RobotBuilder

RobotBuilder

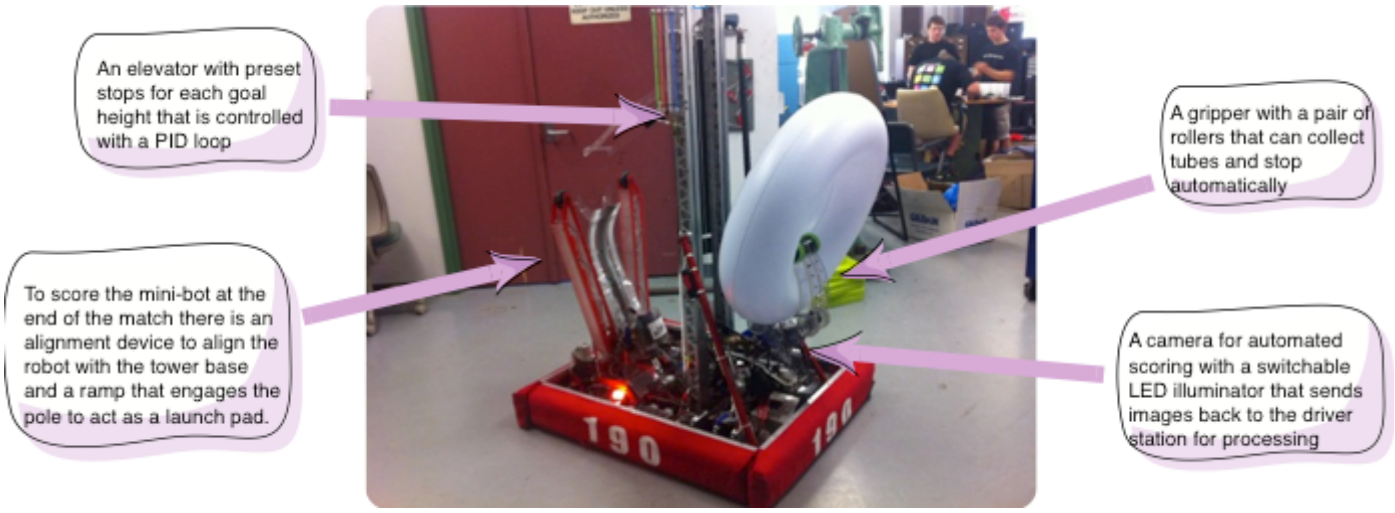
The basic steps to create a robot program

Overview of RobotBuilder

Creating a program with RobotBuilder is a very straight forward procedure by following a few steps that are the same for any robot. This lesson describes the steps that you can follow. You can find more details about each of these steps in subsequent sections of the document.

See How to write an easy to test robot program for more information about the basic steps in creating a program to control your robot.

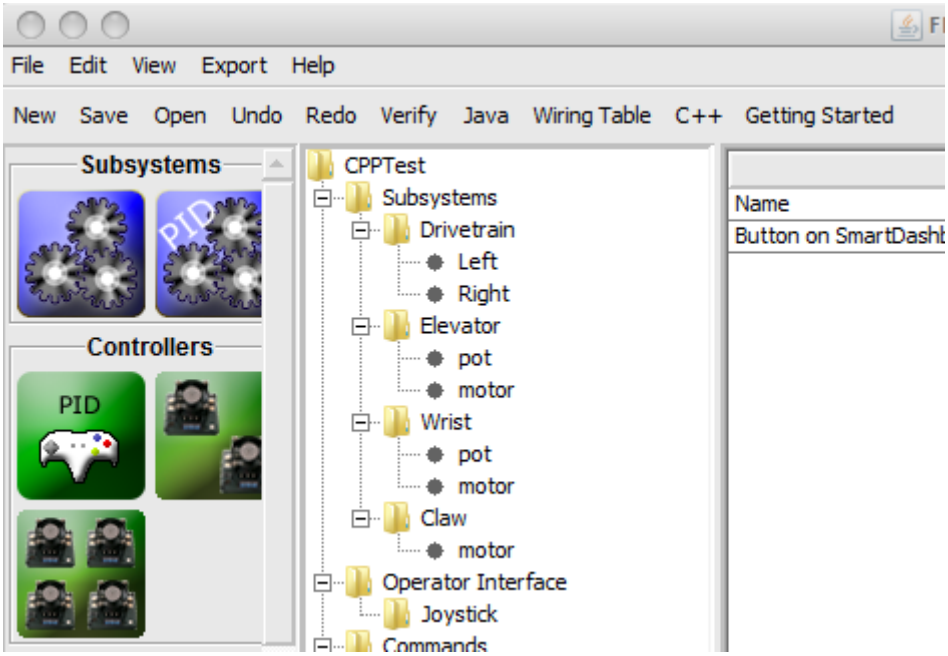
Divide the robot into subsystems



Your robot is naturally made up of a number of smaller systems like the drive trains, arms, shooters, collectors, manipulators, wrist joints, etc. You should look at the design of your robot and break it up into smaller, separately operated subsystems. In this particular example there is an elevator, a minibot alignment device, a gripper, and a camera system. In addition one might include the drive base. Each of these parts of the robot are separately controlled and make good candidates for subsystems.

For more information see: Defining Robot Subsystems

Add each subsystem to the RobotBuilder project



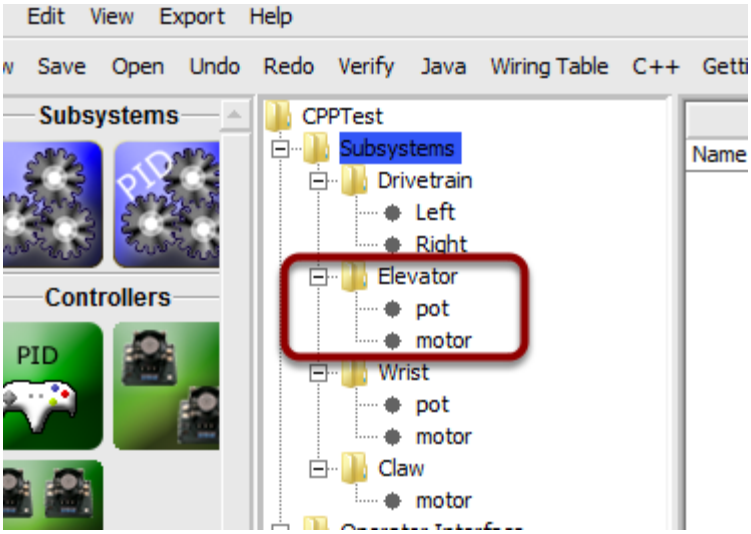
Each subsystem will be added to the "Subsystems" folder in the RobotBuilder and given a meaningful name. For each of the subsystems there are several attributes that get filled in to specify more information about the subsystems. In addition there are two types of subsystems that you might want to create:

1. PIDSubsystems - often it is desirable to control a subsystems operation with a PID controller. This is code in your program that makes the subsystem element, for example arm angle, more quickly to a desired position then stop when reaching it. PIDSubsystems have the PID Controller code built-in and are often more convenient then adding it yourself. PIDSubsystems have a sensor that determines when the device has reached the target position and an actuator (speed controller) that is driven to the setpoint.
2. Regular subsystem - these subsystems don't have an integrated PID controller and are used for subsystems without PID control for feedback or for subsystems requiring more complex control than can be handled with the default imbedded PID controller.

As you look through more of this documentation the differences between the subsystem types will become more apparent.

For more information see: Creating a subsystem, Writing Java code for a subsystem and Writing C++ code for a subsystem

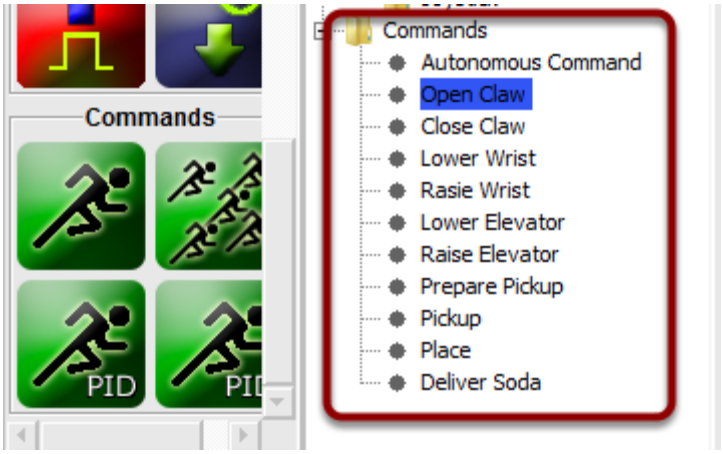
Add components to each of the subsystems



Each subsystem consists of a number of actuators, sensors and controllers that it uses to perform its operations. These sensors and actuators are added to the subsystem with which they are associated. Each of the sensors and actuators comes from the RobotBuilder palette and is dragged to the appropriate subsystem. For each, there are usually other properties that must be set such as port numbers and other parameters specific to the component.

In this example there is an Elevator subsystem that uses a motor and a potentiometer (motor and pot) that have been dragged to the Elevator subsystem.

Add commands to describe the goals for each subsystem

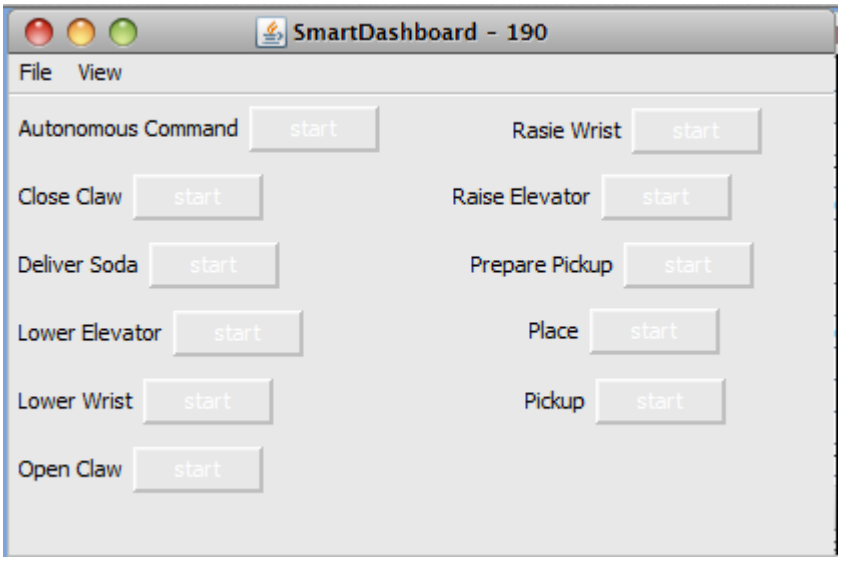


Commands are distinct goals that the robot will perform. These commands are added by dragging the command under the "Commands" folder. When creating a command, there are 3 primary choices (shown on the palette on the left of the picture):

- Normal commands - these are the most flexible command, you have to right all of the code to perform the desired actions necessary to accomplish the goal.
- Command groups - these commands are a combination of other commands running both in a sequential order and in parallel. Use these to build up more complicated actions after you have a number of basic commands implemented.
- Setpoint commands - setpoint commands move a PID Subsystem to a fixed setpoint, or the desired location.

For more information see: Creating a command, Writing the code for a command in Java and Writing the code for a command in C++

Test each command individually by starting it from the SmartDashboard

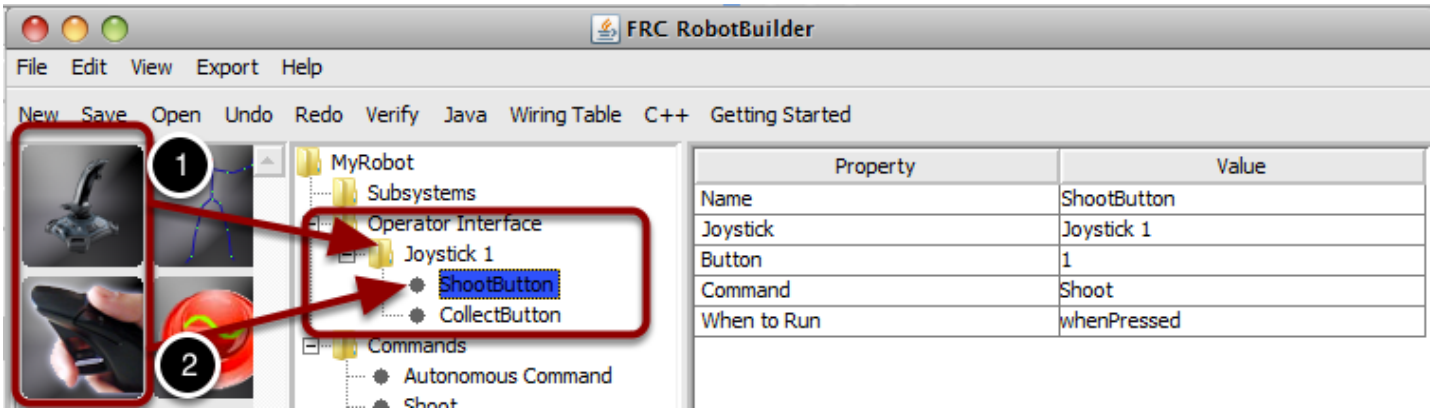


Each command can be run from the SmartDashboard. This is useful for testing commands before you add them to the operator interface or to a command group. As long as you leave the "Button on SmartDashboard" property checked, a button will be created on the SmartDashboard. When you press the start button, the command will run and you can check that it performs the desired action.

By creating buttons, each command can be tested individually. If all the commands work individually, you can be pretty sure that the robot will work as a whole.

For more information see: Adding a button to SmartDashboard to run a command

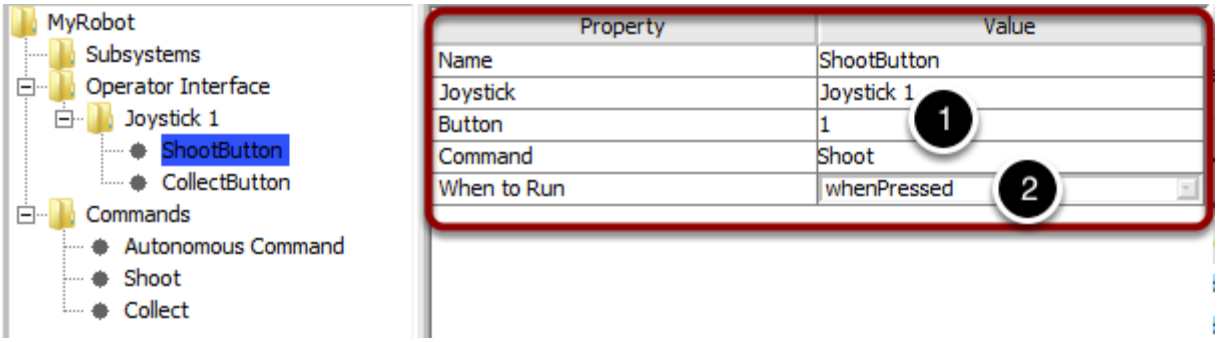
Add Operator Interface components



The operator interface consists of joysticks and devices connected through the extended I/O device (Cypress module). You can add operator interface components (joysticks, joystick buttons, and analog and digital inputs) to your program in RobotBuilder. It will automatically generate code that will initialize all of the components and allow them to be connected to commands.

The operator interface components are dragged from the palette to the "Operator Interface" folder in the RobotBuilder program. First (1) add Joysticks to the program then put buttons under the associated joysticks (2) and give them meaningful names, like ShootButton.

Connect the commands to the Operator Interface

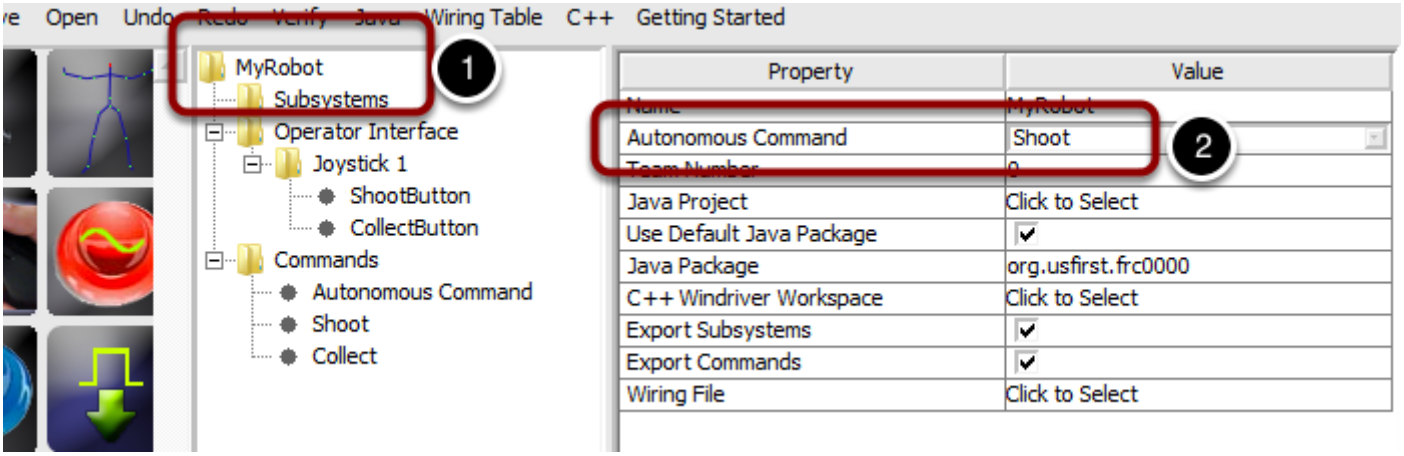


Commands can be associated with buttons so that when a button is pressed the command is scheduled. This should, for the most part, handle most of the tele-operated part of your robot program.

This is simply done by (1) adding the command to the JoystickButton object in the RobotBuilder program, then (2) setting the condition in which the command is scheduled.

For more information see: Connecting the operator interface to a command

Develop one or more Autonomous commands

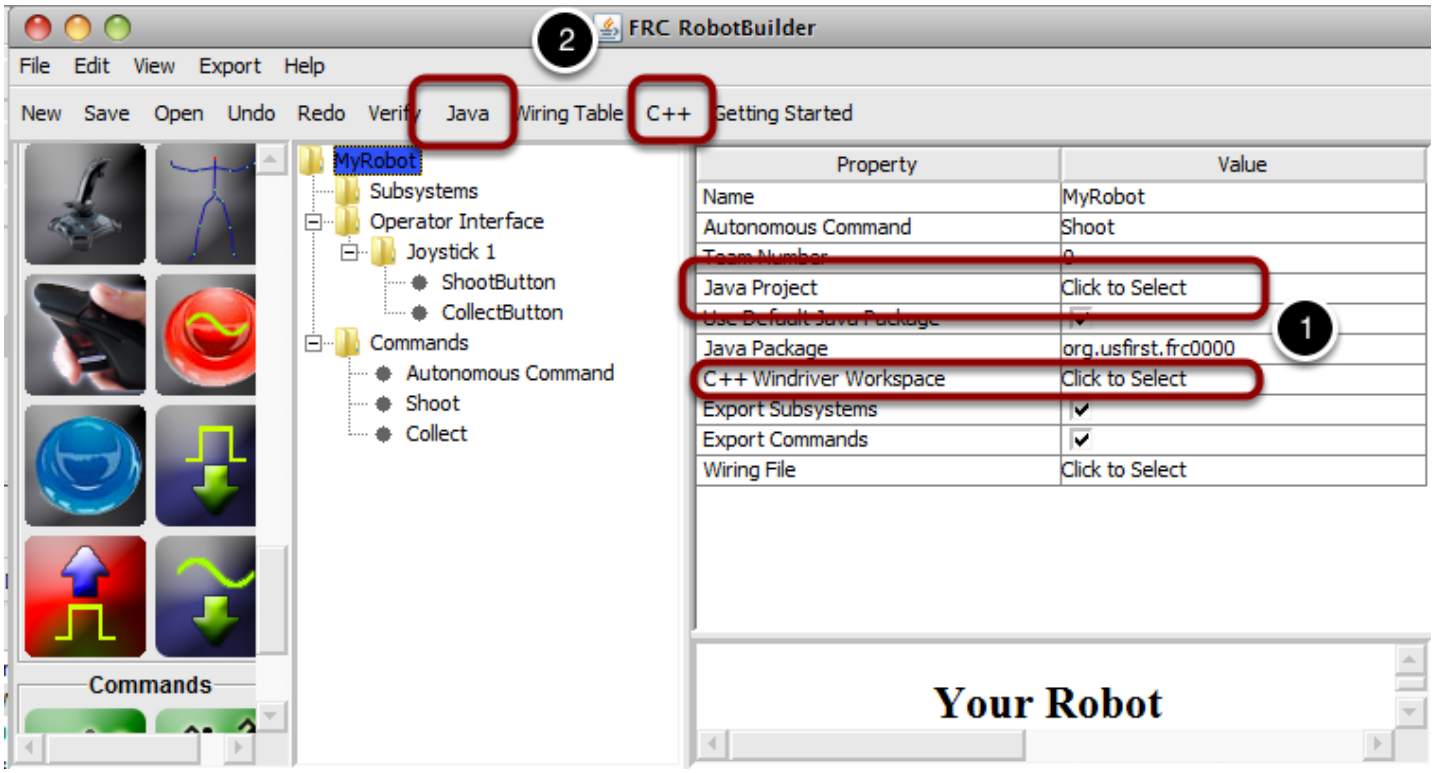


Commands make it simple to develop autonomous programs. You simply specify which command should run when the robot enters the autonomous period and it will automatically be scheduled. If you have tested commands as discussed above, this should simply be a matter of choosing which command should run.

Select the robot at the root of the RobotBuilder project, then edit the Autonomous Command property to choose the command to run. It's that simple!

