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QUALCOMM

2017-2018 FIRST® Tech Challenge OnBot Java Tutorial



www.firstinspires.org

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FOR INSPIRATION & RECOGNITION OF SCIENCE & TECHNOLOGY



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Table of Contents

1	Introduction	3
1.1	What is FIRST® Tech Challenge?	3
1.2	FIRST Tech Challenge Core Values	3
2	Gracious Professionalism®	3
2.1	Gracious Professionalism for Volunteers.....	4
3	Youth Protection Program	4
3.1	Youth Protection Expectations and Guidelines	4
3.2	NOTICE OF NON-DISCRIMINATION	4
4	Training Manual Introduction	5
4.1	The Java Programming Language.....	5
4.2	Point-to-Point Control System	5
4.3	REV Robotics Expansion Hub	5
5	Required Materials.....	6
6	Setting Up Your Smartphones.....	9
6.1	Renaming Your Smartphones	9
6.2	Installing the FIRST Tech Challenge Apps.....	13
6.3	Placing Phones into Airplane Mode with Wi-Fi On.....	17
6.4	Pairing the Driver Station to the Robot Controller	18
7	Connecting Devices to an Expansion Hub.....	22
7.1	Connecting 12V Power to the Expansion Hub	22
7.2	Connecting a Motor to the Expansion Hub.....	25
7.3	Connecting a Servo to the Expansion Hub.....	26
7.4	Connecting a Color-Distance Sensor to the Expansion Hub	27
7.5	Connecting a Touch Sensor to the Expansion Hub	28
8	Configuring Your Hardware on the Robot Controller	29
9	Writing an Op Mode	42
9.1	What's an Op Mode?	42
9.2	The FTC OnBot Java Programming Tool.....	42
9.3	Installing a Javascript-Enabled Browser.....	43
9.4	Connecting Your Laptop to the Program & Manage Server	45
9.5	Troubleshooting Your Wireless Connection	48

9.6	Creating Your First Op Mode	49
9.7	Examining the Structure of Your Op Mode.....	52
9.8	Building Your Op Mode	54
9.9	Troubleshooting Build Messages	55
9.10	Running Your Op Mode.....	56
9.11	Modifying Your Op Mode to Control a Motor	58
9.12	Running Your Op Mode with a Gamepad Connected.....	59
10	Controlling a Servo Motor with an Op Mode	60
10.1	What is a Servo Motor?	60
10.2	Modifying Your Op Mode to Control a Servo	61
11	Using Sensors	62
11.1	Color-Distance Sensor.....	62
11.2	Touch Sensor.....	63
12	FIRST Tech Challenge Reference Information.....	64
12.1	Javadoc Reference Pages	64
12.2	Sample Op Modes.....	64
12.3	Control System Wiki.....	64
12.4	Technology Forum	64
13	Troubleshooting	65
13.1	Manually Connecting to the Program & Manage Wi-Fi Network.....	65
13.2	Troubleshooting Tips.....	68
13.2.1	Driver Station Appears Unresponsive	68
13.2.2	Warning: problem communicating...	69

1 Introduction

1.1 What is FIRST® Tech Challenge?

FIRST Tech Challenge is a student-centered program that focuses on giving students a unique and stimulating experience. Each year, teams engage in a new Game where they design, build, test, and program autonomous and driver operated robots that must perform a series of tasks.

They also cultivate life skills such as:

- Planning, brainstorming, and creative problem-solving.
- Research and technical skills.
- Collaboration and teamwork.
- Appreciating differences and respecting the ideas and contributions of others.

To learn more about FIRST Tech Challenge and other FIRST® Programs, visit www.firstinspires.org.

1.2 FIRST Tech Challenge Core Values

FIRST asks everyone who takes part in FIRST Tech Challenge to uphold the following values:

- We display *Gracious Professionalism*® with everyone we engage with and in everything we do.
- We act with integrity.
- We have fun.
- We are a welcoming community of students, mentors, and volunteers.
- What we learn is more important than what we win.
- We respect each other and celebrate our diversity.
- Students and adults work together to find solutions to challenges.
- We honor the spirit of friendly competition.
- We behave with courtesy and compassion for others always.
- We act as ambassadors for FIRST and FIRST Tech Challenge.
- We inspire others to adopt these values.

2 Gracious Professionalism®

FIRST uses this term to describe our programs' intent and is shared with all young people engaging in FIRST programs. At FIRST, team members help other team members, but they also help other teams.

Gracious Professionalism® is not clearly defined for a reason. It has different meanings to everyone.

Some possible meanings of *Gracious Professionalism* include:

- Gracious attitudes and behaviors are win-win.
- Gracious folks respect others and let that respect show in their actions.
- Gracious Professionals make valued contributions in a way that is pleasing to others and to themselves.

In FIRST, *Gracious Professionalism* teaches teams and student participants:

FIRST Tech Challenge is MORE THAN ROBOTSSM! While competing, students develop personal and professional skills they will be able to rely on throughout their life.

An example of *Gracious Professionalism* is patiently listening to a team's question and providing support despite having several pressing things to do on the day of the event.

- Learn to be strong competitors, but also treat one another with respect and kindness in the process.
- Avoid leaving anyone feeling as if they are excluded or unappreciated.
- Knowledge, pride and empathy should be comfortably and genuinely blended.

In the end, *Gracious Professionalism*® is part of everyday life. When professionals use their knowledge in a graciously and individuals act with integrity and sensitivity, everyone wins, and society benefits.

Watch Dr. Woodie Flowers explain *Gracious Professionalism* in this [short video](#).

2.1 Gracious Professionalism for Volunteers

It is a good idea to spend time going over this concept with volunteers. Provide volunteers with real-life examples of *Gracious Professionalism* in practice before, during, and after the event and recognize great *Gracious Professionalism* when you see it in action!

3 Youth Protection Program

The *FIRST* YPP sets minimum standards recommended for all *FIRST* activities. Adults working in *FIRST* programs must be knowledgeable of the standards set by the *FIRST* YPP, as well as those set by the school or organization hosting their team.

3.1 Youth Protection Expectations and Guidelines

Coaches and mentors should read and follow the [FIRST Youth Protection Program guide](#). Anything labeled as required is mandatory in the United States and Canada, and cannot be waived without approval from the *FIRST* Youth Protection Department. *FIRST* recommends that the standards set forth in the *FIRST* Youth Protection Program guide be applied outside of the United States and Canada to the extent possible. At a minimum, local regulations regarding youth protection must be complied with.

Most up to date forms are available here: <http://firstinspires.org/resource-library/youth-protection-policy>

The US Screening process, the Canadian Screen process, Frequently Asked Questions (FAQ), and additional information are on the *FIRST* Youth Protection Program Website: <http://firstinspires.org/resource-library/youth-protection-policy>

3.2 NOTICE OF NON-DISCRIMINATION

For Inspiration and Recognition of Science and Technology (*FIRST*®) does not discriminate based on race, color, national origin, sex, disability, age, status as a veteran who served in the military, religion, gender, gender identity, or gender expression in its programs and activities.

Keep updated at: <http://www.firstinspires.org/about/legal-notices>

4 Training Manual Introduction

This document shows how to set up, configure and program the control system used for the *FIRST* Tech Challenge competition using the FTC OnBot Java Programming Tool. The basic examples in this document use the REV Robotics Expansion Hub as the primary input/output module. For detailed information about the REV Robotics Expansion Hub, refer to the *REV Robotics Expansion Hub Guide* which is available from the REV Robotics website (<http://www.revrobotics.com/>).

4.1 The Java Programming Language

This tutorial assumes that you have a sound understanding of the Java programming language. If you do not know Java, then you should consider using the FTC Blocks Programming Tool, which is a visual development tool. Information about the FTC Blocks Programming Tool can be found at the following address:

https://github.com/ftctechhn/ftc_app/wiki/Writing-an-Op-Mode-with-FTC-Blocks

Or, you can learn the Java programming language by completing the Oracle Java Tutorial, which is available at the following address:

<https://docs.oracle.com/javase/tutorial/>

4.2 Point-to-Point Control System

Teams competing in the *FIRST* Tech Challenge use a *point-to-point* system to control their robots.



Figure 1 – The control system has a Driver Station connected wirelessly to a Robot Controller.

The *Robot Controller* acts as the “brains” of the robot and is mounted on the frame of the robot. The *Driver Station* lets humans interact with the Robot Controller through a wireless connection.

4.3 REV Robotics Expansion Hub

The REV Robotics Expansion Hub is the electronic *input/output* (or “I/O”) module that lets the Robot Controller talk to the robot’s motors, servos, and sensors. The Robot Controller communicates with the Expansion Hub through a USB connection.

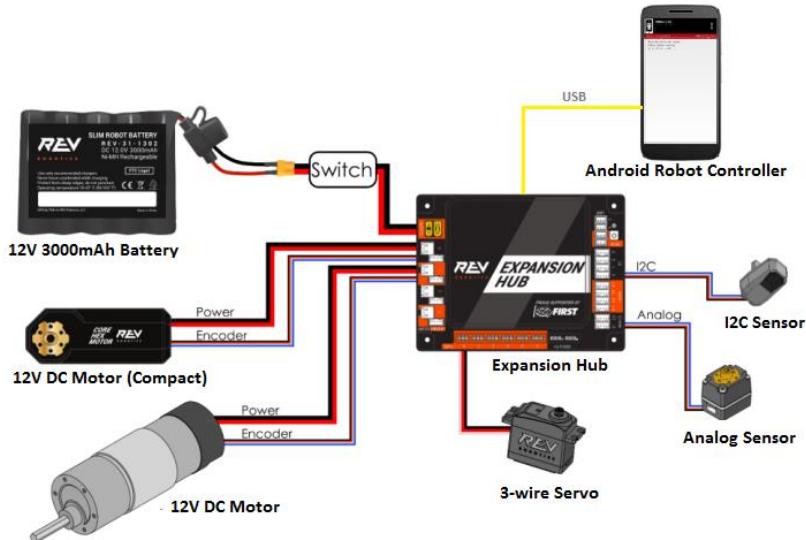


Figure 2 - The Expansion Hub lets the Robot Controller talk to the sensors, motors and servos.

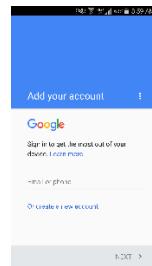
5 Required Materials

To follow along with the examples in this document, you will need the following items:

Two (2) FIRST-approved Android smartphones¹



A Google account (available for free from Google) to access the Google Play store



Wireless Internet access



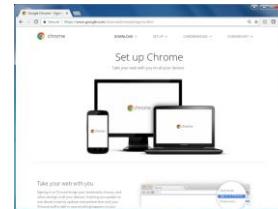
¹ Consult the official FIRST Tech Challenge Game Manual, Part 1 for a list of approved devices.

Laptop with Microsoft Windows 7, 8 or 10 and Wi-Fi capability.

Note that your laptop should also have the most current service packs and system updates from Microsoft.



Javascript-enabled web browser (Google Chrome is the recommended browser).



REV Robotics Expansion Hub (REV-31-1153)



REV Robotics Switch, Cable, and Bracket (REV-31-1387)



REV Robotics Tamiya to XT30 Adapter (REV-31-1382)



FIRST-approved 12V Battery (such as Tetrix W39057)



FIRST-approved 12V DC Motor (such as Tetrix W39530, with power cable W41352)²



REV Robotics Anderson to JST VH Cable (REV-31-1381)



180-Degree Standard Scale Servo (such as Hitec HS-485HB)



REV Robotics Color Sensor with 4-Pin JST PH Cable (REV-31-1154)



REV Robotics Touch sensor with 4-Pin JST PH Cable (REV-31-1425)



² Note that for the examples listed in this document, it is recommended that the user builds a simple structure using a compatible build kit (such as TETRIX Max) to properly secure the DC motor and prevent it from rolling about uncontrollably while running the sample op modes.

USB Type A male to type mini-B male cable



Two (2) micro USB OTG adapters



Logitech F310 USB Gamepad



6 Setting Up Your Smartphones

6.1 Renaming Your Smartphones

You will need to have two *FIRST*-approved Android smartphones for the control system. One phone will be used as the Robot Controller, the other will be used as the Driver Station.³

By establishing unique names for your phones, you can ensure that your phones will be communicating with each other rather than other teams' phones at meets and tournaments. The official rules of the *FIRST* Tech Challenge require that you change the Wi-Fi name of your smartphones to include your team number and “-RC” if the phone is a Robot Controller or “-DS” if it is a Driver Station. A team can insert an additional dash and a letter (“A”, “B”, “C”, etc.) if the team has more than one set of Android phones.

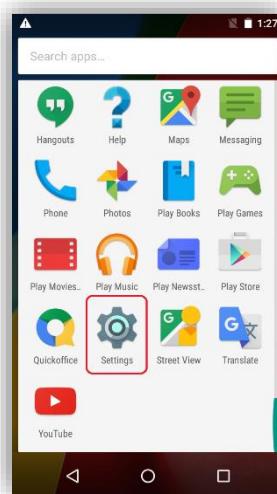
If, for example, a team has a team number of 9999 and the team has multiple sets of phones, the team might decide to name one phone “9999-C-RC” for the Robot Controller and the other phone “9999-C-DS” for the Driver Station. The “-C” indicates that these devices belong to the third set of phones for this team.

³ Note that the screen images for this document were made using a pair of Motorola Android smartphones. The actual screen images on your smartphones might differ slightly from the images depicted in this document.

Renaming Your Smartphones
(Time Needed to Complete Task: 5 Minutes per Phone)

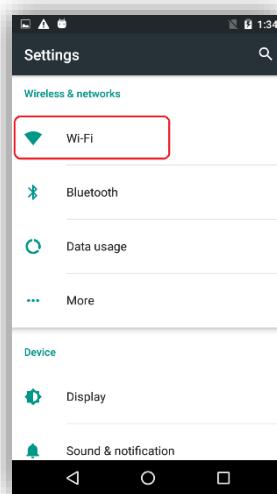
Step 1:

Click on **Settings** icon to display the Android Settings screen.



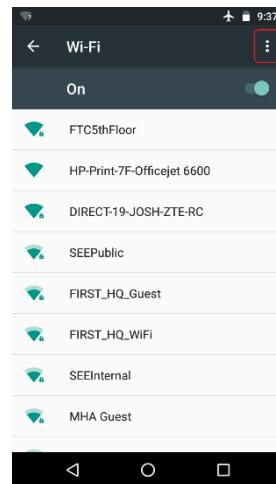
Step 2:

Click on **Wi-Fi** to launch the Wi-Fi screen.

