TROUBLESHOOTING

Last Updated: 01-07-2019

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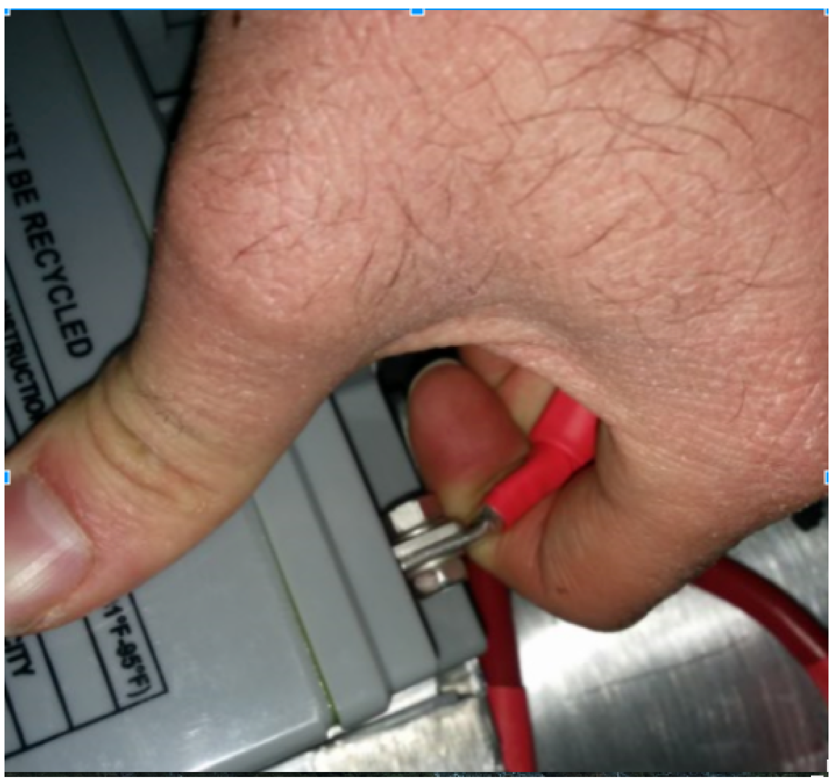
General Troubleshooting

Robot Preemptive Troubleshooting

In FIRST Robotics Competion, robots take a lot of stress while driving around the field. It is important to make sure that connections are tight, parts are bolted securely in place and that everthing is mounted so that a robot bouncing around the field does not break.