For more information see: Setting the default autonomous command

Generating code for the program

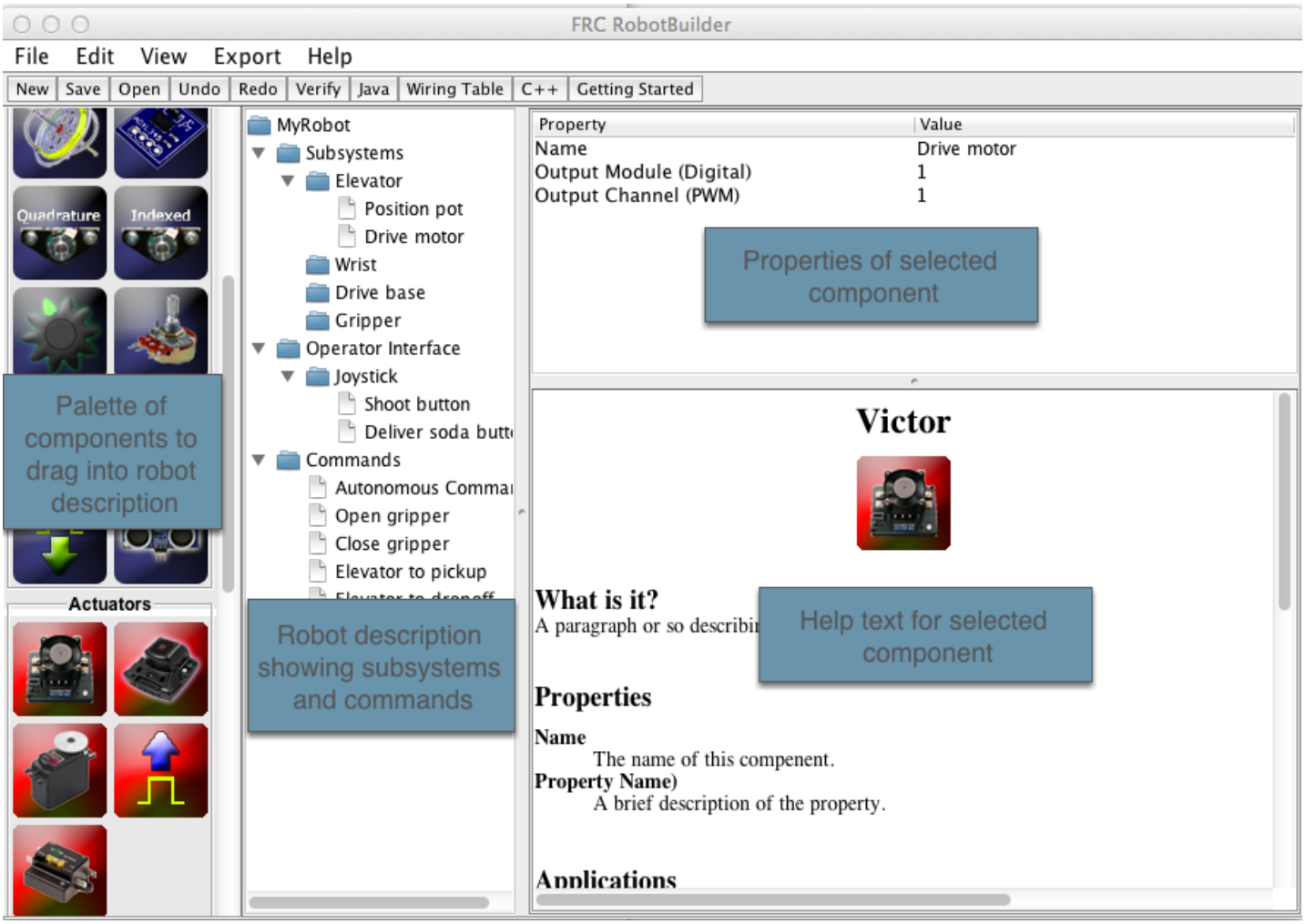


At any point in the process outlined above you can have RobotBuilder generate a C++ or Java program that will represent the project you have created. This is done by specifying the location of the project in the project properties (1), then clicking the appropriate toolbar button to generate the code.

For more information see: Generating Netbeans project files and Generating C++ code for a project.

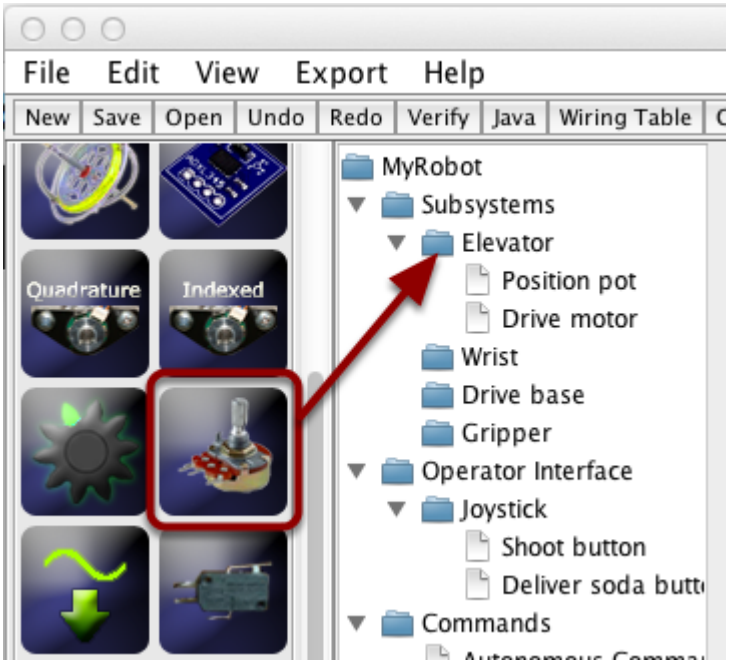
The RobotBuilder user interface

RobotBuilder User Interface



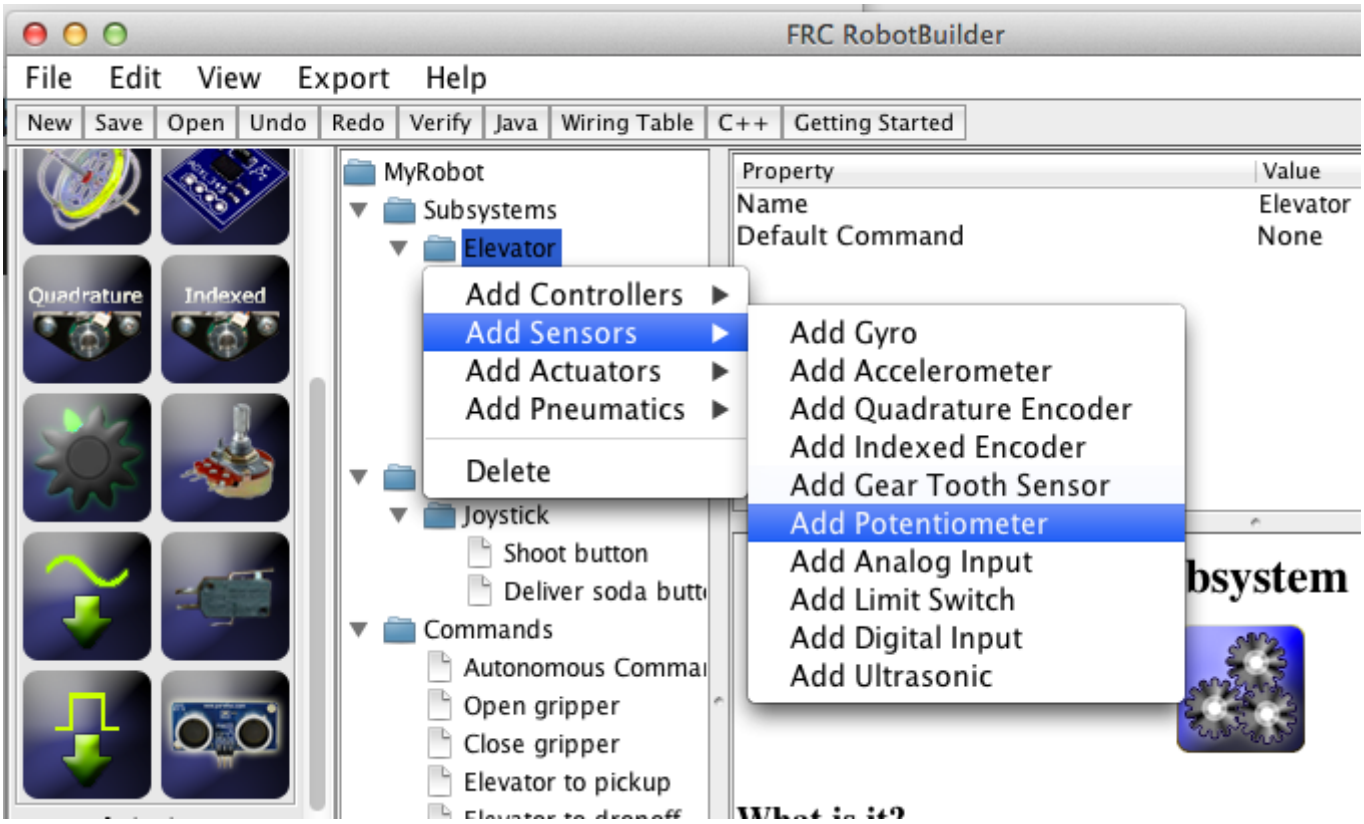
RobotBuilder has a user interface designed for rapid development of robot programs. Almost all operations are performed by drag and drop or selecting options from drop-down lists.

Dragging items from the palette to the robot description



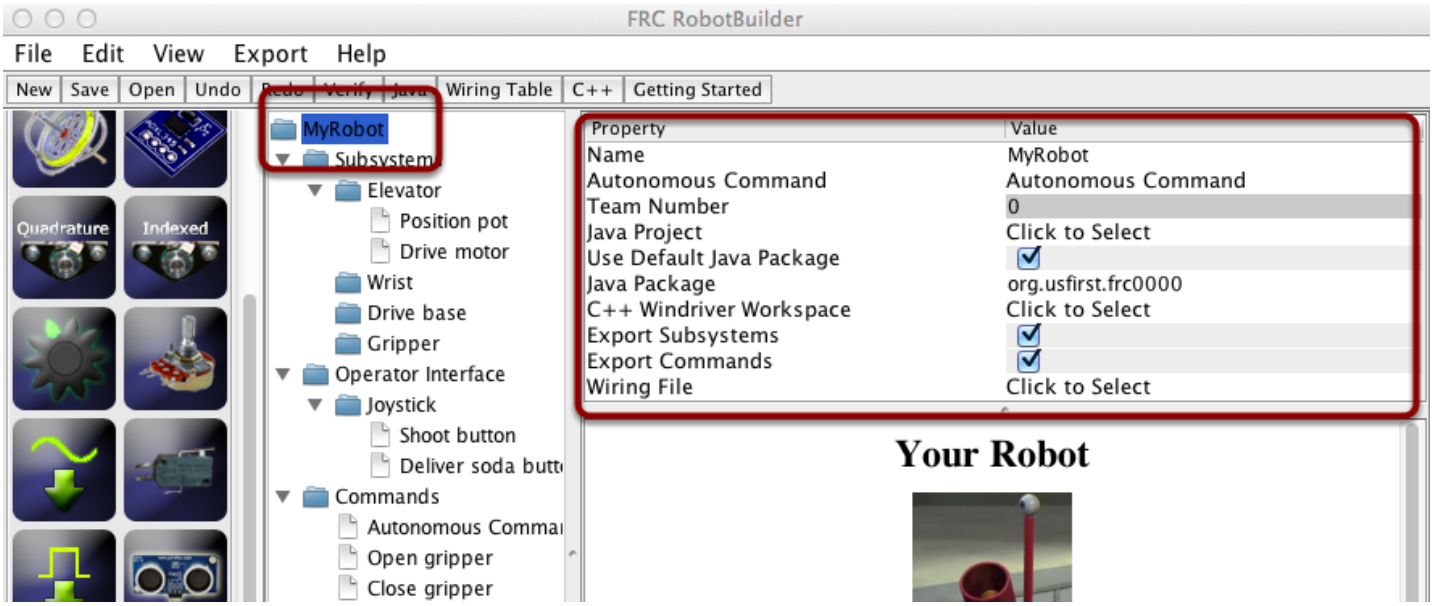
You can drag items from the palette to the robot description by starting the drag on the palette item and ending on the container where you would like the item to be located. In this example, dropping a potentiometer to the Elevator subsystem.

Adding components using the right-click context menu



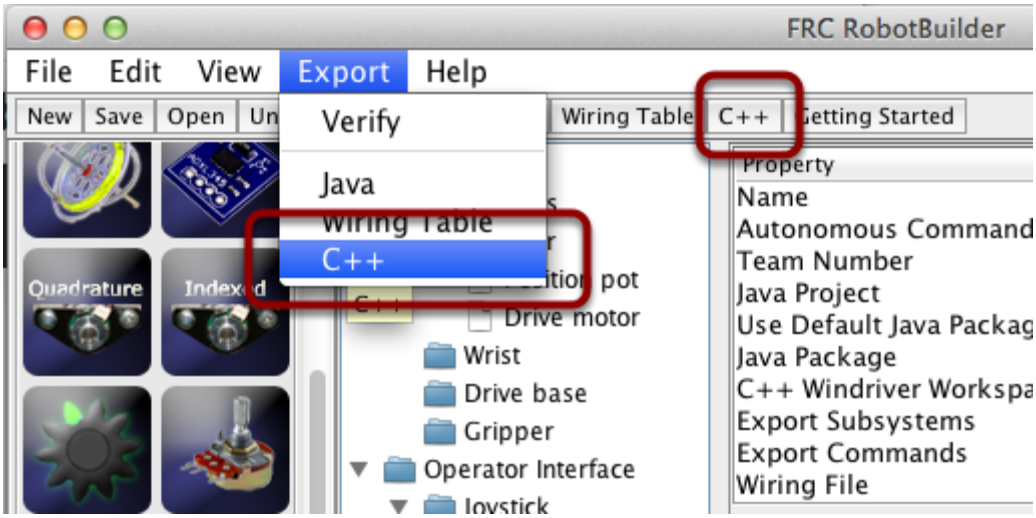
A shortcut method of adding items to the robot description is to right-click on the container object (Elevator) and select the item that should be added (Potentiometer). This is identical to using drag and drop but might be easier for some people.

Editing properties of robot desciption items



The properties for a selected item will apear in the properties viewer. The properties can be edited by selecting the value in the right hand column.

Using the menu system

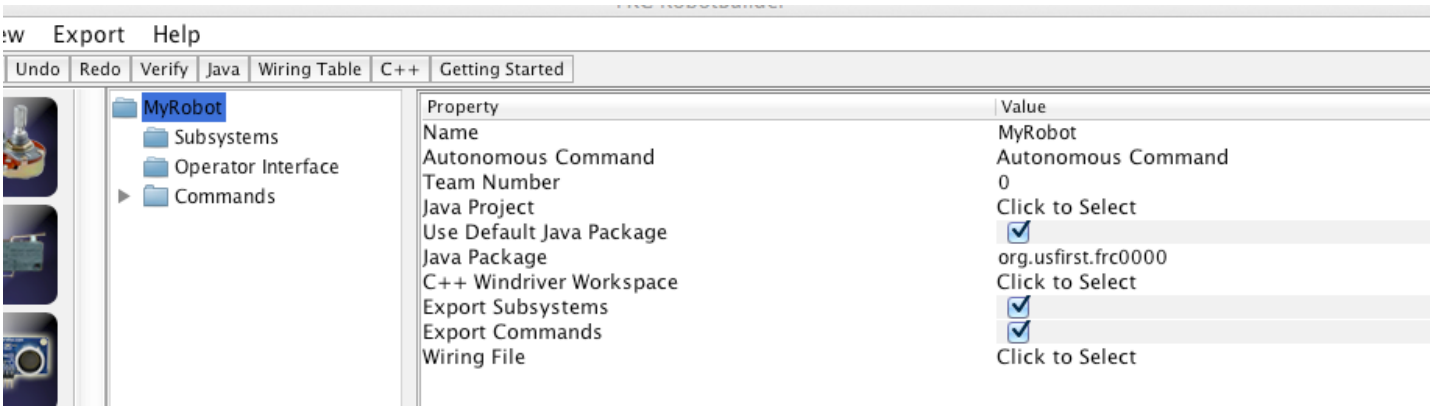


Operations for RobotBuilder can either be selected through the menu system or the equivalent item (if it is available) from the toolbar.

Setting up the robot project

The RobotBuilder program has some default properties that need to be set up so the generated program and other generated files work properly. This setup information is stored in the properties for robot description (the first line).

Robot project properties



The properties that describe the robot are:

Name - The name of the robot project that is created

Autnomous Command - the command that will run by default when the program is placed in autonomous mode

Team Number - the team number is used for creating the package names

Java Project - The folder that the java project is generated into when Export to Java is selected

Use Default Java Package - If checked RobotBuilder will use the default package (org.usfirst.frc####). Otherwise you can specify a custom package name to be used.

Java Package - The name of the generated Java package used when generating the project code

C++ Windriver Workspace - the location of the Windriver workspace directory where the project will be generated. Typically this is c:\Windriver\workspace

Export Subsystems - Checked if RobotBuilder should export the Subsystem classes from your project

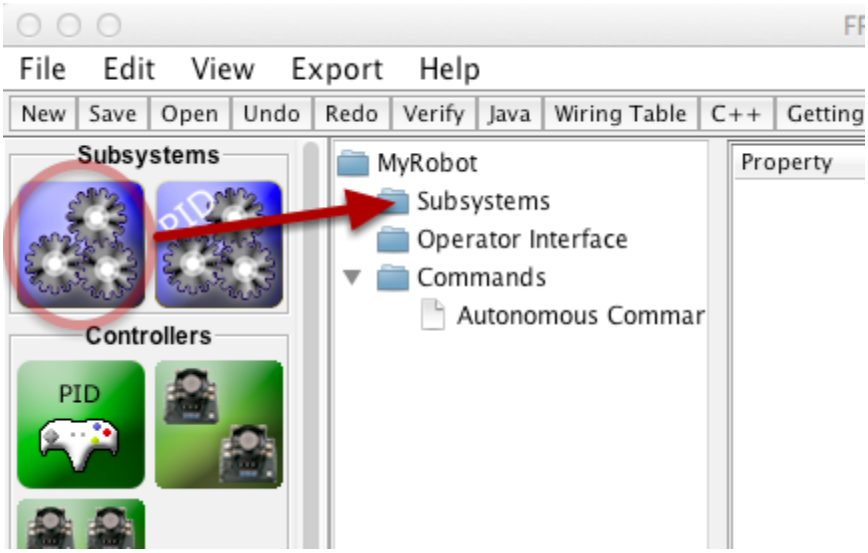
Export Commands - Checked if RobotBuilder should export the Command classes from your project

Wiring File - the location of the html file that contains the wiring diagram for your robot

Creating a subsystem

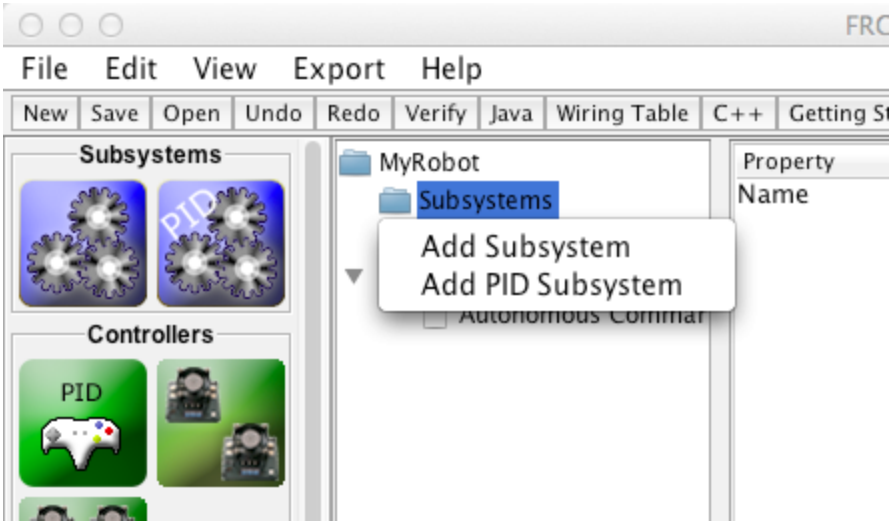
Subsystems are classes that encapsulate (or contain) all the data and code that make a subsystem on your robot operate. The first step in creating a robot program with the RobotBuilder is to identify and create all the subsystems on the robot. Examples of subsystems are grippers, ball collectors, the drive base, elevators, arms, etc. Each subsystem contains all the sensors and actuators that are used to make it work. For example, an elevator might have a Jaguar speed controller and a potentiometer to provide feedback of the robot position.

Creating a subsystem by dragging from the palette



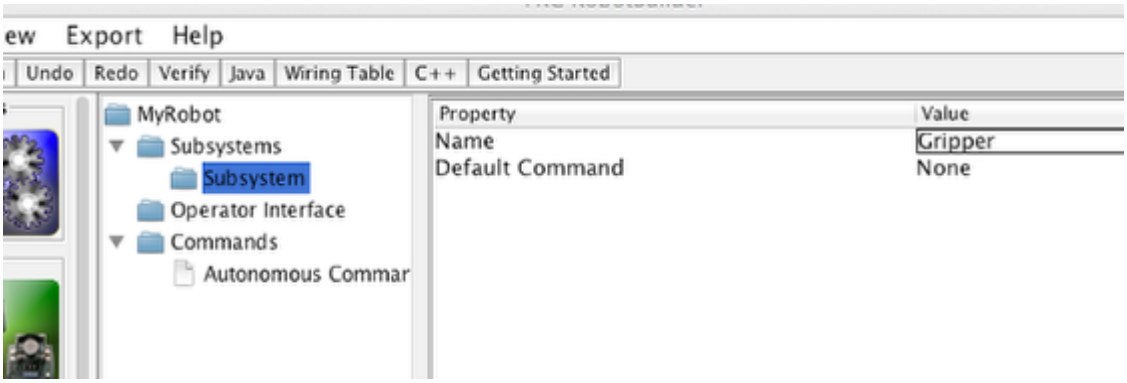
Drag the subsystem icon from the palette to the Subsystems folder in the robot description to create a subsystem class.

