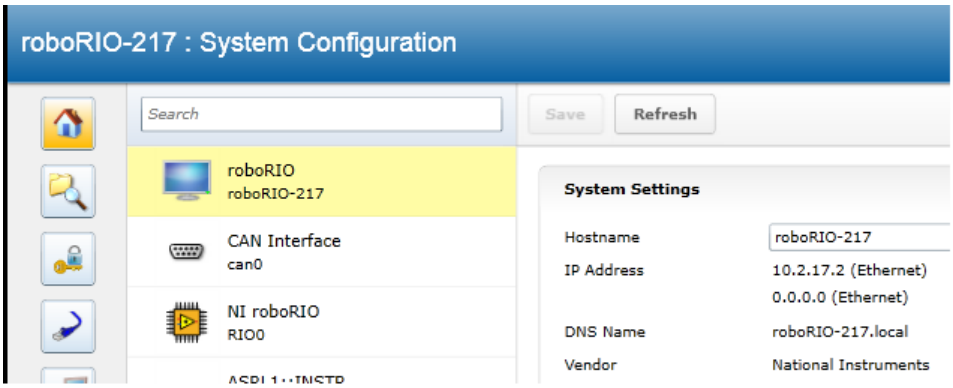
Additionally, check that the correct Feedback Device is selected (Section 7). Remember that the Feedback Device Select is sent only when the robot is enabled. Since there is only one control frame that contains all control signals, this ensures Talon has the correct sensor selected when Talon is enabled (Section 20.6).

16.26. CAN devices do not appear in the roboRIO Web-based config.

Normally devices appear under the “CAN Interface” tree node…



…however if the roboRIO is not correctly wired to the CAN Bus, then the tree node will have no elements listed underneath…



…in which case double-check the CAN bus wiring and termination strategy. See the Talon SRX User’s Guide for more information on wiring Talon SRXs. Also see the “FRC Screen steps” online documentation for more information on wiring the other CAN devices in the control system. Additionally, check the status LEDs of the CAN devices. Generally, red LED states reflect an unhealthy CAN connection, which will help diagnose wiring issues.

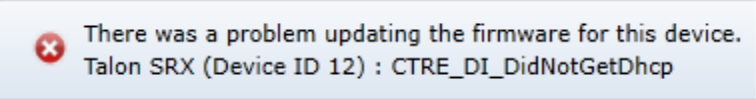
16.27. After a power boot of the robot, and then enabling, occasionally a single CAN actuator does not enable (blinks orange as though it is disabled). Issue corrects itself after pressing “Restart Robot Code” in Driver Station and re-enabling robot.

See section 21.18. If using C++, an alternative solution is to simply update to **WPILib 2015-02-24**.

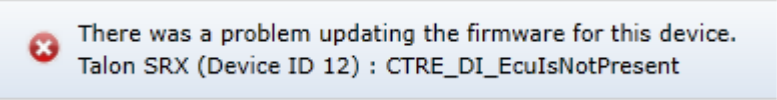
16.28. Occasionally when a firmware update is attempted we get an immediate error. Talon SRX is blinking green/orange. However when we re-imaged the RIO the issue went away?

The root-cause of this issue has been address in the 2016 release.

If you are a C++ team using a WPLib version prior to **2015-02-24**, then you may be susceptible to Functional Limitation 21.18. A secondary symptom of the roboRIO startup issue is that the first attempt at field-updating a CAN device will cause this error.



A second attempt at field-updating it will cause this error.



Although the root-cause is a startup condition in the roboRIO, there are many solutions to this…

16.28.1. The simplest solution is to update your **C++ WPILib to 2015-02-24** or newer. This resolves the root-cause, the startup race that creates Functional Limitation 21.18. Rebuild, redeploy, and reboot the roboRIO, then reattempt flashing CAN devices.

16.28.2. Another alternative is to "undeploy" your C++ built FRCUserProgram application. Deleting/renaming the file (inside /home/lvuser using SSH or FTP) is sufficient. Then reboot roboRIO and re-attempt flashing CAN devices. Re-deploy your robot application when you've finished re-flashing your CAN devices.

16.28.3. A third alternative is to re-image the roboRIO, however this is an excessive solution and is **not recommended**. The reason this has worked for teams previously is because it has the side effect of removing the deployed application, just like **16.28.2**. However reimaging the RIO takes considerably more time (several minutes) whereas the two previous solutions are much faster and lower risk.

16.29. When I make a change to a setting in the roboRIO Web-based configuration and immediately flash firmware into the Talon, the setting does not stick?

When any of the Motor Control Profile (MCP) settings are changed, a certain amount of time must pass before the settings are committed to persistent storage (if a previous change hadn't been made recently). See section 11.1 for an explanation of how the wear-leveling works. This only occurs when re-flashing the firmware immediately after two subsequent setting changes where the two changes are also done immediately after each other.

16.30. My mechanism has multiple Talon SRXs and one sensor. Can I still use the closed-loop/motion-profile modes?

See Section 7.6 for recommended procedure.

16.31. My Closed-Loop is not working? Now what?

The common observations when setting up a closed-loop initially is

- The motor output saturates immediately when enabled.
- The motor output is neutral despite sensor not being near target position/velocity.
- Oscillation or over-shooting the target.
- Motor output is not enough to reach target.

When debugging a closed-loop mechanism, follow the procedure **in order**.

16.31.1. Make sure Talon has latest firmware.

See Section 2.3 for instructions. See Section 22 for firmware release notes.

16.31.2. Confirm sensor is in phase with motor.

See Section 7.4 for instructions on how to check if sensor and motor are in phase.
This is often the culprit if the closed-loop "runs away" or reaches maximum motor output immediately.

16.31.3. Confirm Slave/Follower Talons are driving

If there are slave Talon SRXs, ensure their LED output matches the master Talon. If a slave Talon is not driving due to improper software setup or incorrect wiring, a master Talon may back-drive the slave Talon(s), causing excessive current-draw and/or breaker trips.

To test that the Slave Talons are functioning, unplug all motors and manually drive while looking at the Talon LEDs. Generally the LEDs of all involved Talons should blink red or green synchronously (all Talons are the same color and blink rate). The exception to this is if a slave Talon is inverted using the API in Section 7.4.

See Section 7.6 for complete instructions on testing Slave/Follower Talons setup.

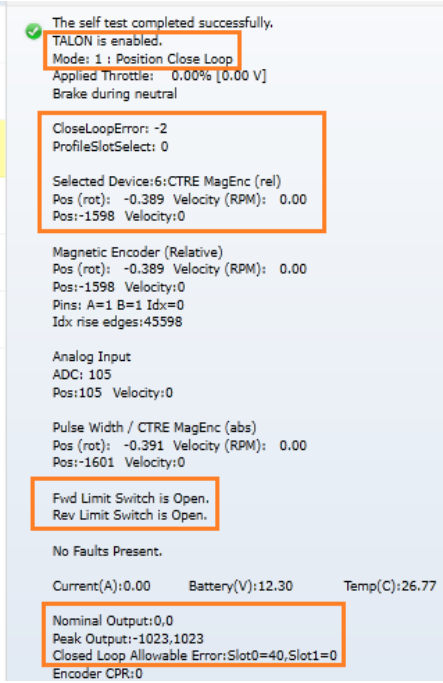
16.31.4. Drive (Master) Talon manually

Drive the Talon (or if using slave Talons, drive the master Talon) using PercentVoltage mode. Cover the full range of speed to ensure mechanical system is functioning as expected. Measure the sensor positions at the critical points to ensure sensor is functioning. This also aids in confirming what the target sensor positions should be if the goal is to use Position Closed-Loop.

See Section 17.2.1 to lookup sensor resolution of each sensor type.

16.31.5. Re-enable Closed-Loop

Zero all four gains (F, P, I, D) and place Talon SRX into Closed-Loop mode. Use the Self-Test to ensure Talon is enabled and in the appropriate mode (Section 2.4).



If Mode is "No Drive", see Section 16.12. If Mode is the wrong one, inspect robot-code to see why the wrong mode is selected.

Applied Throttle will be 0% since the gains are all zeroed.

Ensure the Closed-Loop Peak Outputs are correct. "-1023, 1023" represent the full range (no restriction) of motor-output (default).

Ensure the Closed-Loop Nominal Outputs are correct. "0, 0" represent no restriction on the "smallest" nonzero motor-output of the Closed-Loop (default).

Ensure that Allowable Closed Loop Error is correct. A value of zero represent motor output is allowed anytime Closed Loop Error is nonzero (default).

16.31.6. Start with a simple gain set

The next step depends on whether you are using Position or Velocity Closed-Loop.

16.31.6.1. Start with a simple gain set – Position Closed-Loop

If using Position Closed-Loop, look at the Closed-Loop Error. This is the error between the target and currently-sampled position. It will be measured in Talon native units (see Section 17.2.1). This value is multiplied by the P gain and sent to the motor output.

For example, if the Closed Loop error is **4096** and the **P gain is 0.10**, then…

4096 X **0.10**

409 or 39.98% (409/1023) motor output.

An error of **4096** represent an error of one-full rotation when using the CTRE Magnetic Encoder). So with a **P gain of 0.10**, the Closed-Loop output will be 39.98% when sensor is off by one rotation.

Choose a P gain so that the worst case error yields a small motor-output. Set the P gain and re-enable the Closed-Loop. The motor-output will be "soft" meaning the movement will likely fail to reach the final target (or come up "short"). Double the P gain accordingly until the response is sharp without major overshoot. If the P gain is too large, the mechanism will oscillate about the target position.

At this point, the Closed-Loop will have the basic ability to servo to a target position. Additionally tune the remaining Closed Loop Parameters (ramping, I, D, Peak/Nominal Output, etc.) to dial in the acceleration and near-target response of the closed-loop.

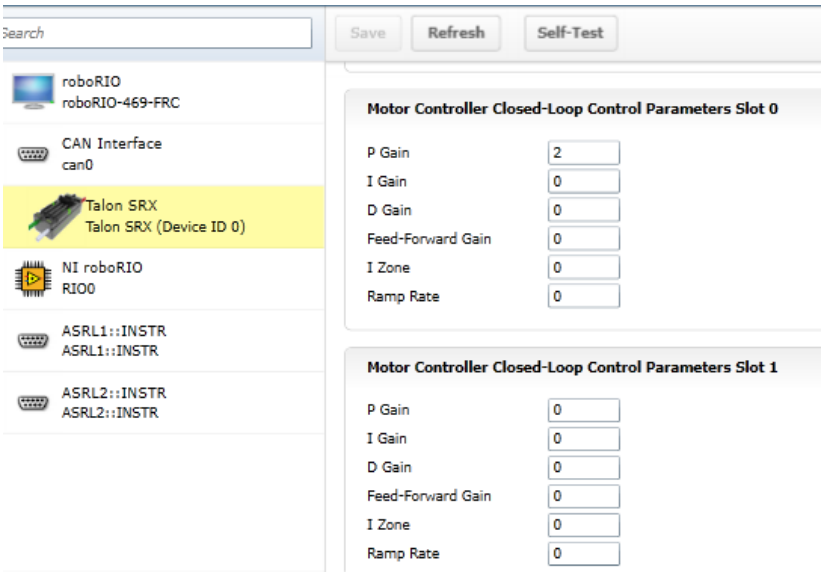
16.31.6.2. Start with a simple gain set – Velocity Closed-Loop

The first gain to set is the F gain. See Section 12.6 for LabVIEW instruction/examples on how this is done. See Section 12.4 for Java instruction/examples (C++ users should also review this section as the procedure is identical).