Check battery connections

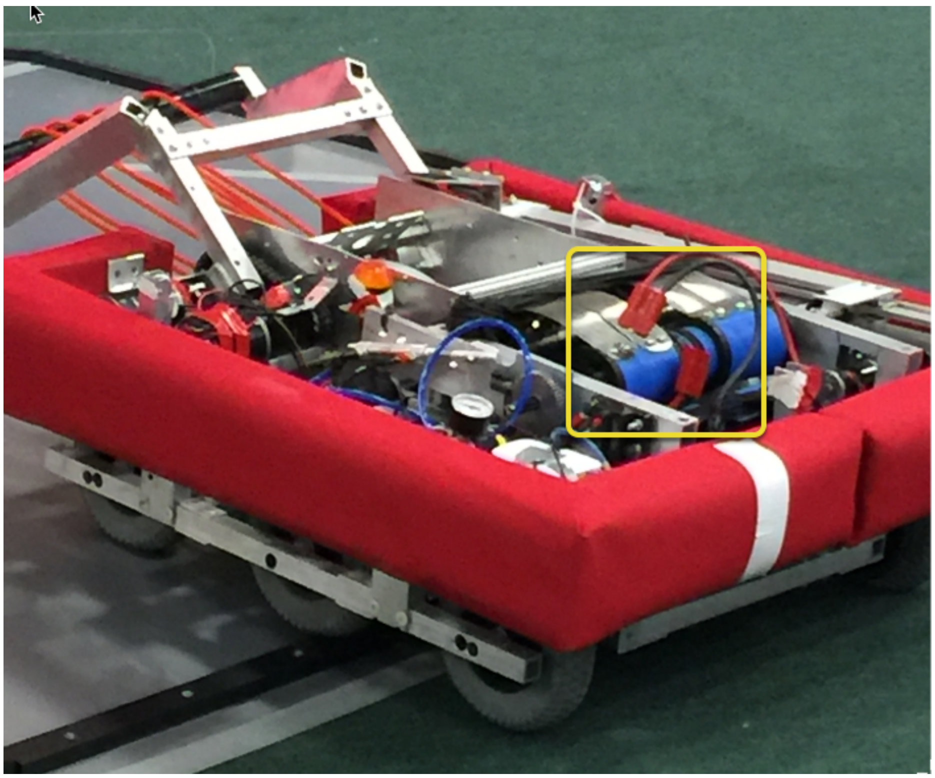


The tape the should be covering the battery connection in these examples has been removed to illustrate what is going on. On your robots, the connections should be covered.

Wiggle battery harness connector. Often these are loose because the screws loosen, or sometimes the crimp is not completely closed. You will only catch the really bad ones though because often the electrical tape stiffens the connection to a point where it feels stiff. Using a voltmeter or Battery Beak will help with this.

Apply considerable force onto the battery cable at 90 degrees to try to move the direction of the cable leaving the battery, if successful the connection was not tight enough to begin with and it should be redone.

Secure the battery to robot connection



In almost every event we see at least one robot where a not properly secured battery connector (the large Anderson) comes apart and disconnects power from the robot. This has happened in championship matches on the Einstein and everywhere else. Its an easy to ensure that this doesn't happen to you by securing the two connectors by wrapping a tie wrap around the connection. 10 or 12 tie wraps for the piece of mind during an event is not a high price to pay to guarantee that you will not have the problem of this robot from an actual event after a bumpy ride over a defense.

Troubleshooting

120 Amp circuit breaker

Apply a twisting force onto the cable to rotate the harness. If you are successful then the screw is not tight enough. Split washers might help here, but in the mean time, these require checking every few matches.

Because the metal is just molded into the case, every once in awhile you will break off the bolt, ask any veteran team and they'll tell you they go through a number of these every few seasons. After tightening the nut, retest by once again trying to twist the cable.

Troubleshooting

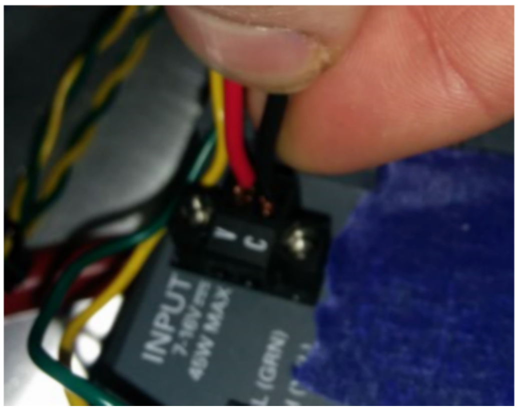
Power Distribution Panel (PDP)

Just by removing the battery cover, often you can confirm the washer.

Make sure that split washers were placed under the PDP screws, but it is not easy to visually confirm, and sometimes you can't. You can check by removing the case.   Also if you squeeze the red and black wires together, sometimes you can catch the really lose connections.