Creating a subsystem by using the context menu on the Subsystem folder



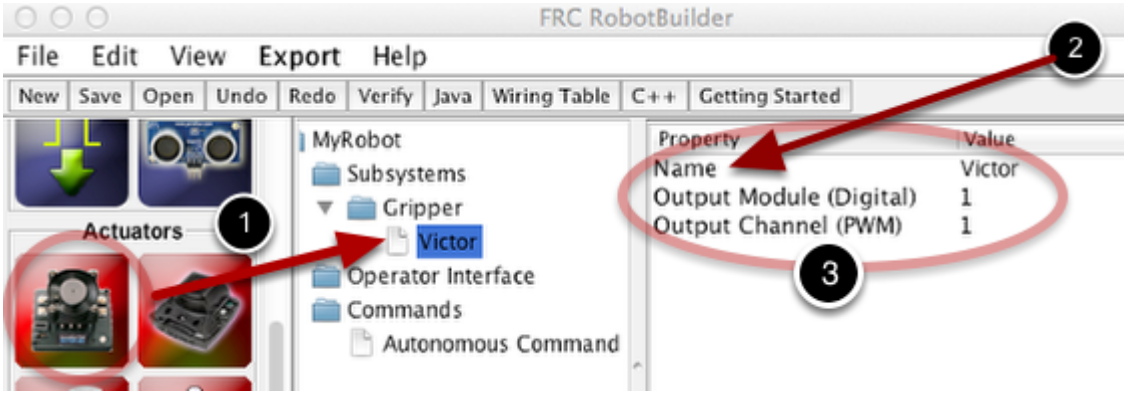
Right-click on the Subsystem folder in the robot description to add a subsystem to that folder.

Name the subsystem



After creating the subsystem by either dragging or using the context menu as described above, simply type the name you would like to give the subsystem. The name can be multiple words separated by spaces, RobotBuilder will concatenate the words to make a proper Java or C++ class name for you.

Drag actuators and sensors into the subsystem



There are two steps to adding components to a subsystem:

1. Drag actuators or sensors from the palette into the subsystem as required.
2. Give the actuator or sensor a meaningful name
3. Edit the properties such as module numbers and channel numbers for each item in the subsystem.

RobotBuilder will automatically use incrementing channel numbers for each module on the robot. If you haven't yet wired the robot you can just let RobotBuilder assign unique channel numbers for each sensor or actuator and wire the robot according to the generating wiring table.

This just creates the subsystem in RobotBuilder, and will subsequently generate skeleton code for the subsystem. To make it actually operate your robot please refer to: Writing the code for a subsystem in Java or Writing the code for a subsystem in C++.

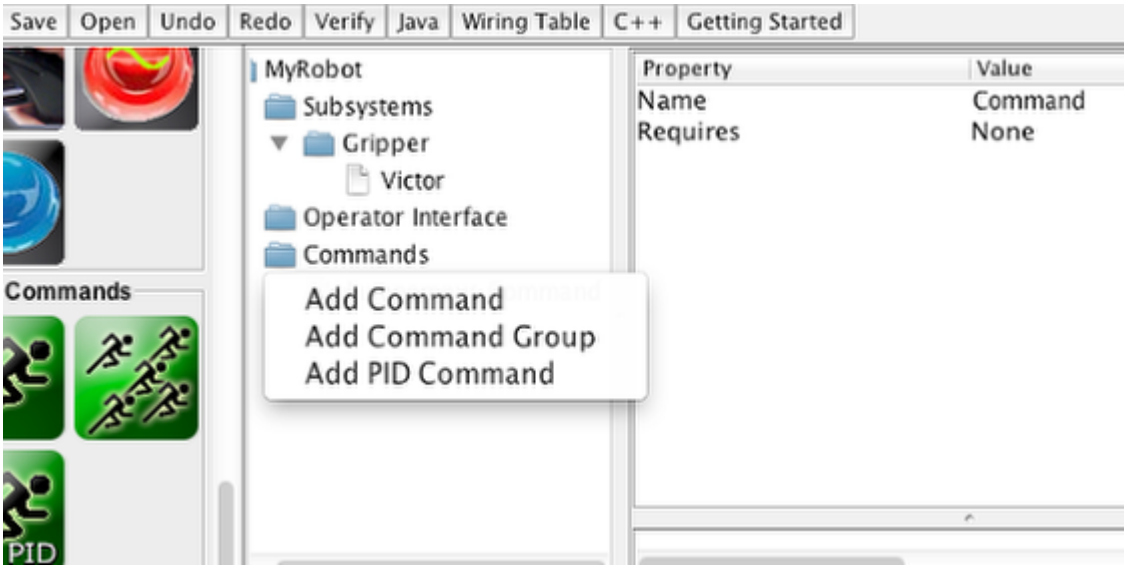
Creating a command

Commands are classes you create that provide behaviors or actions for your subsystems. The subsystem class should set the operation of the subsystem, like ElevatorUp to start the elevator moving up, or ElevatorToSetPoint to make the elevators PID setpoint. The commands initiate the subystem operation and keep track of when it is finished.

Drag a command to the robot description Commands folder

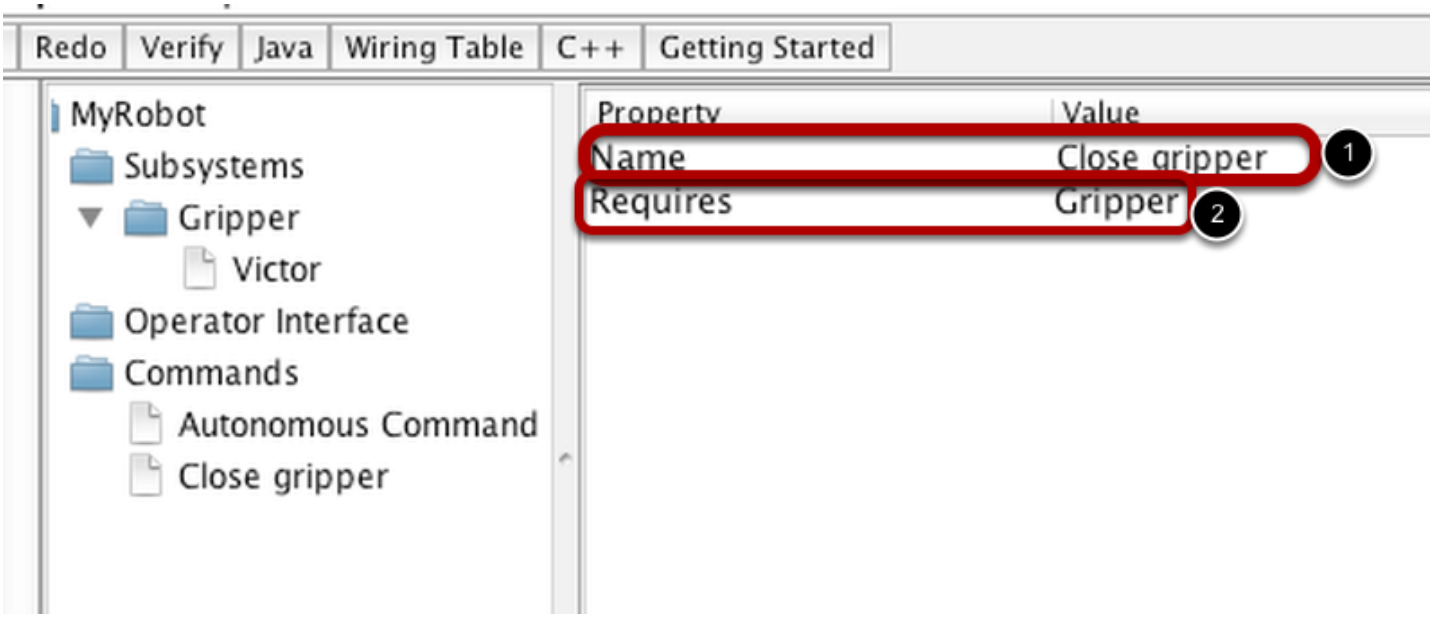
Simple commands can be dragged from the palette to the robot description. The command will be created under the Commands folder.

Creating commands using the context menu



You can also create commands using the right-click context menu on the Command folder in the robot description.

Give the command a name and set the required subsystem

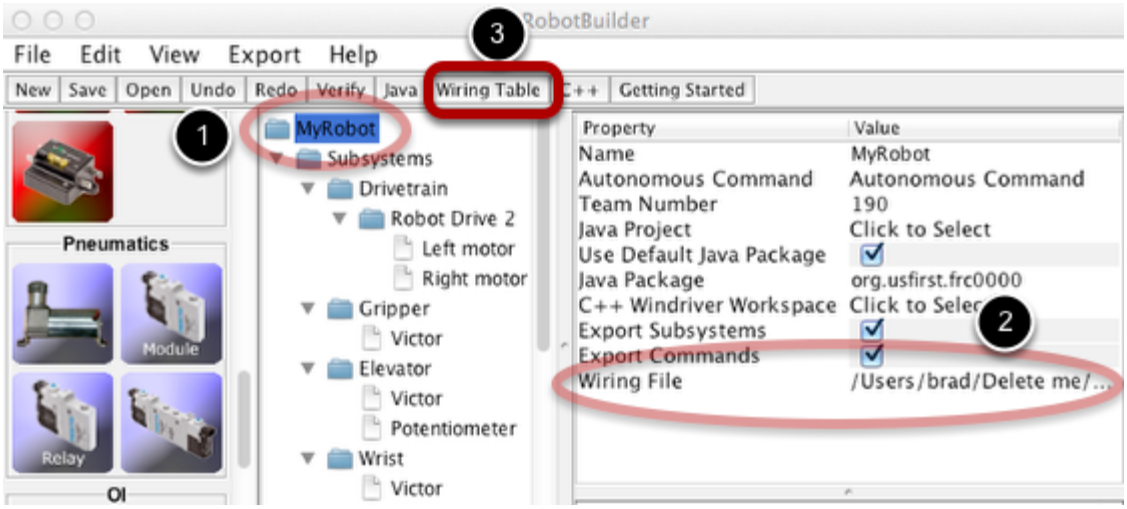


Name the command with something meaningful that describes what the command will do. Then set the subsystem that is used by this command. When this command is scheduled, it will automatically stop any command currently running that also requires this command. If a command to open the gripper is currently running (requiring the gripper subsystem) and the close gripper command is scheduled, it will immediately stop opening and start closing.

Producing a wiring diagram for your robot

Once all the subsystems are defined and filled with sensors and actuators you can produce a wiring diagram that will help the team wiring the robot to make sure that the electrical connections between the components and the cRIO robot controller are correct.

Filling in the wiring file location

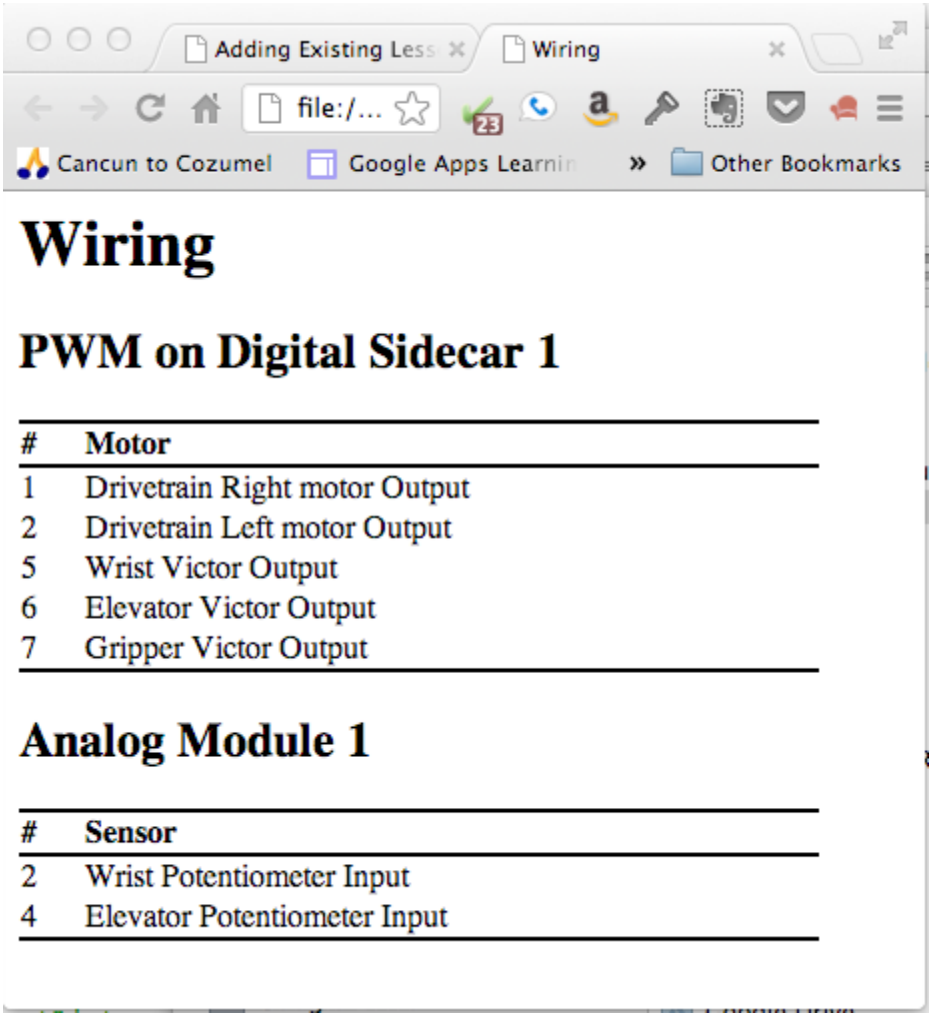


There are three steps to getting a wiring diagram for your robot.

1. Select the top of the robot description to view the robot program properties
2. Click on the wiring file name (initially not filled in) to set where the wiring file should be generated
3. Click on the Wiring Table toolbar item to create the wiring diagram

It is only necessary to do steps 1 and 2 the first time, the RobotBuilder will remember the location of the wiring file once it is set for the project.

View the wiring file your web browser



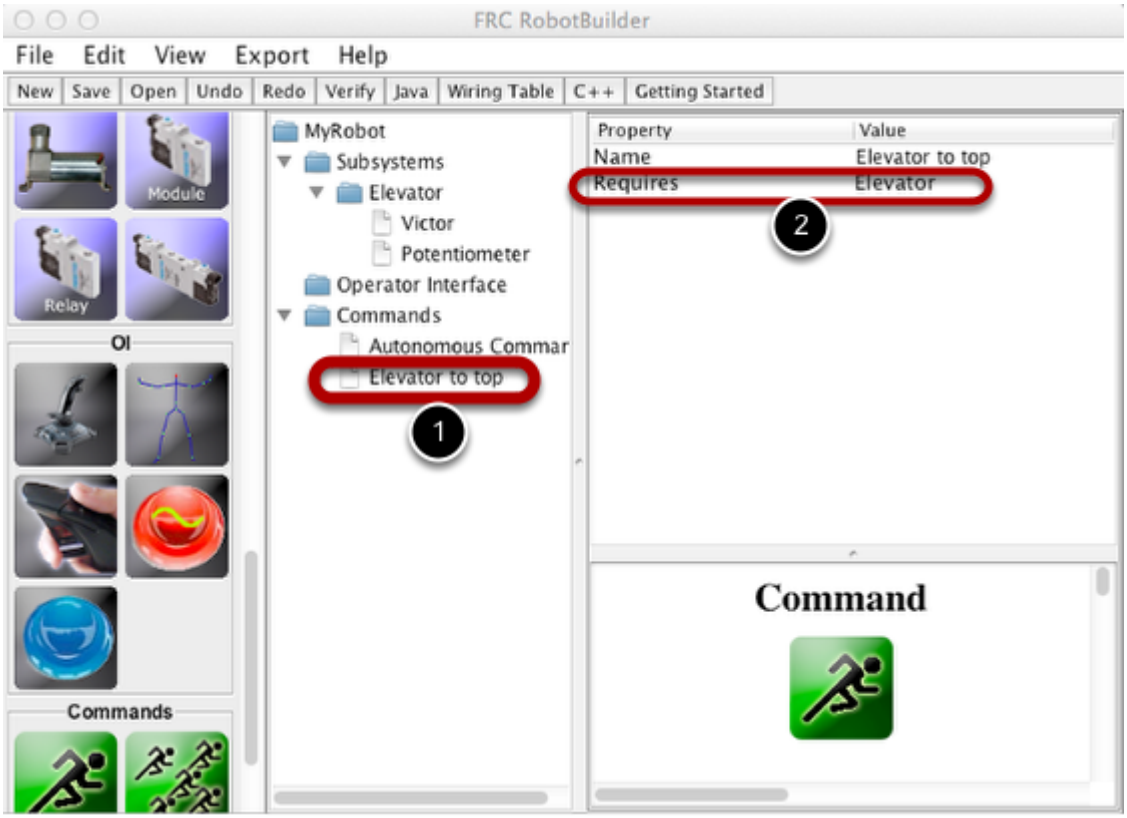
The wiring file may be opened with the system web browser and printed to hand off to the robot wiring team. You should keep the final version of the wiring diagram with the robot in case connections are pulled out during a competition so that it can be quickly rewired.

Connecting the operator interface to a command

Commands handle the behaviors for your robot. The command starts a subsystem to some operating mode like raising and elevator and continues running until it reaches some setpoint or timeout. The command then handles waiting for the subsystem to finish. That way commands can run in sequence to develop more complex behaviors.

RobotBuilder will also generate code to schedule a command to run whenever a button on your operator interface is pressed. You can also write code to run a command when a particular trigger condition has happened.

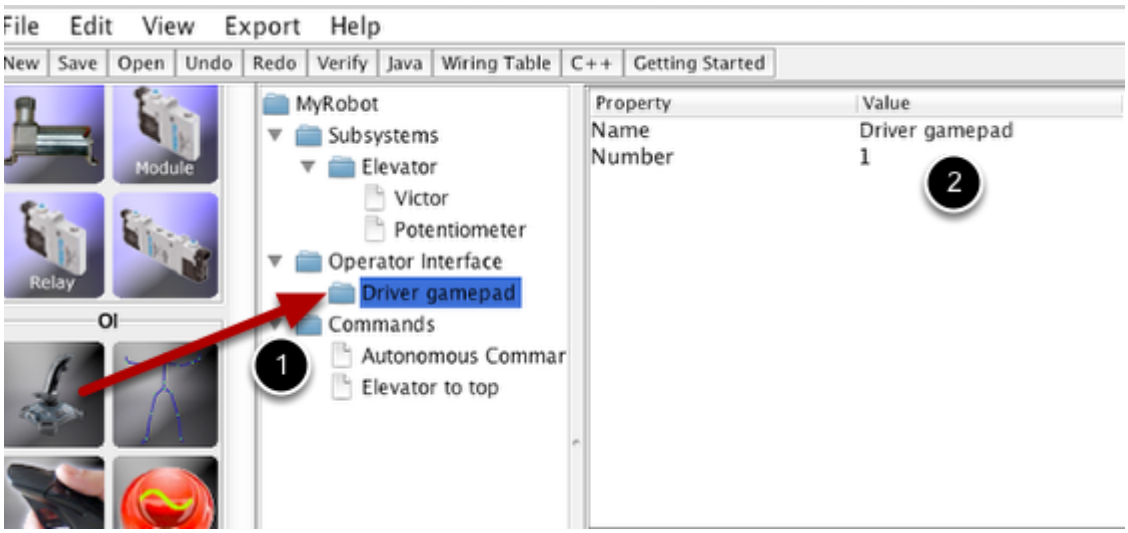
Set up a command to be run by the button press



In this example we want to schedule the "Elevator to top" command to run whenever joystick button 1 is pressed.

1. The command to run is called "Elevator to top" and its function is to move the elevator on the robot to the top position
2. Notice that the command requires the Elevator subsystem. This will ensure that this command starts running even if there was another operation happening at the same time that used the elevator. In this case the previous command would be interrupted.

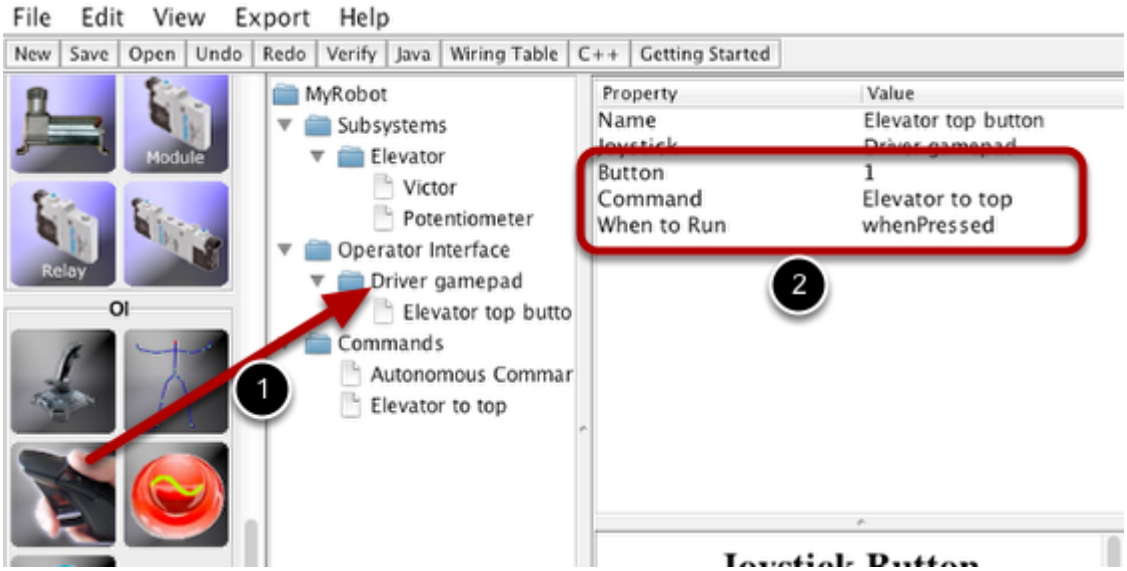
Adding the Joystick to the robot program



Add the joystick to the robot program

1. Drag the joystick to the Operator Interface folder in the robot program
2. Name the joystick so that it reflects the use of the joystick and set the USB port number

Add a button and link it to the Elevator to top command



Add the button that should be pressed to the program

1. Drag the joystick button to the Joystick (Driver gamepad) so that it's under the joystick
2. Set the properties for the button: the button number, the command to run when the button is pressed, and the "When to run" property to "whenPressed" to indicate that the command should run whenever the joystick button is pressed.