With just F gain, the motor's output should follow the requested target velocity reasonably. At this point you can begin dialing in P gain so that the closed-loop performs error correction.

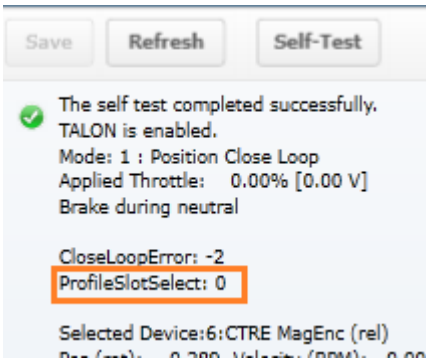
16.31.7. Confirm gains are set

If the motion output is still neutral, use the roboRIO Web based configuration page to confirm that gains are actually nonzero, and that the correct slot is selected.



Here P gain of '2' is in Slot 0.

Now perform the Self-Test to confirm which Profile Slot is selected. In this example we would like to use slot '0'.



16.32. Where can I find application examples?

Example projects for Talon SRX can also be found in the CTR GitHub account.
https://github.com/CrossTheRoadElec/FRC-Examples

16.33. Can RobotDrive be used with CAN Talons? What if there are six Talons?

The default RobotDrive object in LabVIEW/C++/Java already supports two-Talon and four-Talon drivetrains. Simply create the CANTalon objects and pass them into the RobotDrive example.

For six drive Talons, the four-motor examples for Robot Drive can be used with four CANTalon objects, then create the final two Talons and set them to slave/follower mode.

The JAVA_Six_CANTalon_ArcadeDrive example can be downloaded at…
https://github.com/CrossTheRoadElec/FRC-Examples
The screenshot below can be used as a reference.

Although the example is in Java, the strategy can be used in all three FRC languages.
Although the example uses `arcadeDrive`, the robot application could use `tankDrive` as well.

```
10
11 public class Robot extends IterativeRobot {
12
13     /* talons for arcade drive */
14     CANTalon _frontLeftMotor = new CANTalon(11);        /* device IDs here (1 of 2) */
15     CANTalon _rearLeftMotor = new CANTalon(13);
16     CANTalon _frontRightMotor = new CANTalon(14);
17     CANTalon _rearRightMotor = new CANTalon(15);
18
19     /* extra talons for six motor drives */
20     CANTalon _leftSlave = new CANTalon(16);
21     CANTalon _rightSlave = new CANTalon(17);
22
23     RobotDrive _drive = new RobotDrive(_frontLeftMotor, _rearLeftMotor, _frontRightMotor, _rearRightMotor);
24     Joystick _joy = new Joystick(0);
25     /**
26      * This function is run when the robot is first started up and should be
27      * used for any initialization code.
28      */
29     public void robotInit() {
30         /* take our extra talons and just have them follow the Talons updated in arcadeDrive */
31         _leftSlave.changeControlMode(TalonControlMode.Follower);
32         _rightSlave.changeControlMode(TalonControlMode.Follower);
33         _leftSlave.set(11);                              /* device IDs here (2 of 2) */
34         _rightSlave.set(14);
35
36         /* the Talons on the left-side of my robot needs to drive reverse(red) to move robot forward.
37          * Since _leftSlave just follows frontLeftMotor, no need to invert it anywhere. */
38         _drive.setInvertedMotor(MotorType.kFrontLeft, true);
39         _drive.setInvertedMotor(MotorType.kRearLeft, true);
40     }
41     /**
42      * This function is called periodically during operator control
43      */
44     public void teleopPeriodic() {
45         double forward = _joy.getRawAxis(1); // logitech gampad left X, positive is forward
46         double turn = _joy.getRawAxis(2); //logitech gampad right X, positive means turn right
47         _drive.arcadeDrive(forward, turn);
48     }
```

16.34. How fast does the closed-loop run?

Talon SRX updates the motor output every 1ms by recalculating the PIDF output.

Additionally, when using the motion magic control mode, the target position and target velocity is recalculated every 10ms to honor the user's specified acceleration and cruise-velocity.

16.35. Driver Station log reports: **The transmission queue is full. Wait until frames in the queue have been sent and try again.**

This error means the roboRIO is sending more CAN bus frames than can be physically sent. Usually because of a cable disconnect. Check your wiring for opportunities for CAN bus to disconnect.

Check for changes in the CAN error counts (Section 15) to confirm cable integrity.

Section 16.24 has additional cable troubleshooting tips.

16.36. Adding CANTalon to my C++ FRC application causes the Driver Station log to report: **ERROR -52010 NIFPGA: Resource not initialized, GetFPGATime, or similar.**

A full example of the crashed call stack is below…

```
ERROR  -52010  NIFPGA: Resource not initialized  GetFPGATime
[Utility.cpp:171]
 Error at GetFPGATime [Utility.cpp:171]: NIFPGA: Resource not initialized
        at frc::GetFPGATime()
        at frc::Timer::GetFPGATimestamp()
        at frc::MotorSafetyHelper::MotorSafetyHelper(frc::MotorSafety*)
```

… this can happen if a CANTalon is constructed before the C++ WPILIB initialization routine is called.

At the time of writing, this condition can occur when cleanly creating a C++ Command-based project with the latest Eclipse Plugins. An example workaround can be found here…
https://github.com/CrossTheRoadElec/FRC-Examples/commit/24deb61fef6df69f83d5f6436d74df894f7bbf2d
…demonstrating how to ensure motor controller object is constructed after WPILIB initialization.

C++ Command-based projects generated with latest Robot Builder appears to ensure that motor controller objects are created after WPILIB initialization, and therefore do not cause this failure symptom.

More information on C++ Command-based projects can be found at the FRC screenstepslive page, as this is not maintained by CTRE.
https://wpilib.screenstepslive.com

17. Units and Signal Definitions

Listed below are the native units used for various signals.

17.1. Signal Definitions and Talon Native Units

17.1.1. (Quadrature) Encoder Position

When measuring the position of a Quadrature Encoder, the position is measured in 4X encoder edges. For example, if a US Digital Encoder with a 360 cycles per revolution (CPR) will count 1440 units per rotation when read using “Encoder Position” or “Sensor Position”.

The velocity units of a Quadrature Encoder is the change in Encoder Position per T_{velMea} ($T_{velMeas}$=0.1sec). For example, if a US Digital Encoder (CPR=360) spins at 20 rotations per second, this will result in a velocity of 2880 (28800 position units per second).

17.1.2. Analog Potentiometer

When measuring the position of a 3.3V Analog Potentiometer, the position is measured as a 10 bit ADC value. A value of 1023 corresponds to 3.3V. A value of 0 corresponds to 0.0V.

The velocity units of a 3.3V Analog Potentiometer is the change in Analog Position per T_{velMea} ($T_{velMeas}$=0.1sec). For example if an Analog Potentiometer transitions from 0V to 3.3V (1023 units) in one second, the Analog Velocity will be 102.

17.1.3. Analog Encoder, “Analog-In Position”

Like 3.3V Analog Potentiometers, the 10 bit ADC is used to scale [0 V, 3.3 V] => [0, 1023]. However when the Analog Encoder “wraps around” from 1023 to 0, the Analog Position will continue to 1024. In other words, the sensor is treated as “continuous”.

The velocity units of a 3.3V Analog Encoder is the change in Analog Position per 100ms ($T_{velMeas}$=0.1sec). For example if an Analog Encoder transitions from 0V to 3.3V (1023 units) in one second, the Analog Velocity will be 102.

17.1.4. EncRise (a.k.a. Rising Counter)

Every rising edge seen on the Quadrature A pin is counted as a unit.
The velocity units is the change in RisingEdge Count per T_{velMea} ($T_{velMeas}$=0.1sec).
This mode is useful for single direction sensors (tachometer / gear-tooth sensor).

17.1.5. Duty-Cycle (Throttle)

The Talon SRX uses 10bit resolution for the output duty cycle. This means a -1023 represents full reverse, +1023 represents full forward, and 0 represents neutral.

The programming API made available in LabVIEW and C++/Java performs the scaling into percent, so the duty cycle resolution is not necessary for programming purposes. However when evaluating PIDF gain values, it is helpful to understand how the calculated output of the closed-loop is interpreted.

17.1.6. (Voltage) Ramp Rate

The Talon SRX natively represents Ramp Rate as the change in throttle per $T_{RampRate}$ ($T_{RampRate}$=10ms). Throttle is represented as a 10bit signed value (1023 is full forward, -1023 is full reverse). For example, if the robot application requires motor drive ramping from 0% to 100% to take one second of ramping, the result Ramp Rate would be ([1023 – 0] / 1000ms X $T_{RampRate}$) or 10 units.

The programming API made available in LabVIEW and C++/Java performs the scaling into appropriate units (Voltage or percent).

17.1.7. (Closed-Loop) Ramp Rate

The Closed Loop Ramp Rate that can be specified in the selected Motor Control Profile is measured in change in output throttle (from PIDF loop) per $T_{ClosedLoopRampRate}$ ($T_{ClosedLoopRampRate}$ =1ms). For example, if the selected Motor Control Profile requires motor drive ramping from 0% to 100% to take one second of ramping, the result Ramp Rate would be ([1023 – 0] / 1000ms X $T_{RampRate}$) or 1 unit.

The programming API made available in LabVIEW and C++/Java performs the scaling into appropriate units (Voltage or percent).

However when inspecting/setting the Closed-Loop Ramp Rate in the roboRIO webpage, the units will be shown in output throttle per $T_{ClosedLoopRampRate}$.

17.1.8. Integral Zone (I Zone)

The motor control profile contains Integral Zone (I Zone), which (when nonzero), is the maximum error where Integral Accumulation will occur during a closed-loop Mode. If the Closed-loop error is outside of the I Zone, “I Accum” is automatically cleared. This can prevent total instability due to integral windup, particularly when tweaking gains.

The units are in the same units as the selected feedback device (Quadrature Encoder, Analog Potentiometer, Analog Encoder, and EncRise).

17.1.9. Integral Accumulator (I Accum)

The accumulated sum of Closed-Loop Error. It is accumulated in line with Closed-Loop math every 1ms.

17.1.10. Reverse Feedback Sensor

Boolean signal for inverting the selected Feedback Sensor’s position and velocity. This is the preferred method for keeping the motor and sensor in phase for limit switch, soft limit, and closed-loop mode.