Troubleshooting

Tug test everything



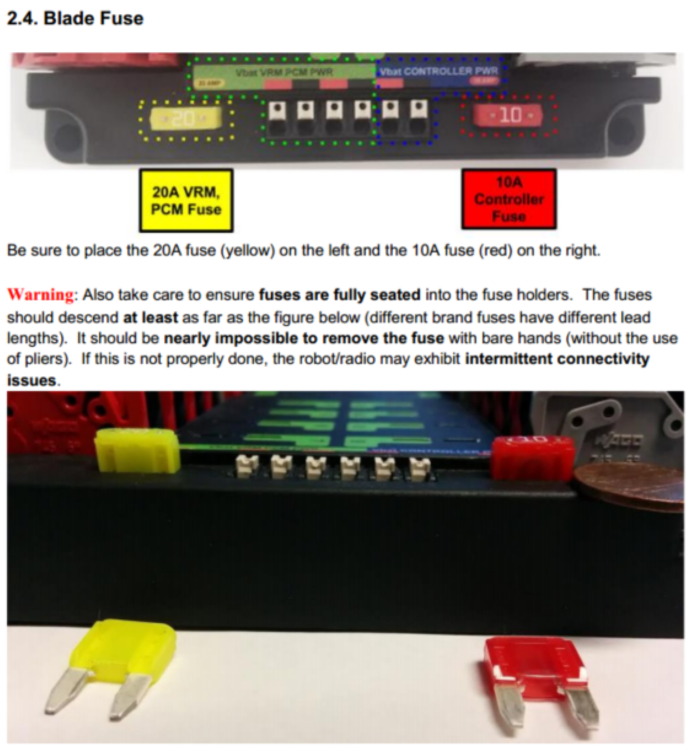
The **Weidmuller** contacts for power, compressor output, **roboRIO power connector**, and **radio power** are important to verify by tugging on the connections as shown. Make sure that none of the connections pull out.

Look for possible or impending shorts with Weidmuller connections that are close to each other, and have too-long wire-lead lengths (wires that are stripped extra long).

Spade connectors can also fail due to improper crimps, so tug-test those as well.

Troubleshooting

Blade fuses



2.4. Blade Fuse

20A VRM, PCM Fuse

10A Controller Fuse

Be sure to place the 20A fuse (yellow) on the left and the 10A fuse (red) on the right.

Warning: Also take care to ensure **fuses are fully seated** into the fuse holders. The fuses should descend **at least** as far as the figure below (different brand fuses have different lead lengths). It should be **nearly impossible to remove the fuse** with bare hands (without the use of pliers). If this is not properly done, the robot/radio may exhibit **intermittent connectivity issues**.

If you can remove the blade fuses by hand then they are not in completely. Make sure that they are completely seated in the PDP so that they don't pop out during robot operation.

RoboRIO swarf

Swarf is: fine chips or filings of stone, metal, or other material produced by a machining operation. Often modifications must be made to a robot while the control system parts are in place. The circuit board for the roboRIO is conformally coated, but that doesn't absolutely guarantee that metal chips won't short out traces or components inside the case. In this case, you must exercise care in making sure that none of the chips end up in the roboRIO or any of the other components. In particular, the exposed 3 pin headers are a place where chips can enter the case. A quick sweep through each of the four sides with a flashlight is usually sufficient to find the really bad areas of infiltration.

Troubleshooting

Radio barrel jack

Make sure the correct barrel jack is used, not one that is too small and falls out for no reason. This isn't common, but ask an FTA and every once in awhile a team will use some random barrel jack that is not sized correctly, and it falls out in a match on first contact.

Ethernet cable

If the RIO to radio ethernet cable is missing the clip that locks the connector in, get another cable. This is a common problem that will happen several times in every competition. Make sure that your cables are secure. The clip often breaks off, especially when pulling it through a tight path, it snags on something then breaks.

Cable slack

Cables must be tightened down, particularly the radio power and ethernet cable. The radio power cables don't have a lot of friction force and will fall out (even if it is the correct barrel) if the weight of the cable-slack is allowed to swing freely.

Ethernet cable is also pretty heavy, if it's allowed to swing freely, the plastic clip may not be enough to hold the ethernet pin connectors in circuit.