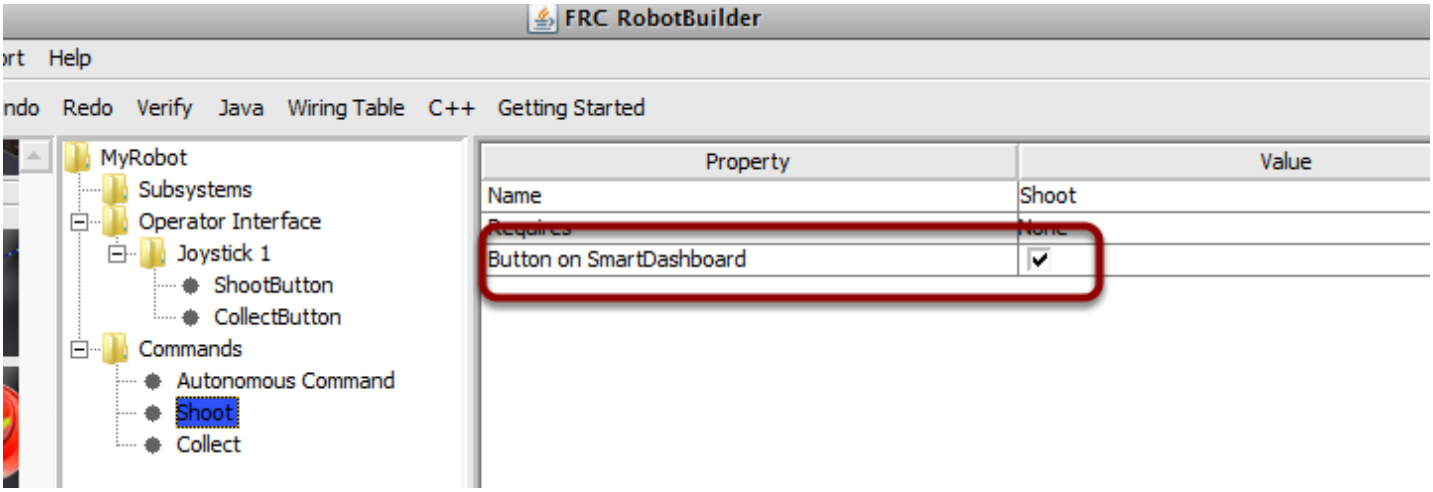
Note: **Joystick buttons must be dragged to (under) a Joystick**. You must have a joystick at the in the Operator Interface folder before adding buttons.

Adding a button to SmartDashboard to test a command

Commands are easily tested by adding a button to the SmartDashboard to trigger the command. In this way, no integration with the rest of the robot program is necessary and commands can easily be independently tested. This is the easiest way to verify commands since with a single line of code in your program, a button can be created on the SmartDashboard that will run the command. These buttons can then be left in place to verify subsystems and command operations in the future.

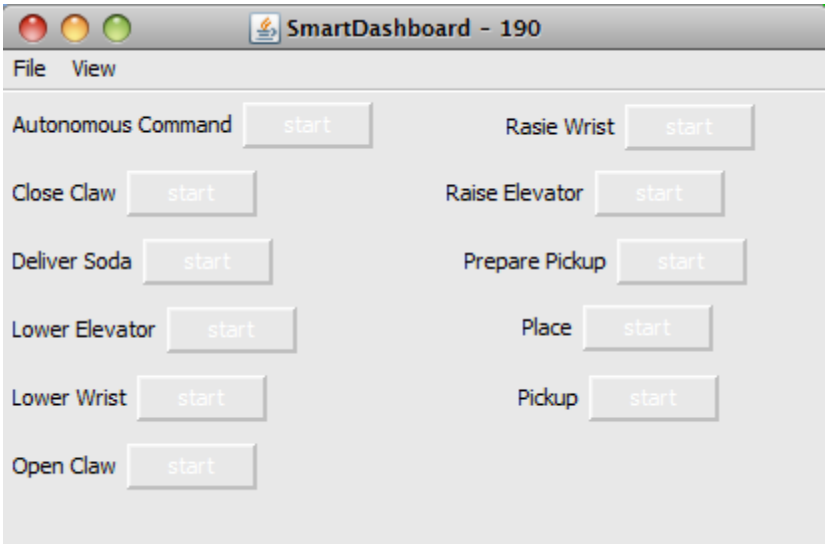
This has the added benefit of accommodating multiple programmers, each writing commands. As the code is checked into the main robot project, the commands can be individually tested.

Creating the button on the SmartDashboard



The button is created on the SmartDashboard by putting an instance of the command from the robot program to the dashboard. This is such a common operation that it has been added to RobotBuilder as a checkbox. When writing your commands, be sure that the box is checked, and buttons will be automatically generated for you.

How to operate the buttons on the SmartDashboard



The buttons will be generated automatically and will appear on the dashboard screen. You can put the SmartDashboard into edit mode, and the buttons can then be rearranged along with other values that are being generated. In this example there are a number of commands, each with an associated button for testing. The button is labeled "Start" and pressing it will run the command. As soon as it is pressed, the label changes to "Cancel" and pressing it will interrupt the command causing the Interrupted() method to be called.

Adding commands manually

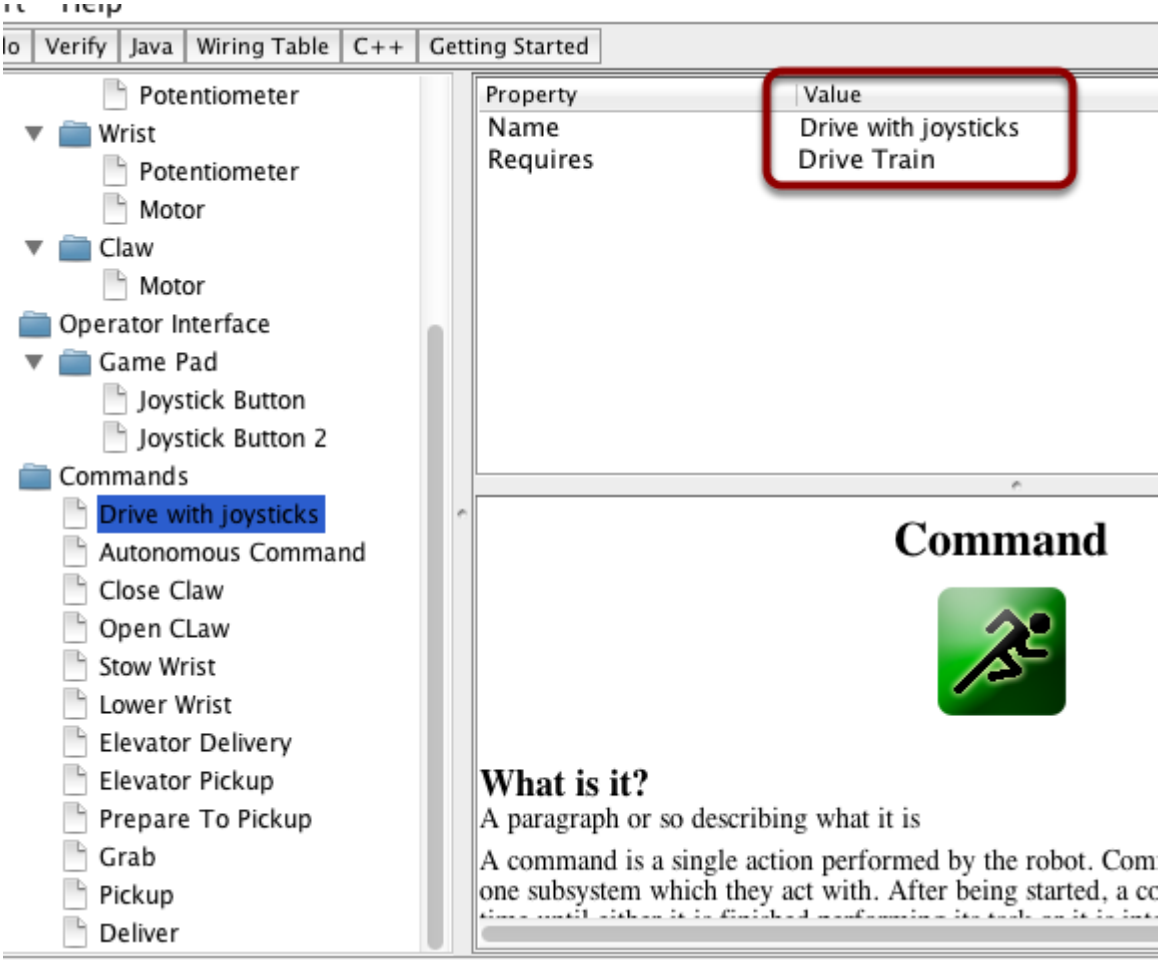
```
SmartDashboard::PutData("Autonomous Command", new AutonomousCommand());
SmartDashboard::PutData("Open Claw", new OpenClaw());
SmartDashboard::PutData("Close Claw", new CloseClaw());
SmartDashboard::PutData("Lower Wrist", new LowerWrist());
SmartDashboard::PutData("Rasie Wrist", new RasieWrist());
SmartDashboard::PutData("Lower Elevator", new LowerElevator());
SmartDashboard::PutData("Raise Elevator", new RaiseElevator());
SmartDashboard::PutData("Prepare Pickup", new PreparePickup());
SmartDashboard::PutData("Pickup", new Pickup());
SmartDashboard::PutData("Place", new Place());
SmartDashboard::PutData("Deliver Soda", new DeliverSoda());
```

Commands can be added to the SmartDashboard manually by writing the code yourself. This is done by passing instances of the command to the PutData method along with the name that should be associated with the button on the SmartDashboard. These instances are scheduled whenever the button is pressed. The result is exactly the same as RobotBuilder generated code, although clicking the checkbox in RobotBuilder is much easier than writing all the code by hand.

Setting the default command for a subsystem

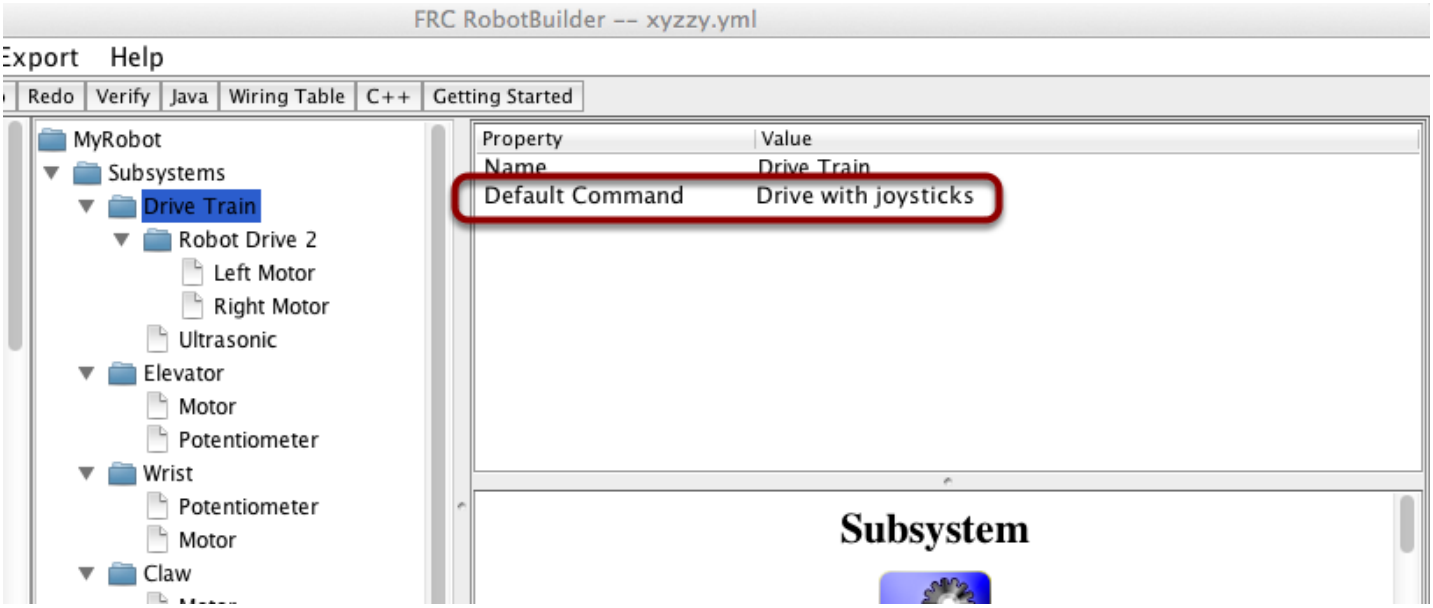
Once you have some commands created, you can set one of them to be the default command for a subsystem. Default commands run automatically when nothing else is running that requires that subsystem. A good example is having a drive train subsystem with a default command that reads joysticks. That way, whenever the robot program isn't running other commands to operate the drive train under program control, it will operate with joysticks.

Create the command that should be the default for a subsystem



Here a command is created called "Drive with joysticks" that would read the joystick values and set them in the Drive Train subsystem. This is what the Drive Train should be doing if it isn't being asked to do anything else.

Set the command as the default for the subsystem

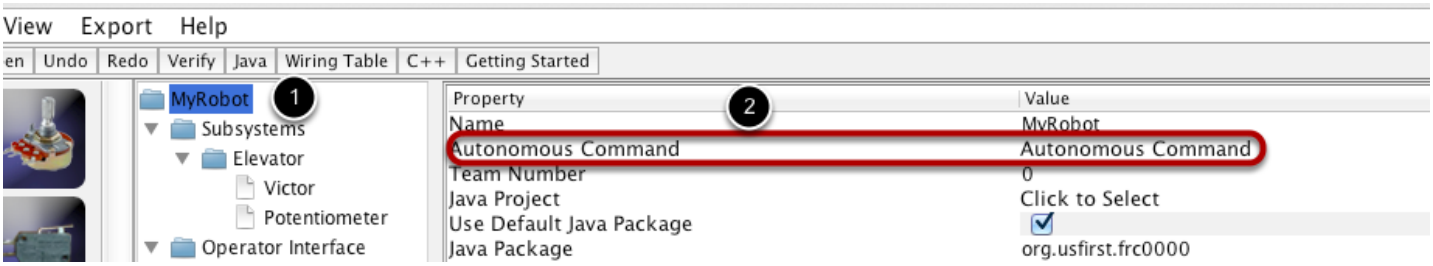


The "Drive with joysticks" command is set as the default command for the Drive Train subsystem.

You can also set the default Autonomous command, that is the command that runs when the robot enters the Autonomous state.

Setting the default autonomous command

Since a command is simply a one or more actions (behaviors) that the robot performs it makes sense to describe the autonomous operation of a robot as a command. While it could be a single command, it is more likely going to be a command group (a group of commands that happen together).



To designate a command that runs when the robot starts during the autonomous period of a competition:

1. Select the robot in the robot program description
2. Fill in the Autonomous command field with the command that should run when the robot is placed in autonomous mode. This is a drop-down field and will give you the option to select any command that has been defined.

When the robot is put into autonomous mode, the defined Autonomous command will be scheduled.

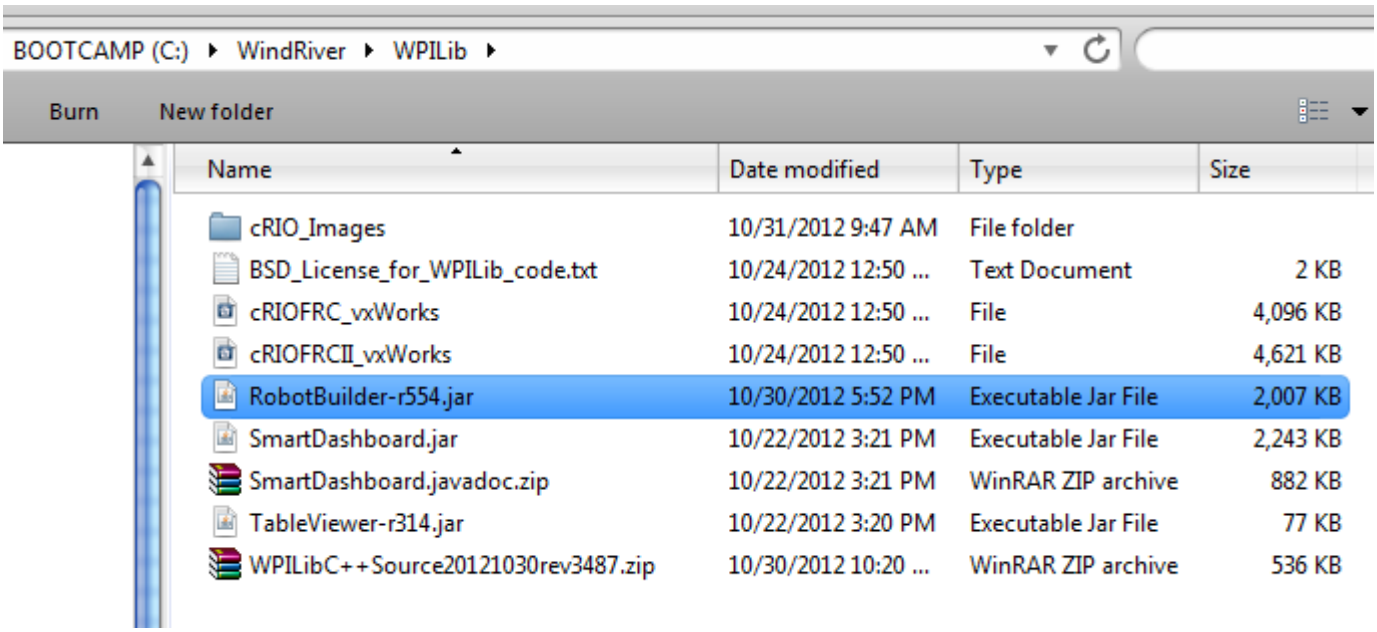
See: Creating a command and Setting the default command for a subsystem.

Debugging the actuators and sensors on your robot

Starting RobotBuilder

RobotBuilder is a Java program and as such should be able to run on any platform that is supported by Java. We have been running RobotBuilder on Mac OS X, Windows 7, and various versions of Linux successfully.

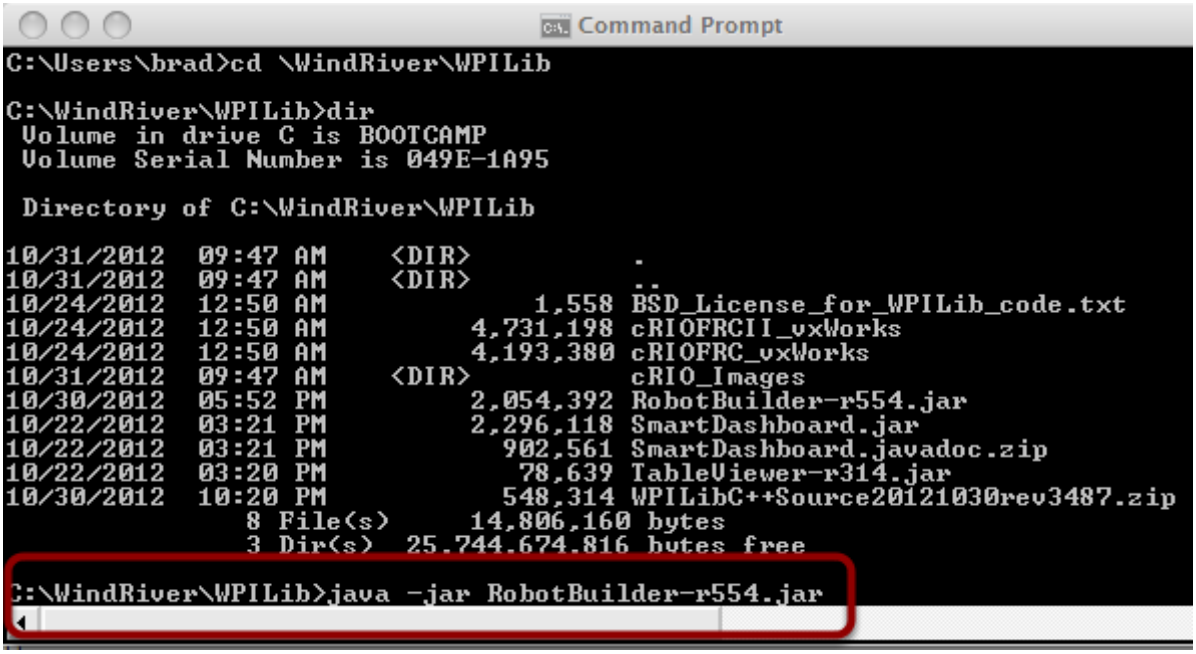
Locating the RobotBuilder .jar file



RobotBuilder is shipped as a .jar file (Java archive). In most cases you can simply double-click on the file in a graphical file browser for your operating system and it will start.

- For java users RobotBuilder is located in the sunspotfrcsdk/tools directory. This directory is in your user home directory, usually something like /Users/<username>/sunspotfrcsdk.
- For C++ users RobotBuilder is located in the C;\WindRiver\WPILib folder (shown in the example above).

Starting RobotBuilder from the command line



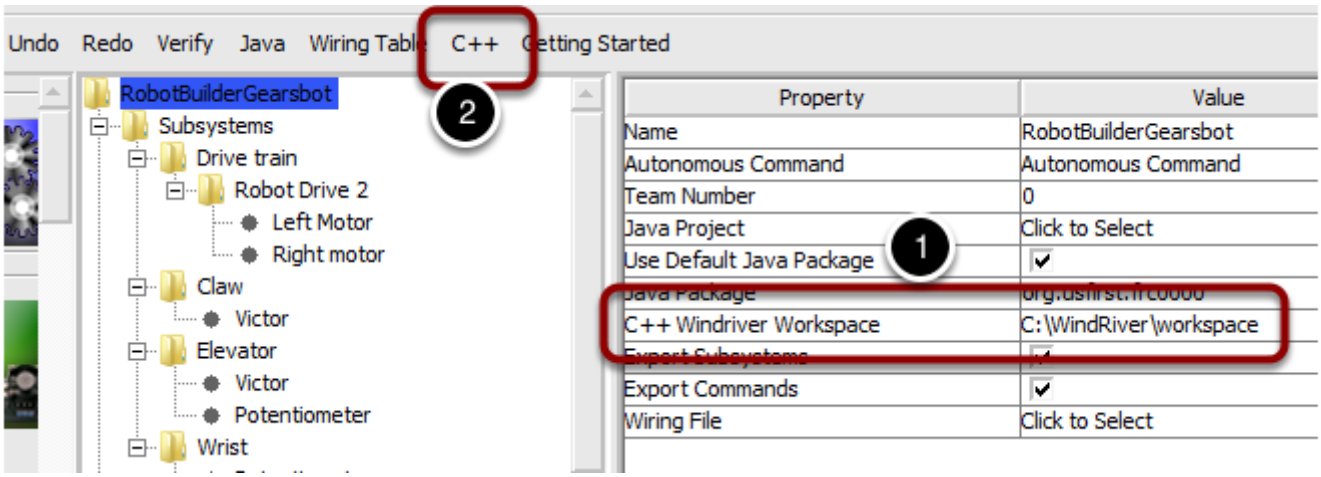
In some cases Java and your file browser might not be properly configured to run the .jar file by double-clicking. Simply type "java -jar RobotBuilder.jar" from the directory that contains RobotBuilder. Be sure to append the correct version number to the RobotBuilder name as shown in the example above.