17.1.11. Reverse Closed-Loop Output

Boolean signal for inverting the output of the closed-loop PIDF controller. This signal is also used during slave-follower mode to drive slave Talon in the opposite direction of the master.

17.1.12. Closed-Loop Error

Calculated as the difference between target set point and the actual Sensor Position/Velocity.

The units are matched to Analog-In or Encoder depending on which “Feedback Device” and control mode (position vs. speed) is selected.

17.1.13. Closed-Loop gains

P gain is specified in throttle per error unit. For example, a value of 102 is ~9.97% (which is 102/1023) throttle per 1 unit of Closed-Loop Error.

I gain is specified in throttle per integrated error. For example, a value of 10 equates to ~0.97% for each accumulated error (Integral Accumulator). Integral accumulation is done every 1ms.

D gain is specified in throttle per derivative error. For example a value of 102 equates to ~9.97% (which is 102/1023) per change of Sensor Position/Velocity unit per 1ms.

F gain is multiplied directly by the set point passed into the programming API made available in LabVIEW and C++/Java. This allows the robot to feed-forward using the target set-point.

17.2. API Unit Scaling

The Talon's firmware uses a native unit set for the various signals. However the programming API allows for conversion into human-readable units, such as rotations and RPM. Depending on sensor selection, this may require the application to inform the API the resolution of the sensor using configuration routines.

17.2.1. API requirements and Native Units for Unit Scaling

The following table shows the sensor resolution (which is the native unit of measure in Talon firmware), and the requirements of the robot application to leverage unit scaling (rotations and RPM). The requirements column shows the **C++** functions, however Java, LabVIEW, and HERO C# have comparable APIs.

Selected Sensor Type	Native Units Per Mechanical Rotation (also the resolution)	Requirements to leverage Unit Scaling	IsSensorPresent() supported
Quadrature Encoder	**4 X CPR**	**ConfigEncoderCodesPerRev()**	
Edge Counter (On-Rise or On-Fall on QuadA pin)	**1 X CPR**	**ConfigEncoderCodesPerRev()**	
Analog Encoder or Potentiometer	**1024 / TotalPotentiometerTurns units per rotation**	**ConfigPotentiometerTurns()**	
CTRE Mag Encoder (absolute or relative)	**4096 units per rotation**	**No requirements**	**Yes**
Pulse Width Position Sensors	**4096 units per rotation**	**No requirements**	**Yes**

17.2.2. Unit Scaling Features (C++/Java)

Listed below is the expected scaling of each sensor-related API.

Robot API Group	Robot API	Units
Selected Sensor API	Getting/Setting Selected Sensor Position	Rotations if requirements are met, otherwise its Native Units.
	Getting Selected Sensor Velocity	RPM if requirements are met, otherwise its change in Native Units per 100ms
	Setting Soft Limit Thresholds	Rotations if requirements are met, otherwise its Native Units.
Specific Sensor API (low level debugging or managing multiple sensors)	Getting/Setting Analog Position	Native Units only
	Getting Analog Velocity	Native Units only
	Getting/Setting Quadrature (Enc) Position	Native Units only
	Getting Quadrature (Enc) Velocity	Native Units only
	Getting/Setting Pulse Width Position	Native Units only
	Getting Pulse Width Velocity	Native Units only
Closed-Loop Terms in Talon Firmware	Setting Allowable Closed-Loop Error	Raw Units for Position/Velocity Closed-Loop. mA if using Current closed-loop
	Closed-Loop Error	Raw Units for Position/Velocity Closed-Loop. mA if using Current closed-loop
	The target of the closed-loop via Set().	if requirements are met… Position Set Param is in rotations. Velocity Set Param is in RPM. If requirements are not met… Position Set Param is in Native Units. Velocity Set Param is in Native Units per 100ms. Current Set Param is in Amperes.
	FeedForward Term	Fgain X SetPoint in native units. A final result of 1023 represent full throttle
	Proportional Term	Pgain X (Closed-Loop Error) in native units. A final result of 1023 represent full throttle
	Integral Term	Igain X sum, where sum adds the Closed-Loop Error every 1ms.
	Derivative Term	The derivate term is the Dgain multiplied by the change in Closed-Loop Error. Position Closed-Loop: Dgain X Change in [Native Units] per 1ms. Velocity Closed-Loop: Dgain X Change in [Native Unit per 100ms] per 1ms. Current Closed-Loop: Dgain X Change in [mA] per 1ms. A final result of 1023 represent full throttle
Motion Magic	Cruise Velocity	RPM (if requirements are met), otherwise its change in Native Units per 100ms
	Acceleration	RPM per second (if requirements are met), otherwise its change in Native Units per 100ms per second

17.2.3. Java – Configuring Quadrature Encoder (4x)

In addition to selecting the Quadrature Encoder, the robot application can also set the counts per rotation.

```
/* set the reverse flag to ensure positive output
 * moves sensor in positive direction.  */
_tal.reverseSensor(true);
/* select quadrature and encoder CPR so the functions
 * below are in rotations. */
_tal.setFeedbackDevice(FeedbackDevice.QuadEncoder);
_tal.configEncoderCodesPerRev(360);
/* set the sensor position to 0 rotations */
_tal.setPosition(0);
/* forward limit 15 rotations */
_tal.setForwardSoftLimit(+15.0);
/* reverse limit -15 rotations */
_tal.setReverseSoftLimit(-15.0);
```

This then allows various functions to be in terms of rotations and RPM instead of the Talon's native units.

17.2.4. Java – Configuring CTR Magnetic Encoder

In the case of the CTR Magnetic Encoder, setting the CPR is not required. However it is noteworthy that the Magnetic Encoder in relative mode is equivalent to a 1024 CPR encoder.

```
/* set the reverse flag to ensure positive output
 * moves sensor in positive direction.  */
_tal.reverseSensor(false);
/* select Magnetic encoder. No need to config() CPR or number of pot turns.*/
_tal.setFeedbackDevice(FeedbackDevice.CtreMagEncoder_Absolute);
/* set the sensor position to 0 rotations. */
_tal.setPosition(0);
/* forward limit 15 rotations */
_tal.setForwardSoftLimit(+15.0);
/* reverse limit -15 rotations */
_tal.setReverseSoftLimit(-15.0);
_tal.configPeakOutputVoltage(5.0, -5.0);
```

17.2.5. Java – Configuring Edge Counter

The Count Rising and Falling Edge feedback types are used to count single direction sensors. Using the same routine as in the Quadrature use case, the application can provides the number of counts per rotation.

```
/* set the reverse flag to ensure positive output
 * moves sensor in positive direction.  */
_tal.reverseSensor(false);
/* select Magnetic encoder. No need to config() CPR or number of pot turns.*/
_tal.setFeedbackDevice(FeedbackDevice.EncFalling);
_tal.configEncoderCodesPerRev(360);
/* set the sensor position to 0 rotations. */
_tal.setPosition(0);
/* allow full speeds */
_tal.configPeakOutputVoltage(12.0, -12.0);
```

18. How is the closed-loop implemented?

The closed-loop logic is the same regardless of which feedback sensor or closed-loop mode is selected. The verbatim implementation in the Talon firmware is displayed below.
This includes…

- The logic for PIDF style closed-loop.
- Inverting the output of the closed-loop if enabled in API.
- Capping the output to positive values only IF using a single direction feedback sensor.
- Closed- Loop Ramp Rate, ramping the output if enabled.

Note: The `PID_Mux_Unsigned` and `PID_Mux_Sign` routines are merely multiply functions.

```
/**
 * 1ms process for PIDF closed-loop.
 * @param pid ptr to pid object
 * @param pos signed integral position (or velocity when in velocity mode).
 *                  The target pos/velocity is ramped into the target member from caller's 'in'.
 *                  If the CloseLoopRamp in the selected Motor Controller Profile is zero then
 *                  there is no ramping applied. (throttle units per ms)
 *                  PIDF is traditional, unsigned coefficients for P,i,D, signed for F.
 *                  Target pos/velocity is feed forward.
 *
 *                  Izone gives the abilty to autoclear the integral sum if error is wound up.
 * @param revMotDuringCloseLoopEn nonzero to reverse PID output direction.
 * @param oneDirOnly when using positive only sensor, keep the closed-loop from outputing negative throttle.
 */
void PID_Calc1Ms(pid_t * pid, int32_t pos,uint8_t revMotDuringCloseLoopEn, uint8_t oneDirOnly)
{
          /* grab selected slot */
          MotorControlProfile_t * slot = MotControlProf_GetSlot();
          /* calc error : err = target - pos*/
          int32_t err = pid->target - pos;
          pid->err = err;
          /*abs error */
          int32_t absErr = err;
          if(err < 0)
                    absErr = -absErr;
          /* integrate error */
          if(0 == pid->notFirst){
                    /* first pass since reset/init */
                    pid->iAccum = 0;
                    /* also tare the before ramp throt */
                    pid->out = BDC_GetThrot(); /* the save the current ramp */
          }else if((!slot->IZone) || (absErr < slot->IZone) ){
                    /* izone is not used OR absErr is within iZone */
                    pid->iAccum += err;
          }else{
                    pid->iAccum = 0;
          }
          /* dErr/dt */
          if(pid->notFirst){
                    /* calc dErr */
                    pid->dErr = (err - pid->prevErr);
          }else{
                    /* clear dErr */
                    pid->dErr = 0;
          }
          /* P gain X the distance away from where we want */
          pid->outBeforRmp = PID_Mux_Unsigned(err, slot->P);
          if(pid->iAccum && slot->I){
                    /* our accumulated error times I gain.  If you want the robot to creep up then pass a nonzero Igain */
                    pid->outBeforRmp += PID_Mux_Unsigned(pid->iAccum, slot->I);
          }
          /* derivative gain, if you want to react to sharp changes in error (smooth things out). */
          pid->outBeforRmp += PID_Mux_Unsigned(pid->dErr,   slot->D);
          /* feedforward on the set point */
          pid->outBeforRmp += PID_Mux_Signed(pid->target,   slot->F);
          /* arm for next pass */
          {
                    pid->prevErr = err; /* save the prev error for D */
                    pid->notFirst = 1;  /* already serviced first pass */
          }
          /* if we are using one-direction sensor, only allow throttle in one dir.
```

```
                If it's the wrong direction, use revMotDuringCloseLoopEn to flip it */
        if(oneDirOnly){
                if(pid->outBeforRmp < 0)
                        pid->outBeforRmp = 0;
        }
        /* honor the direction flip from control */
        if(revMotDuringCloseLoopEn)
                pid->outBeforRmp = -pid->outBeforRmp;
        /* honor closeloopramprate, ramp out towards outBeforRmp  */
        if(0 != slot->CloseLoopRampRate){
                if(pid->outBeforRmp >= pid->out){
                        /* we want to increase our throt */
                        int32_t deltaUp = pid->outBeforRmp - pid->out;
                        if(deltaUp > slot->CloseLoopRampRate)
                                deltaUp = slot->CloseLoopRampRate;
                        pid->out += deltaUp;
                }else{
                        /* we want to decrease our throt */
                        int32_t deltaDn = pid->out - pid->outBeforRmp;
                        if(deltaDn > slot->CloseLoopRampRate)
                                deltaDn = slot->CloseLoopRampRate;
                        pid->out -= deltaDn;
                }
        }else{
                pid->out = pid->outBeforRmp;
        }
}
```

19. Motor Safety Helper

The Motor Safety feature works in a similar manner as the other motor controllers. The goal is to set an expiration time to a given motor controller, such that, if the `Set()/set()` routine is not called within the expiration time, the motor controller will disable. Additionally the DS will report the error and the roboRIO Web-based Configuration Self-Test will report kDisabled as the mode. As a result, the set routine must be called periodically for sustained motor drive when motor safety is enabled.