Reproducing problems in the pit

Beyond the normal shaking and rattling of all cables while the robot is power and tethered, you might try picking up one side of the robot off the ground and drop it, and see if you lose connection. The driving on the field, especially when trying to breach defenses will often be very violent. It's better to see it fail in the pit rather than in a critical match.

When doing this test it's important to be ethernet tethered and not USB tethered, otherwise you are not testing all of the critical paths.

Troubleshooting

Check firmware and versions

Robot inspectors do this, but you should do it as well, it helps robot inspectors out and they appreciate it. And it guarantees that you are running with the most recent, bug fixed code. You wouldn't want to lose a match because of an out of date piece of control system software on your robot.

Driver station checks

We often see problems with the Drivers Station. You should:

- ALWAYS bring the laptop power cable to the field, it doesn’t matter how good the battery is, you are allowed to plug in at the field.
- Check the power and sleep settings, turn off sleep and hybernate, screen savers, etc.
- Turn off power management for USB devices (dev manager)
- Turn off power management for ethernet ports (dev manager)
- Turn off windows defender
- Turn off firewall
- Close all apps except for DS/Dashboard when out on the field.
- Verify that there is nothing unnecessary running in the application tray in the start menu (bottom right side)

Troubleshooting

Handy tools

There never seems to be enough light inside robots, at least not enough to scrutinize the critical connection points, so consider using a handheld LED flashlight to inspect the connections on your robot. They're available from home depot or any hardware/automotive store.

Wago tool is nice to for redoing weidmuller connections with stranded wires. Often I'll do one to show the team, and then have them do the rest using the WAGO tool to press down the white-plunger while they insert the stranded wire. The angle of the WAGO tool makes this particularly helpful.

Status Light Quick Reference

Many of the components of the FRC Control System have indicator lights that can be used to quickly diagnose problems with your robot. This guide shows each of the hardware components and describes the meaning of the indicators. Photos and information from Innovation FIRST and Cross the Road Electronics.

Robot Signal Light (RSL)

Robot Signal Light (RSL)

- Solid ON - Robot On and Disabled
- Blinking - Robot On and Enabled
- Off - Robot Off, roboRIO not powered or RSL not wired properly.

RoboRIO

RoboRIO

Power

- Green - Power is good
- Amber - Brownout protection tripped, outputs disabled
- Red - Power fault, check user rails for short circuit

Status

- On while the controller is booting, then should turn off
- 2 blinks - Software error, reimage roboRIO
- 3 blinks - Safe Mode, restart roboRIO, reimage if not resolved
- 4 blinks - Software crashed twice without rebooting, reboot roboRIO, reimage if not resolved
- Constant flash or stays solid on - Unrecoverable error

Radio

Troubleshooting

Not currently implemented

Comm

- Off - No Communication
- Red Solid - Communication with DS, but no user code
- Red Blinking - E-stop
- Green Solid - Good communication with DS

Mode

- Off - Outputs disabled (robot in Disabled, brown-out, etc.)
- Amber/Orange - Autonomous Enabled
- Green - Teleop Enabled
- Red - Test Enabled

RSL

See above

OpenMesh Radio

OpenMesh Radio

Power

- Blue - On or Powering Up
- Blue Blinking - Powering Up

Eth Link

- Blue - Link Up
- Blue Blinking - Link Up + Traffic Present

WiFi

- Off - Bridge Mode Unlinked or Non-FRC Firmware
- Red - AP Mode Unlinked
- Yellow\Orange - AP Mode Linked
- Green - Bridge Mode Linked

Troubleshooting

Power Distribution Panel

Power Distribution Panel

Voltage Regulator Module

Voltage Regulator Module

The status LEDs on the VRM indicate the state of the two power supplies. If the supply is functioning properly the LED should be lit bright green. If the LED is not lit or is dim, the output may be shorted or drawing too much current.