Writing C++ code for your robot

Generating C++ code for a project

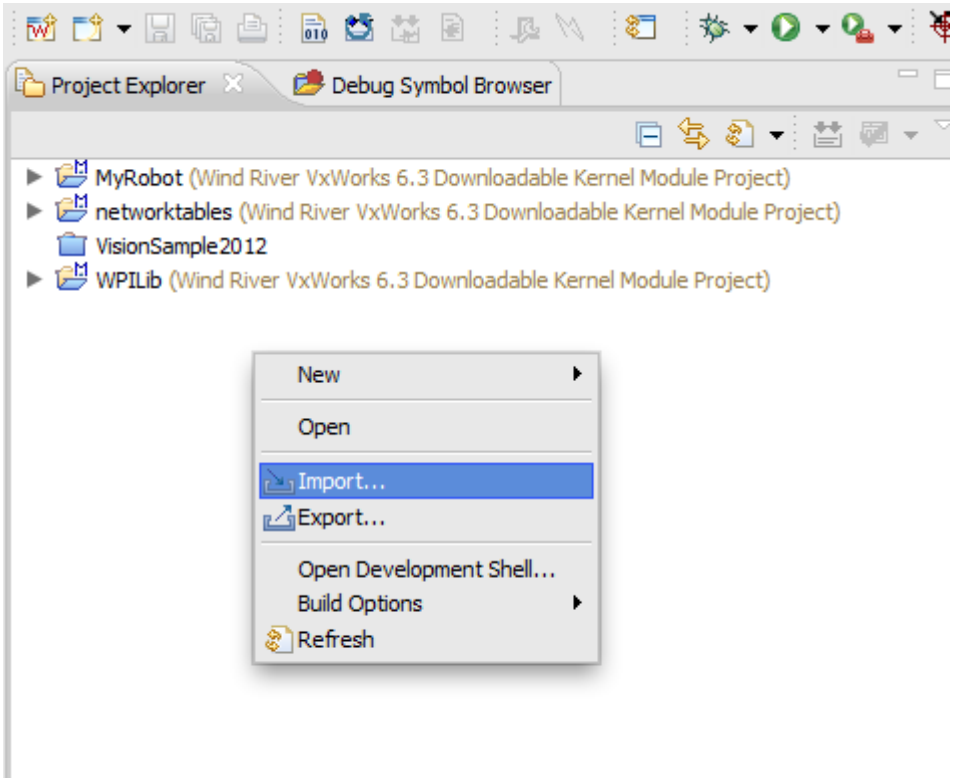
Adding code to create an actual working subsystem is very straightforward. For simple subsystems that don't use feedback it turns out to be extremely simple. In this section we will look at an example of a Claw subsystem that operates the motor for some amount of time to open or close a claw on the robot arm.

Generate the code for the project



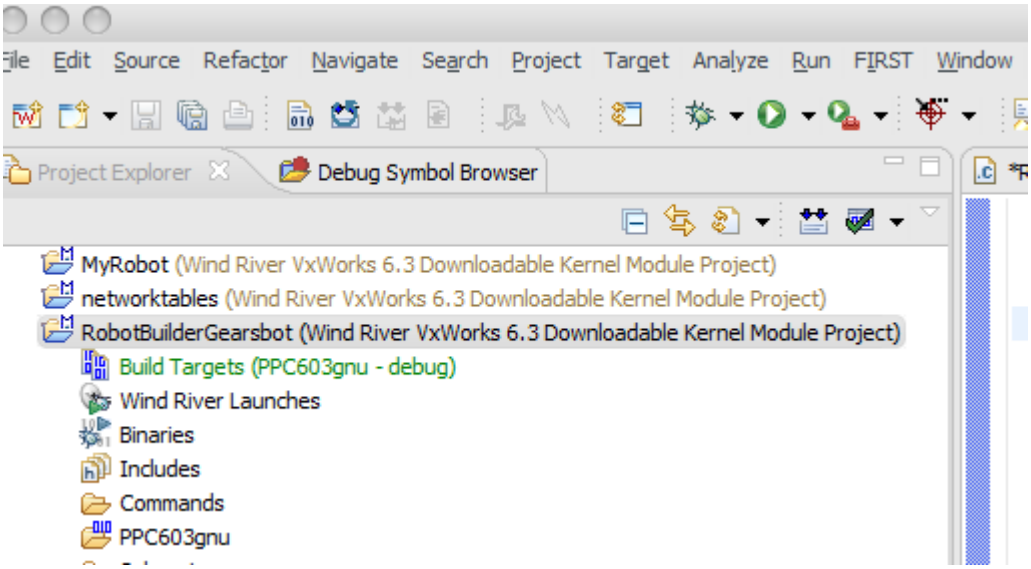
Verity that the C++ WindRiver workspace location is set properly (1) and generate code for the C++ robot project (2).

Import the project into WindRiver Workbench



Right-click in the Project Explorer and import your project from the location set in RobotBuilder. Ideally the project has been saved in your workspace.

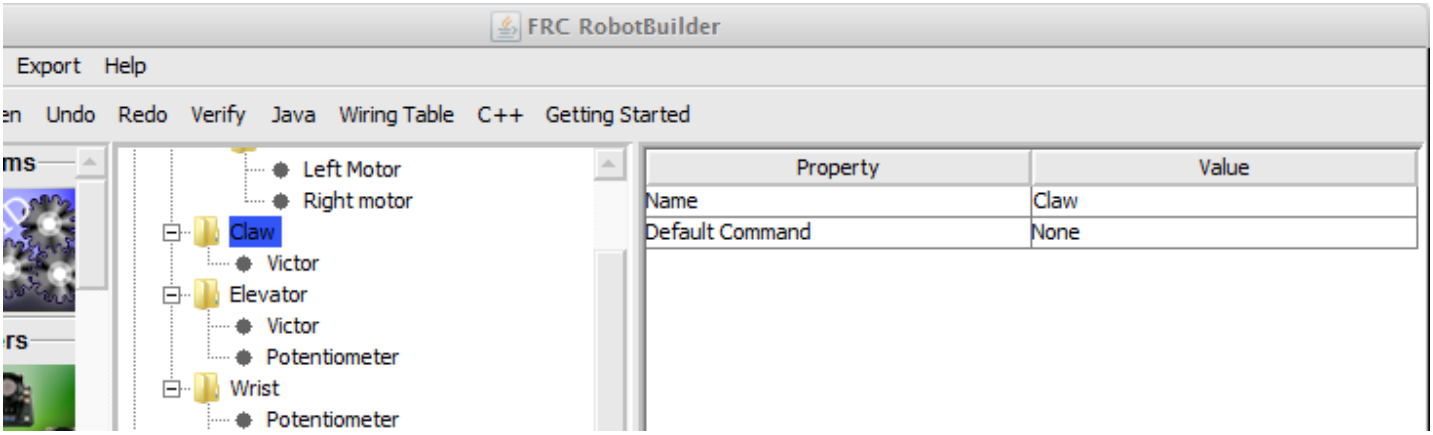
Viewing the imported project



You can view the project in the project explorer by double-clicking on the project name in the project explorer. From there you can see all the project files. Your subsystems are in the Subsystems folder and the commands are in the Commands folder.

Writing the C++ code for a subsystem

RobotBuilder representation of the Claw subsystem



The claw at the end of a robot arm is a subsystem operated by a single Victor speed controller. There are three things we want the claw to do, start opening, start closing, and stop moving. This is the responsibility of the subsystem. The timing for opening and closing will be handled by a command later in this tutorial.

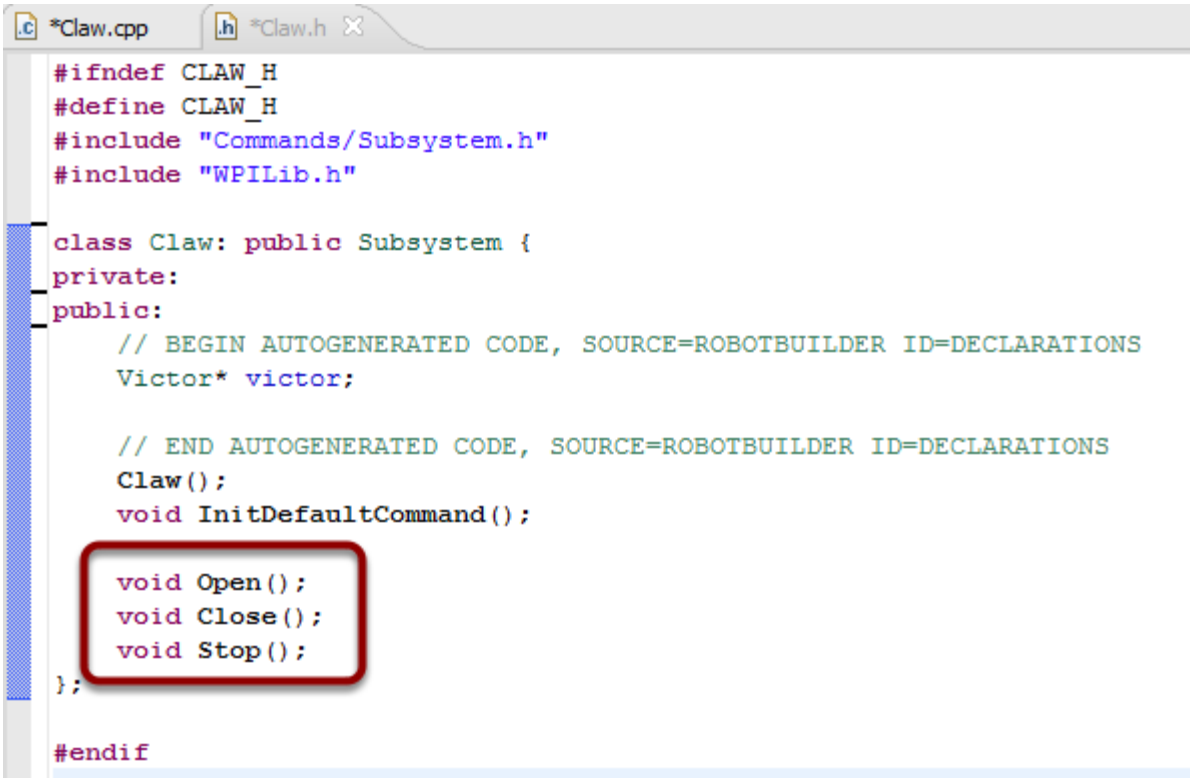
Adding capabilities to a simple subsystem

*Claw.cpp

```
#include "Claw.h"
#include "../Robotmap.h"

Claw::Claw() :
    Subsystem("Claw") {
    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    victor = RobotMap::CLAW_VICTOR;
    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
}

void Claw::InitDefaultCommand() {
    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
}

void Claw::Open() {
    victor->Set(1);
}

void Claw::Close() {
    victor->Set(-1);
}

void Claw::Stop() {
    victor->Set(0);
}
```

The subsystem generated by RobotBuilder has the code to create the Claw class that corresponds to the subsystem and the code to copy the reference to the generated Victor object into the class to make it easily referenced. To add the capabilities to the subsystem to actually operate the motor add 3 methods, Open(), Close(), and Stop() to start the motor moving in the open or close direction or stop the motor.

Adding the method declarations to the generated header file - Claw.h

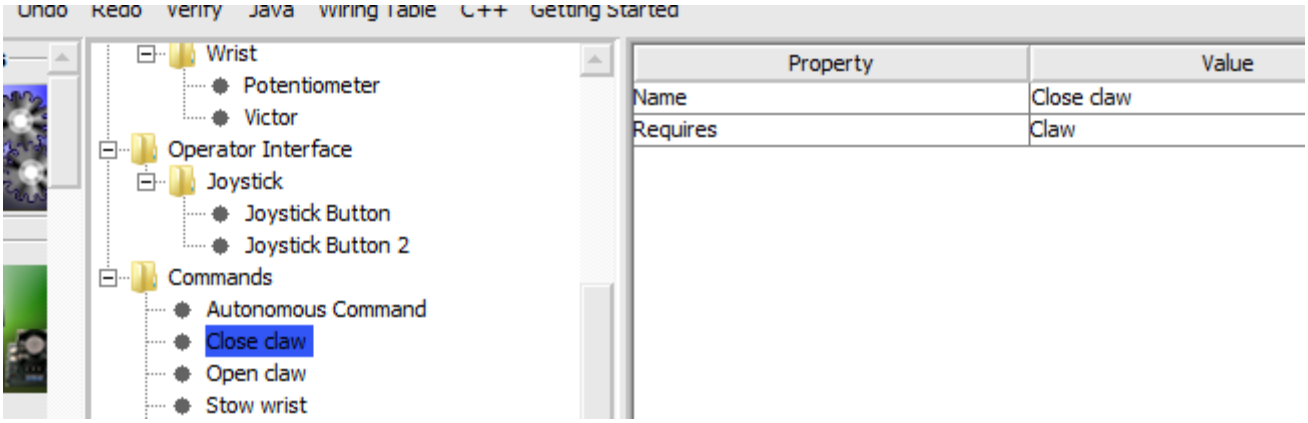


In addition to adding the methods to the class implementation file, Claw.cpp, the declarations for the methods need to be added to the header file, Claw.h. Those declarations that must be added are shown here.

To add the behavior to the claw subsystem to operate it to handle opening and closing you need to define commands.

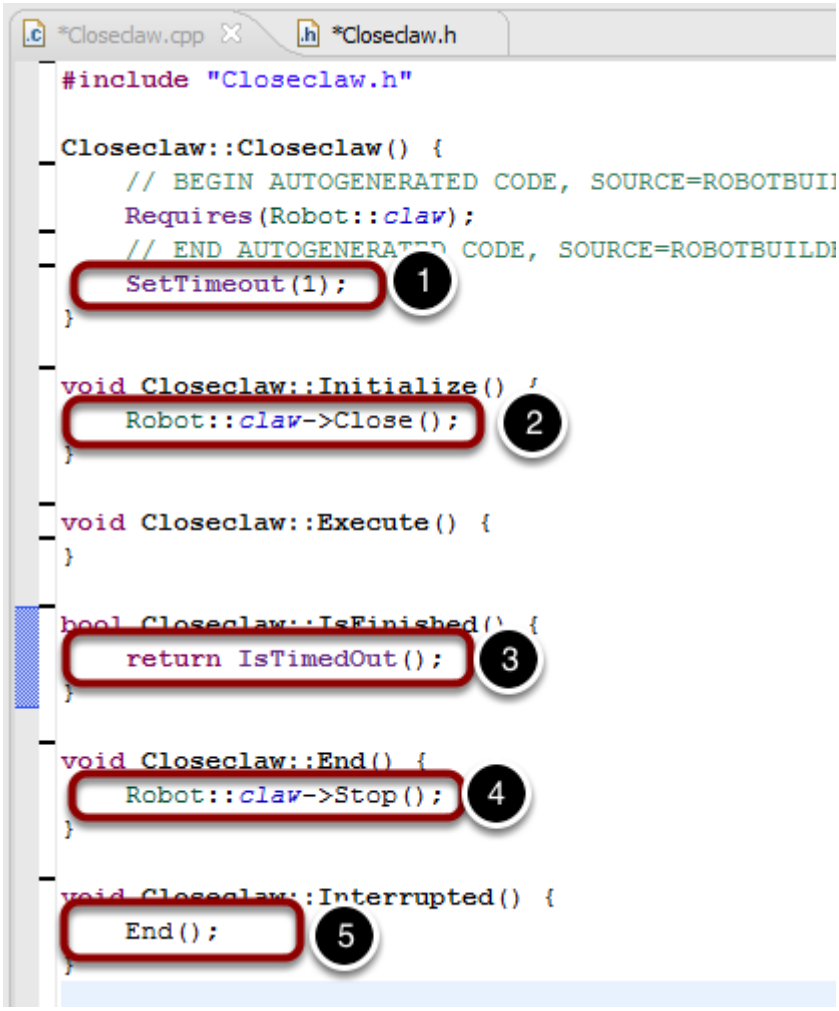
Writing the code for a command in C++

Close claw command in RobotBuilder



This is the definition of the Close claw command in RobotBuilder. Notice that it requires the Claw subsystem. This is explained in the next step.

Generated Closeclaw class generated in Closeclaw.cpp



RobotBuilder will generate the class files (header and implementation) for the Closeclaw command. The command represents the behavior of the claw, that is the operation over time. To operate this very simple claw mechanism the motor needs to operate for 1 second in the close direction. The Claw subsystem has methods to start the motor running in the right direction and to stop it. The commands responsibility is to run the motor for the correct time. The lines of code that are shown in the boxes are added to add this behavior.

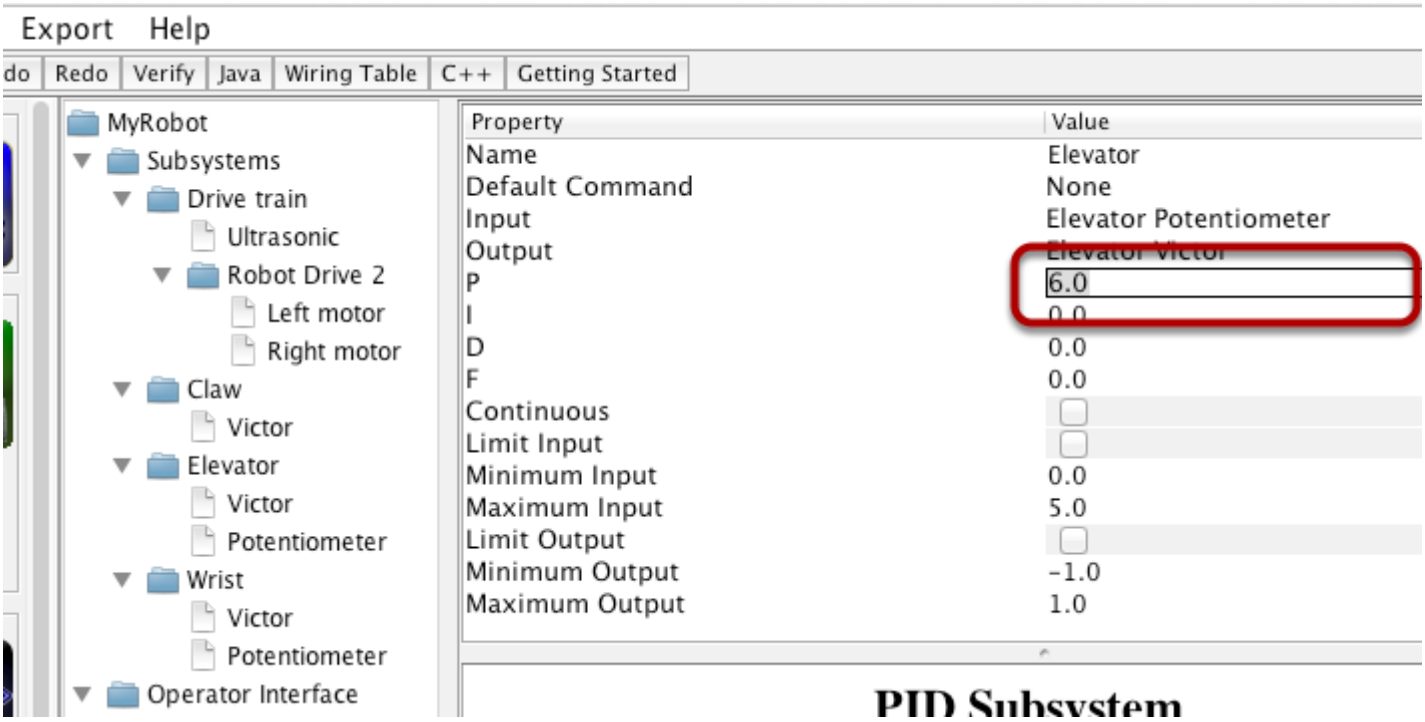
1. Set the one second timeout for this command. When the command is scheduled, a timer will be started so the one second operation can easily be tested.
2. Start the claw motor moving in the closing direction by calling the Close method that was added to the Claw subsystem.
3. This command is finished when the timer runs out which happens after one second has passed. This is the timer set in step 1.
4. The End() method is called when the command is finished and is a place to clean up. In this case, the motor is stopped since the time has run out.
5. The Interrupted() method is called is this command is interrupted if another command that also requires the Claw subsystem is scheduled before this finishes. For example, if the Closeclaw command was scheduled and running, then the Openclaw command was

scheduled it would interrupt the Openclaw command, call its Interrupted() method, and the motor would stop.

Writing the code for a PIDSubsystem in C++

PIDSubsystems use feedback to control the actuator and drive it to a particular position. In this example we use an elevator with a 10-turn potentiometer connected to it to give feedback on the height. The skeleton of the PIDSubsystem is generated by the RobotBuilder and we have to fill in the rest of the code to provide the potentiometer value and drive the motor with the output of the imbedded PIDController.

Setting the PID constants



Make sure the Elevator PID subsystem has been created in the RobotBuiler. In the case of our elevator we use a propertional constant of 6.0 and 0 for the I and D terms. Once it's all set, generate C++ code for the project using the Export menu or the C++ toolbar menu.

Add constants for the Elevator preset positions

Closeclaw.cpp | Closeclaw.h | Elevator.cpp | Wrist.cpp | Elevator.h

```
#ifndef ELEVATOR_H
#define ELEVATOR_H

#include "Commands/PIDSubsystem.h"
#include "WPILib.h"

class Elevator: public PIDSubsystem {
 public:
    static const double BOTTOM = 4.6;
    static const double STOW = 1.65;
    static const double TABLE_HEIGHT = 1.58;

    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    AnalogChannel* potentiometer;
    Victor* victor;
    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    Elevator();
    double ReturnPIDInput();
    void UsePIDOutput(double output);
    void InitDefaultCommand();
};

#endif
```

Elevator constants define potentiometer voltages that correspond to fixed positions on the elevator. These values can be determined using the print statements, the LiveWindow or SmartDashboard.