One example where this feature is useful is when laying breakpoints with the debugger while the robot is enabled and moving. Ideally when a breakpoint lands, its safest to disable motor drive while the developer performs source-level debugging.

19.1. Best practices

Be sure to test that the time between enabling Motor Safety features, and the first `Set()/set()` call is small enough to not risk accidently timing out. Calling `Set()/set()` immediately after enabling the feature can be used to ensure transitioning into the enabled modes doesn't intermittently cause a timeout.

Even if tripping the motor-safety expiration time is not an expected condition, it's best to re-enable the motors somewhere in the source so that the timeouts can be reset easily, for example in AutonInit()/TeleopInit(). That way normal robot functionality can be safely resumed after a motor controller expires (usually during source-level debugging).

Additionally if source-level debugging is not required (for example during a competition or if logging-style debugging is preferred) the motor-safety enable can be turned off.

19.2. C++ example

`SetSafetyEnabled()` can be used to turn on this feature. `SetExpiration()` can be used to set the expiration time. The default expiration time is typically 100ms.

```
class Robot: public IterativeRobot
{
private:
    CANTalon *_talons[20]; //!< Create a bunch of Talons
    Joystick _joy;
    static const int masterId = 2; //!< Which Talon device ID to make the master.

public:
    Robot() : _joy(0)
    {
        /* create a bunch of talons, say 20 of them.  Doesn't matter if 20 are actually wired or not. */
        for(int i=0;i<20;++i){
            _talons[i] = new CANTalon(i);
            /* make every Talon follow master ID */
            _talons[i]->SetControlMode(CANSpeedController::kFollower);
            _talons[i]->Set(masterId);
        }
    }
    void TeleopInit()
    {
        /* just in case we already safety-timed out previously, when we re-enter teleop we
            need to re-Enable the motor controller, otherwise it will stay timed out. */
        _talons[masterId]->EnableControl();

        /* turn on safety enable features */
        _talons[masterId]->SetSafetyEnabled(true);
        _talons[masterId]->SetExpiration(0.100);
        _talons[masterId]->Set(0);
    }
    void TeleopPeriodic()
    {
        /* grab some gamepad values */
        double dThrot = -1*_joy.GetY();
        double bBtn1 = _joy.GetRawButton(1);

        /* make the master Percent Vbus.  you can do this once or every loop, it doesn't hurt anything */
        _talons[masterId]->SetControlMode(CANSpeedController::kPercentVbus);

        if(bBtn1){
            /* button is pressed, don't update motor to negative test safety features */
        }else{
            /* button not pressed, keeping updating ~20ms per set */
            _talons[masterId]->Set(dThrot);
        }
    }
};
```

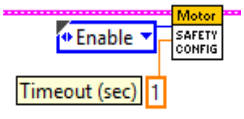
19.3. Java example

`setSafetyEnabled()` can be used to turn on this feature. `setExpiration()` can be used to set the expiration time. The default expiration time is typically 100ms.

```
10 public class Robot extends IterativeRobot {
11
12     CANTalon [] _talons = new CANTalon[20]; //!< Create a bunch of Talons
13     Joystick _joy = new Joystick(0);
14     int masterId = 2; //!< Which Talon device ID to make the master.
15
16     public Robot(){
17         /* create a bunch of talons, say 20 of them.  Doesn't matter if 20 are actually wired or not. */
18         for(int i=0;i<20;++i){
19             _talons[i] = new CANTalon(i);
20             /* make every Talon follow master ID */
21             _talons[i].changeControlMode(ControlMode.Follower);
22             _talons[i].set(masterId);
23         }
24     }
25
26     public void teleopInit(){
27         /* just in case we already safety-timed out previously, when we re-enter teleop we
28         need to re-Enable the motor controller, otherwise it will stay timed out. */
29         _talons[masterId].enableControl();
30
31         /* turn on safety enable features */
32         _talons[masterId].setSafetyEnabled(true);
33         _talons[masterId].setExpiration(0.100);
34         _talons[masterId].set(0);
35     }
36
37     /**
38      * This function is called periodically during operator control
39      */
40     public void teleopPeriodic() {
41         /* grab some gamepad values */
42         double dThrot = -1*_joy.getY();
43         boolean bBtn1 = _joy.getRawButton(1);
44
45         /* make the master Percent Vbus.  you can do this once or every loop, it doesn't hurt anything */
46         _talons[masterId].changeControlMode(ControlMode.PercentVbus);
47
48         if(bBtn1){
49             /* button is pressed, don't update motor to negative test safety features */
50         }else{
51             /* button not pressed, keeping updating ~20ms per set */
52             _talons[masterId].set(dThrot);
53         }
54     }
55
56
57
58 }
```

19.4. LabVIEW Example

The `Motor SAFETY CONFIG VI` can be used to turn on this feature. Select “Enable” for the mode and specify the timeout in seconds.



19.5. RobotDrive

The examples in this section refer to the CANTalon objects directly. However higher level class types such as `RobotDrive` can have their own motor safety objects as well. Although CANTalon safety features default **off**, the higher level drive objects tend to default safety enable to **on**. If you are still witnessing disabled motor drive behavior and Motor Safety Driver Station Log Messages (see Section 16.14) then you may need to call `setSafetyEnabled(false)` (or similar routines/VI) on `RobotDrive` objects as well. Keep in mind that disabling safety enable means that motor drive is allowed to continue if a source-level breakpoint halts program flow. Take the necessary precautions to debug the robot safely or alternatively only enable motor safety features when performing source level debugging.

20. Going deeper - How does the framing work?

The Talon periodically transmits four status frames with sensor data at the given periods. This ensures that certain signals are always available with a deterministic update rate. This also keeps bus utilization stable.

Similarly the control frame sent to the Talon SRX is periodic and contains almost all the information necessary for all control modes.

Although the frame rates are default to ensure stable CAN bandwidth, there *may* be available API to override the frame rates for performance reasons. If this is done, be sure to check the CAN performance metrics to ensure custom settings don't exceed the available CAN bandwidth, see "CAN bus Utilization and Performance metrics".

20.1. General Status

The General Status frame has a default period of 10ms, and provides…
-Closed Loop Error: the closed-loop target minus actual position/velocity.
-Throttle: The current 10bit motor output duty cycle (-1023 full reverse to +1023 full forward).
-Forward Limit Switch Pin State
-Reverse Limit Switch Pin State
-Fault bits
-Applied Control Mode
… These signals are accessible in the various get functions in the programming API.

20.2. Feedback Status

The Feedback Status frame has a default period of 20ms, and provides…
-Sensor Position: Position of the selected sensor
-Sensor Velocity: Velocity of the selected sensor
-Motor Current
-Sticky Faults
-Brake Neutral State
-Motor Control Profile Select
… These signals are accessible in the various get functions in the programming API.

20.3. Quadrature Encoder Status

The Quadrature Encoder Status frame has a default period of 100ms.
-Encoder Position: Position of the quadrature sensor
-Encoder Velocity: Velocity of the selected sensor
-Number of rising edges counted on the Index Pin.
-Quad A pin state.
-Quad B pin state.
-Quad Index pin state.
… These signals are accessible in the various get functions in the programming API.

The quadrature decoder is always engaged, whether the feedback device is selected or not, and whether a quadrature encoder is actually wired or not. This means that the Quadrature Encoder signals are always available in programming API regardless of how the Talon is used. The 100ms update rate is sufficient for logging, instrumentation and debugging. If a faster update rate is required the robot application can select the appropriate sensor and leverage the Sensor Position and Sensor Velocity.

20.4. Analog Input / Temperature / Battery Voltage Status

The Analog/Temp/BattV status frame has a default period of 100ms.
-Analog Position: Position of the selected sensor
-Analog Velocity: Velocity of the selected sensor
-Temperature
-Battery Voltage
… These signals are accessible in the various get functions in the programming API.

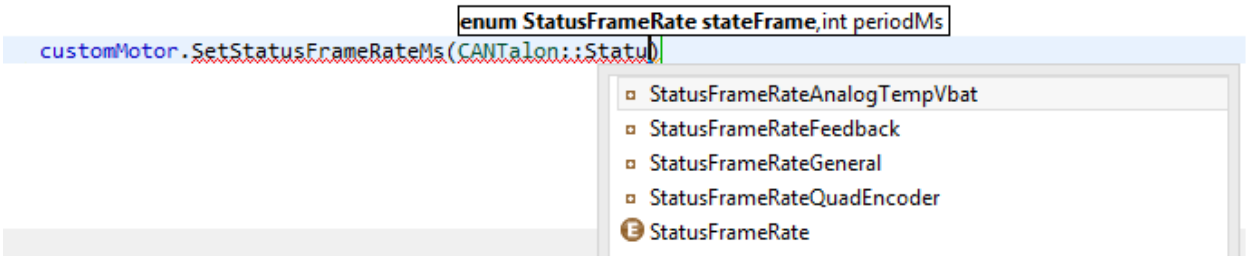
The Analog to Digital Convertor is always engaged, whether the feedback device is selected or not, and whether an analog sensor is actually wired or not. This means that the Analog In signals are always available in programming API regardless of how the Talon is used. The 100ms update rate is sufficient for logging, instrumentation and debugging. If a faster update rate is required the robot application can select the appropriate sensor and leverage the Sensor Position and Sensor Velocity.

20.5. Modifying Status Frame Rates

The frame rates of these signals may be modifiable through programming API.

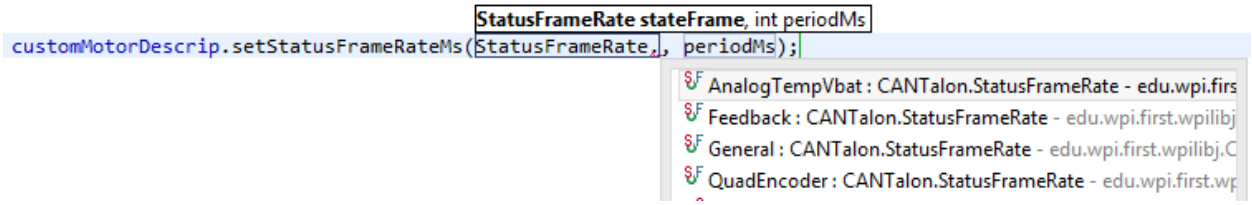
20.5.1. C++

The `SetStatusFrameMs()` function can be used to modify the frame rate period of a particular Status Frame. Use the **StatusFrameRate…** enumerations to specify which frame period to modify.