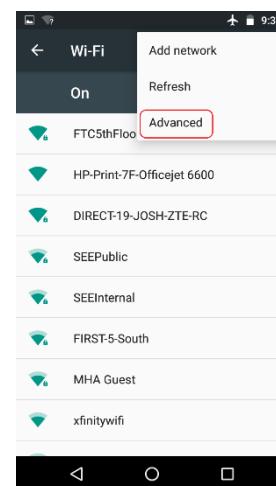


Step 3:

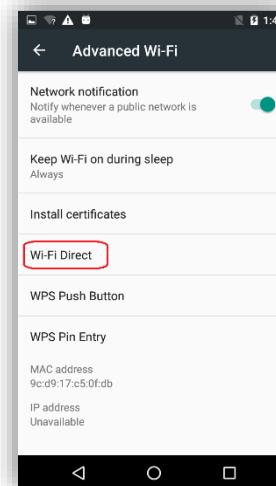
Touch the three vertical dots in upper right-hand corner to display a pop-up menu.

**Step 4:**

Select **Advanced** from the pop-up menu to display the Advanced Wi-Fi screen.

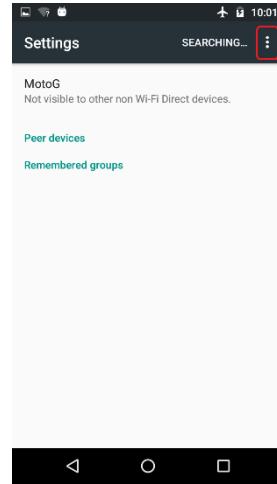
**Step 5:**

Select **Wi-Fi Direct** to display the Wi-Fi Direct menu.



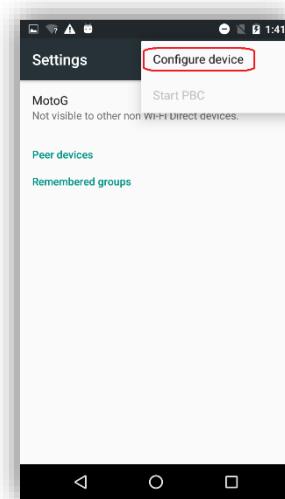
Step 6:

Touch the three vertical dots to display the pop-up menu.



Step 7:

Select **Configure Device** from the pop-up menu.



Step 8:

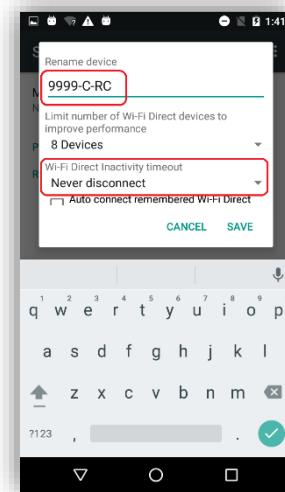
In the **Configure Device** screen, use the touch keypad to type in the new name of the device. If it is going to be a Robot Controller device, specify your team number and “-RC”. If it is going to be a Driver Station, specify your team number and “-DS”.

You can also set the Wi-Fi Direct Inactivity timeout to “Never disconnect” and then hit the **SAVE** button to save your changes.

Note that in the screenshot shown to the right, the team number is “9999”. The “-C” indicates that this is from the third pair of smartphones for this team. The “-RC” indicates that this phone will be a Robot Controller.

Step 9:

After you have renamed your phone, power cycle (i.e., restart) your smartphone.



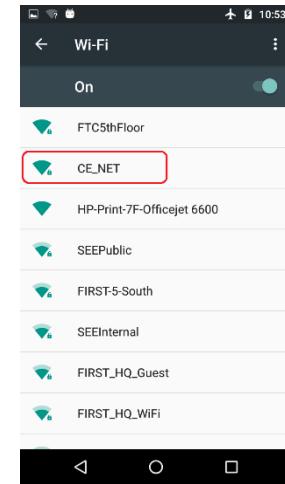
6.2 Installing the FIRST Tech Challenge Apps

The FTC apps are available to download for free from the Google Play store. You will need to have your Android phones connected to a Wi-Fi network that has Internet access before you can access the Google Play store. You will also need a Google account to be able to download the apps from the Google Play store.

Installing the FIRST Tech Challenge Apps (Time Needed to Complete Task: 7.5 Minutes per Phone)

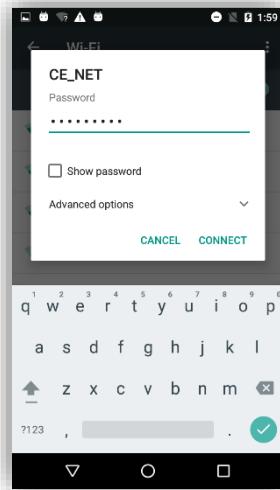
Step 1:

From the Android Wi-Fi screen look for the name of your wireless network (“CE_NET” in this example) and touch the wireless network name to login to the network.

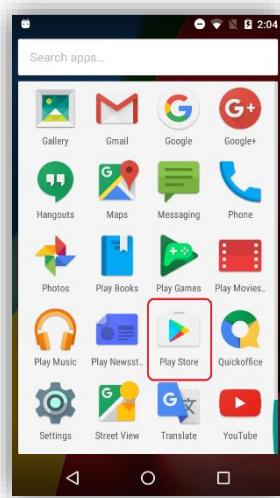


Step 2:

Specify the password using the touch keypad and hit **CONNECT** to connect to this wireless network.

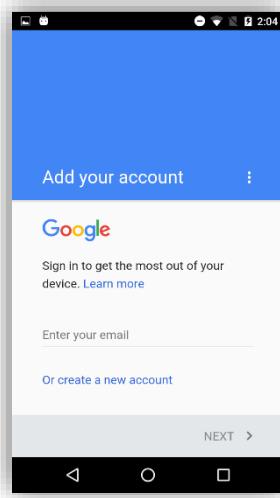
**Step 3:**

Find the Google Play Store icon on your phone and click it to launch the Google Play Store app.

**Step 4:**

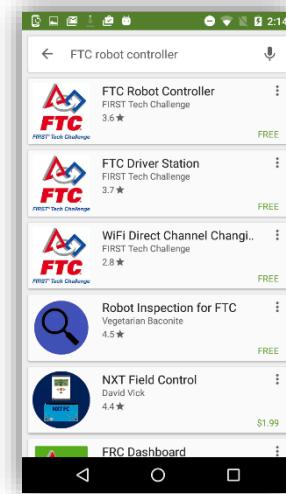
If you haven't signed into your Google account yet, follow the onscreen instructions to log into your Google account.

If you don't have a Google account, follow the onscreen instructions to create a new account.



Step 5:

In the search window of the Google Play app, type in the words “FTC Robot Controller” to find the Robot Controller or “FTC Driver Station” to find the appropriate FTC app for your phone.

**Step 6:**

Tap on the app in the Google Play listing to bring up the installation screen. Follow the onscreen instructions to install the appropriate app for your phone.

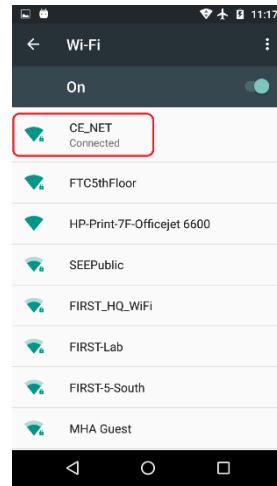
Important note: When you install the FTC apps, **only install one FTC app** (FTC Robot Controller or FTC Driver Station) **per phone**. You should avoid installing both apps onto the same phone. Doing so can cause Wi-Fi connection problems. You should only install the FTC Robot Controller app onto the phone that will be the Robot Controller and the FTC Driver Station app onto the phone that will be the Driver Station.



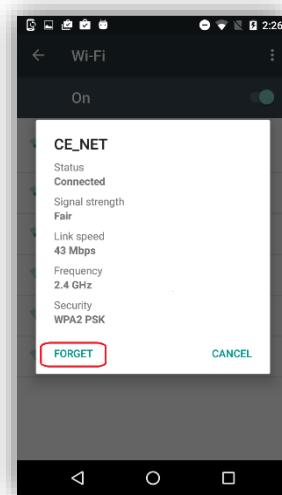
Step 7:

After you have successfully installed the app, you should forget the external wireless network on your phone.

Go to the Android Wi-Fi screen, find the name of the currently connected network, and tap on the network name to bring up a pop-up box with info about the network.

**Step 8:**

Click on **FORGET** button to forget the wireless network.



6.3 Placing Phones into Airplane Mode with Wi-Fi On

For the FIRST Tech Challenge competitions, it is important that you place your Robot Controller and Driver Station phones into Airplane mode but keep their Wi-Fi radios turned on. This is important because you do not want any of the cellular telephone functions to be enabled during a match. The cellular telephone functions could disrupt the function of the robot during a match.

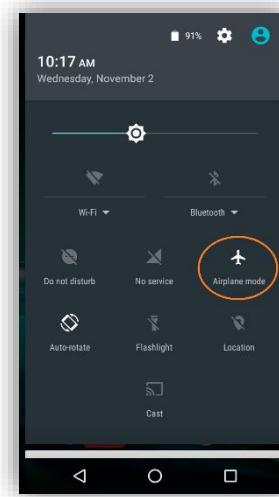
Placing Phones into Airplane Mode with Wi-Fi On (Time Needed to Complete Task: 2.5 Minutes per Phone)

Step 1:

On the main Android screen of each smartphone, use your finger to slide from the top of the screen down towards the bottom of the screen to display the quick configuration screen.

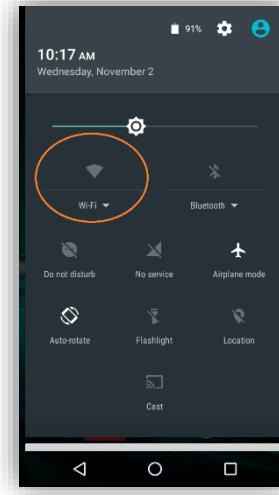
Note that for some smartphones you might have to swipe down more than once to display the quick configuration screen, particularly if there are messages or notifications displayed at the top of your screen.

Look for the Airplane mode icon (which is shaped like an airplane) and if the icon is not activated, touch the icon to put the phone into airplane mode.



Step 2:

Placing the phone into airplane mode will turn off the Wi-Fi radio. If the Wi-Fi icon has a diagonal line through it (see Step 1 above), then the Wi-Fi radio is disabled. You will need to touch the “Wi-Fi” icon on the quick configuration screen to turn the Wi-Fi radio back on.



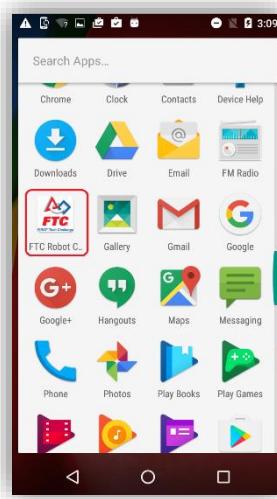
6.4 Pairing the Driver Station to the Robot Controller

Once you have successfully installed the FTC apps onto your Android phones, you will want to establish a secure wireless connection between the two devices. This connection will allow your Driver Station phone to select op modes on your Robot Controller phone and send gamepad input to these programs. Likewise, it will allow your op modes running on your Robot Controller phone to send telemetry data to your Driver Station phone where it can be displayed for your drivers. The process to connect the two phones is known as “pairing.”

Pairing the Driver Station to the Robot Controller (Time Needed to Complete Task: 10 minutes)

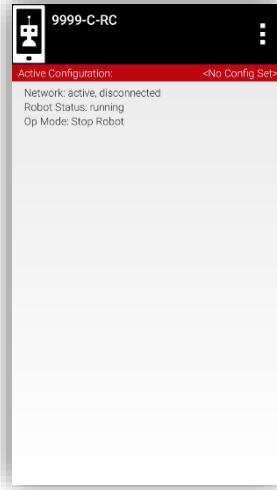
Step 1:

On the main Robot Controller smartphone, look for the FTC Robot Controller icon. Tap on the icon to launch the Robot Controller app.



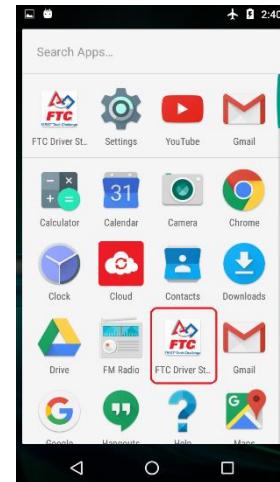
Step 2:

Verify that the Robot Controller app is running. The **Robot Status** field should read “running” if it is working properly.

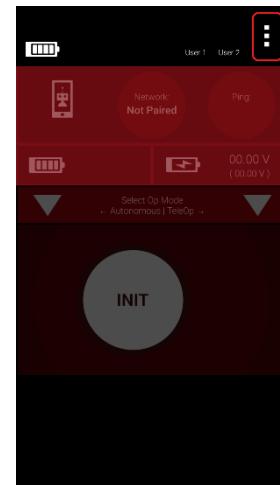


Step 3:

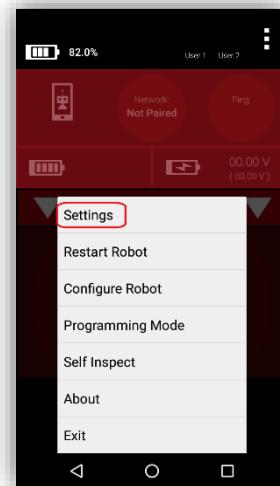
On your Driver Station phone, find the FTC Driver Station app icon. Tap on the icon to launch the Driver Station app.

**Step 4:**

Touch the three vertical dots on the upper right hand corner of the main screen of the FTC Driver Station app. This will launch a pop-up menu.

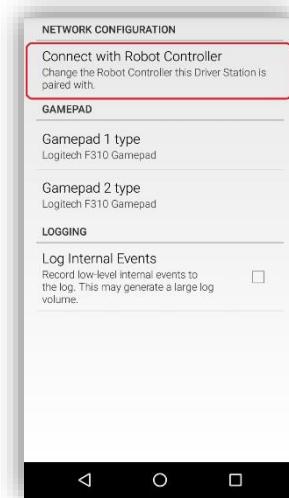
**Step 5:**

Select **Settings** from the pop-up menu.



Step 6:

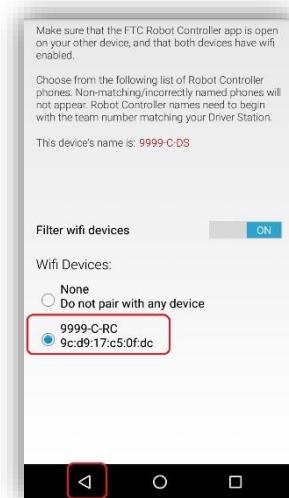
From the Settings screen, look for and select “Connect with Robot Controller” to launch the Connect with Robot Controller screen.

**Step 7:**

Find the name of your Robot Controller from the list and select it.