Initialize the elevator position in the Elevator constructor

Closeclaw.cpp | Closeclaw.h | Elevator.cpp | Wrist.cpp | Elevator.h

```
#include "Elevator.h"
#include "../Robotmap.h"
#include "SmartDashboard/SmartDashboard.h"
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=PID
Elevator::Elevator() : PIDSubsystem("Elevator", 1.0, 0.0, 0.0) {
        GetPIDController()->SetContinuous(false);

    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=PID
    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    potentiometer = RobotMap::ELEVATOR_POTENTIOMETER;
    victor = RobotMap::ELEVATOR_VICTOR;

    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    SetSetpoint(STOW);
    Enable();
}
```

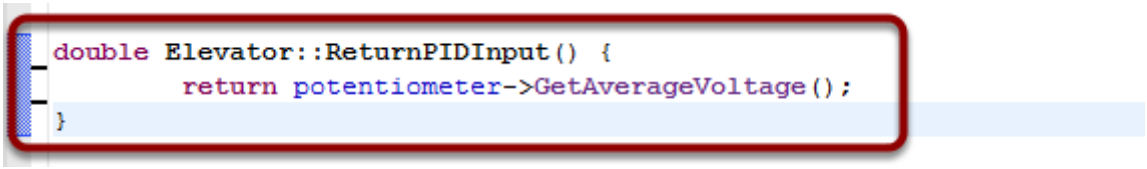
Set the elevator initial position so when the robot starts up it will move to that position. This will get the robot to a known starting point. Then enable the PIDController that is part of the PIDSubsystem. The elevator won't actually move until the robot itself is enabled because the motor outputs are initially off, but when the robot is enabled, the PID controller will already be running and the elevator will move to the "STOW" starting position.

The autogenerated code to return the PID input values

```
double Elevator::ReturnPIDInput() {
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=SOURCE
        return potentiometer->PIDGet();
    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=SOURCE
}
```

If you look at the RobotBuilder generated code for ReturnPIDInput() you can see that there is a //BEGIN and //END comment delimiting the return statement. In between //BEGIN and //END comments is where RobotBuilder will rewrite code on subsequent exports. So in general you should not change any code in that block. But, the function returns the value in raw analog units (0-1023). The setpoints are in units of Volts, so this won't work.

Set the ReturnPIDInput method to return voltage



```
double Elevator::ReturnPIDInput() {
        return potentiometer->GetAverageVoltage();
}
```

The function must be changed to return voltage. If we change the code inside the //BEGIN and //END block, it will just be overwritten next time RobotBuilder exports the file. **The solution is to remove the //BEGIN and //END comments, then make the change. This will prevent RobotBuilder from changing the code back again later.**

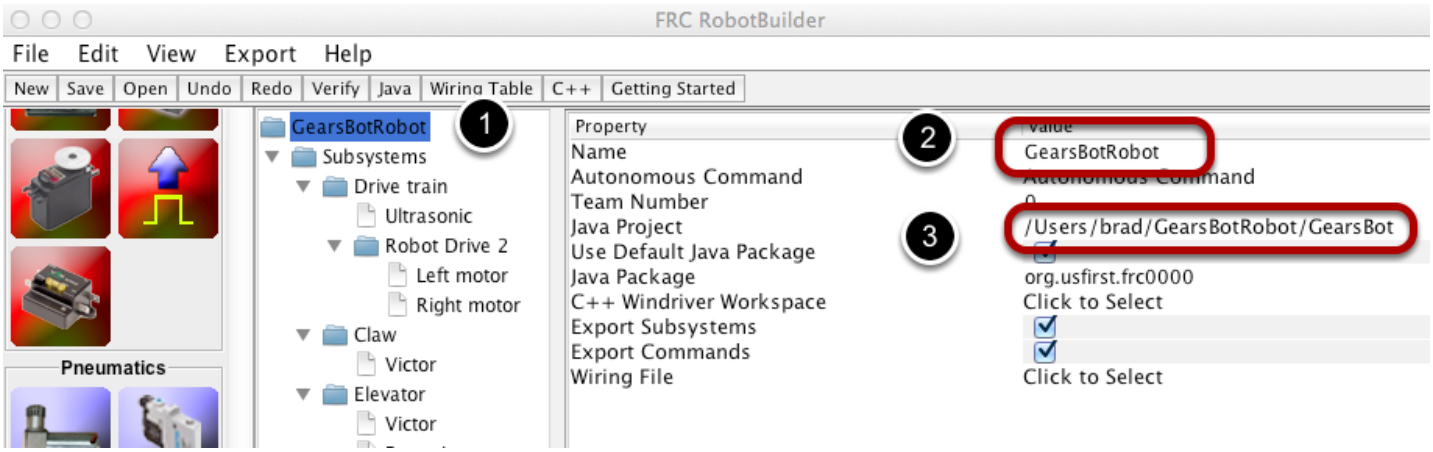
That's all that is required to create the Elevator PIDSubsystem in C++. To operate it with commands to actually control the motion see: Operating a PIDSubsystem from a command in C++.

Writing Java code for your robot

Generating Netbeans project files

After you start getting a significant part of your robot designed in RobotBuilder you can generate a Java project for use with Netbeans. The code that is generated includes project files that will let you just open the project and start adding your robot specific code. In addition, if you later make changes in RobotBuilder, you can regenerate the project again and it will not overwrite your changes. This process is described in detail below.

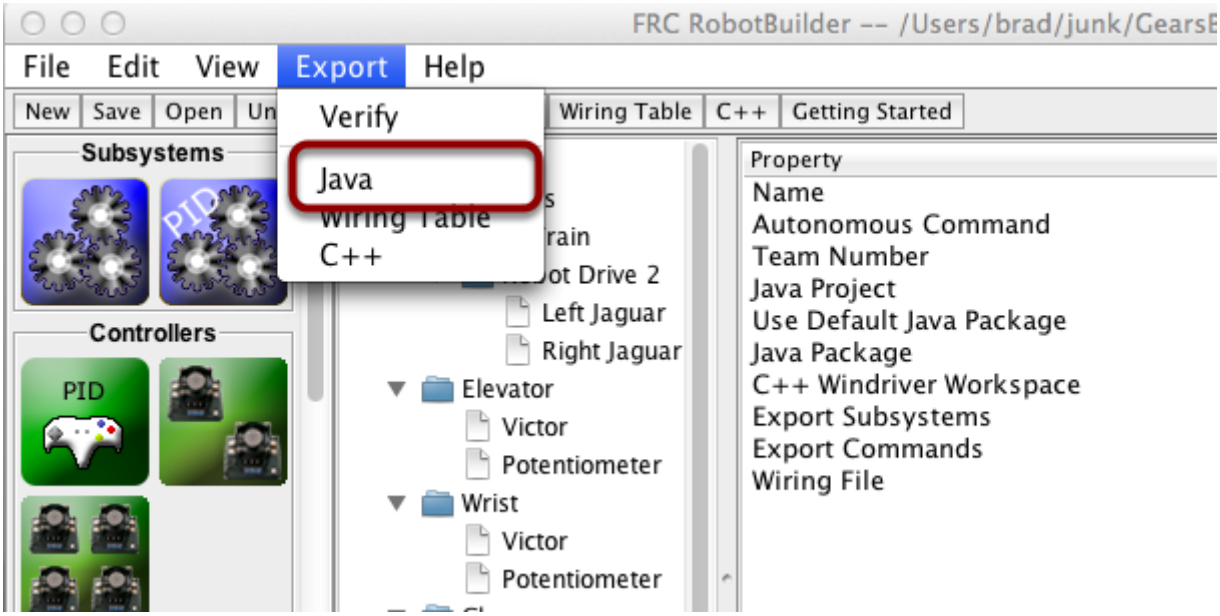
Setting up the project properties for export



Here is the procedure for setting up the project for Java code generation (export).

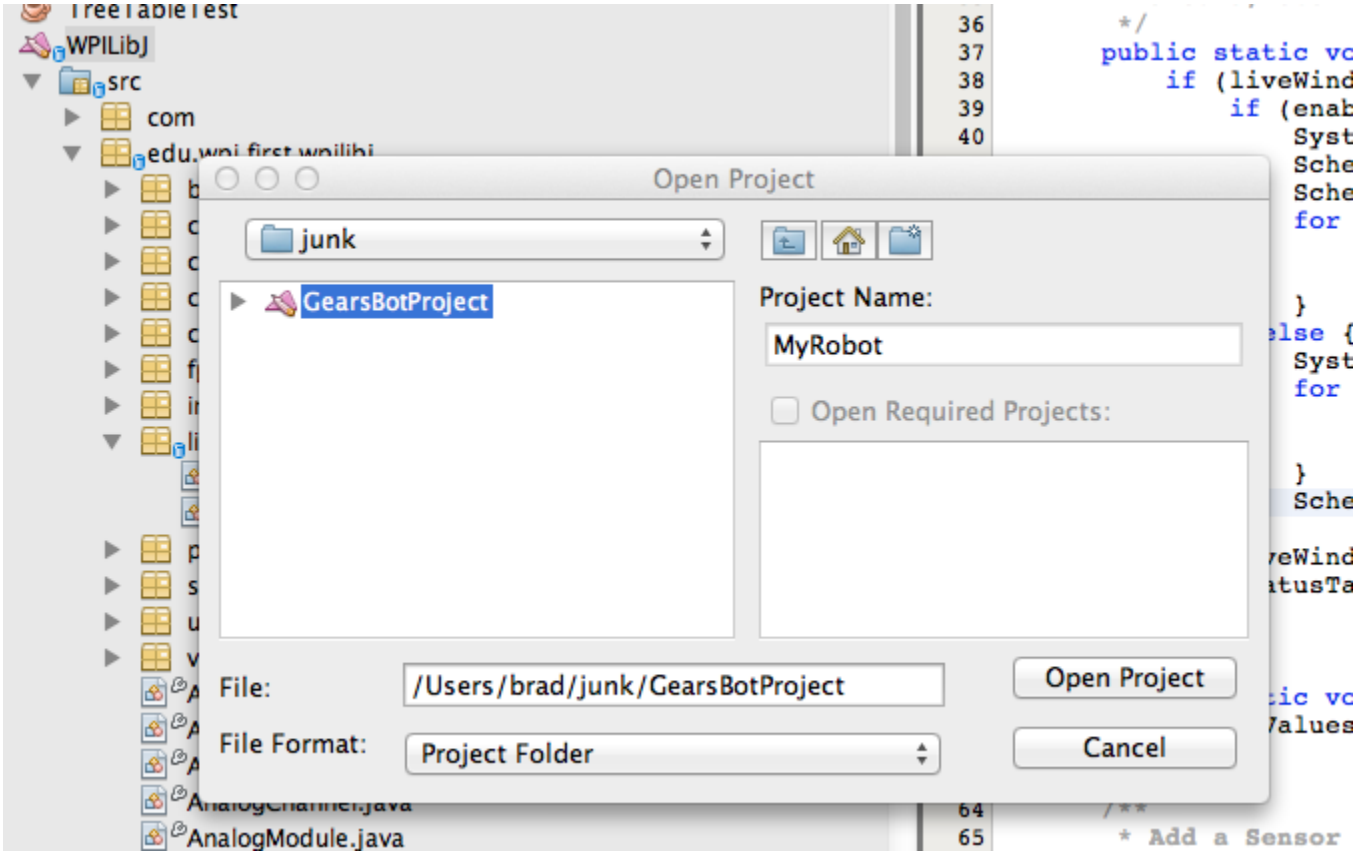
1. Select the project name in the top of the robot description to see the project properties.
2. Set the project name to something meaningful for your teams robot.
3. Set the directory where the project should be saved. This might be inside your NetbeansProjects directory or some other folder.

Generate the project files



Once the location of the exported project files is defined (previous step) either click on Java from the Export menu or use the "Java" item in the toolbar to generate code to the correct location. This will generate a full project the first time the button is pressed, or it will update the project with changes on subsequent exports.

Open the project in NetBeans

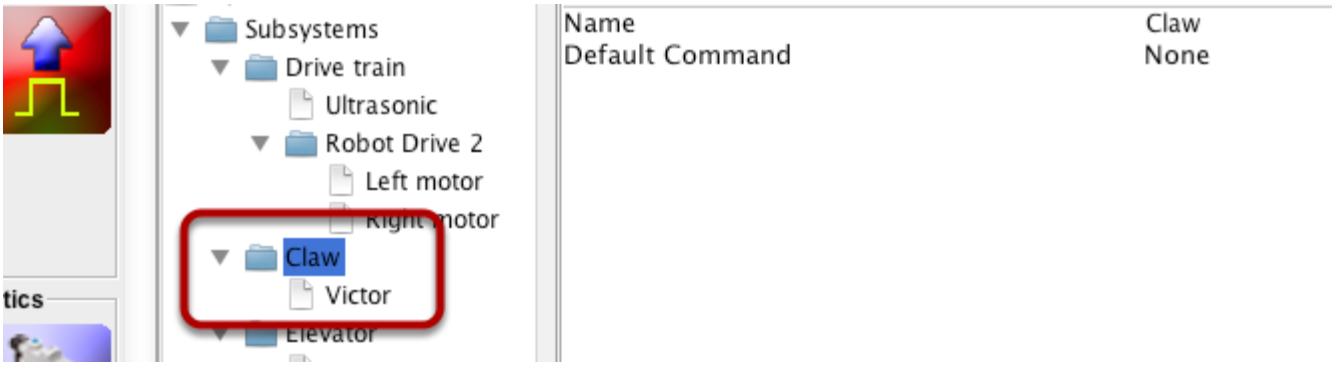


In NetBeans, select "File" from the menu bar, then "Open project..." and select the location where the file was saved from RobotBuilder. The project will be opened and you will see it in the "Projects" tab on the left side of the NetBeans window. **The project name will be the same as the name of the top folder in RobotBuilder.**

Writing the code for a subsystem in Java

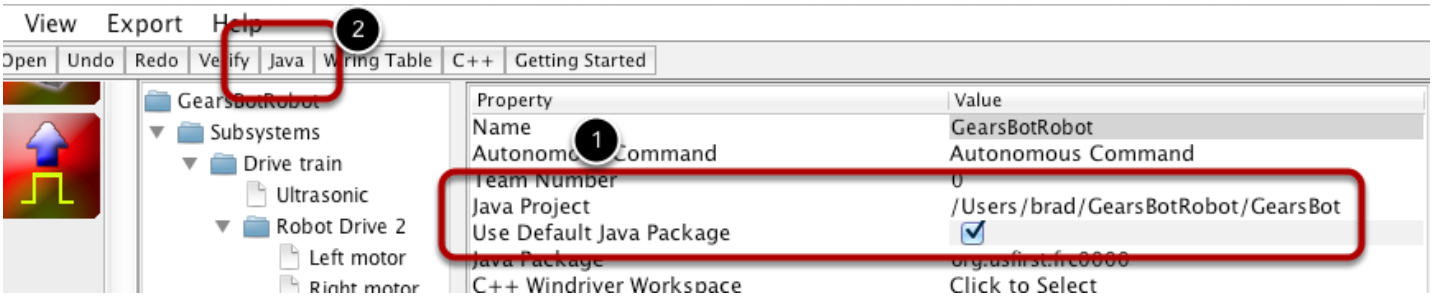
Adding code to create an actual working subsystem is very straightforward. For simple subsystems that don't use feedback it turns out to be extremely simple. In this section we will look at an example of a Claw subsystem that operates the motor for some amount of time to open or close a claw on the robot arm.

Create the subsystem



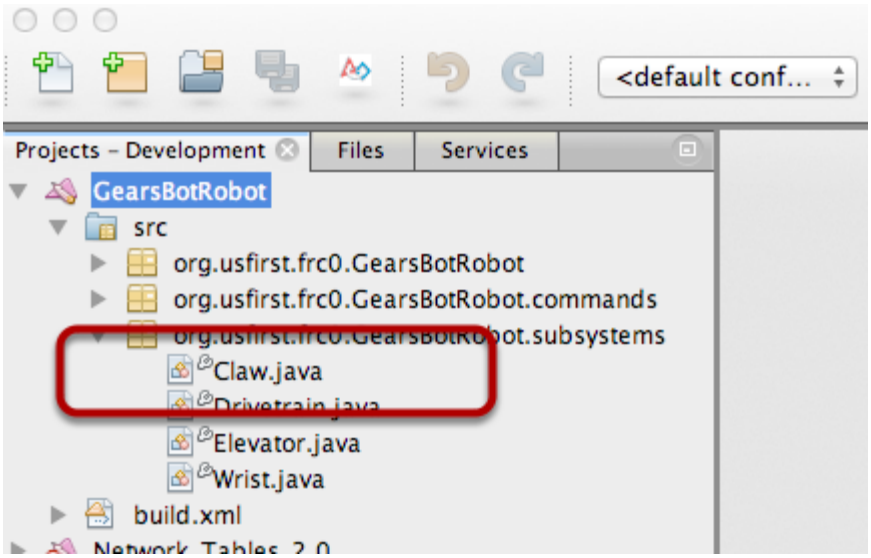
Be sure that the subsystem is defined in the RobotBuilder robot description. The Claw subsystem has a single Victor and no sensors since the claw motor operates for one second in either direction to open or close the claw.

Generate code for the project



Verify that the java project location is set up (1) and generate code for the robot project (2).

Open the project in Netbeans



Open the generated project in Netbeans and notice the subsystems package containing each of the subsystem files. Open the Claw.java file to add code that will open and close the claw.

Add methods to open, close, and stop the claw

```
2
3   package org.usfirst.frc0.GearsBotRobot.subsystems;
4
5   import edu.wpi.first.wpilibj.*;
6   import edu.wpi.first.wpilibj.command.Subsystem;
7   import org.usfirst.frc0.GearsBotRobot.RobotMap;
8
9
10  public class Claw extends Subsystem {
11
12      // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
13      Victor victor = RobotMap.CLAW_VICTOR;
14      // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
15
16      public void initDefaultCommand() {
17          // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
18          // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
19
20      }
21
22      public void openClaw() {
23          victor.set(1.0);
24      }
25
26      public void closeClaw() {
27          victor.set(-1.0);
28      }
29
30      public void stop() {
31          victor.set(0.0);
32      }
33  }
34
35
```

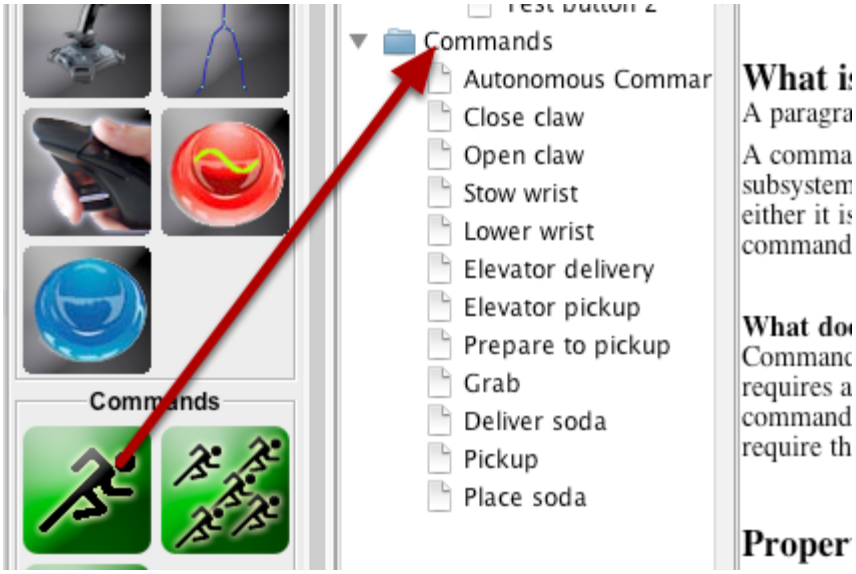
Add methods to the claw.java that will open, close, and stop the claw from moving. Those will be used by commands that actually operate the claw. The comments have been removed from this file to make it easier to see the changes for this document. Notice that a local variable called "victor" is created by RobotBuilder so it can be used throughout the subsystem. **Each of your dragged in palette items will have a local variable with the name given in RobotBuilder**.

See: Writing the code for a command in Java to see how to get this Claw subsystem to operate using commands. See: Writing the code for a PIDSubystem in Java to write the code for a more complex subsystem with feedback (PIDSubsystem).

Writing the code for a simple command in Java

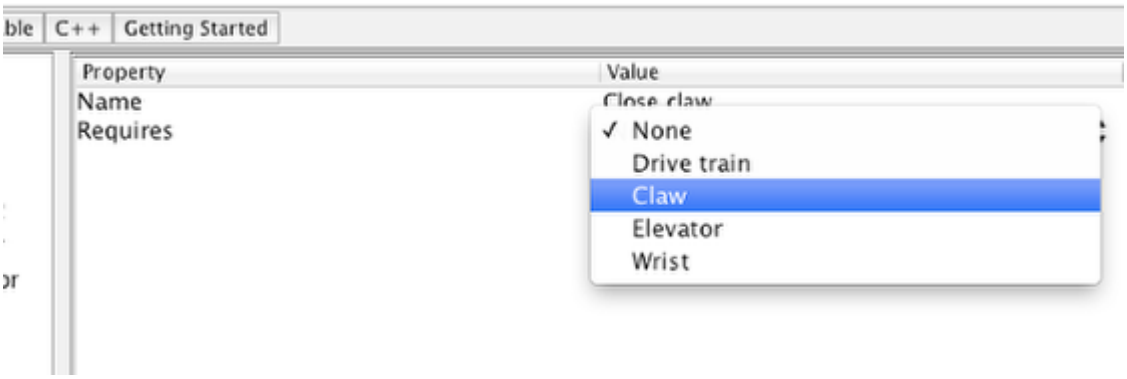
Subsystem classes get the mechanisms on your robot moving, but to get it to stop at the right time and sequence through more complex operations you write Commands. Previously in Writing the code for a subsystem in Java we developed the code for the Claw subsystem on a robot to start the claw opening, closing, or to stop moving. Now we will write the code for a command that will actually run the Claw motor for the right time to get the claw to open and close. Our claw example is a very simple mechanism where we run the motor for 1 second to open it or 0.9 seconds to close it.

Adding a command



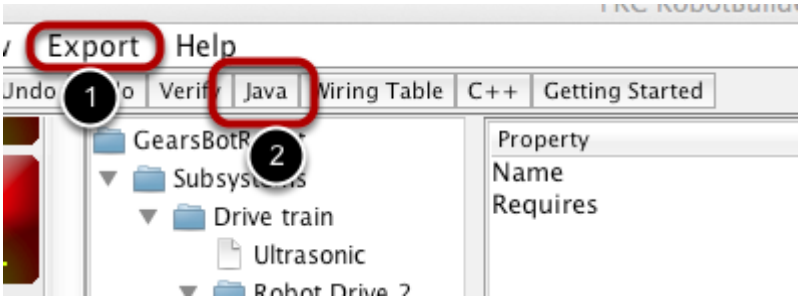
To create a command drag the command icon from the palette to the Commands folder in the robot description. This will create a command with a default name, then rename the command to be something meaningful, in this case "Open claw" or "Close claw".