20.5.2. Java

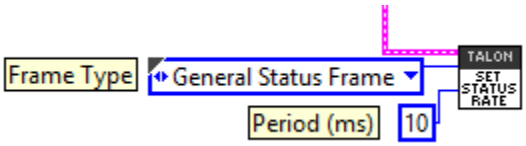
The `setStatusFrameMs()` function can be used to modify the frame rate period of a particular Status Frame. Use the **StatusFrameRate…** enumerations to specify which frame period to modify.



20.5.3. LabVIEW Example

The 

VI can be used to adjust the period of a particular status frame.



20.6. Control Frame

The Talon is primarily controlled by one periodic control frame. The default period of this frame is 10ms. The control frame provides the Talon…
-which Motor Control Profile Slot to use.
-which control mode (position, velocity, duty cycle, slave mode)
-which feedback sensor to use
-if the feedback sensor should be reversed
-if the closed-loop output should be reversed
-the target/set point or duty cycle or which Talon to follow
-the (voltage) ramp rate
-brake neutral mode override if specified
-limit switch overrides if specified
… These signals are accessible in the various set functions in the programming API.

20.7. Modifying the Control Frame Rate

Advanced users can modify the Control Frame Rate to increase the update rate of the control parameters, or decrease to reduce total bus bandwidth.

20.7.1. Modifying the Control Frame Rate – C++

The CANTalon constructor contains a second parameter to specify control frame period in milliseconds.

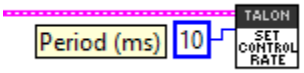
```
CANTalon * customMotorDescrip;
Robot()
{
    customMotorDescrip = new CANTalon(1,10); /* SRX has a deviceID of 1 and control period of 10ms */
```

20.7.2. Modifying the Control Frame Rate – Java

The CANTalon constructor contains a second parameter to specify control frame period in milliseconds.

```
CANTalon customMotorDescrip = new CANTalon(1, 10);/* SRX has a deviceID of 1 and control period of 10ms */
```

20.7.3. Modifying the Control Frame Rate – LabVIEW



21. Functional Limitations

Functional Limitations describe behavior that deviates than what is documented. Feature additions and improvements are always possible thanks to the field-upgrade features of the Talon SRX.

- 2016 season refers to Kickoff January 2016 (FIRST Stronghold). Issues that have been resolved since then are grayed out.
- 2015 season refers to Kickoff January 2015 (Recycle Rush). Issues that have been resolved since then are grayed out.
- Just because a firmware issue has been resolved does not mean your out-of-the-box hardware doesn't have old firmware. **Immediately** update your CAN devices to ensure your development time is not wasted chasing down an issue that has already been solved.

21.1. Firmware 1.1-1.4: Voltage Compensation Mode is not supported.

Feature was not prioritized for FRC 2015 season.

21.2. Firmware 1.1-1.4: Current Closed-Loop Mode is not supported.

Feature was not prioritized for FRC 2015 season.

21.3. Firmware 1.1-1.4: EncFalling Feedback device not supported.

Feature was not prioritized for FRC 2015 season. Firmware does support EncRising Mode (a.k.a. Rising Edge Counter).

21.4. Firmware 1.1-1.4: `ConfigMaxOutputVoltage()` not supported.

Feature was not prioritized for FRC 2015 season.

21.5. Firmware 1.1-1.4: `ConfigFaultTime()` not needed

Firmware only disables drive for limit faults and soft limits (which are time invariant). Motor drive is not disabled due to current, temp, or battery voltage, therefore there is no fault time.

21.6. Firmware 1.1: Changes in Limit Switch "Normally Open" vs "Normally Closed" may require power cycle during a specific circumstance.

In the specific situation where programming API overrides a limit switch enable (to true or false), then changes the NO/NC mode of the same limit switch using programming API, the setting will not take effect until the motor controller is power cycled, or until the limit switch is no longer overridden.

The "first" time a new Talon SRX's NO/NC setting is changed programmatically, power cycle the Talon so the setting takes effect. After the initial power cycle, new NO/NC setting will be loaded correctly and match what the robot controller is requesting, therefore Talon will honor the new NO/NC state from then on.

If not setting NO/NC state programmatically, then no symptoms are observed that deviate from reference manual. Changing the NO/NC state in the the roboRIO Web-based Configuration works as expected.

This is fixed in 1.4.

21.7. FRC2015 LabVIEW: EncRising Feedback mode not selectable.

Release software of LabVIEW does not provide option to select EncRising Mode.

21.8. FRC2015 LabVIEW/C++/Java API: `ConfigEncoderCodesPerRev()` is not supported.

Talon does not configure units. Instead the quadrature units are always in 4X mode.

21.9. FRC2015 LabVIEW/C++/Java API: `ConfigPotentiometerTurns()` is not supported.

Talon does not configure units. Instead the 3.3V ADC is 10 bit, therefore 0 => 3.3V scales to 0 => 1023 units.

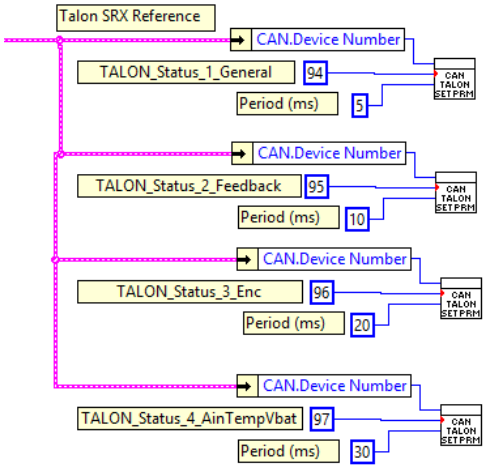
21.10. Java: Once a Limit Switch is overridden, they can't be un-overridden.

This does not cause any observable symptoms, just an inconsistency between C++ and Java API.

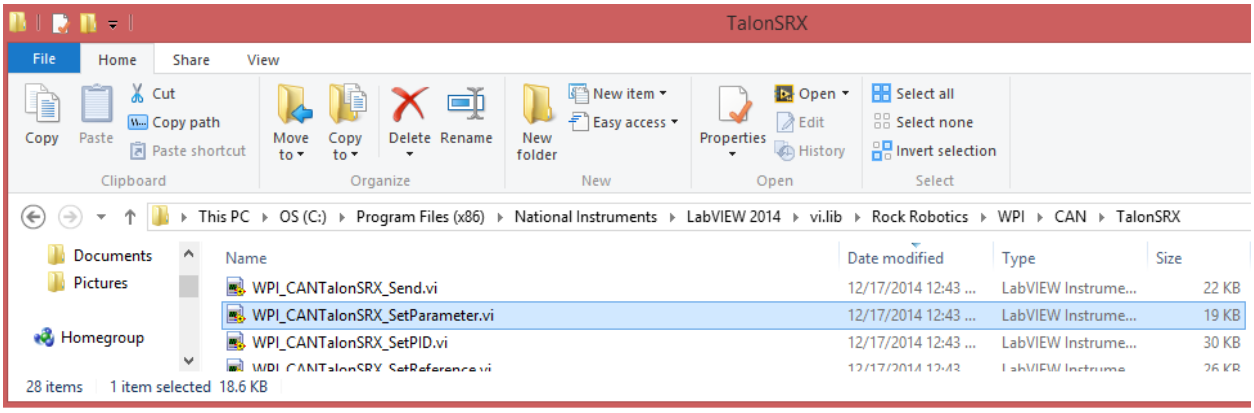
21.11. FRC2015 LabVIEW: Modifying status frame rate is not available.

See below for an example workaround as well as Functional Limitation Section 21.14.

Although there is no explicit VI for modifying the Status Frame Rates, modifying the frame rates can be accomplished with the generic `CAN TALON SETPRM`.



The `WPI_CANTalonSRX_SetParameter.vi` can be drag and dropped from where it resides.



21.12. FRC2015 LabVIEW: Modifying control frame rate is not available.

This will not be available in the initial season release.

21.13. Firmware 1.1: After selecting “Analog Encoder”, “Sensor Position” does not reliably decode when sensor wraps around (3.3V => 0V).

Sensor Position may not travel above 1023 or below 0, despite selecting “Analog Encoder” and spinning the sensor in one direction in a continuous fashion.

This is fixed in 1.4.

21.14. FRC2015 LabVIEW: Certain SRX VI's running in parallel can affect the GET PID VI signals.

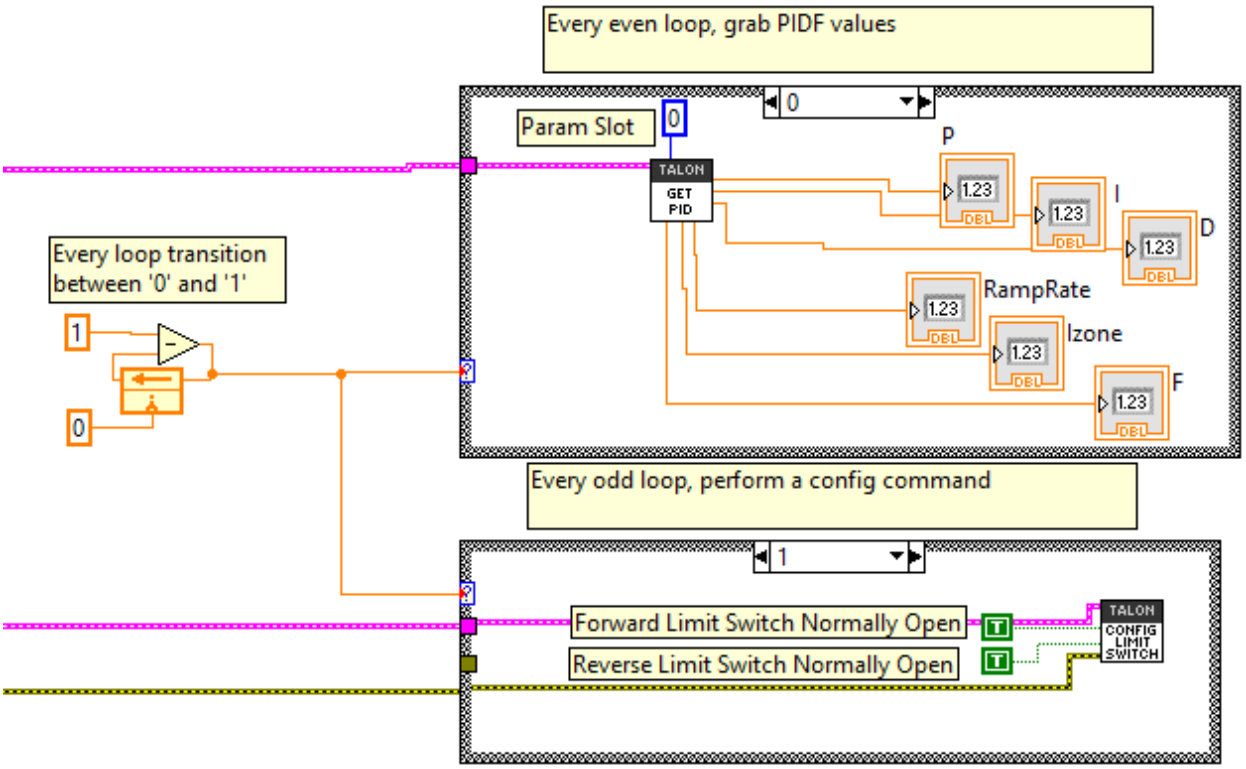
Avoid using the following VIs in “parallel” to reading the signals provided by `GET PID`.