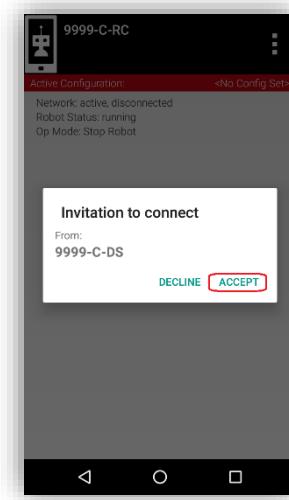
After you have made your selection, use the back-arrow key to return to the Settings screen.

Then press the back-arrow key one more time to return to the main Driver Station screen.

**Step 8:**

When the Driver Station returns to its main screen, the first time you attempt to connect to the Robot Controller a prompt should appear on the Robot Controller screen.

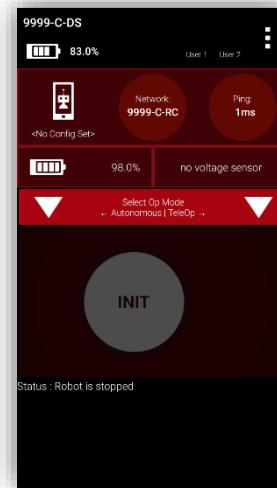
Click on the “ACCEPT” button to accept the connection request from the Driver Station.



Step 9:

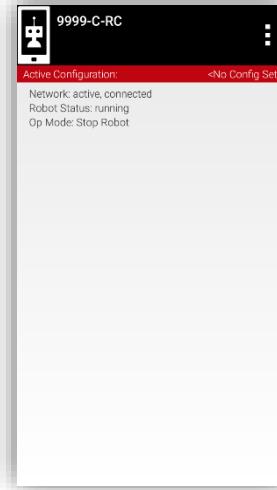
Verify that the Driver Station screen has changed and that it now indicates that it is connected to the Robot Controller.

The name of the Robot Controller's remote network ("9999-C-RC" in this example) should be displayed in the **Network** field on the Driver Station.

**Step 10:**

Verify that the Robot Controller screen has changed and that it now indicates that it is connected to the Driver Station.

The **Network** status should read "active, connected" on the Robot Controller's main screen.



7 Connecting Devices to an Expansion Hub

This section demonstrates how to connect and configure devices to your REV Robotics Expansion Hub. For the examples in this document, we will connect the Expansion Hub through a switch to a 12V battery. We will then connect a DC motor, a servo and some sensors to the Expansion Hub.

7.1 Connecting 12V Power to the Expansion Hub

The Expansion Hub draws power from a 12V rechargeable battery. For safety reasons, the battery has a 20A fuse built in. A mechanical switch is used to turn on/turn off the power.

Connecting 12V Power to the Expansion Hub (Time Needed to Complete Task: 5 minutes)

Step 1:

If your 12V battery has a Tamiya style connector, connect the Tamiya to XT30 adapter cable to the matching end of the switch cable.



Do not plug connect the 12V battery to the Tamiya adapter yet. We will connect the battery during a later step.

Step 2:

Connect the other end of the switch cable to a matching XT30 port on the Expansion Hub.



Step 3:

Verify that the switch is in the OFF position.

**Step 4:**

Connect the 12V battery to the Tamiya to XT30 cable.



Step 5:

Turn on the switch and verify that the Expansion Hub is drawing power from the battery. Note that the Expansion Hub's LED should be illuminated (notice blue LED in image below).

**Step 6:**

Turn off the switch and verify that the Expansion Hub is off. Note that the Expansion Hub's LED should not be illuminated.



7.2 Connecting a Motor to the Expansion Hub

The Expansion Hub can drive up to four (4) 12V DC motors per Expansion Hub. The Expansion Hub uses a type of electrical connector known as a 2-pin JST VH connector. At the time that this document was written, the FIRST-approved 12V DC motors were equipped with Anderson Powerpole connectors. An adapter cable is used to connect the Anderson Powerpole connectors to the Expansion Hub motor port.

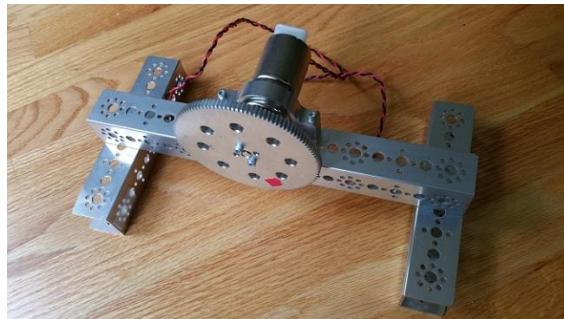


Figure 3 - Motor test rig made from Tetrix build components.

For the examples in this document, FIRST recommends that the user build a simple rig to secure the motor in place and prevent it from moving about during the test runs. The image above shows a Tetrix motor installed in a rig built with a Tetrix motor mount and some Tetrix C-channels. A gear was mounted on the motor shaft to make it easier for the user to see the rotation of the shaft.

Connecting a 12V DC Motor to the Expansion Hub (Time Needed to Complete Task: 2.5 minutes)

Step 1:

Connect the Anderson Powerpole end of the motor's power cable to the Powerpole end of the Anderson to JST VH adapter cable.



Step 2:

Connect the other end of the Anderson to JST VH adapter cable into the motor port labeled "0" on the Expansion Hub.



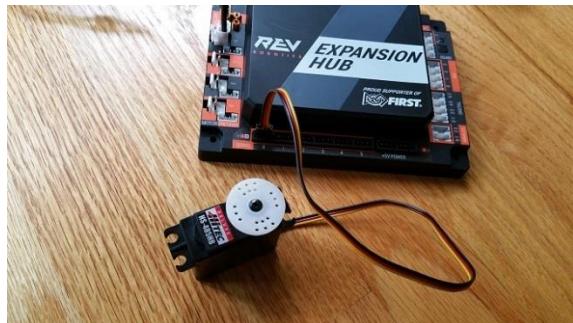
7.3 Connecting a Servo to the Expansion Hub

The REV Robotics Expansion Hub has 6 built-in servo ports. The servo ports accept the standard 3-wire header style connectors commonly found on servos. Note that ground pin is on the left side of the servo port.

Connecting a Servo to the Expansion Hub (Time Needed to Complete Task: 2.5 minutes)

Step 1:

Connect the servo cable to the servo port labeled “0” on the Expansion Hub. Note that the ground pin is on the left side of the servo port.



Step 2:

Verify that the black ground wire of the servo cable matches the ground pin of the servo port (which is aligned on the left side of the port).



7.4 Connecting a Color-Distance Sensor to the Expansion Hub

The Expansion Hub has 4 independent I2C buses. Each bus has its own port on the Hub. We will connect a REV Robotics Color-Distance sensor to the I2C bus #0 on the Expansion Hub.

Connecting a Color-Distance Sensor to the Expansion Hub (Time Needed to Complete Task: 2.5 minutes)

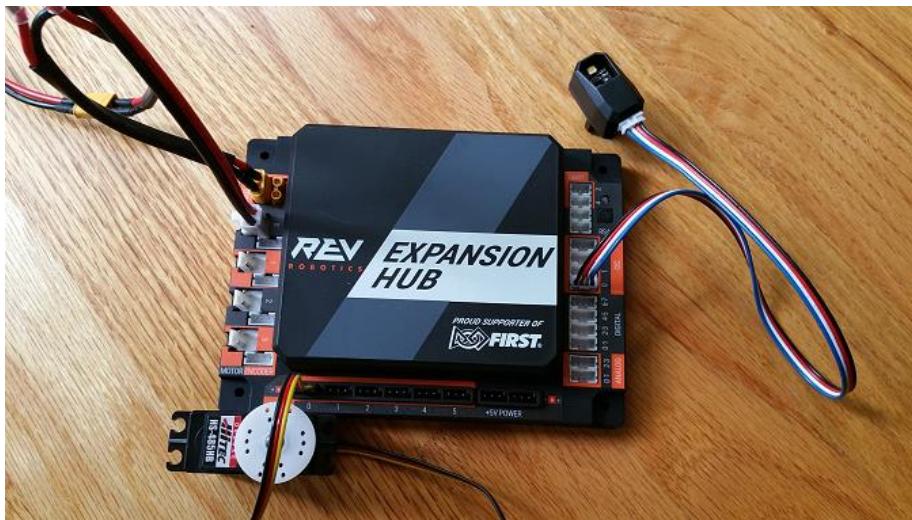
Step 1:

Connect the one end of the 4-pin JST PH cable to the REV Robotics Color-Distance sensor.



Step 2:

Plug the other end of the 4-pin JST PH cable to the I2C port labeled “0” on the Expansion Hub.



7.5 Connecting a Touch Sensor to the Expansion Hub

The Expansion Hub has 4 independent digital input/output (I/O) ports. Each port has two digital I/O pins for a total of 8 digital I/O pins on an Expansion Hub. You will connect a REV Robotics Touch sensor to one of the digital I/O ports.

Note that in the case of the REV Robotics Touch Sensor, the device has a connector port for a 4-pin sensor cable. However, the device only needs to connect to one of the two available digital I/O pins. For the REV Robotics Touch Sensor, the second digital I/O in the port is the one that gets connected when a standard REV Robotics 4-pin JST PH cable is used. For the “0-1” port, it is the pin labeled “1” that gets connected through the 4-pin cable. Similarly, for the “2-3” port, it is the pin labeled “3” that gets connected through the 4-pin cable.

Connecting a Touch Sensor to the Expansion Hub (Time Needed to Complete Task: 2.5 minutes)

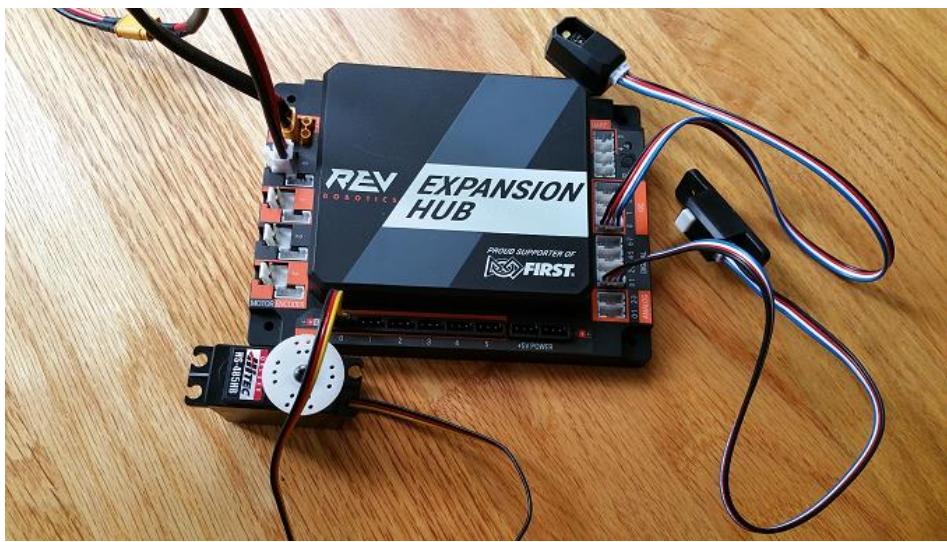
Step 1:

Connect the one end of the 4-pin JST PH cable to the REV Robotics Touch sensor.



Step 2:

Plug the other end of the 4-pin JST PH cable to digital I/O port labeled “0-1” on the Expansion Hub.



8 Configuring Your Hardware on the Robot Controller

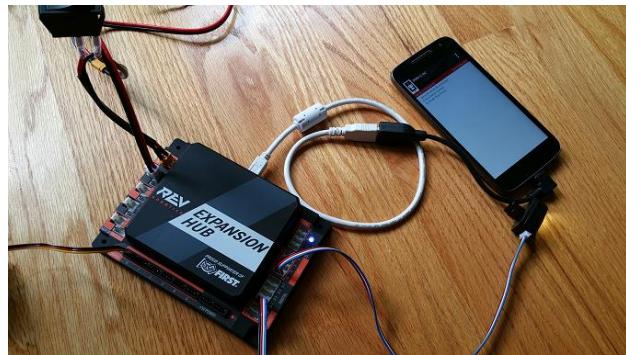
Before you can communicate with the motor, servo and sensors that are connected to the Expansion Hub, you first must create a configuration file on your Robot Controller smartphone, so that the Robot Controller will know what hardware is available on the Expansion Hub.

Creating a Configuration File on the Robot Controller (Time Needed to Complete Task: 20 minutes)	
Connecting the Phone to the Expansion Hub	
Step 1: Power on the Expansion Hub by turning on the power switch.	
Step 2: Plug the Type B Mini end of the USB cable into the USB mini port on the Expansion Hub.	
Step 3: Plug the Type A end of the USB cable into the OTG adapter.	

Step 4:

Verify that your Robot Controller smartphone is powered on and unlocked. Plug in the USB Micro OTG adapter into the OTG port of the Robot Controller phone.

Note that when the OTG adapter is plugged into the smartphone, the phone will detect the presence of the Expansion Hub and launch the Robot Controller app.

**Step 5:**

The first time you connect the Robot Controller smartphone to the Expansion Hub, the Android operating system should prompt you to ask if it is OK to associate the newly detected USB device (which is the Expansion Hub) with the FTC Robot Controller app.

Important Information!

You might be prompted multiple times to associate the USB hardware with the FTC Robot Controller. Whenever you are prompted by your phone with this message, you should **always** select the “Use by default for this USB device” option and hit the “OK” button to associate the USB device with the FTC Robot Controller app.

If you fail to make this association, then the Robot Controller app might not reliably connect to this Expansion Hub the next time you turn your system on.

FTC Robot Controller

Open FTC Robot Controller when this USB device is connected?

Use by default for this USB device

Clear default in System settings > Apps > Downloaded.

CANCEL

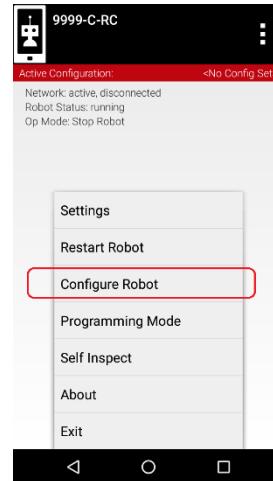
OK

Step 6:

Touch the three vertical dots in the upper right hand corner of the Robot Controller. This will launch a pop-up menu.

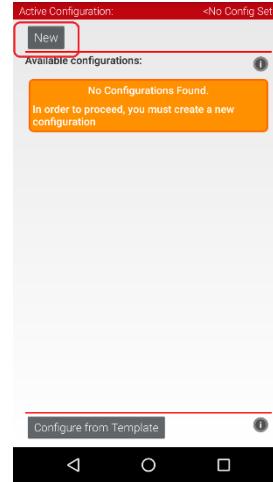
**Step 7:**

Select **Configure Robot** from the pop up menu to display the Configuration screen.