Pneumatics Control Module

Pneumatics Control Module

Solenoid Channel LEDs - These LEDs are lit red if the Solenoid channel is enabled and not lit if it is disabled.

Comp - This is the Compressor LED. This LED is green when the compressor output is active (compressor is currently on) and off when the compressor output is not active.

Status - The status LED indicates device status as indicated by the two tables above. For more information on resolving PCM faults see the PCM User Manual. Note that the No CAN Comm fault will not occur only if the device cannot see communicate with any other device, if the PCM and PDP can communicate with each other, but not the roboRIO you will NOT see a No Can Comm fault.

Digilent DMC-60

Digilent DMC-60

When the center LED is off the device is operating in coast mode. When the center LED is illuminated the device is operating in brake mode. The Brake/Coast mode can be toggled by pressing down on the center of the triangle and then releasing the button.

Jaguar speed controllers

Jaguar speed controllers

Mindsensors SD 540

Mindsensors SD 540

REV Robotics Servo Power Module

REV Robotics Servo Power Module

6V Power LED off, dim or flickering with power applied = Over-current shutdown

REV Robotics SPARK

REV Robotics SPARK

Talon speed controllers

Talon speed controllers

The LED is used to indicate the direction and percentage of throttle and state of calibration. The LED may be one of three colors; red, orange or green. A solid green LED indicates positive output voltage equal to the input voltage of the Talon. A solid Red LED indicates an output voltage that is equal to the input voltage multiplied by -1(input voltage = 12 volts, output equals -12 volts). The LED will blink it's corresponding color for any throttle less than 100% (red indicates negative polarity, green indicates positive). The rate at which the led blinks is proportional to the percent throttle. The faster the LED blinks the closer the output is to 100% in either polarity.

Troubleshooting

The LED will blink orange any time the Talon is in the disabled state. This will happen if the PWM input signal is lost, or in FRC, when the robot is disabled. If the Talon is in the enabled state and the throttle is within the 4% dead band, the LED will remain solid orange.

Flashing Red/Green indicate ready for calibration. Several green flashes indicates successful calibration, and red several times indicates unsuccessful calibration.

Victor speed controllers

Victor speed controllers

LED Indicator Status:

Green - full forward
Orange - neutral / brake
Red - full reverse
Flashing orange - no PWM signal
Flashing red/green - calibration mode
Flashing green - successful calibration
Flashing red - unsuccessful calibration

Victor-SP speed controllers

Victor-SP speed controllers

Brake/Coast/Cal Button/LED - Red if the controller is in brake mode, off if the controller is in coast mode

Status

The Status LEDs are used to indicate the direction and percentage of throttle and state of calibration. The LEDs may be one of three colors; red, orange or green. Solid green LEDs indicate positive output voltage equal to the input voltage of the Victor-SP. Solid Red LEDs indicate an output voltage that is equal to the input voltage multiplied by -1(input voltage = 12 volts, output equals -12 volts). The LEDs will blink in the corresponding color for any throttle less than 100% (red indicates negative polarity, green indicates positive). The rate at which the LEDs blink is proportional to the percent throttle. The faster the LEDs blink the closer the output is to 100% in either polarity.

Troubleshooting

The LEDs will blink orange any time the Victor-SP is in the disabled state. This will happen if the PWM input signal is lost, or in FRC, when the robot is disabled. If the Victor-SP is in the enabled state and the throttle is within the 4% dead band, the LED will remain solid orange.

Flashing Red/Green indicate ready for calibration. Several green flashes indicates successful calibration, and red several times indicates unsuccessful calibration.