Affected VIs:

```
RESET INTEGRAL ACCUM,
CONFIG LIMIT SWITCH,
CONFIG SOFT LIMIT,
SET PID,
CAN TALON SETPRM,
```

For example, use a state variable to control whether GET PID is used, or the other mentioned VIs are used per periodic loop. Otherwise the GET PID signals may erroneously return zero.

Example Workaround



21.15. C++: There is no method to reverse the output of a slave Talon SRX.

The initial release of WPILIB C++ does not have a method for setting the "Reverse Closed-Loop output" signal. This signal is useful for reversing the output of a slave Talon SRX, ensuring it drives in the opposite direction of its master Talon SRX.

Additionally when using a single-direction sensor in EncRising mode (Rising Counter) this is the preferred method for keeping motor and sensor in phase since "Reverse Feedback Sensor" must be false for single-direction sensors.

The following example can be used to work around this limitation by using the core class `CanTalonSrx` to directly reverse the output signal. Notice the additional include for `"ctre/CanTalonSRX.h"` and the use of `SetRevMotDuringCloseLoopEn()` to accomplish reversing the output.

Although using `CanTalonSRX` is *generally* not recommended (`CANTalon` is the top-level class designed for team-use) this functional limitation is an example where using the lower level class is beneficial.

Example Workaround – Inverting a Slave Talon SRX

Robot.cpp

```
#include "WPILib.h"
#include "ctre/CanTalonSRX.h"  /* use this to grab the underlying core class */
class Robot: public IterativeRobot
{
public:
    Joystick * joy0; /* the first gamepad */
    CANTalon * tal1; /* pointer to a CANTalon */
    CanTalonSRX * tal2; /* pointer to a CanTalonSRX - the low level class */
    Robot()
    {
        tal1 = new CANTalon(1);     /* master Talon device id 1 */
        tal2 = new CanTalonSRX(2);  /* slave Talon device id 2 */
        joy0 = new Joystick(0); /* first gamepad */

        /* just use the CanTalonSRX class since WPILIB is missing the reverseOuput() func */
        tal2->SetModeSelect(CanTalonSRX::kMode_SlaveFollower);  /* Talon2 will follow another Talon */
        tal2->SetDemand(1);                                      /* Talon2 will follow Talon1 */
        tal2->SetRevMotDuringCloseLoopEn(1);                    /* ClosedLoopOut/SlaveOut reverse set to "true" */
    }

    void TeleopPeriodic()
    {
        /* create vars */
        double leftYaxis;
        /* get left axis Y */
        leftYaxis = joy0->GetY(Joystick::kLeftHand);
        /* Left Y => Talon 1 */
        tal1->Set(leftYaxis);

    }
};

START_ROBOT_CLASS(Robot);
```

Note: This example also demonstrates using heap class pointers instead of regular member variables in the interest of covering different methods for allocating objects. Teams may use non-pointer variables if desired.

21.16. Firmware <0.36: Limit Switch Faults and Soft Limit Faults may cause Talon SRX to disable for approximately two seconds during the “first time”.

In the specific situation where a particular limit switch or particular soft limit fault trips for the “first time” when using a Talon SRX with pre-FRC2015-kickoff firmware, the Talon SRX may blink orange for a two second period of time, during which it behaves as though it’s disabled. This can only happen when a Talon SRX is initially out-of-the-box or when a Talon SRX’s sticky faults have been cleared (using the roboRIO web-based configuration or through programming API). The cause is due to the way that firmware earlier than 0.36 saves the sticky faults in persistent memory.

Since teams using CAN are required to update to at least 1.1, this functional limitation will not occur.

Also Talon SRXs used with PWM have no method for clearing sticky faults, so this symptom will only appear once and then never occur again. Additionally PWM-use Talons can easily be firmware updated using the method described in Talon SRX User’s Guide Section 1.3.4.2.

Fixed in 0.36.

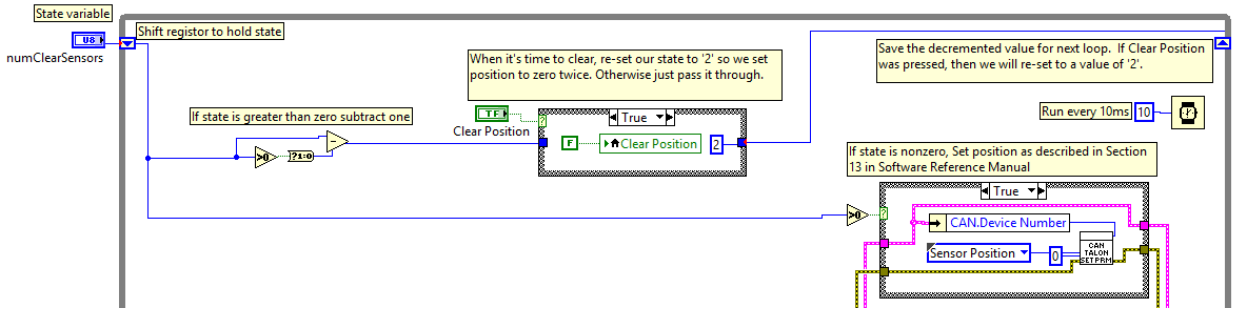
21.17. Firmware 1.4: When setting the “Sensor Position” of an analog encoder, multiple set commands are required.

In the specific situation of setting the “Sensor Position” when the selected feedback device is an analog encoder, the robot application will have to send two set commands to reliably change the sensor position. Additionally there must be at least 9 ms between the two set commands.

The symptom occurs when a sensor position is changed by a large enough value to cause a false detection of an analog encoder wraparound. By re-setting the sensor position to the same new value a second time after the false wrap around is detected, the analog encoder position can be reliably modified.

In C++/Java this can be done by calling the `SetPosition()`/`setPosition()` function twice with the same parameter, and ensuring there is at least 9 ms between the calls.

In LabVIEW this can be accomplished by using state (shift register) to count the number times to consecutively set the Sensor Position. The following example demonstrates clearing the sensor position when the “Clear Position” front panel button is pressed.



21.18. roboRIO power up: roboRIO startup software may not be ready for Robot Application. As a result, certain resources (like CAN actuators) may not enable on teleOp-Enabled after a roboRIO power boot.

This is a specific race condition that causes the RIO's start up processes to boot in a different order then intended. The symptom a team would see is: we power cycled the robot, enabled, and some of our CAN devices (Talon SRX for example) does not enabled (LEDs blink orange). Although the circumstances are intermittent, the workaround to guarantee the Robot Application is robust is simple. In the Disable Loop, "set" one of the following signals periodically to ensure the roboRIO background process is well-aware of what CAN actuators the Robot Application intends to use.

Setting **any** of these signals in the disabled loop will meet the workaround requirements. Also setting these will have no effect on the Talon itself since these signals are not sent over CAN bus until the robot is enabled. The signals that can be used for this workaround are…

```
Brake Mode during Neutral,
Throttle or Closed-Loop set point,
Control Mode,
Limit Switch Enable Overrides,
Feedback Device Select,
(Voltage) Ramp Rate,
Reverse Feedback Sensor,
Reverse Closed-Loop Output,
Profile Slot Select,
```

These signals exist in the periodic control frame. As such, setting them will not block or hold up program execution.

In this C++ workaround example, we redundantly set the brake mode to its default setting. The brake mode already defaults to kNeutralMode_Jumper so the actual behavior of the Talon hasn't changed, and no additional CAN traffic is generated since the control frame is unsolicited and periodic.

In this example any brake mode will work and the new signal value does **not** have to be different than the original signal value.

```
void DisabledPeriodic()
{
    /* periodically "touch" the CANTalons to ensure they get re-registered.
     * Any set() methods that are wired to the normal-mode signals will work.
     * For example, re-affirming the default neutral mode is sufficient.  */
    driveBaseFrontLeftSteer->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    driveBaseFrontRightSteer->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    driveBaseRearLeftSteer->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    driveBaseRearRightSteer->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    stackerLiftFrontRight->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    stackerLiftFrontLeft->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    stackerDart->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
    grabberExtension->ConfigNeutralMode(CANTalon::kNeutralMode_Jumper);
}
```

21.19. roboRIO power up: User should manually refresh the web-based configuration after rebooting roboRIO.

It is recommended to manually refresh the web browser if the roboRIO has been reset or power cycled. This ensures that the web browser and roboRIO are synchronized well. Otherwise device icons may not match the device type in the web-based config.

21.20. LabVIEW: Settings applied in begin.vi may not stick unless there is a terminating "Set Output".

Because not all of the modifiers have a terminating 

, it's possible that SRX motor controller objects that are configured in `begin.vi` may not have the initial settings applied. This is specific to situations where a Talon SRX object is created and configured in begin.vi, and then is never modified in any of the active loops, thereby never providing the programming API an opportunity to flush all changes into the lower level.

To ensure the configuration "takes", add a terminating `Set Output` (

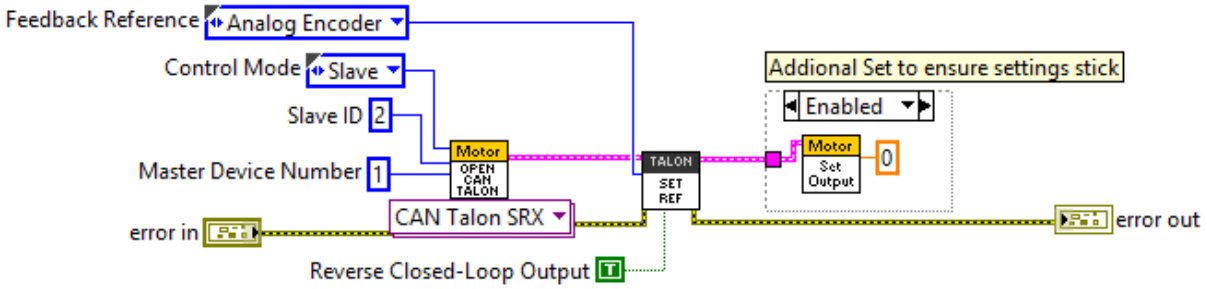
) or any other VI that utilizes 

.