**Step 8:**

If your Robot Controller does not have any existing configuration files, the screen will display a message indicating that you need to create a file before proceeding.

Hit the “New” button to create a new configuration file for your Robot Controller



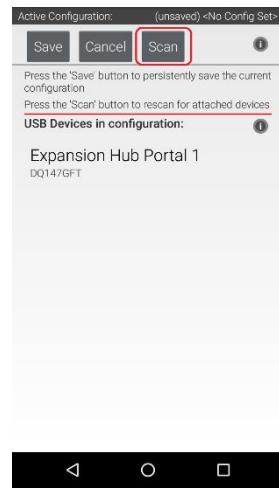
Step 9:

When the new configuration screen appears, the Robot Controller app will do a scan of the USB bus to see what devices are connected to the phone.

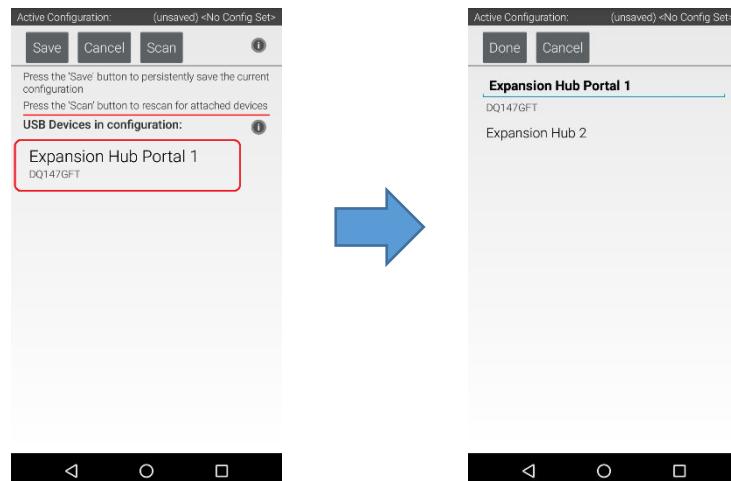
It will display the devices that it found in a list underneath the words “USB Devices in configuration.” You should see an entry that says something like “Expansion Hub Portal 1” in the list.

Your Expansion Hub is listed as a **Portal** because it is directly connected to the Robot Controller phone through the USB cable.

If you do not see your Expansion Hub Portal listed, check the wired connections and then press the **Scan** button one or two times to see if the phone detects the device on a re-scan of the USB bus.

**Step 12:**

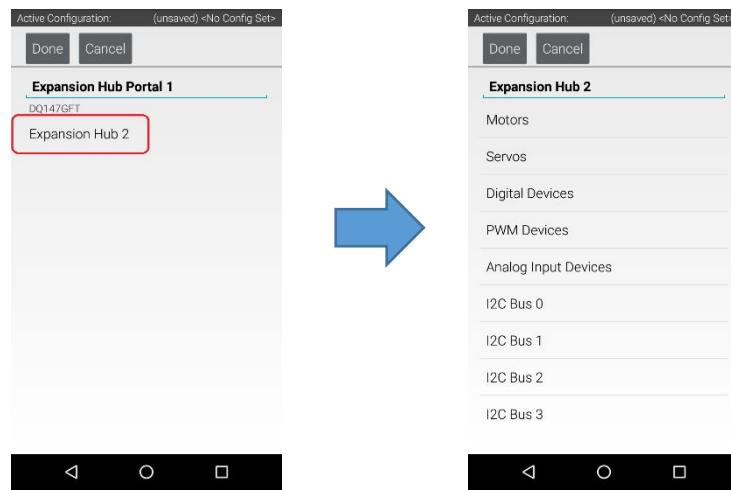
Touch the Portal listing (“Expansion Hub Portal 1” in this example) to display what Expansion Hubs are connected through this Portal.



Since we only have a single Expansion Hub connected, we should only see a single Expansion Hub configured (“Expansion Hub 2” in this example).

Step 13:

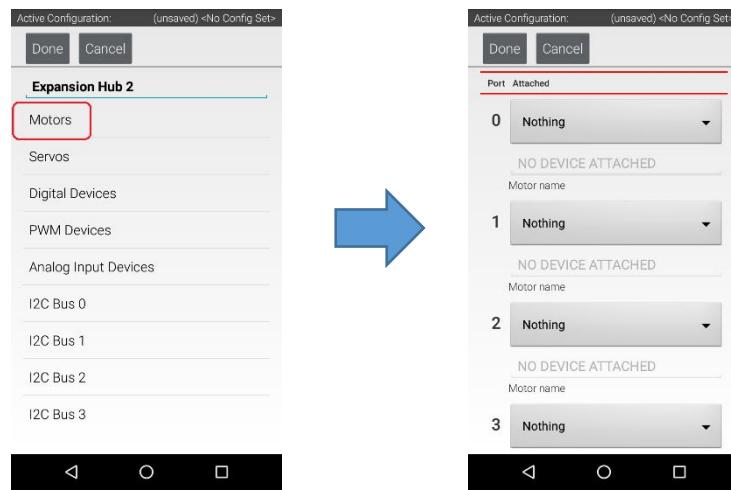
Touch the Expansion Hub listing (“Expansion Hub 2” in this example) to display the Input/Output ports for that device.



The screen should switch and list all the motor, servo and sensor ports that are available on the selected Expansion Hub.

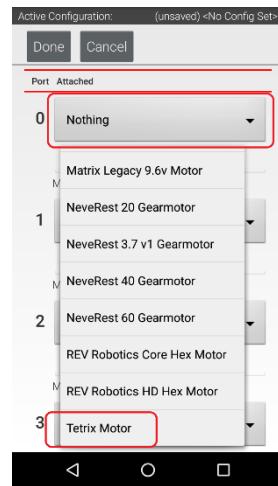
Configuring the DC Motor
Step 14:

Touch the word **Motors** on the screen to display the Motor Configuration screen.

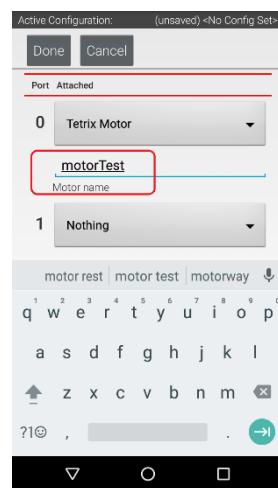


Step 15:

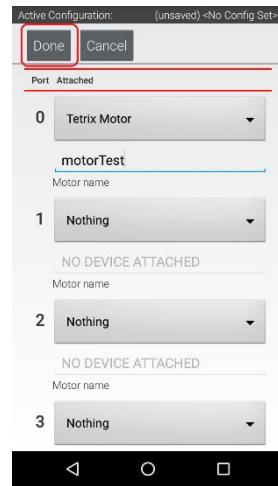
Since we installed our motor onto port #0 of the Expansion Hub, use the dropdown control for port 0 to select the motor type (Tetrix Motor for this example).

**Step 16:**

Use the touch screen keypad to specify a name for your motor ("motorTest" in this example).

**Step 17:**

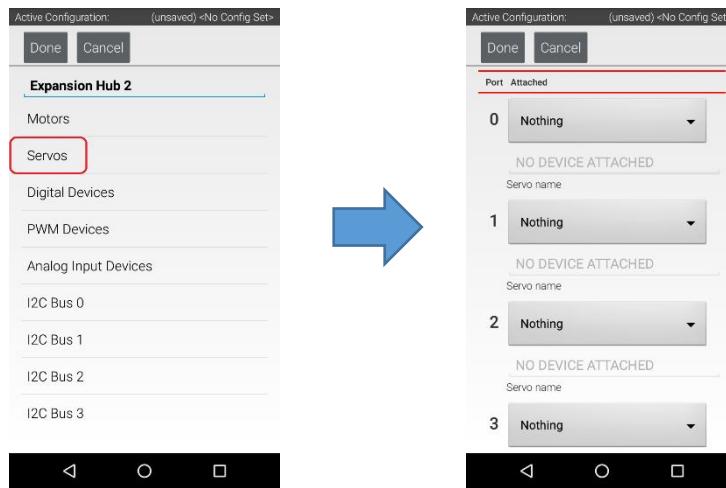
Press the **Done** button to complete the motor configuration. The app should return to the previous screen.



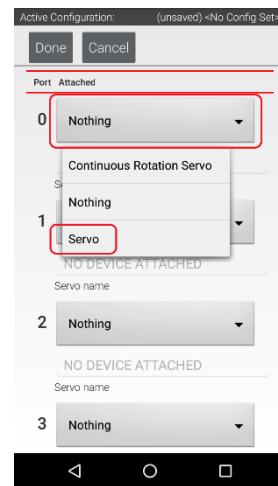
Configuring the Servo

Step 18:

Touch on the word **Servos** on the screen to display the Servo Configuration screen.


Step 19:

Use the dropdown control to select “Servo” as the servo type for port #0.

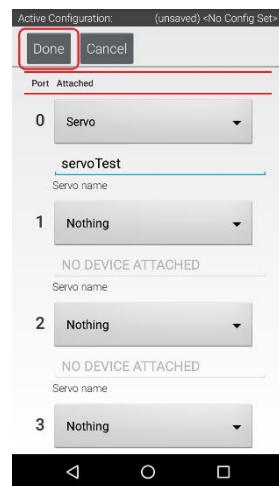


Step 20:

Use the touch pad to specify the name of the servo (“servoTest” for this example) for port #0.

**Step 21:**

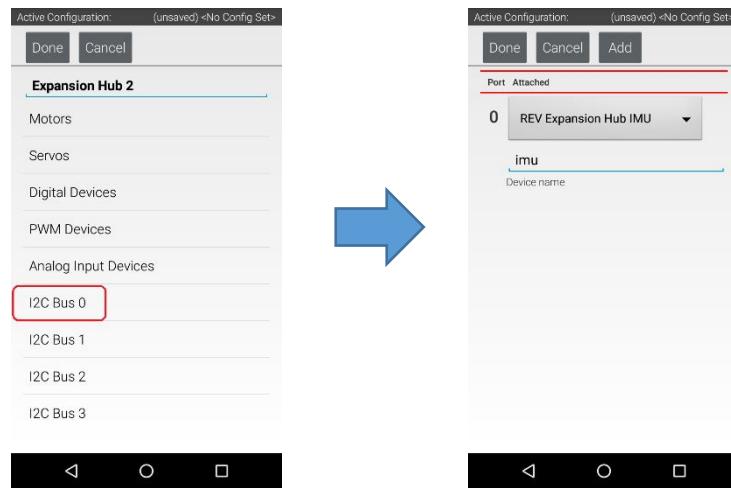
Press the **Done** button to complete the servo configuration. The app should return to the previous screen.



Configuring the Color Sensor

Step 22:

Touch the words **I2C Bus 0** on the screen to launch the I2C configuration screen for this I2C bus.



The Expansion Hub has four independent I2C buses, labeled "0" through "3". In this example, since you connected the Color Sensor to the port labeled "0", it resides on I2C Bus 0.

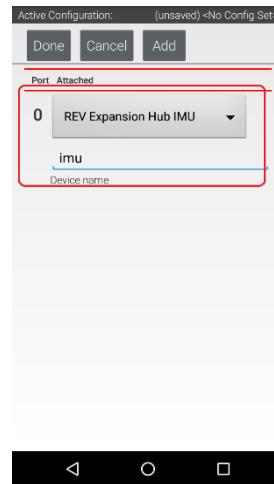
Step 23:

Look at the I2C Bus 0 screen. There should already be a sensor configured for this bus.

The Expansion Hub has its own built-in inertial measurement unit (IMU) sensor. This sensor can be used to determine the orientation of a robot, as well as measure the accelerations on a robot.

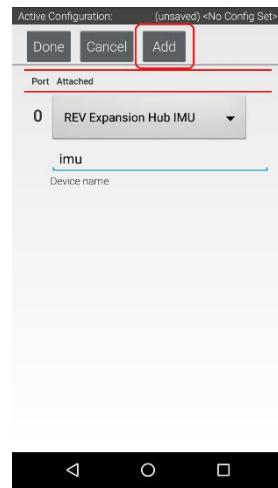
The built-in IMU is internally connected to I2C Bus 0 on each Expansion Hub. Whenever you configure an Expansion Hub using the Robot Controller, the app automatically configures the IMU for I2C Bus 0.

You will need to add another I2C device for this bus to be able to configure the color sensor.

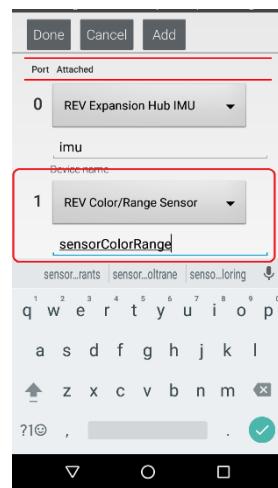


Step 24:

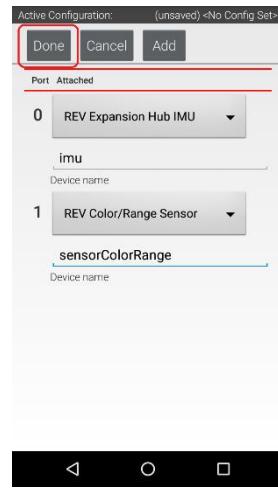
Press the **Add** button to add another I2C device to this bus.

**Step 25:**

Select “REV Color/Range Sensor” from the dropdown selector for this new device. Use the touchscreen keyboard to name this device “sensorColorRange”.

**Step 26:**

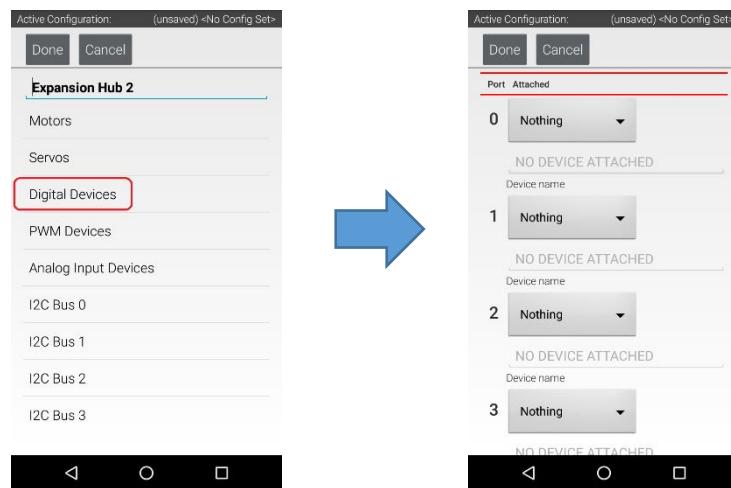
Press the **Done** button to complete the I2C sensor configuration. The app should return to the previous screen.