Setting the Requires property to the correct subsystem



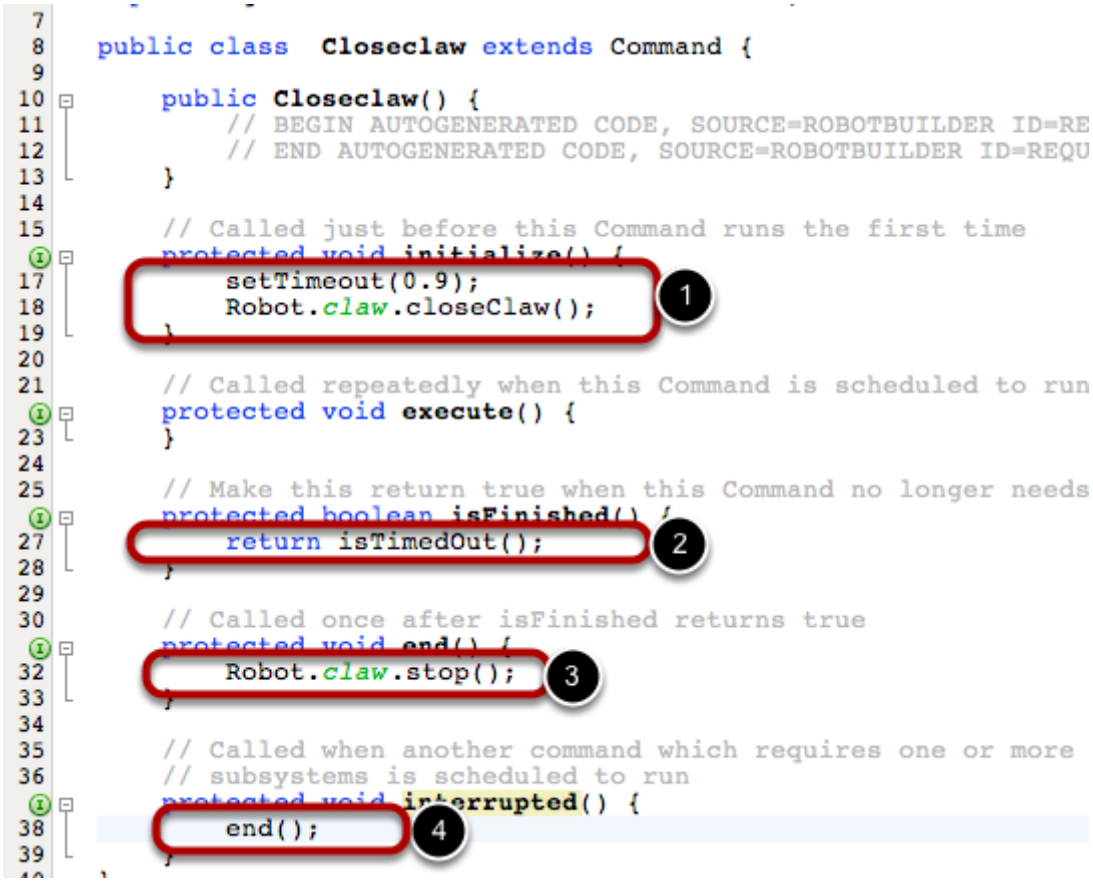
Set the Requires propert to the subsystem that this command is controlling. In this case, the "Close claw" command controls the Claw subsystem. If the "Close claw" command is scheduled while another command that uses the Claw is also running, the "Close claw" command will preempt the other command and start. For example, if the "Open claw" was running, then the robot operator decided that they really wanted to close it, since they both require the Claw, the second command (Close claw) would cancel the running open command.

Generate code for the project



Using either the Export menu (1) or the Java toolbar item (2), generate the code for the project.

Write the code to close the claw



Add these 5 lines of code to the Closeclaw command to it can be used:

1. The claw needs to run in the close direction for 0.9 seconds to completely get closed. Setting a timeout initializes the timer for this command. Each command can have a single timer that can be used for timing operations or timeouts to make sure that commands don't get stuck in the case of a broken sensor. Then start the claw closing. Notice that we only need to start the claw closing once, so having it in the initialize method is sufficient.
2. The claw should continue closing until the timer runs out. The command has a isTimedOut() method that returns true if the timer that was set in the initialize() method is done.
3. In the end() method stop the claw from moving. This is called when the isFinished() method returns true (the timer runs out in this case).
4. The interrupted() method is called when this command is preempted by another command using the Claw subsystem. In this case, we just call the end() method to stop the claw from moving.

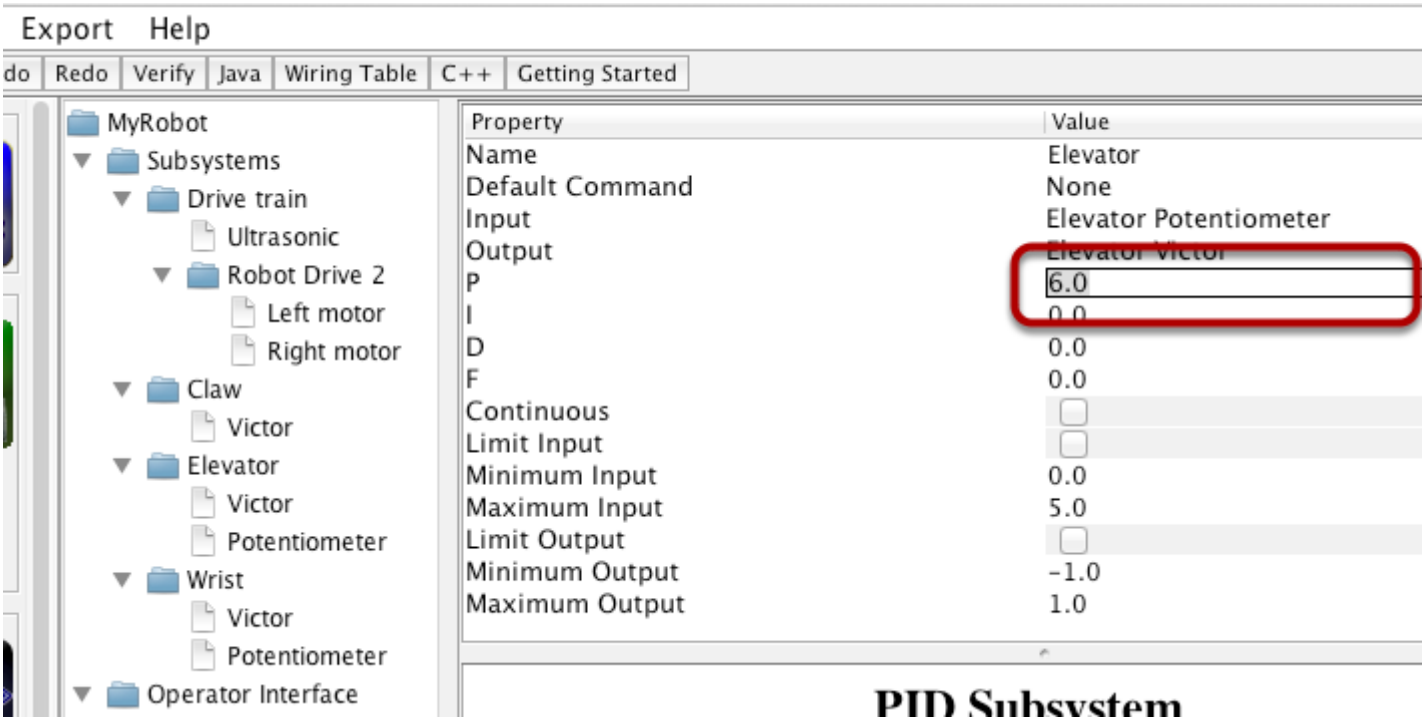
That's all that's required to get the claw to run when the command is run. Notice that **you can refer to any subsystem by using the class name Robot** since subsystem references are automatically generated as static variables. For example, "Robot.claw.closeClaw()" gives you access to the claw class and it's methods.

This command can be part of a more complex Command Group (see: Creating a command that runs other commands) or run from an operator interface button such as a joystick button (see: Connecting the operator interface to a command).

Writing the code for a PIDSubystem in Java

PIDSubsystems use feedback to control the actuator and drive it to a particular position. In this example we use an elevator with a 10-turn potentiometer connected to it to give feedback on the height. The skeleton of the PIDSubsystem is generated by the RobotBuilder and we have to fill in the rest of the code to provide the potentiometer value and drive the motor with the output of the imbedded PIDController.

Setting the PID constants



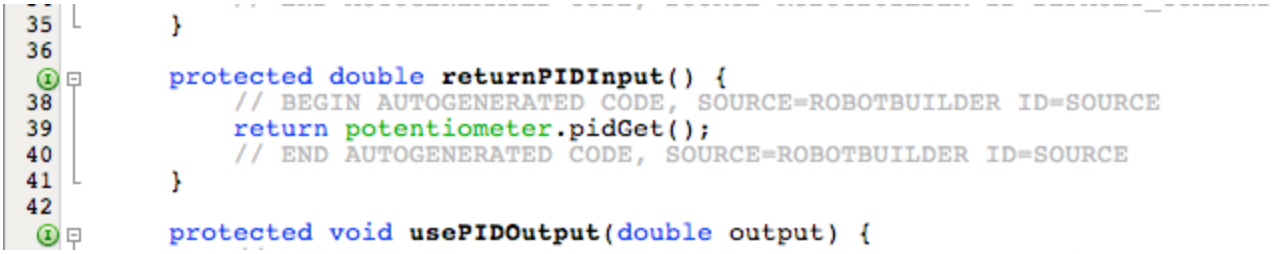
Make sure the Elevator PID subsystem has been created in the RobotBuiler. In the case of our elevator we use a propertional constant of 6.0 and 0 for the I and D terms. Once it's all set, generate Java code for the project using the Export menu or the Java toolbar menu.

Add constants for the Elevator preset positions and enable the PID controller

```
 */
public class Elevator extends PIDSubsystem {
    // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
    AnalogChannel potentiometer = RobotMap.ELEVATOR_POTENTIOMETER;
    Victor victor = RobotMap.ELEVATOR_VICTOR;
    // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS

    public static final double BOTTOM = 4.6,
        STOW = 1.65,
        TABLE_HEIGHT = 1.58;                    (1)

    public Elevator() {
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=PID
        super("Elevator", 1.0, 0.0, 0.0);
        getPIDController().setContinuous(false);
        // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=PID

        setSetpoint(STOW);                      (2)
        enable();
    }

    public void initDefaultCommand() {
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT COMMAND
```

To make it easier to drive the elevator to preset positions, we added preset positions for the bottom, stow, and table height. Then the elevator is set to the STOW position by setting the PID setpoint and the PID controller is enabled. This will cause the elevator to move to the stowed position when the robot is enabled.

Look at the autogenerated code from RobotBuilder for returnPIDInput



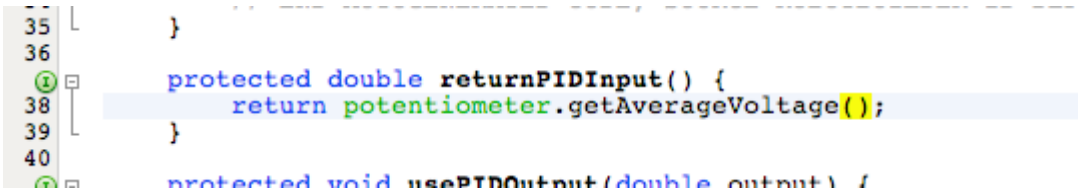
The returnPIDInput() method is used to set the value of the sensor that is providing the feedback for the PID controller. In this case, the code is automatically generated and returns the potentiometer raw analog input value (a number that ranges from 0-1023). In our case we would like the PID controller to be based on the average voltage read by the analog input for the potentiometer, not the raw value.

If we just change the line:

return potentiometer.pidGet();

it will be overwritten by RobotBuilder next time we export to Java. You can tell which lines are automatically generated by looking at the "//BEGIN AUTOGENERATED CODE" and "//END AUTOGENERATED CODE" comments. Any code inbetween those markers will be overwritten next time RobotBuilder is run. You're free to change anything outside of those blocks.

Use the avarage voltage for the PID input



To get around the problem from the last step, the comment blocks can be removed. Then if the line is changed as shown, it will no longer be overwritten by RobotBuilder.

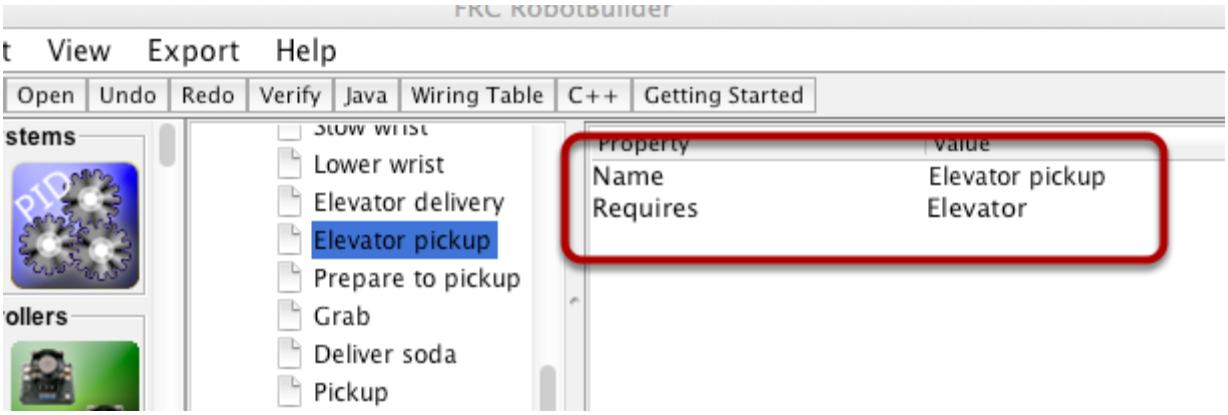
Remember, if we just wanted to add code to a method it could be added safely outside of the comment blocks.

That's all that is required to create the Elevator PIDSubsystem in Java. To operate it with commands to actually control the motion see: Operating a PIDSubsystem from a command

Operating a PIDSubsystem from a command in Java

A PIDSubsystem will automatically control the operation of an actuator with sensor feedback. To actually set the setpoints for the subsystem use a command since commands can be controlled over time and put together to make more complex commands. In this example we move the Elevator subsystem to the pickup (BOTTOM) position. To create the PIDSubsystem for the elevator see: Making a subsystem with feedback from sensors and Writing the code for a PIDSubystem in Java

Create the Elevator pickup command



The elevator pickup command moves the elevator to the pickup (BOTTOM) position. Notice that the Command requires the Elevator subsystem. By requiring the elevator, the command scheduler will automatically stop any "in progress" elevator commands when the Elevator pickup command is scheduled.

Export to Java to generate code for the robot program including the new Elevator pickup command.

Add the methods to finish the command


```
 *
 */
public class  Elevatorpickup extends Command {

    public Elevatorpickup() {
        // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=REQUIRES
        // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=REQUIRES
    }

    protected void initialize() {
        Robot.elevator.setSetpoint(Elevator.BOTTOM);
    }

    protected void execute() {
    }

    protected boolean isFinished() {
        return Math.abs(Robot.elevator.getSetpoint() - Robot.elevator.getPosition()) < 0.1;
    }

    protected void end() {
    }

    protected void interrupted() {
    }
}
```

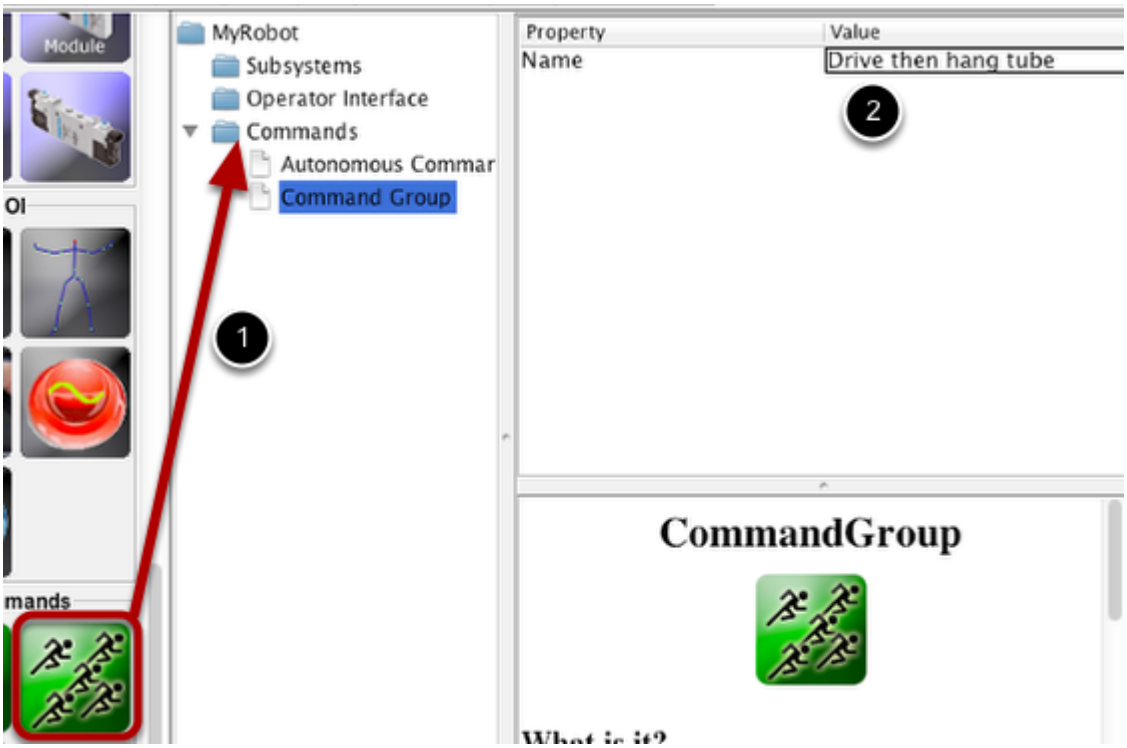
There are two changes that need to be made to make the Command work properly:

1. Set the setpoint on the Subsystem PID controller so that it starts the elevator moving to the right position.
2. Add code to the isFinished() method so the command can finish when the elevator has moved to its target position. This way, other commands that run after this command will start when the elevator has reached its target position.

Advanced techniques

Creating a command that runs other commands

Often you will want to run multiple commands, one after another to enable more complex behaviors in your program. Once each of the individual commands have been debugged, you can create a CommandGroup. A CommandGroup is a named set of commands that may be executed sequentially or in parallel.



To create a CommandGroup

1. Drag the command group from the palette to Commands folder in the robot description
2. Name the command group so that is has a meaningful name

Edit the the generated code in the command group (Java)

```
 *
 * @author Alex Henning
 */
public class SodaDelivery extends CommandGroup {
    public SodaDelivery() {
        addSequential(new PrepareToGrab());
        addSequential(new Grab());
        addSequential(new DriveToDistance(.11));
        addSequential(new PlaceSoda());
        addSequential(new DriveToDistance(.2));
        addSequential(new Stow());
    }
}
```

Add each command to command group that should be sequentially scheduled when the command group is scheduled. This allows you to build up complex commands based on simpler and tested commands. For each command that should run, call the addSequential() method with a reference to the instance of the command.

Edit the generated code in the command group (C++)

FirstSubsystem.h | OI.cpp | Robot.cpp | OI.h | Ro

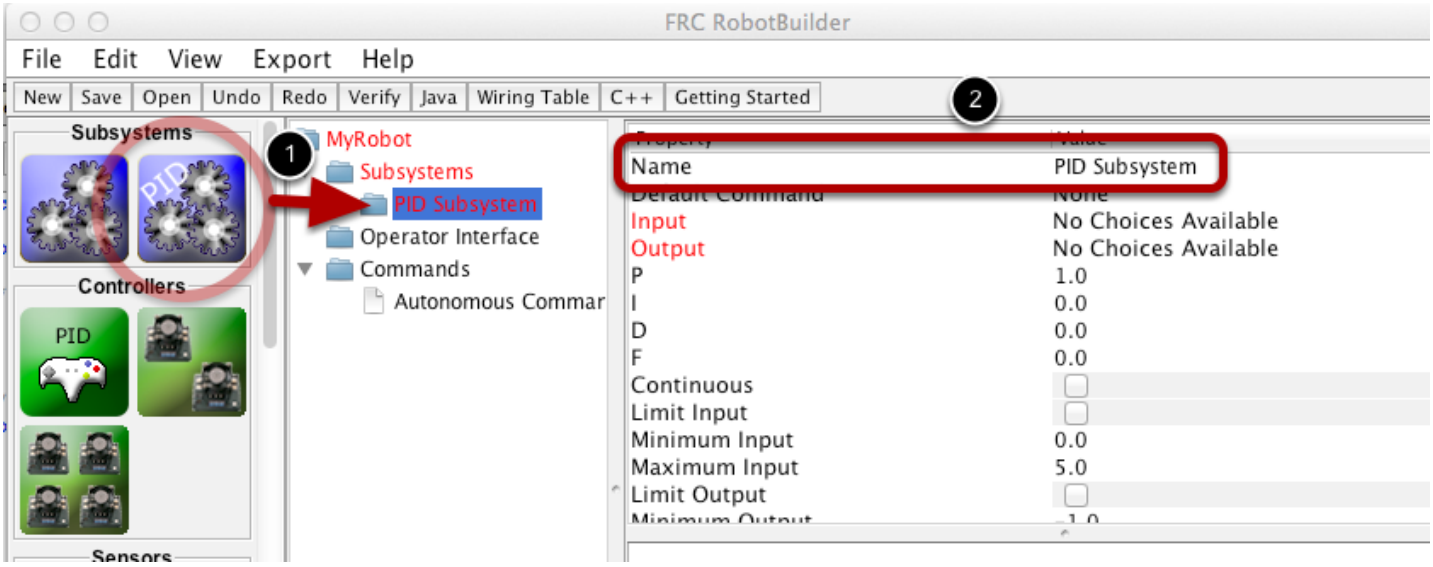
```
#include "SodaDelivery.h"

#include "PrepareToGrab.h"
#include "Grab.h"
#include "DriveToDistance.h"
#include "PlaceSoda.h"
#include "DriveToDistance.h"
#include "Stow.h"

SodaDelivery::SodaDelivery() {
    AddSequential(new PrepareToGrab());
    AddSequential(new Grab());
    AddSequential(new DriveToDistance(.11));
    AddSequential(new PlaceSoda());
    AddSequential(new DriveToDistance(.2));
    AddSequential(new Stow());
}
```

Add each command to command group that should be sequentially scheduled when the command group is scheduled. This allows you to build up complex commands based on simpler and tested commands. For each command that should run, call the addSequential() method with a reference to the instance of the command.