The typical situation where this may occur is when creating a Talon SRX object for the sole purpose of being a slave follower, which only requires initial configuration. However if non-default settings are applied, such as Reverse Closed-Loop Output, the settings are not guaranteed to be applied. If Reverse Closed-Loop Output is not applied, then the slave motor may drive in a direction opposite of what is desired.

In this example we modify several settings of a slave Talon for testing purposes. To ensure the "Reverse Closed-Loop Output" signal is set properly, a final 

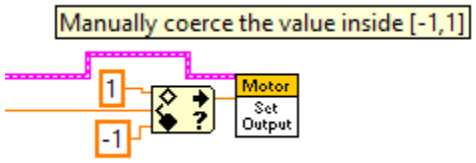
is done. Note that the surrounding structure is unnecessary and merely highlights the workaround.



21.21. LabVIEW 2015, 2016: Set Values outside of [-1,+1] do not saturate in Percent VBus control mode.

When using CANTalons in Percent VBus control mode, ensure the set value stays between -1 and +1. A value outside of this range will cause a wraparound condition causing the throttle to reverse direction.

The workaround is to use the coerce block (or similar logic) to saturate the value to -1 and +1.



21.22. Java 2016: getForwardSoftLimit() and getReverseSoftLimit() returns Native Units.

Although the set routines for soft limits leverages the new Unit Scaling features, getting the soft limits in Java always returns in Native Units. The workaround is to manually scale using the scalars in Section 17.2.1.

21.23. FRC2016 roboRIO: CAN Device does not appear in web page diagnostics.

Under specific conditions, a CAN device may no longer appear in the left tree view in the roboRIO web-based configuration page. For this to occur the following criteria must be met.

- FRC_roboRIO_2016_v19.zip is imaged in the roboRIO.
- The missing device ID must be greater than 20.
- All other device IDs must be either: greater than the missing ID, or less than missing ID minus 50.

If there is a CAN device which has an ID that meets this criteria, and therefore is no longer appearing in the web-page, the user can apply the following procedure. This procedure will force the device to appear, and will allow the user to change the device ID so as to work around this limitation. The user can either…

- Power cycle just the missing-ID-device and manually refresh the browser until device appears…
- …or alternatively disconnect CAN bus between the robot controller and the missing-ID-device. Then power-cycle or reboot the roboRIO. Navigate to the roboRIO's webpage and wait until page fully renders. Now reconnect CAN bus and manually-refresh the browser until device appears.

After forcing the missing device to appear, modify its device ID so that this limitation doesn't occur again. To work around this limitation, either…

- use device IDs less than 20 or …
- …avoid gaps in IDs that exceed 50 and ensure there is (at least) one device ID less than 20.

This limitation will not prevent the robot API from controlling/monitoring CTRE CAN Devices.

21.24. FRC2016 LabVIEW: Un-bundled Sensor Velocity may be one-fourth of the expected value.

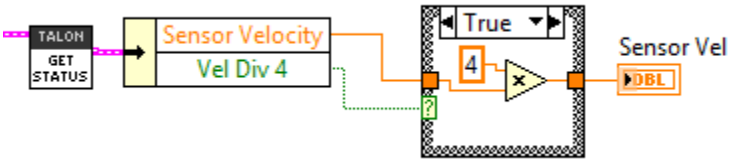
The “Sensor Velocity” will reduce to one-fourth of the expected value at a threshold determined by the sensor resolution. For example if the Sensor has a resolution of 4096 units per rotation (1024CPR Quadrature or CTRE Mag Encoder) an increasing “Sensor Velocity” will abruptly drop to one-fourth of its expected value as it passes above 4800 RPM.

The RPM threshold at which this limitation occurs can be calculated as…

ThresholdRPM = 4800 X 4096 / SensorResolutionPerRotation

There is a signal to determine when this occurs, which was meant to be used by the robot API to adjust the “Sensor Velocity” automatically. As a result, the calling application may have to check “Vel Div 4” and if it is set to true, simply multiple the Sensor Velocity by ‘4’. If “Vel Div 4” is false, then the limitation is not in effect, and “Sensor Velocity” is valid.

This workaround will ensure proper decoding of the Sensor Velocity.



This workaround is necessary regardless if API Unit Scaling is utilized or not (Section 17.2.1).

This limitation does not affect the Closed-Loop features of Talon SRX. It only affects interpreting the reported velocity over CAN bus to the LabVIEW robot API.

This limitation does not affect the reported sensor velocity in C++, Java, and the Self-Test of the roboRIO web-based configuration page.

21.25. FRC2016 LabVIEW: API Unit-Scaling Inconsistencies

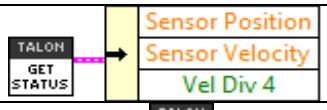
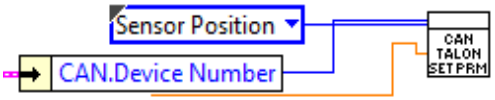
The LabVIEW implementation of API Unit Scaling has the following inconsistencies (see tables below). The unit-scaling features were meant to allow Rotations / RPM to be used in all Position/Velocity APIs, however there are sensor-specific limitations that need to be considered.

As a result, it is recommend to **not** wire 

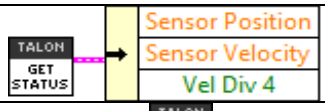
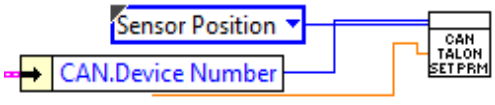
or 

when using any of the Feedback Sensor Types. The following tables can be used to determine what scaling is taking effect per VI, based on the sensor selection.

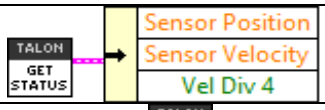
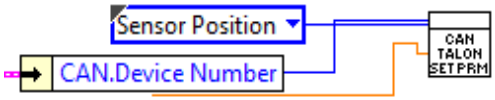
CTRE Magnetic Encoder (Relative)

Operation	VI	Units
Set Target Position/Speed with "Output"		Native Units
Set Target Position/Speed with "Output"		Native Units
Getting Sensor Position/Speed		Rotations / RPM
Setting Sensor Position		Rotations
Setting Sensor Position (FRC 2015)		Native Units

CTRE Magnetic Encoder (Absolute)

Operation	VI	Units
Set Target Position/Speed with "Output"		Native Units
Set Target Position/Speed with "Output"		Native Units
Getting Sensor Position/Speed		Rotations / RPM
Setting Sensor Position		**Not functional. Use the method described in Section 13.1**
Setting Sensor Position (FRC 2015)		Rotations

Quadrature/Analog Encoder/ Analog Potentiometer / Edge Counter

Operation	VI	Units
Set Target Position/Speed with "Output"		*Native Units
Set Target Position/Speed with "Output"		*Native Units
Getting Sensor Position/Speed		*Native Units
Setting Sensor Position		*Native Units
Setting Sensor Position (FRC 2015)		*Native Units

*Native Units – This requires that the  and  VIs are **not** used.

Velocity Closed-Loop Examples with these workarounds can be downloaded at…
https://github.com/CrossTheRoadElec/FRC-Examples/tree/master/LabVIEW%20Speed%20Closed%20Loop

21.26. FRC2016 LabVIEW: Talon SRX Settings Appear to Change After Stopping and Re-Running Code From Robot Main VI

The Talon SRX Settings on the roboRIO persist between Run sessions of LabVIEW (until the roboRIO is reset). Additionally, the hardware initializations in the Begin VI are run 'concurrently', so the order of creation is not consistent.

Intermittently, the initialization order of hardware may be different such that a Talon SRX may be assigned memory that was formerly assigned to a different unit, and if the settings in that memory are not overwritten by the new Talon SRX initialization the former settings will persist.

This is not an issue with permanently deployed code, as the roboRIO will be reset upon 'Run as Start-up' and upon any code re-start from the Driver Station.

The settings that may be affected by this issue are as follows:

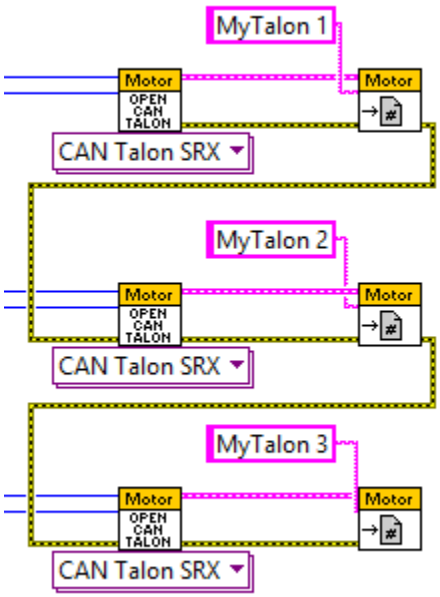
- Reverse Closed-Loop Output (Boolean)
- Reverse Sensor Direction (Boolean)
- Feedback Reference (Sensor Typedef)
- Throttle Ramp Rate (Double)
- Override Limit Switches (Boolean)
- Brake Override (Brake/Coast Typedef)
- Any Output Set in the Begin VI

The recommended workaround is to link the error nodes of the Talon SRX initializations to ensure consistent order of initialization (see example to the right).

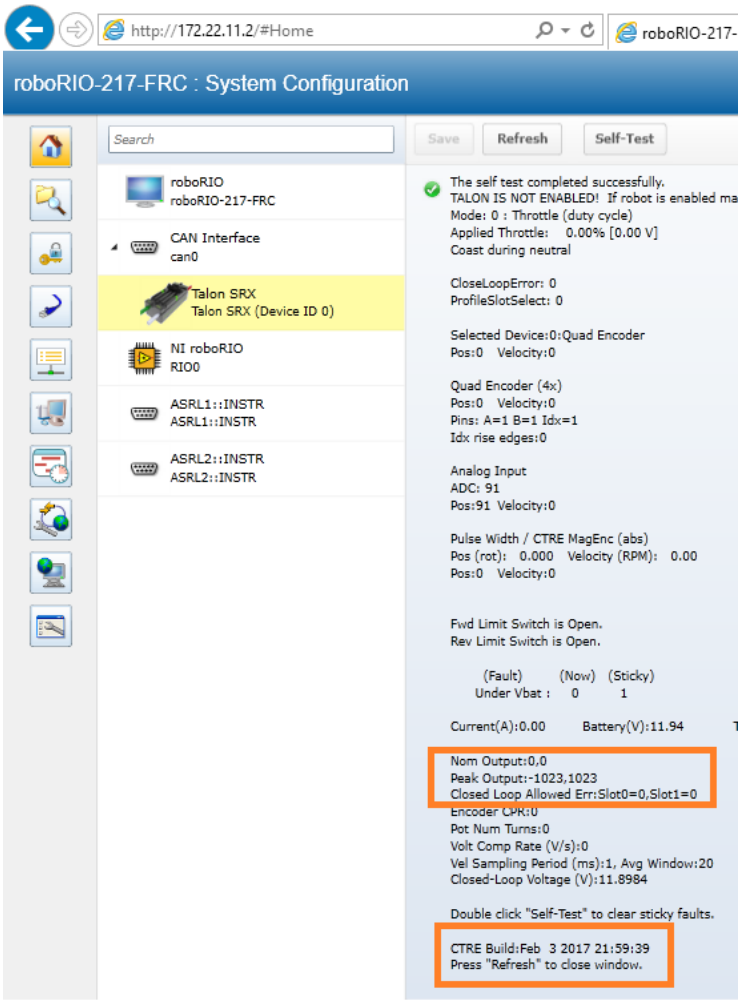
An alternative workaround is to ensure that any parameter being set for any Talon SRX is also set for every other device. This will ensure that any persisting setting will be overwritten upon being re-run.