Configuring the Touch Sensor

Step 27:

Touch the words **Digital Devices** on the screen to launch the Digital I/O configuration screen.


Step 28:

Use the touch screen to add a “Digital Device” for port #1 and name the device “digitalTouch”.

Notice that we are configuring the Touch Sensor on port #1 instead of port #0. This is because when the REV Robotics Touch Sensor is connected to a digital port using a standard 4-wire JST sensor cable, it is the second digital pin that is connected. The first pin remains disconnected.

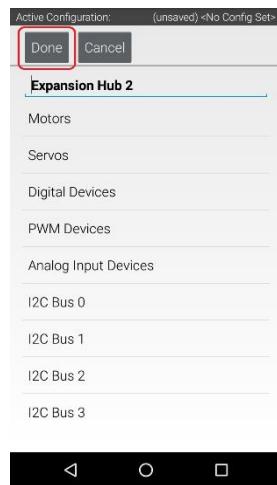


Step 29:

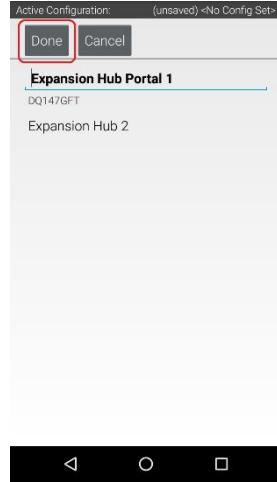
Press the **Done** button to return to the previous screen.

**Saving the Configuration Information****Step 30:**

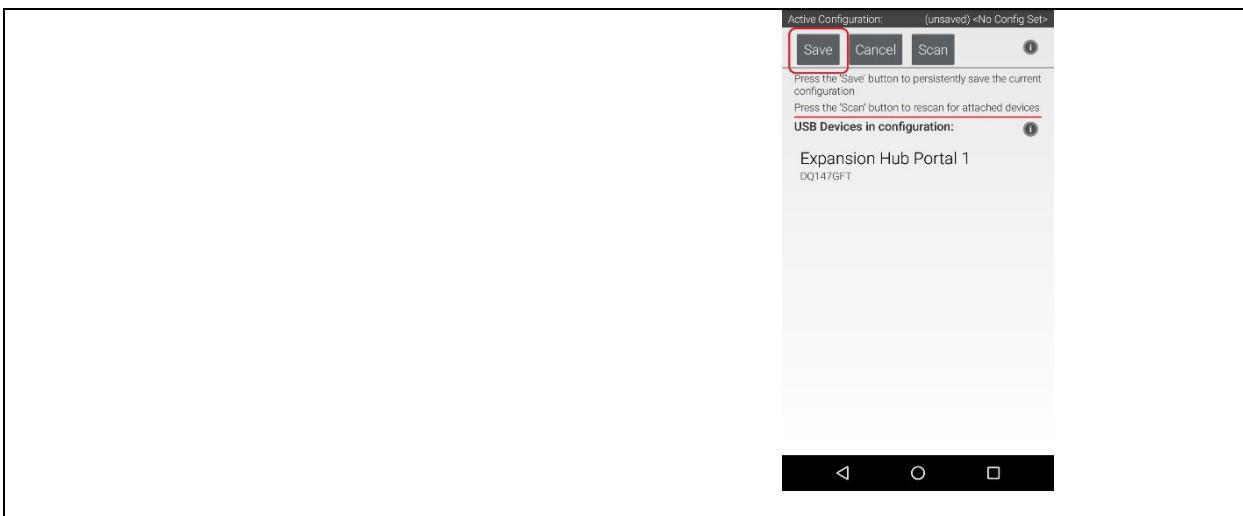
Press the **Done** button to go up one level in the configuration screens.

**Step 31:**

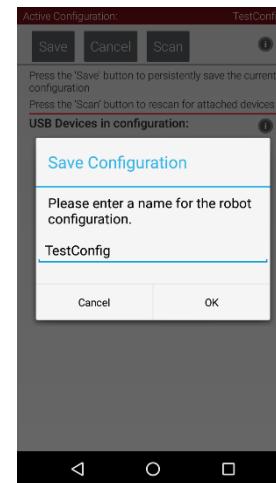
Press the **Done** button again to return to the highest level in the configuration screens.

**Step 32:**

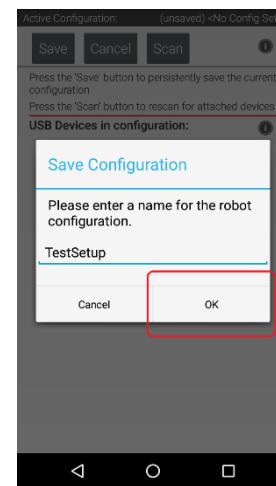
Press the **Save** button.

**Step 33:**

When prompted, specify a configuration file name using the touchscreen's keypad (use "TestConfig" for this example).

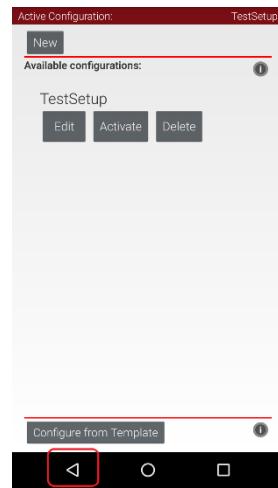
**Step 34:**

Press the **OK** button to save your configuration information using that file name.

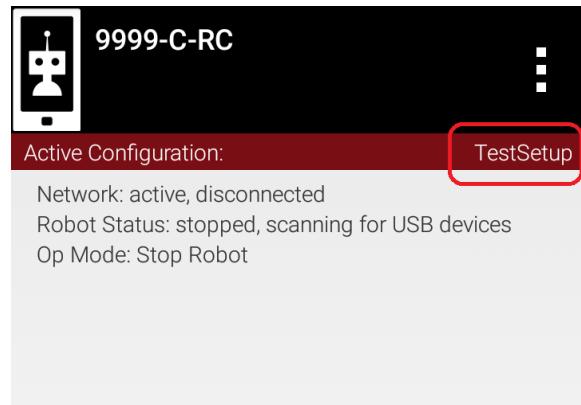


Step 35:

After the configuration file has been saved, touch the Android back-arrow button to return to the main screen of the app.

**Step 36:**

Verify that the configuration file is the active configuration file on the main Robot Controller screen.



9 Writing an Op Mode

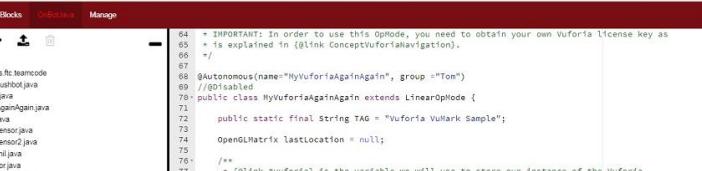
9.1 What's an Op Mode?

During a typical FIRST Tech Challenge match, a team's robot must perform a variety of tasks to score points. For example, a team might want their robot to follow a white line on the competition floor and then score a game element into a goal autonomously during a match. Teams write programs called “op modes” (which stands for “operational modes”) to specify the behavior for their robot. These op modes run on the Robot Controller phone after being selected on the Driver Station phone.

Teams who are participating in the FIRST Tech Challenge have a variety of programming tools that they can use to create their own op modes. This document explains how to use the FTC OnBot Java Programming Tool to write an op mode for an FTC robot.

9.2 The FTC OnBot Java Programming Tool

The *FTC OnBot Java Programming Tool* is a user-friendly programming tool that is served up by the Robot Controller phone. A user can create custom op modes for their robot using this tool and then save these op modes directly onto the Robot Controller. Users write their op modes using Java. The op modes are compiled very quickly on the Robot Controller and then loaded dynamically by the Robot Controller during run time.



The screenshot shows a Java code editor with the following code:

```
64 + IMPORTANT: In order to use this OpMode, you need to obtain your own Vuforia license key as
65 + is explained in {link ConceptVuMarkNavigation}.
66 +/
67 +
68 @Autonomous(name="MyVuforiaAgainAgain", group = "Tom")
69 //@Disabled
70 public class MyVuforiaAgainAgain extends LinearOpMode {
71
72     public static final String TAG = "Vuforia VuMark Sample";
73
74     OpenGLMatrix lastLocation = null;
75
76     /**
77      * {@link #vuforia} is the varable we will use to store our instance of the Vuforia
78      * localization engine.
79     */
80     VuforiaLocalizer vuforia;
81
82     @Override public void runOpMode() {
83
84         /*
85          * To start up Vuforia, tell the view that we wish to use for camera monitor (on the RC phone)
86          * If no camera monitor is desired, use the parameterless constructor instead (commented out).
87         */
88     }
89 }
```

Build started at Tue Sep 05 2017 08:39:26 GMT+0400 (Eastern Daylight Time)

Build finished in 2.6 seconds

Build succeeded!

Figure 4 – Users create, edit and build their op modes using web browser.

The examples in this document use a Windows laptop computer to connect to the Robot Controller. This Windows laptop computer has a Javascript-enabled web browser installed that is used to access the FTC OnBot Java Programming Tool.



Note that if you prefer, you can use an alternate device, such as an Apple Mac laptop, Chromebook, or an iPad instead of a Windows computer to access the OnBot Java Programming Tool. The instructions included in this document, however, assume that you are using a Windows laptop.

9.3 *Installing a Javascript-Enabled Browser*

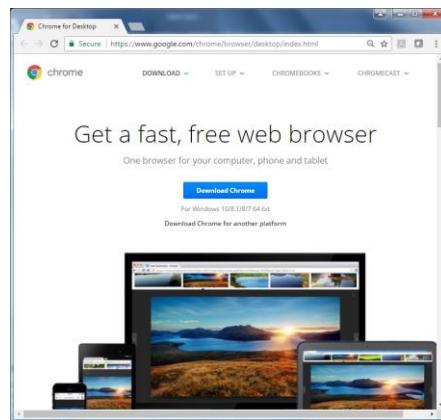
To be able to program using the OnBot Java Programming Tool, your laptop will need a Javascript-enabled browser. FIRST recommends the use of Google Chrome as the Javascript-enabled browser for the OnBot Java Programming Tool. The OnBot Java Programming Tool has been thoroughly tested using Google Chrome.

Installing Javascript-Enabled Browser (Time Needed to Complete Task: 15 minutes)

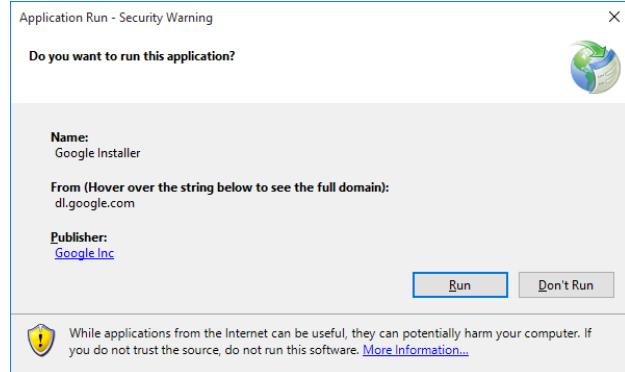
Step 1:

Visit the Google Chrome website (using your computer's existing browser) and follow onscreen instructions to download and install Chrome.

<https://www.google.com/chrome/browser/desktop/index.html>

**Step 2:**

Note that your computer might prompt you with a security warning during the installation process. If you are prompted with this warning, click on the “Run” button to continue with the installation.



9.4 Connecting Your Laptop to the Program & Manage Server

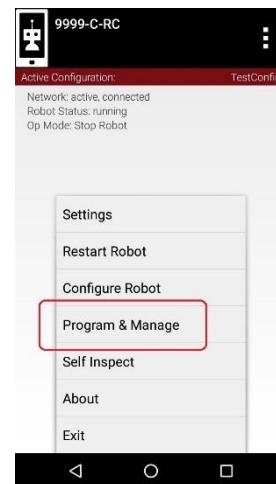
You will need to access the Program & Manage server, which runs on the Robot Controller app. You will want to connect your laptop's wireless adapter to the Program & Manage server's Wi-Fi network. Before you begin this exercise, please make sure that your Windows laptop has the most current service packs and system updates from Microsoft installed.⁴

Connecting Your Laptop to the Programming Mode Server (Time Needed to Complete Task: 20 minutes)

Step 1:

On the Robot Controller, touch the three dots in the upper right hand corner of the screen to launch the pop-up menu.

Select “Program & Manage” from the pop-up menu to display the Program & Manage access information.



Step 2:

Verify that the Robot Controller is now on the Program & Manage screen.

The Program & Manage screen displays important information that you will use to connect your laptop to the Program & Manage server.

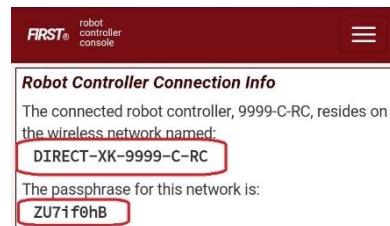


⁴ This example assumes the user has a Windows 10 laptop. If you are not using a Windows laptop, the procedure to connect to the Program & Manager server will differ. Refer to your device's documentation for details on how to connect to a Wi-Fi network.

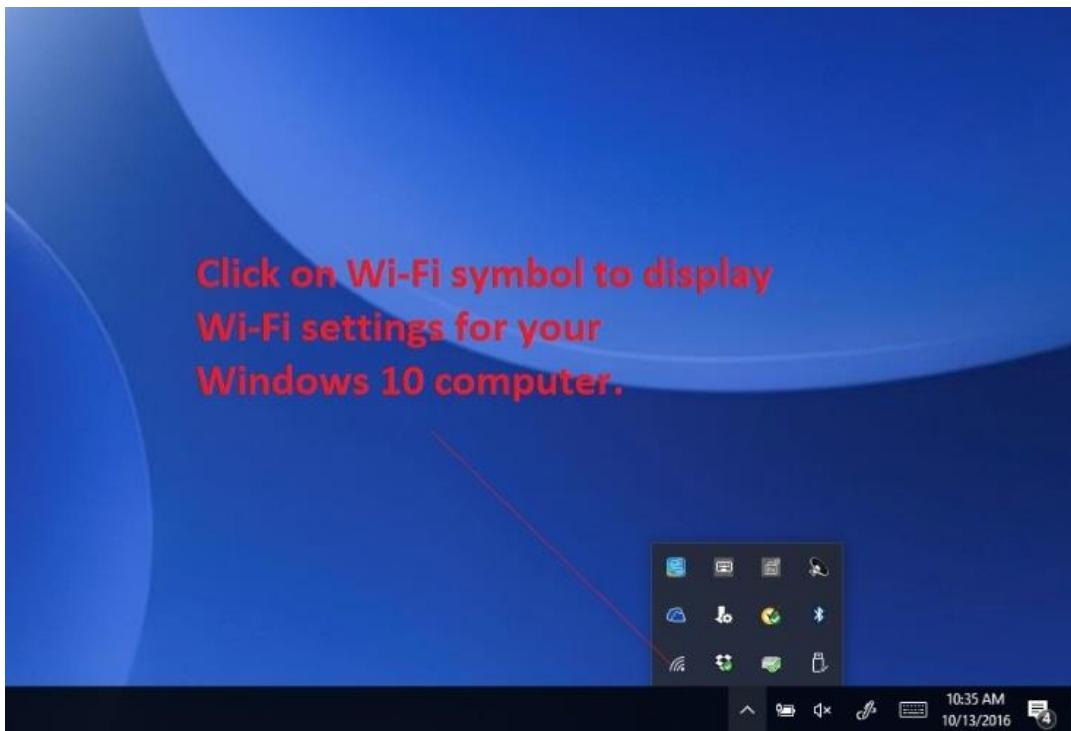
Step 3:

Verify the network name and pass phrase for the Program & Manage server's wireless network.