Using PIDSubsystems to control a actuators with feedback from sensors

More advanced subsystems will use sensors for feedback to get guaranteed results for operations like setting elevator heights or wrist angles. The PIDSubsystem has a built-in PIDController to automatically set the correct setpoints for these types of mechanisms.

Create a PIDSubsystem

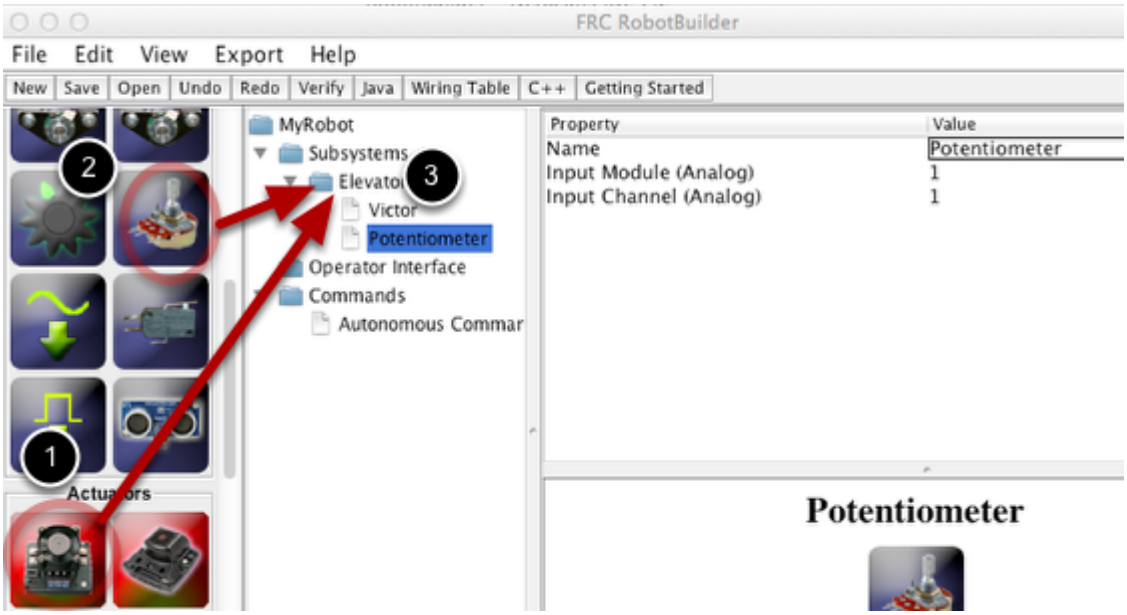


Creating a subsystem that uses feedback to control the position or speed of a mechanism is very easy.

1. Drag a PIDSubsystem from the palette to the Subsystems folder in the robot description
2. Rename the PID Subsystem to a more meaningful name for the subsystem

Notice that some of the parts of the robot description have turned red. This indicates that these components (the PIDSubsystem) haven't been completed and need to be filled in. The properties that are either missing or incorrect are shown in red.

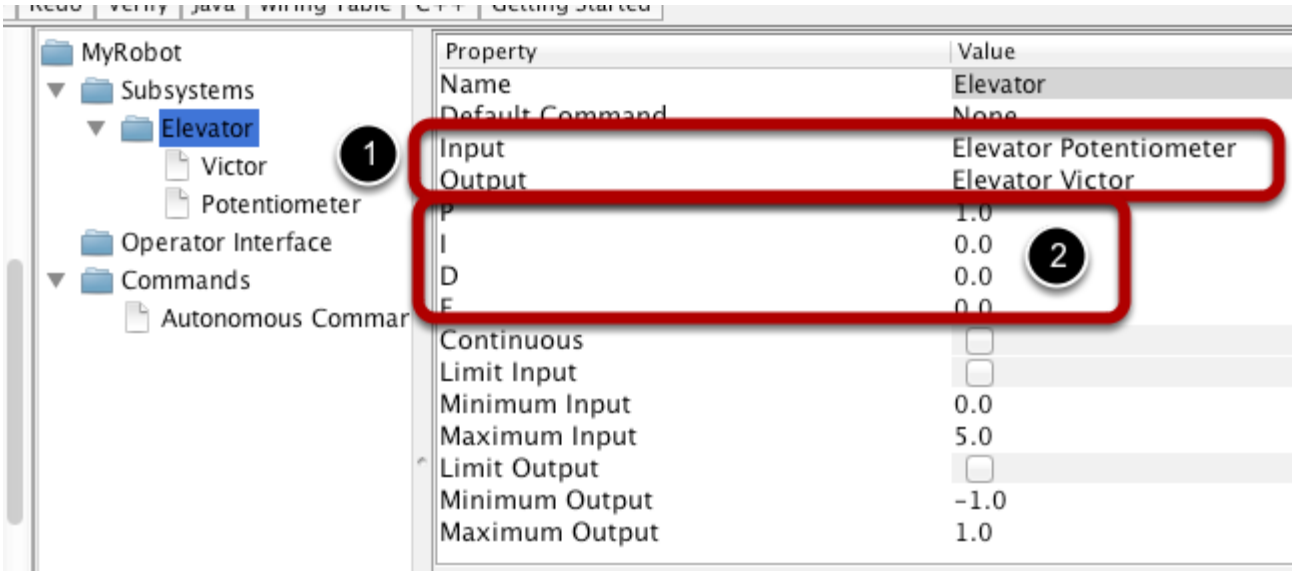
Adding sensors and actuators to the PID Subsystem



Add the missing components for the PIDSubsystem

1. Drag in the actuator (a speed controller) to the particular subsystem - in this case the Elevator
2. Drag the sensor that will be used for feedback to the subsystem, in this case the sensor is a potentiometer that might give elevator height feedback.

Fill in the PIDSubsystem parameters to get the correct operation of the mechanism



There a number of parameters for the PIDSubsystem but only a few need to be filled in for most cases

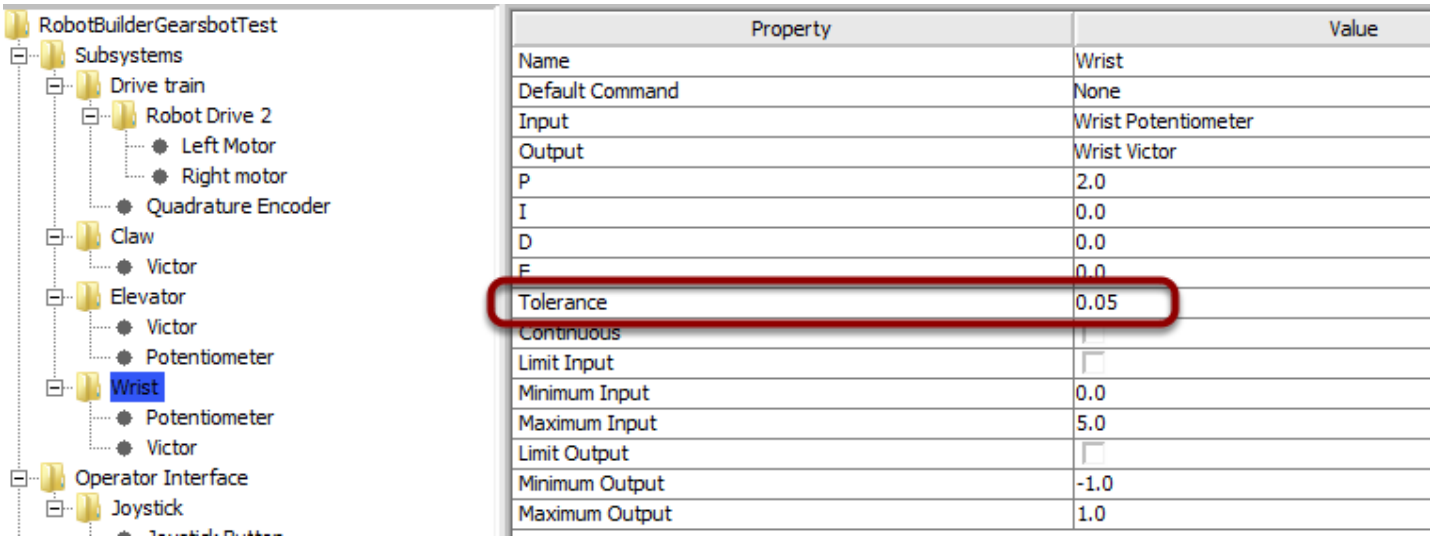
1. The Input and Output compents will have been filled in automatically from the previous step when the actuator and sensor were dragged into the PIDSubsystem
2. The P, I, and D values need to be filled in to get the desired sensitivity and stability of the component

See: Writing the code for a PIDSubystem in Java and Writing the code for a PIDSubsystem in C++

Setpoint command

A common use case in robot programs is to drive an actuator to a particular angle or position that is measured using a potentiometer or encoder. This happens so often that there is a shortcut in RobotBuilder to do this task. It is called the Setpoint command and it's one of the choices on the palette or the right-click context menu that can be inserted under "Commands".

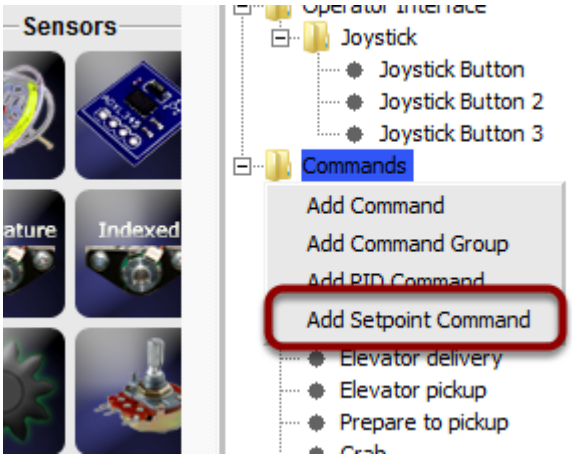
Start with a PIDSubsystem



Suppose in a robot there is a wrist joint with a potentiometer that measures the angle. First create a PIDSubsystem that include the motor that moves the wrist joint and the potentiometer that measures the angle. The PIDSubsystem should have all the PID constants filled in and working properly.

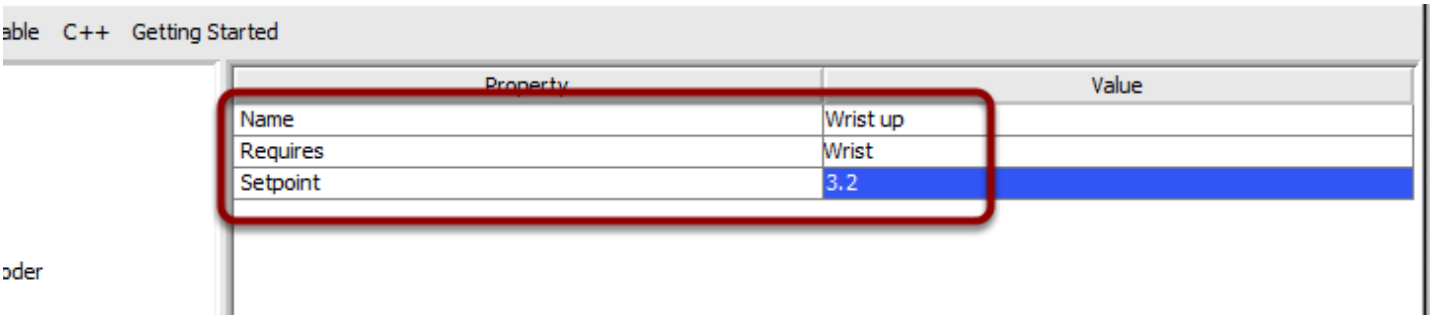
It is important to set the Tolerance parameter. This controls how far off the current value can be from the setpoint and be considered on target. This is the criteria that the SetpointCommand uses to move onto the next command.

Creating the Setpoint Command



Right-click on the Commands folder in the palette and select "Add Setpoint command".

Setpoint Command parameters



Fill in the name of the new command. The Requires field is the PIDSubsystem that is being driven to a setpoint and the Setpoint parameter is the setpoint value for the PIDSubsystem. There is no need to fill in any code for this command, it is automatically created by RobotBuilder.

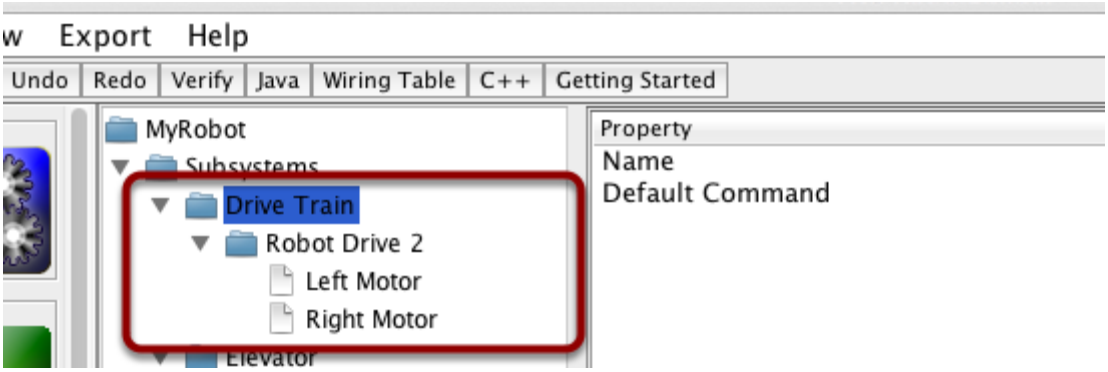
Whenever this command is scheduled, it will automatically drive the subsystem to the specified setpoint. When the setpoint is reached within the tolerance specified in the PIDSubsystem, the command ends and the next command starts. It is important to specify a tolerance in the PIDSubsystem or this command might never end because the tolerance is not achieved.

Driving the robot with tank drive and joysticks

A common use case is to have a joystick that should drive some actuators that are part of a subsystem. The problem is that the joystick is created in the OI class and the motors to be controlled are in the subsystem. The idea is to create a command that, when scheduled, reads input from the joystick and calls a method that is created on the subsystem that drives the motors.

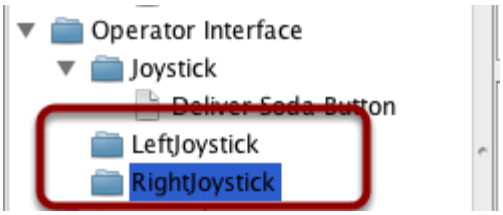
In this example a drive base subsystem is shown that is operated in tank drive using a pair of joysticks.

Create a Drive Train subsystem



Create a subsystem called Drive Train. It's responsibility will be to handle the driving for the robot base. Inside the Drive Train is a Robot Drive object for a two motor drive robot (in this case). There is a left motor and right motor as part of the Robot Drive 2 class.

Add the joysticks to the Operator Interface



Add two joysticks to the Operator Interface, one is the left stick and the other is the right stick. The y-axis on the two joysticks are used to drive the robots left and right sides.

Note: be sure to export your program to C++ or Java before continuing to the next step.

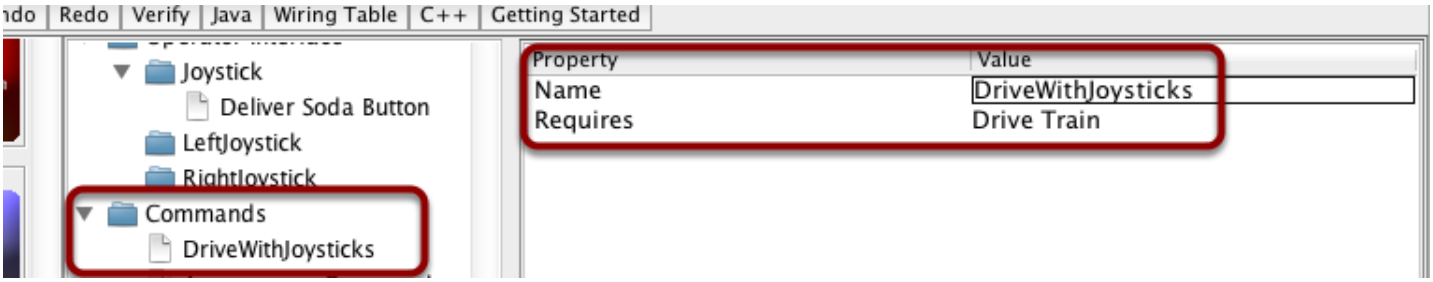
Create a method to write the motors on the subsystem

```
1  // Generated with RobotBuilder version 0.10.1
2  package org.usfirst.frc190.MyRobot.subsystems;
3  import edu.wpi.first.wpilibj.*;
4  import edu.wpi.first.wpilibj.command.Subsystem;
5  import org.usfirst.frc190.MyRobot.RobotMap;
6
7  public class DriveTrain extends Subsystem {
8      // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
9      RobotDrive robotDrive2 = RobotMap.DRIVE_TRAIN_ROBOT_DRIVE_2;
10     Jaguar rightMotor = RobotMap.DRIVE_TRAIN_RIGHT_MOTOR;
11     Jaguar leftMotor = RobotMap.DRIVE_TRAIN_LEFT_MOTOR;
12     // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DECLARATIONS
13
14     public void initDefaultCommand() {
15         // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
16     // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=DEFAULT_COMMAND
17
18         // Set the default command for a subsystem here.
19         //setDefaultCommand(new MySpecialCommand());
20     }
21
22     public void takeJoystickInputs(Joystick left, Joystick right) {
23         robotDrive2.tankDrive(left, right);
24     }
25
26     public void stop() {
27         robotDrive2.drive(0, 0);
28     }
29 }
```

Create a method that takes the joystick inputs, in this case the the left and right driver joystick. The values are passed to the RobotDrive object that in turn does tank steering using the joystick values. Also create a method called stop() that stops the robot from driving, this might come in handy later.

Note: the extra RobotBuilder comments have been removed to format the example for the documentation.

Create a command that reads the joystick values and calls the subsystem method



Create a command, in this case called DriveWithJoysticks. Its purpose will be to read the joystick values and send them to the Drive Base subsystem. Notice that this command Requires the Drive Train subsystem. This will cause it to stop running whenever anything else tries to use the Drive Train.

Note: be sure to export your program to C++ or Java before continuing to the next step.

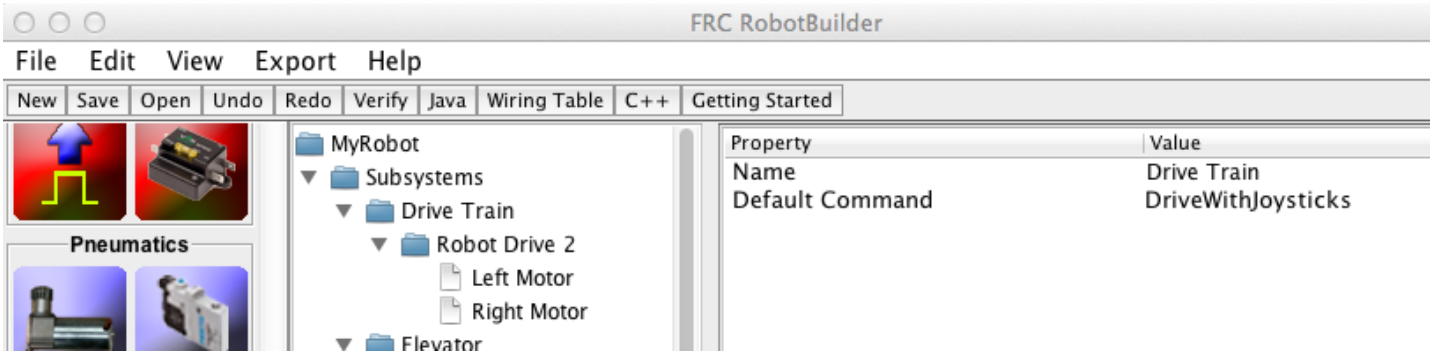
Add the code for the command to do the actual driving

```
3  package org.usfirst.frc190.MyRobot.commands;
4
5  import edu.wpi.first.wpilibj.command.Command;
6  import org.usfirst.frc190.MyRobot.Robot;
7
8  public class  DriveWithJoysticks extends Command {
9
10     public DriveWithJoysticks() {
11         // BEGIN AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=REQUIRES
12         requires(Robot.driveTrain);
13         // END AUTOGENERATED CODE, SOURCE=ROBOTBUILDER ID=REQUIRES
14     }
15
16     protected void initialize() {
17     }
18
19     protected void execute() {
20         Robot.driveTrain.takeJoystickInputs(Robot.oi.getLeftJoystick(),
21                                             Robot.oi.getRightJoystick());
22     }
23
24     protected boolean isFinished() {
25         return false;
26     }
27
28     protected void end() {
29         Robot.driveTrain.stop();
30     }
31
32     protected void interrupted() {
33         end();
34     }
35 }
```

Add code to the execute method to do the actual driving. All that is needed is to get the Joystick objects for the left and right drive joysticks and pass them to the Drive Train subsystem. The subsystem just uses them for the tank steering method on its RobotDrive object. And we get tank steering.

We also filled in the end() and interrupted methods so that when this command is interrupted or stopped, the motors will be stopped as a safety precaution.

Make the command the "default command" for the subsystem



The last step is to make the DriveWIthJoysticks command be the "Default Command" for the Drive Train subsystem. This means that whenever no other command is using the Drive Train, the Joysticks will be in control. This is probably the desirable behavior. When the autonomous code is running, it will also require the drive train and interrupt the "DriveWithJoystick" command. When the autonomous code is finished, the DriveWithJoysticks command will restart automatically (because it is the default command), and the operators will be back in control. If you write any code that does teleop automatic driving, those commands should also "require" the DriveTrain so that they too will interrupt the DriveWithJoysticks command and have full control.

Note: be sure to export your program to C++ or Java before continuing.