For example, passing the error signal through the Open calls will ensure consistent creation order. Passing the error signal through the various TALON configuration VIs is not necessary (and genereally not recommended) however chaining the OPEN calls is sufficient for this workaround.

Workaround to Ensure Consistent Initialization Order



21.27. FRC2017 Web-Based Config: Some settings are defaulted after saving a change in the web-based config.



When a change is saved in the web-based configuration page, certain settings may be defaulted.

The settings defaulted are…

- Peak Forward Output
- Peak Reverse Output
- Nominal Forward Output
- Nominal Reverse Output
- Allowable ClosedLoop Err (slot0)
- Allowable ClosedLoop Err (slot1)

This only affects plugin versions that

- are earlier than Feb 3 2017
- display the signals mentioned above in the self-test.

Plugins versioned at Feb 3 2017 and on do **not** default these values, but instead leave them unmodified.

The plugin installed with CTRE Toolsuite 4.4.1.10 is versioned Feb 3 2017, and therefore will **not** default these signals.

Additionally, these signals can be restored with programming API if roboRIO plugin cannot be updated.

21.28. FRC2017 Firmware 2.21-2.22: Velocity RPM measurement wraps from positive to negative at ~4800 RPM.

Firmware versions 2.21 and 2.22 (and non-FRC 10.22) have an issue where the velocity measurement is truncated and so wraps from positive to negative (or negative to positive) at around +/- 4800 RPM (when using a 12bit sensor).

The exact threshold in RPM is (19660200/sensor-units-per-rotation).

This can be fixed by updating to firmware 2.23 (or non-FRC 10.23) or later.

21.29. FRC2017 Firmware 2.23: Velocity measurement oscillates or velocity closed-loop response is less stable than firmware 2.0. Talon appears to disable momentarily (orange LED blink).

Firmware 2.23 has a known regression issue where the velocity measurement may have a false oscillation that was not observable in earlier firmware. The primary symptom is observing unusual oscillation in the velocity closed-loop, when compared against using older firmware (2.00). A secondary symptom of this regression is occasionally observing the Talon SRX enter the disabled state momentarily during normal use (orange LED Blink and no motor output on just one Talon).

This issue can be resolved by using older firmware (2.20 for example) or FRC firmware ≥2.30 (which has the issue resolved).

21.30. FRC2017: Motion Magic movement stops abruptly at the end of motion. Motion does not decelerate on the final approach to target position.

If the calculated trajectory velocity (RPM) exceeds 8792577/sensor-units-per-rotation, then the motion magic tracking firmware may produce an overflow condition, which prevents the deceleration portion of the motion profile. As a result, the motion will stop at the final set point abruptly.

The condition is remedied in FRC firmware ≥2.33. The upper bound for trajectory velocity (RPM) is then raised to 278045700/sensor-units-per-rotation.

22. CRF Firmware Version Information

CRF Version	Date	Description
2.34 (FRC)	23-Feb-2017	Added feature where Talon can uniquely identify unexpected resets (such as ESD events). **To ensure all features function as documented, Talons should be updated to this version.**
2.33 (FRC) – Internal Build	23-Feb-2017	Functional Limitation 21.30 fixed. Changed Talon SRX current measurement to round instead of truncate (to nearest 125mA).
2.31 (FRC) – Internal Build	22-Feb-2017	Various timing optimizations including faster current-draw math and buffering improvements.
2.30 (FRC) – Internal Build	20-Feb-2017	Functional Limitation 21.29 fixed.
10.23 (HERO) 2.23 (FRC)	14-Feb-2017	Functional Limitation 21.28 fixed. **Function Limitation 21.29 begins in this release.**
10.22 (HERO) 2.22 (FRC)	3-Feb-2017	Closed-Loop Nominal Battery Voltage setting added. Velocity Sampling now has two settings that can be tweaked: Sample Period and Rolling Average Window. **Function Limitation 21.28 begins in this release.**
10.20 (HERO) 2.20 (FRC)	7-Jan-2017	Kickoff Release features the following: New Control Mode: Motion Magic Control Mode New API for limiting current output. New ability to auto-zero Sensor Position using Limit Switches. New Support for CTRE Pigeon IMU.
2.0	9-Jan-2016	Kickoff Release which features the following… New Control Mode: Current-Closed Loop, Voltage Compensation Mode. New Control Mode: Voltage Compensation Mode. New Control Mode: Motion Profile Control Mode. New Support for CTRE Mag Encoder (absolute and relative). New API for selecting the nominal and peak output of closed-loop. New API for AllowableClosedLoop Err (native units) where motor output is neutral. New Unit scaling so robot API uses rotations and RPM for position and velocity. New ability to auto-zero Sensor Position using Digital Edge detection.
1.16	11-Oct-2015	Added bounds checking for Allowable Closed-Loop Error.
1.15	1-Oct-2015	All functional limitations fixed (that were firmware side) from 2015. Unit support. CTR Magnetic Encoder sensor types added. Pulse Width Decoder Improvements. Nominal And Peak Closed Loop Outputs added. Velocity measurements are averaged / smoothed. Voltage Compensation Mode Added Current Closed loop added. Allowable Closed-Loop Error added for each slot.
1.4	20-Jan-2015	Functional Limitation 21.6 fixed. Functional Limitation 21.13 fixed. Analog Encoder/Potentiometer Velocity uses a rolling window average to reduce noise. Analog Encoder/Potentiometer Position averaged to reduce noise.
1.1	26-Dec-2014	Initial Release for 2015 FRC Season – Any firmware **earlier** than this will likely **not support most of the documented features**.

0.19 or 0.28	Factory Firmware	An out-of-box Talon will contain ship firmware which will **not support most of the documented features** and will **likely not be FRC legal for CAN-use**.

23. Document Revision Information

Rev	Date	Description
1.26	26-Feb-2017	-Section 7 renamed. -Section 7.8.1 Updated with additional content. -Section 7.8.3 Added. -Section 21.28 Added expression for calculating threshold. -Section 21.29 Added. -Section 21.30 Added. -Section 22 Updated with latest CRF information.
1.25	14-Feb-2017	-Added Section 21.28
1.24	11-Feb-2017	-Section 21.25 grayed out. -Section 12.8 added. -Content added to Section 10.7. -Section 17.2.2 updated with motion magic. -Removed references to the 2016 LabVIEW workaround in Section 21.25.
1.23	7-Feb-2017	-Section 21.27 added.
1.22	5-Feb-2017	-Section 7.8 added. -Added Motion Magic to support list in sections 10.5, 10.6, 10.8. -Spelling correction in Section 19.2, 19.3. -Section 16.34 added. -Section 16.35 added. -Section 16.36 added. -Section 10.8 added. -Whitespace fix above Section 1.
1.21	26-Jan-2017	-Section 3.4 added.
1.20	25-Jan-2017	-Section 3.2 Updated. -Section 10.7, 12.7 added.
1.19	8-Jan-2017	-Section 3.1.1 added.
1.18	2-Aug-2016	-Section 10.1 Typo Fix.
1.17	30-Mar-2016	-Section 7.5.4 Mag Encoder Max RPM updated. -Section 21.26 added
1.16	6-Mar-2016	-Section 21.25 correction to table
1.15	31-Jan-2016	-Section 7.4.1, 7.4.2, 7.4.3 added -Section 7.6 and 7.7 added -Section 10.5 added -Section 10.6 added -Section 11.1 updated to include new parameters.

		-Section 12.3.1, 12.3.2, 12.3.3 added -Section 12.4.1, 12.4.2, 12.4.3 added -Section 16.15 updated. -Section 16.30 added -Section 16.31 added -Section 16.32 added -Section 16.33 added
1.14	25-Jan-2016	-Section 21.24 added. -Section 21.25 added. -Section 12.6 added.
1.13	24-Jan-2016	-Section 21.23 added. -Section 9.1.4 subsection bookmarks corrected.
1.12	20-Jan-2016	-Section 3.3.3 updated for FRC 2016 season.
1.11	9-Jan-2016	-Section 17.2.1 corrected.
1.10	8-Jan-2016	-Section 16 updated for FRC 2016 season. -Section 21 updated for FRC 2016 season. -Section 21.21 and 21.22 added. -Section 17.2 added. -Section 12.2, 12.3, 12.4 added.
1.9	28-Dec-2015	-Magnetic Encoder added to section 7.2 and 7.3. -Section 10 Tips added. -Section 10.2, 10.3, 10.4
1.8	12-Oct-2015	-Various 2016 FRC Season updates. -Follower mode moved from Section 9 to 9.1. -Sections 3.3,3.4,3.5 moved under Section 3.2
1.7	17-August-2015	-Added section 16.29 -Updated company logo.
1.6	1-April-2015	-Added Section 21.20
1.5	26-Feb-2015	-Added Section 16.27 -Added Section 16.28
1.4	17-Feb-2015	-Added screenshot of wrong CRF in Section 2.3.3. -Section 13.1.1 added. -Section 16.25 added. -Section 16.26 added. -Section 19.5 added. -Section 21.18 added. -Section 21.19 added.
1.3	1-Feb-2015	-Section 6.4 added.

		-Section 12.2.3 added. -Section 16.24 added. -Section 21.16 and 21.17 added.
1.2	23-Jan-2015	-Section 21.15 added. Reversing a slave Talon in C++. -Section 3.6 Added for changing Talon SRX mode.
1.1	20-Jan-2015	-Section 22 moved to Section 23. -New Section 22 added for CRF Firmware. -Updates relating to CRF 1.4. -Section 21.14 Added. Workaround for GET PID VI. -Section 20.5.3 Added. Example for LabVIEW status frame modification. -Section 2.5 Added. Custom Device Names. -Section 13, Clarifying statement added for CRF 1.4.
1.0	26-Dec-2014	-Initial Release for 2015 FRC Season