Towards the top of the screen, the name of the Program & Manage wireless network is displayed. In this example, the name of the Wi-Fi network is "DIRECT-XK-9999-C-RC" and the secure passphrase is "ZU7if0hB".

**Step 4:**

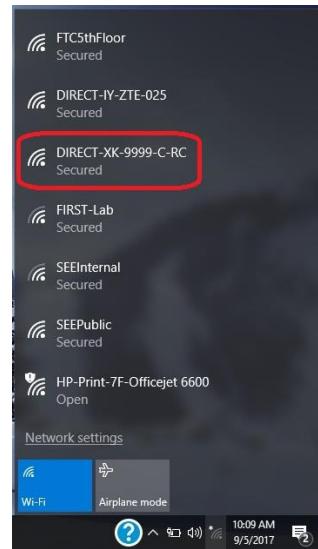
On your Windows 10 computer, look in the lower right hand corner of your desktop for a Wi-Fi symbol. Click on the Wi-Fi symbol to display a list of available Wi-Fi Networks in your vicinity.



Step 5:

Look for the wireless network that matches the name displayed on the Robot Controller.

In this example, the name of the wireless network is “DIRECT-XK-9999-C-RC” and the network is visible in the list displayed on the Windows 10 computer.

**Step 6:**

Once you have found the target network in the list, click on it to select it.

Press the **Connect** button to connect to the network.

**Step 7:**

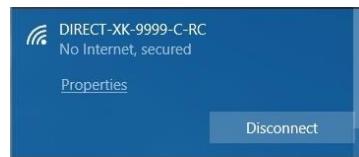
When prompted, provide the network passphrase (in this example “ZU7if0hB”) and press “Next” to continue.

Note that the passphrase is *case sensitive*. Make sure that your spelling and capitalization matches the original spelling and capitalization shown on the Program & Manage screen.



Step 8:

Once you have successfully established a wireless connection between your Windows 10 laptop and your Robot Controller Android device, the status should be displayed in the wireless settings for your laptop.



If the display is not updated as shown after a few seconds, try clicking on Network Connections at the bottom of the blue box showing the Wi-Fi connections. This will bring up a Setting dialog box that includes a link to "Show available networks.", which can be used to force the list of Wi-Fi connections to be updated.

Note that when you are connected to the blocks programming mode server on your Robot Controller phone, *your laptop will not have access to the Internet*. It only has direct access to the Robot Controller.

9.5 Troubleshooting Your Wireless Connection

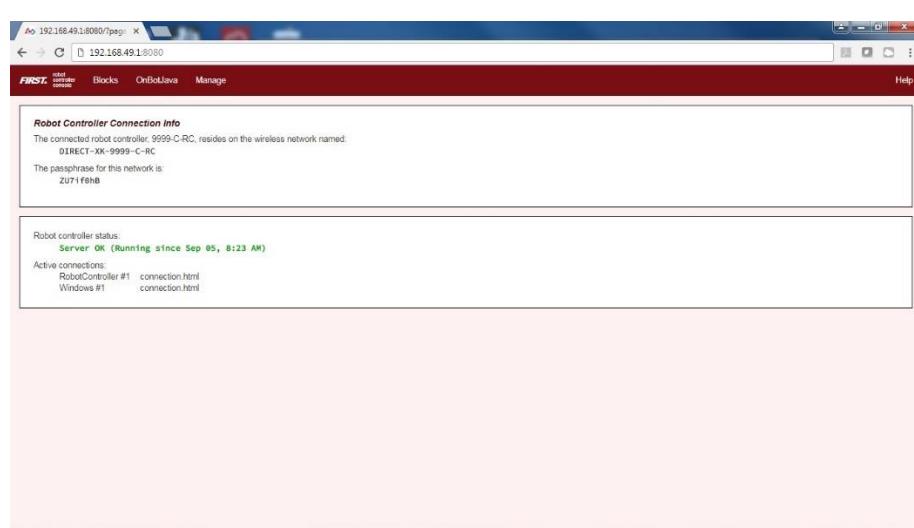
If you cannot see your Program & Manage wireless network in the list of available networks, or, if you are having problems connecting your laptop to Program & Manage wireless network, make sure you answer the following questions:

1. Is the Robot Controller running and connected to the Driver Station?
2. Is your Windows laptop updated with the most current system updates and service packs? Older versions of Windows 8 and 10, for example, had issues that could prevent the laptop from displaying the Program & Manage wireless network in the list of available networks.

If you are still having issues with connecting the laptop to the Robot Controller, visit section 13.1 of this document for instructions on how to manually connect to the Program & Manage wireless network with a Windows 10 laptop.

9.6 Creating Your First Op Mode

If you connected your laptop successfully to the Program & Manage wireless network of the Robot Controller, then you are ready to create your first op mode. In this section, you will use the OnBot Java Programming Tool to create the program logic for your first op mode.

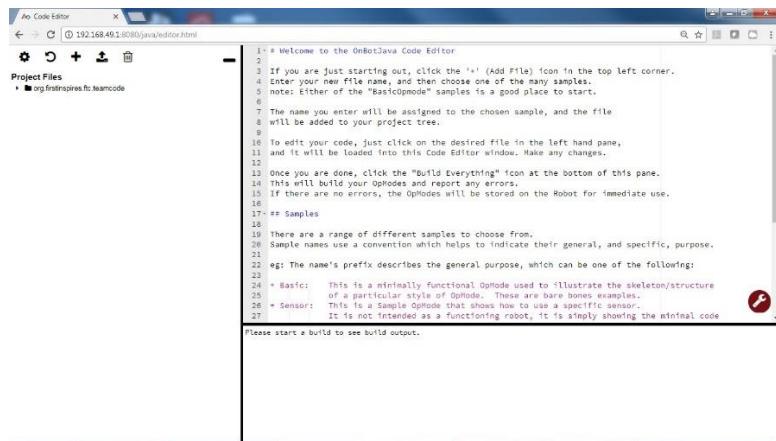
Creating Your First Op Mode (Time Needed to Complete Task: 10 minutes)	
<p>Step 1:</p> <p>Launch the web browser on your laptop (FIRST recommends using Google Chrome).</p> <p>Find the web address that is displayed on the Program & Manage screen of the Robot Controller. In our example, the web address is “192.168.49.1:8080”.</p> <p>Type this web address into the address field of your browser to navigate to the Program & Manage web server.</p>	<p>To remotely connect to the controller, connect your laptop's wireless adapter to this network, using the passphrase to gain access. Once connected, enter the following address into your web browser:</p> <p style="border: 1px solid red; padding: 2px;">http://192.168.49.1:8080</p> 
<p>Step 2:</p> <p>Verify that your web browser is connected to the Program & Manage server. If it connected to the Program & Manage server successfully, then you should see the main Robot Controller Connection screen.</p> 	

Step 3:

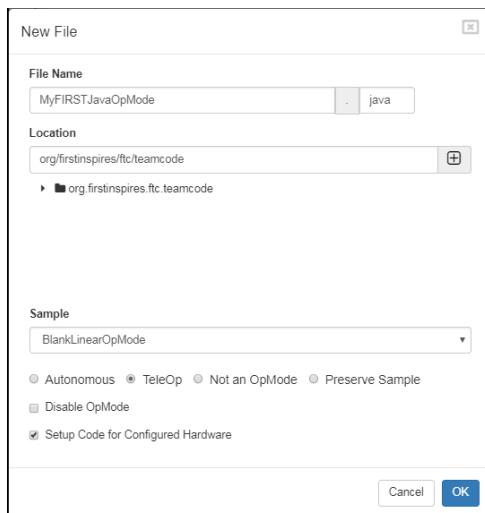
Click on the word “OnBotJava” towards the top of the screen. This will switch the browser to the OnBot Java Programming mode.

**Step 4:**

Take a look at the OnBot Java user interface. On the left hand side, there is the project browser pane. In the upper right hand corner, there is the source code editing pane. In the lower right hand corner, there is the message pane.

**Step 5:**

In the project browser pane, press the “+” symbol to create a new file. Pushing this button will launch the New File dialog box. This dialog box has several parameters that you can configure to customize your new file.



For this example, specify “MyFIRSTJavaOpMode” as the File Name in the New File dialog box.

Using the Sample dropdown list control, select “BlankLinearOpMode” from the list of available sample op modes (see image above). By selecting “BlankLinearOpMode” the OnBot Java editor will automatically generate a basic LinearOpMode framework for you.

Check the option labeled “TeleOp” to ensure that this new file will be configured as a tele-operated (i.e., driver controlled) op mode.

Also, make sure you check the “Setup Code for Configured Hardware” option. If this option is enabled, the OnBot Java editor will look at the hardware configuration file for your Robot Controller and automatically generate the code that you will need to access the configured devices in your op mode.

Press the “OK” button to create your new op mode.

Step 6

You should see your newly created op mode in the editing pane of the OnBot Java user interface.

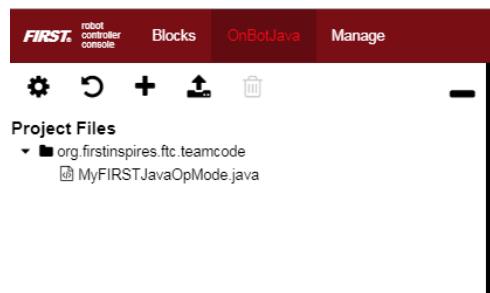
```

1  /*
2  Copyright 2017 FIRST Tech Challenge Team 9999
3
4  Permission is hereby granted, free of charge, to any person obtaining a copy of this software and
5  associated documentation files (the "Software"), to deal in the Software without restriction,
6  including without limitation the rights to use, copy, modify, merge, publish, distribute,
7  sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is
8  furnished to do so, subject to the following conditions:
9
10 The above copyright notice and this permission notice shall be included in all copies or substantial
11 portions of the Software.
12
13 THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT
14 NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND
15 NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM,
16 DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
17 OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.
18 */
19 package org.firstinspires.ftc.teamcode;
20
21 import com.qualcomm.robotcore.eventloop.opmode.LinearOpMode;
22 import com.qualcomm.robotcore.hardware.Gyroscope;
23 import com.qualcomm.robotcore.hardware.DigitalChannel;
24 import com.qualcomm.robotcore.hardware.DistanceSensor;
25 import com.qualcomm.robotcore.hardware.Servo;
26 import com.qualcomm.robotcore.eventloop.opmode.TeleOp;

```



Congratulations, you created your first op mode! The op mode currently does not do much, but you will eventually modify it to make it more useful.



Note that when you create an OnBot op mode, you create a .java file that is stored on the Robot Controller. You can access your saved op modes using the project browser on the left side of the screen. You can also organize your saved op modes by right mouse clicking on the project browser to display a list of options to create, edit or delete files and folders.

Also, note that the OnBot Java editor automatically saves your op mode as you are editing it, provided that you are connected to the Program & Manage server.

9.7 Examining the Structure of Your Op Mode

It can be helpful to think of an op mode as a list of tasks for the Robot Controller to perform. For a linear op mode, the Robot Controller will process this list of tasks sequentially. Users can also use control loops (such as a *while* loop) to have the Robot Controller repeat (or iterate) certain tasks within a linear op mode.



Figure 5 - It can be helpful to think of an op mode as a task list for the Robot Controller.⁵

If you think about an op mode as a list of instructions for the robot, this set of instructions that you created will be executed by the robot whenever a team member selects the op mode called “MyFIRSTJavaOpMode” from the list of available op modes for this Robot Controller.

Let’s look at the structure of your newly created op mode. Here’s a copy of the op mode text (minus some comments, the package definition, and some import package statements):

```
@TeleOp

public class MyFIRSTJavaOpMode extends LinearOpMode {
    private Gyroscope imu;
    private DcMotor motorTest;
    private DigitalChannel digitalTouch;
    private DistanceSensor sensorColorRange;
    private Servo servoTest;

    @Override
    public void runOpMode() {
        imu = hardwareMap.get(Gyroscope.class, "imu");
        motorTest = hardwareMap.get(DcMotor.class, "motorTest");
        digitalTouch = hardwareMap.get(DigitalChannel.class, "digitalTouch");
        sensorColorRange = hardwareMap.get(DistanceSensor.class, "sensorColorRange");
        servoTest = hardwareMap.get(Servo.class, "servoTest");

        telemetry.addData("Status", "Initialized");
        telemetry.update();
        // Wait for the game to start (driver presses PLAY)
        waitForStart();

        // run until the end of the match (driver presses STOP)
        while (opModeIsActive()) {
            telemetry.addData("Status", "Running");
            telemetry.update();
        }
    }
}
```

At the start of the op mode there is an annotation that occurs before the class definition. This annotation states that this is a tele-operated (i.e., driver controlled) op mode:

```
@TeleOp
```

⁵ Clip art image was downloaded from ClipArtBest.com on 10/13/16.

If you wanted to change this op mode to an autonomous op mode, you would replace the “@TeleOp” with an “@Autonomous” annotation instead.

You can see from the sample code that an op mode is defined as a Java class. In this example, the op mode name is called “MyFIRSTJavaOpMode” and it inherits characteristics from the LinearOpMode class.

```
public class MyFIRSTJavaOpMode extends LinearOpMode {
```

You can also see that the OnBot Java editor created five private member variables for this op mode. These variables will hold references to the five configured devices that the OnBot Java editor detected in the configuration file of your Robot Controller.

```
private Gyroscope imu;
private DcMotor motorTest;
private DigitalChannel digitalTouch;
private DistanceSensor sensorColorRange;
private Servo servoTest;
```

Next, there is an overridden method called runOpMode. Every op mode of type LinearOpMode must implement this method. This method gets called when a user selects and runs the op mode.

```
@Override
public void runOpMode() {
```

At the start of the runOpMode method, the op mode uses an object named *hardwareMap* to get references to the hardware devices that are listed in the Robot Controller’s configuration file:

```
imu = hardwareMap.get(Gyroscope.class, "imu");
motorTest = hardwareMap.get(DcMotor.class, "motorTest");
digitalTouch = hardwareMap.get(DigitalChannel.class, "digitalTouch");
sensorColorRange = hardwareMap.get(DistanceSensor.class, "sensorColorRange");
servoTest = hardwareMap.get(Servo.class, "servoTest");
```

The hardwareMap object is available to use in the runOpMode method. It is an object of type HardwareMap class.

Note that when you attempt to retrieve a reference to a specific device in your op mode, the name that you specify as the second argument of the HardwareMap.get method must match the name used to define the device in your configuration file. For example, if you created a configuration file that had a DC motor named “motorTest”, then you must use this same name (it is case sensitive) to retrieve this motor from the hardwareMap object. If the names do not match, the op mode will throw an exception indicating that it cannot find the device.

In the next few statements of the example, the op mode prompts the user to push the start button to continue. It uses another object that is available in the runOpMode method. This object is called *telemetry* and the op mode uses the addData method to add a message to be sent to the Driver Station. The op mode then calls the update method to send the message to the Driver Station. Then it calls the waitForStart method, to wait until the user pushes the start button on the driver station to begin the op mode run.

```
telemetry.addData("Status", "Initialized");
telemetry.update();
// Wait for the game to start (driver presses PLAY)
waitForStart();
```

Note that all linear op modes should have a waitForStart statement to ensure that the robot will not begin executing the op mode until the driver pushes the start button.

After a start command has been received, the op mode enters a while loop and keeps iterating in this loop until the op mode is no longer active (i.e., until the user pushes the stop button on the Driver Station):

```
// run until the end of the match (driver presses STOP)
while (opModeIsActive()) {
    telemetry.addData("Status", "Running");
    telemetry.update();
}
```

As the op mode iterates in the while loop, it will continue to send telemetry messages with the index of “Status” and the message of “Running” to be displayed on the Driver Station.

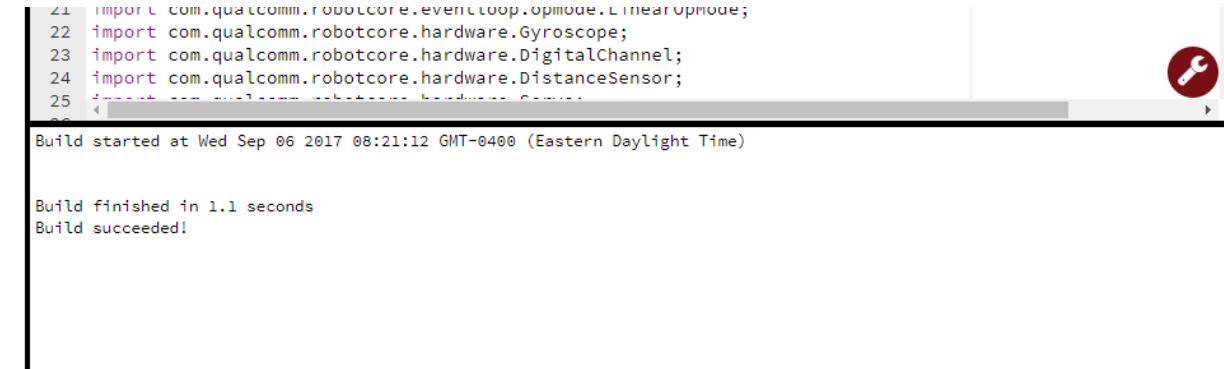
9.8 Building Your Op Mode

When you create or edit an op mode the OnBot Java editor will auto-save the .java file to the file system of the Robot Controller. However, before you can execute your changes on the Robot Controller, you must first build the op mode and convert it from a Java text file to a binary that can be loaded dynamically into the FTC Robot Controller app.

If you are satisfied with your op mode and are ready to build, press the Build button (which is the button with the wrench symbol, see image below) to start the build process. Note that the build process will build ***all of the .java files*** on your Robot Controller.



You should see messages appear in the message pane, which is located in the lower right hand side of the window. If your build was successful, you should see a “Build succeeded!” message in the message pane.



The screenshot shows the OnBot Java IDE interface. In the top left, there's a code editor with several import statements for Qualcomm RobotCore classes. In the bottom right corner of the IDE window, there is a red circular icon containing a white wrench symbol, which is the standard icon for a build or run operation. Below the code editor, the message pane displays the following text:

```

21 import com.qualcomm.robotcore.eventloop.opmode.LinearOpMode;
22 import com.qualcomm.robotcore.hardware.Gyroscope;
23 import com.qualcomm.robotcore.hardware.DigitalChannel;
24 import com.qualcomm.robotcore.hardware.DistanceSensor;
25
Build started at Wed Sep 06 2017 08:21:12 GMT-0400 (Eastern Daylight Time)

Build finished in 1.1 seconds
Build succeeded!

```

Once you have built the binary files with your updated op modes, they are ready to run on the Robot Controller. Before we run our example op mode, let’s see what happens if a problem occurs during the build process.

9.9 Troubleshooting Build Messages

In the previous section, the build process went smoothly. Let’s modify your op mode slightly to cause an error in the build process.

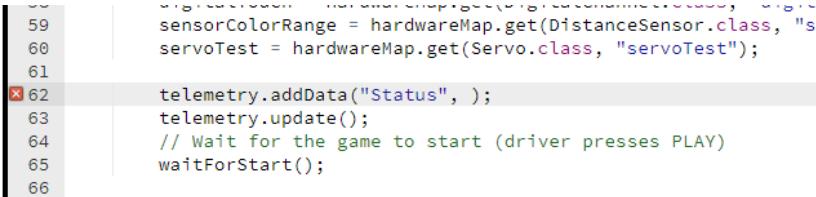
In the editing pane of the OnBot Java window, look for the line that reads “private Servo servoTest;”. This should appear somewhere near the beginning of your op mode class definition. Change the word “Servo” to the word “Zervo”:

```
private Zervo servoTest;
```

Also, let’s modify the telemetry statement that informs the user that the op mode has been initialized, and let’s remove one of the two arguments so that the statement looks like this:

```
telemetry.addData("Status", );
```

Note that when you eliminate the second argument, a little “x” should appear next to the line with the modified addData statement. This “x” indicates that there is a syntax error in the statement.



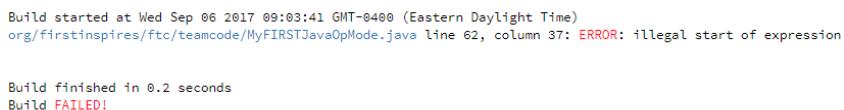
The screenshot shows the OnBot Java IDE with a code editor containing Java code. A line of code is highlighted with a red border and a small red ‘x’ icon to its left, indicating a syntax error. The code is as follows:

```

55
56
57
58
59 sensorColorRange = hardwareMap.get(DistanceSensor.class, "s");
60 servotest = hardwareMap.get(Servo.class, "servoTest");
61
62 telemetry.addData("Status", );
63 telemetry.update();
64 // Wait for the game to start (driver presses PLAY)
65 waitForStart();
66

```

After you have modified your op mode, you can press the build button and see what error messages appear.



The screenshot shows the OnBot Java IDE with a message pane displaying an error message. The message is:

```

Build started at Wed Sep 06 2017 09:03:41 GMT-0400 (Eastern Daylight Time)
org/firstinspires/ftc/teamcode/MyFIRSTJavaOpMode.java line 62, column 37: ERROR: illegal start of expression

Build finished in 0.2 seconds
Build FAILED!

```

When you first attempt to build the op mode, you should get an “illegal start of expression error”. This is because the addData method is missing its second argument. The OnBot Java system also directs you to the file that has the error, and the location within the file where the error occurs.

In this example, the problem file is called “org/firstinspires/ftc/teamcode/MyFIRSTJavaOpMode.java” and the error occurs at line 62, column 37. It is important to note that the build process builds all of the .java files on the Robot

Controller. If there is an error in a different file (one that you are not currently editing) you will need to look at the file name to determine which file is causing the problem.

Let's restore this statement back to its original, correct form:

```
telemetry.addData("Status", "Initialized");
```

After you have corrected the addData statement, push the build button again to see what happens. The OnBot Java system should complain that it cannot find the symbol “Zervo” in a source file called “org/firstinspires/ftc/teamcode/MyFIRSTJavaOpMode.java” at line 51, column 13.

```
Build started at Wed Sep 06 2017 09:10:46 GMT-0400 (Eastern Daylight Time)
org/firstinspires/ftc/teamcode/MyFIRSTJavaOpMode.java line 51, column 13: ERROR: cannot find symbol
  symbol:   class Zervo
  location: class org.firstinspires.ftc.teamcode.MyFIRSTJavaOpMode

Build finished in 0.4 seconds
Build FAILED!
```

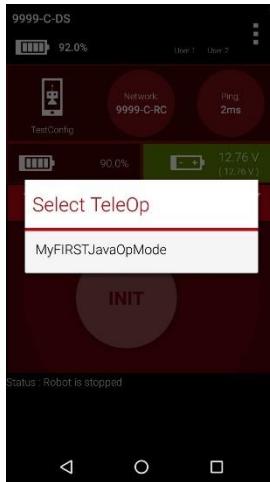
You should restore the statement back to its original form and then push the build button and verify that the op mode gets built properly.

```
private Servo servoTest;
```

9.10 Running Your Op Mode

If you successfully rebuilt your op mode, you are ready to run the op mode. Verify that the Driver Station is still connected to the Robot Controller. Since you designated that your example op mode is a tele-operated op mode, it will be listed as a “TeleOp” op mode.

On the Driver Station, use the “TeleOp” dropdown list control to display the list of available op modes. Select your op mode (“MyFIRSTJavaOpMode”) from the list.



Press the INIT button to initialize the op mode.



The op mode will execute the statements in the runOpMode method up to the waitForStart statement. It will then wait until you press the start button (which is represented by the triangular shaped symbol) to continue.



Once you press the start button, the op mode will continue to iterate and send the “Status: Initialized” message to the Driver Station. To stop the op mode, press the square-shaped stop button.



Congratulations! You ran your first java op mode!

9.11 Modifying Your Op Mode to Control a Motor

Let's modify your op mode to control the DC motor that you connected and configured for your REV Expansion Hub. Modify the code for the program loop so that it looks like the following:

```
// run until the end of the match (driver presses STOP)
double tgtPower = 0;
while (opModeIsActive()) {
    tgtPower = -this.gamepad1.left_stick_y;
    motorTest.setPower(tgtPower);
    telemetry.addData("Target Power", tgtPower);
    telemetry.addData("Motor Power", motorTest.getPower());
    telemetry.addData("Status", "Running");
    telemetry.update();
}
```

The additions are highlighted in yellow in the above code snippet. If you look at these code additions, you will see that we defined a new variable called target power before we enter the while loop.

```
double tgtPower = 0;
```

At the start of the while loop we set the variable tgtPower equal to the negative value of the gamepad1's left joystick:

```
tgtPower = -this.gamepad1.left_stick_y;
```

The object *gamepad1* is available for you to access in the runOpMode method. It represents the state of gamepad #1 on your Driver Station. Note that for the F310 gamepads that are used during the competition, the Y value of a joystick ranges from -1, when a joystick is in its topmost position, to +1, when a joystick is in its bottommost position. In the example code above, you negate the left_stick_y value so that pushing the left joystick forward will result in a positive power being applied to the motor.



The next set of statements sets the power of motorTest to the value represented by the variable tgtPower. The values for target power and actual motor power are then added to the set of data that will be sent via the telemetry mechanism to the Driver Station.

```
tgtPower = -this.gamepad1.left_stick_y;
motorTest.setPower(tgtPower);
telemetry.addData("Target Power", tgtPower);
telemetry.addData("Motor Power", motorTest.getPower());
```

After you have modified your op mode to include these new statements, press the build button and verify that the op mode was built successfully.

9.12 Running Your Op Mode with a Gamepad Connected

Your op mode takes input from a gamepad and uses this input to control a DC motor. To run your op mode, you will need to connect a Logitech F310 gamepad to the Driver Station.

Before you connect your gamepad to the phone, verify that the switch on the bottom of the gamepad is set to the “X” position.



Connect the gamepad to the Driver Station using the Micro USB OTG adapter cable.



Your example op mode is looking for input from the gamepad designated as the user or driver #1. Press the **Start** button and the **A** button simultaneously on the Logitech F310 controller to designate your gamepad as user #1. Note that pushing the **Start** button and the **B** button simultaneously would designate the gamepad as user #2.



If you successfully designated the gamepad to be user #1, you should see a little gamepad icon above the text “User 1” in the upper right hand corner of the Driver Station Screen. Whenever there is activity on gamepad #1, the little icon should be highlighted in green. If the icon is missing or if it does not highlight in green when you use your gamepad, then there is a problem with the connection to the gamepad.

Select, initialize and run your “MyFIRSTJavaOpMode” op mode. It is important to note that whenever you rebuild an op mode, you must stop the current op mode run and then restart it before the changes that you just built take effect.

If you configured your gamepad properly, then the left joystick should control the motion of the motor. As you run your op mode, be careful and make sure you do not get anything caught in the turning motor. Note that the User #1 gamepad icon should highlight green each time you move the joystick. Also note that the target power and actual motor power values should be displayed in the telemetry area on the Driver Station.



10 Controlling a Servo Motor with an Op Mode

In this section, you will modify your op mode to control a servo motor with the buttons of the gamepad.

10.1 What is a Servo Motor?

A servo motor is a special type of motor. A servo motor is designed for precise motion. A typical servo motor has a limited range of motion.

In the figure below, “standard scale” 180-degree servo is shown. This type of servo is popular with hobbyists and with FIRST Tech Challenge teams. This servo motor can rotate its shaft through a range of 180 degrees. Using an electronic module known as a *servo controller* you can write an op mode that will move a servo motor to a specific position. Once the motor reaches this target position, it will hold the position, even if external forces are applied to the shaft of the servo.



Figure 6 – An example of a servo motor that is commonly used on FIRST Tech Challenge robots.⁶

Servo motors are useful when you want to do precise movements (for example, sweep an area with a sensor to look for a target or move the control surfaces on a remotely controlled airplane).

⁶ Image taken from the Pitsco website on 10/17/2016 (see https://c10645061.ssl.cf2.rackcdn.com/product/icongo/icg_39197_180deg servo.jpg).

10.2 Modifying Your Op Mode to Control a Servo

Let's modify your op mode to add the logic required to control a servo motor. For this example, you will use the buttons on the Logitech F310 gamepad to control the position of the servo motor.

With a typical servo, you can specify a target position for the servo. The servo will turn its motor shaft to move to the target position, and then maintain that position, even if moderate forces are applied to try and disturb its position.

For the *FIRST* Tech Challenge control system, you can specify a target position that ranges from 0 to 1 for a servo. A target position of 0 corresponds to zero degrees of rotation and a target position of 1 corresponds to 180 degrees of rotation for a typical servo motor.



Figure 7 - A typical servo motor can rotate to and hold a position from 0 to 180 degrees.

In this example, you will use the colored buttons on the right side of the F310 controller to control the position of the servo. Initially, the op mode will move the servo to the midway position (90 degrees of its 180-degree range). Pushing the yellow "Y" button will move the servo to the zero-degree position. Pushing the blue "X" button or the red "B" button will move the servo to the 90-degree position. Pushing the green "A" button will move the servo to the 180-degree position.



Figure 8 – The colored buttons on the right side of the gamepad will be used to control servo position.

Modify your op mode to add the following code:

```
// run until the end of the match (driver presses STOP)
double tgtPower = 0;
while (opModeIsActive()) {
    tgtPower = -this.gamepad1.left_stick_y;
    motorTest.setPower(tgtPower);
    // check to see if we need to move the servo.
    if(gamepad1.y) {
        // move to 0 degrees.
        servoTest.setPosition(0);
    } else if (gamepad1.x || gamepad1.b) {
        // move to 90 degrees.
        servoTest.setPosition(0.5);
    } else if (gamepad1.a) {
        // move to 180 degrees.
        servoTest.setPosition(1);
    }
    telemetry.addData("Servo Position", servoTest.getPosition());
    telemetry.addData("Target Power", tgtPower);
    telemetry.addData("Motor Power", motorTest.getPower());
    telemetry.addData("Status", "Running");
    telemetry.update();
}
```

This added code will check to see if any of the colored buttons on the F310 gamepad are pressed. If the Y button is pressed, it will move the servo to the 0-degree position. If either the X button or B button is pressed, it will move the servo to the 90-degree position. If the A button is pressed, it will move the servo to the 180-degree position. The op mode will also send telemetry data on the servo position to the Driver Station.

After you have modified your op mode, you can build it and then run it. Verify that gamepad #1 is still configured and then use the colored buttons to move the position of the servo.

11 Using Sensors

11.1 Color-Distance Sensor

A *sensor* is a device that lets the Robot Controller get information about its environment. In this example, you will use a REV Robotics Color-Distance sensor to display range (distance from an object) info to the driver station.

The Color-Range sensor uses reflected light to determine the distance from the sensor to the target object. It can be used to measure close distances (up 5" or more) with reasonable accuracy. Note that at the time this document was most recently edited, the REV Color-Range sensor saturates around 2" (5cm). This means that for distances less than or equal to 2", the sensor returns a measured distance equal to 2" or so.

Modify your op mode to add a telemetry statement that will send the distance information (in centimeters) to the Driver Station.

```
telemetry.addData("Servo Position", servoTest.getPosition());
telemetry.addData("Target Power", tgtPower);
telemetry.addData("Motor Power", motorTest.getPower());
telemetry.addData("Distance (cm)", sensorColorRange.getDistance(DistanceUnit.CM));
telemetry.addData("Status", "Running");
telemetry.update();
```

After you have modified your op mode, push the build button, then run the op mode to verify that it now displays distance on your Driver Station. Note that if the distance reads “NaN” (short for “Not a Number”) it probably means that your sensor is too far from the target (zero reflection). Also note that the sensor saturates at around 5 cm.

11.2 Touch Sensor

The REV Robotics Touch Sensor can be connected to a digital port on the Expansion Hub. The Touch Sensor is HIGH (returns TRUE) when it is not pressed. It is *pulled* LOW (returns FALSE) when it is pressed.



Figure 9 - REV Robotics Touch Sensor.

The Expansion Hub digital ports contain two digital pins per port. When you use a 4-wire JST cable to connect a REV Robotics Touch sensor to an Expansion Hub digital port, the Touch Sensor is wired to the second of the two digital pins within the port. The first digital pin of the 4-wire cable remains disconnected.

For example, if you connect a Touch Sensor to the “0,1” digital port of the Expansion Hub, the Touch Sensor will be connected to the second pin (labeled “1”) of the port. The first pin (labeled “0”) will stay disconnected.

Modify the code in your op mode that occurs *before* the waitForStart command to set the digital channel for input mode.

```
// set digital channel to input mode.
digitalTouch.setMode(DigitalChannel.Mode.INPUT);

telemetry.addData("Status", "Initialized");
telemetry.update();
// Wait for the game to start (driver presses PLAY)
waitForStart();
```

Also, modify the code in your while loop to add an if-else statement that checks the state of the digital input channel. If the channel is LOW (false), the touch sensor button is pressed and being pulled LOW to ground. Otherwise, the touch sensor button is not pressed.

```
// is button pressed?
if (digitalTouch.getState() == false) {
    // button is pressed.
    telemetry.addData("Button", "PRESSED");
} else {
    // button is not pressed.
    telemetry.addData("Button", "NOT PRESSED");
}

telemetry.addData("Status", "Running");
telemetry.update();
```

Rebuild your op mode, then reinitialize and restart your op mode. The op mode should now display the state of the button (“PRESSED” or “NOT PRESSED”).

12 FIRST Tech Challenge Reference Information

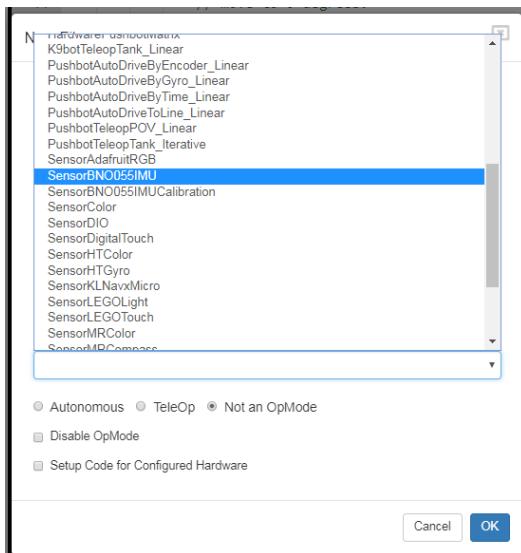
12.1 Javadoc Reference Pages

As you start to write more complicated op modes, you will need to use more features of the FIRST Tech Challenge software development kit (SDK). You can reference online Javadoc material that provide descriptions of the available FIRST Tech Challenge-related classes and methods, at the following web address:

http://ftctechnh.github.io/ftc_app/doc/javadoc/index.html

12.2 Sample Op Modes

The OnBot Java Programming Tool has several built-in example op modes that demonstrate how to do different tasks with the FIRST Tech Challenge control system. As you create a new file, you can use the Sample dropdown list control to display a list of available sample op modes or templates. The comments in these examples help explain what the program statements do.



12.3 Control System Wiki

There is an up-to-date online wiki for the FTC Android control system. This document serves as a convenient online reference for all topics related to the control system:

https://github.com/ftctechnh/ftc_app/wiki

12.4 Technology Forum

Registered teams can create user accounts on the FIRST Tech Challenge forum. Teams can use the forum to ask questions and receive support from the FIRST Tech Challenge community.

The technology forum can be found at the following address:

<https://ftcforum.usfirst.org/forum/ftc-technology?156-FTC-Technology>

13 Troubleshooting

13.1 Manually Connecting to the Program & Manage Wi-Fi Network

Section 9.4 describes how to search for the Program & Manage Wi-Fi network from a list of available networks and then connect to it with a Windows laptop. For some Windows devices, the laptop might not display your Program & Manage Wi-Fi network in its list of available networks. This problem can occur with some Windows 10 machines (and possibly with some Windows 8 machines), especially if the computer does not have current system updates and service packs.

If you are having problems seeing your Program & Manage Wi-Fi network in your list of available networks, make sure that your Driver Station is paired and connected to your Robot Controller (see section 6.4 of this document). Also, make sure that you have the correct network name and passphrase. Also, make sure that your Windows 10 device has its most current updates installed from Microsoft.

If you have verified that the Driver Station is paired and connected to the Robot Controller and that you have the correct network name and passphrase, and if you have verified that your Windows 10 updates are current, then you might have to manually connect your Windows 10 computer to the Program & Manage Wi-Fi network.

You can manually connect to this network as if the network were a *hidden* network (i.e., a network that does not broadcast its presence to other Wi-Fi devices).

Manually Connecting to the Programming Mode Wi-Fi Network

(Time Needed to Complete Task: 15 minutes)

Step 1:

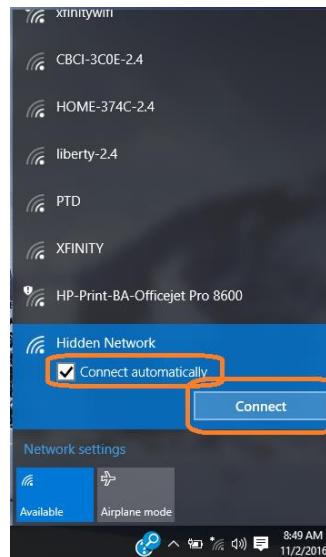
In the lower right hand corner of the Windows 10 desktop, click on the network icon in the system tray to display a list of available Wi-Fi networks.

If you still do not see your Program & Manage network listed, then scroll to the bottom of the list and look for the item "Hidden Network".

**Step 2:**

Click on the "Hidden Network" listing to start the connection process. The listing should display a "Connect" button.

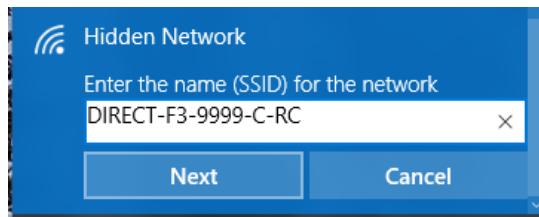
Make sure the option "Connect automatically" is checked and then click on the "Connect" button to continue with the process.



Step 3:

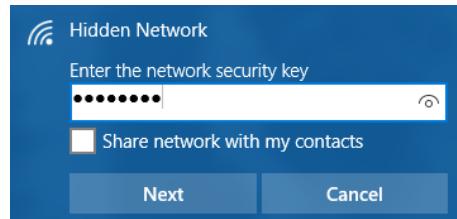
The computer should prompt you for the name or *SSID* of your Program & Manage mode Wi-Fi network. You should type in the network name that is displayed in the Program & Manage window of the Android device.

Note, the SSID or network name is *case sensitive*. Make sure the capitalization of the name that you enter matches the capitalization of the name displayed in the Program & Manage screen.

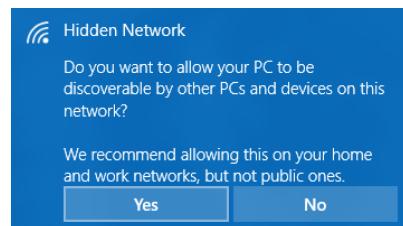
**Step 4:**

The computer should then prompt you for the passphrase to access this Wi-Fi network. You should type in the network passphrase that is displayed in the Program & Manage window of the Android device.

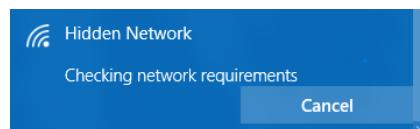
Note that the passphrase is *case sensitive*. Make sure that your spelling and capitalization matches the original spelling and capitalization shown on the Program & Manage screen.

**Step 5:**

Your computer will prompt you on whether you want to make your PC discoverable by other devices on this network. Click "Yes" to continue.

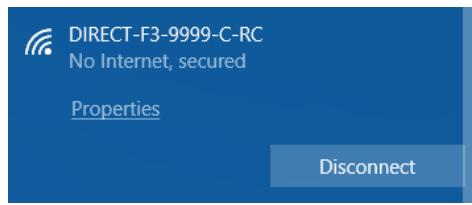
**Step 6:**

The computer will attempt to connect to your network. Note that it could take several minutes before it connects.

**Step 7:**

If you could successfully connect to the network, it will eventually appear in the list of networks on your computer.

Note that when your computer is connected to the blocks programming server on your Robot Controller phone, *it will not have access to the Internet*.



13.2 Troubleshooting Tips

In this section, we provide some basic tips on troubleshooting problems that you might encounter when using the OnBot Java Programming Tool to write op modes for your Robot Controller.

13.2.1 Driver Station Appears Unresponsive

If you are ready to run an op mode, but the Driver Station is unresponsive and you cannot initialize or start your selected op mode, check the following items:

1. Verify that the Driver Station is properly paired to the Robot Controller.
2. Make sure that the Robot Controller is not in Programming Mode.
3. Check the *ping* times on the Driver Station main screen. The ping time is the average time it takes for the Driver Station to send a message to the Robot Controller and for the Robot Controller to acknowledged that it received the message. If the ping time is low (< 20 msec) the wireless connection between the Driver Station and Robot Controller is good. If the ping time is consistently high (> 50 msec) there could be some wireless interference in your venue that is causing the problems between the Driver Station and the Robot Controller.



13.2.2 Warning: problem communicating...

If you are trying to run an op mode and you notice error messages like the ones displayed below, it could be that your wired connection between the phone and the electronic modules is bad.

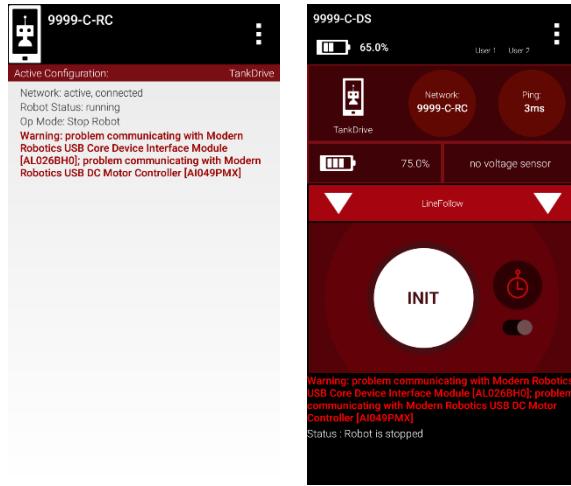


Figure 10 - A "problem communicating with..." message often indicates a bad connection between the phone and modules.

If you notice this error message, here are some things you can try:

1. Verify that the USB cable connecting the phone to the Expansion Hub is secure and well connected.
2. Verify that the 12V power cables connecting the battery to the switch and the Expansion Hub are properly secured and connected. Also, verify that the power switch is in the on position.
3. Try to do a “Restart Robot” from the pop up menu (touch the three vertical dots in the upper right hand screen of the Robot Controller or Driver Station apps).
4. If that does not work, disconnect the USB cable from the phone, then shut down the main power switch on the Expansion Hub. Wait for 5 seconds, then power the device back on and reconnect the USB cable to the phone.