Talon-SRX speed controllers

Talon-SRX speed controllers

Spike relay configured as a motor, light, or solenoid switch

Spike relay configured as a motor, light, or solenoid switch

Spike relay configured as for one or two solenoids

Spike relay configured as for one or two solenoids

Driver Station Log File Viewer

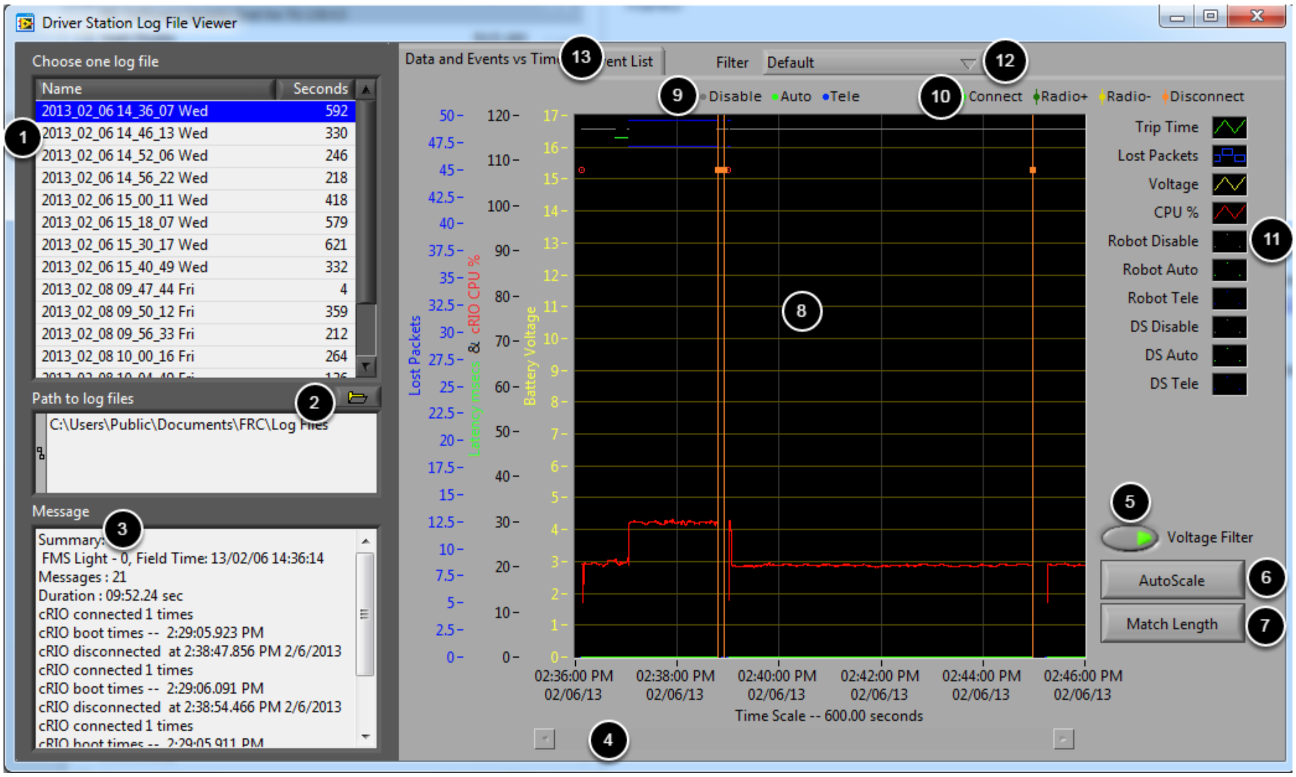
In an effort to provide information to aid in debugging, the FRC Driver Station creates log files of important diagnostic data while running. These logs can be reviewed later using the FRC Driver Station Log Viewer. The Log Viewer can be found via the shortcut installed in the Start menu or in the FRC Driver Station folder in Program Files.

Event Logs

A new addition to the Driver Station logging this year is the Event Log. The Driver Station now logs all messages sent to the Messages box on the Diagnostics tab (not the User Messages box on the Operation tab) into a new Event Log file. When viewing Log Files with the Driver Station Log File Viewer, the Event Log and DSLog files are overlaid in a single display.

Troubleshooting

Log Viewer UI



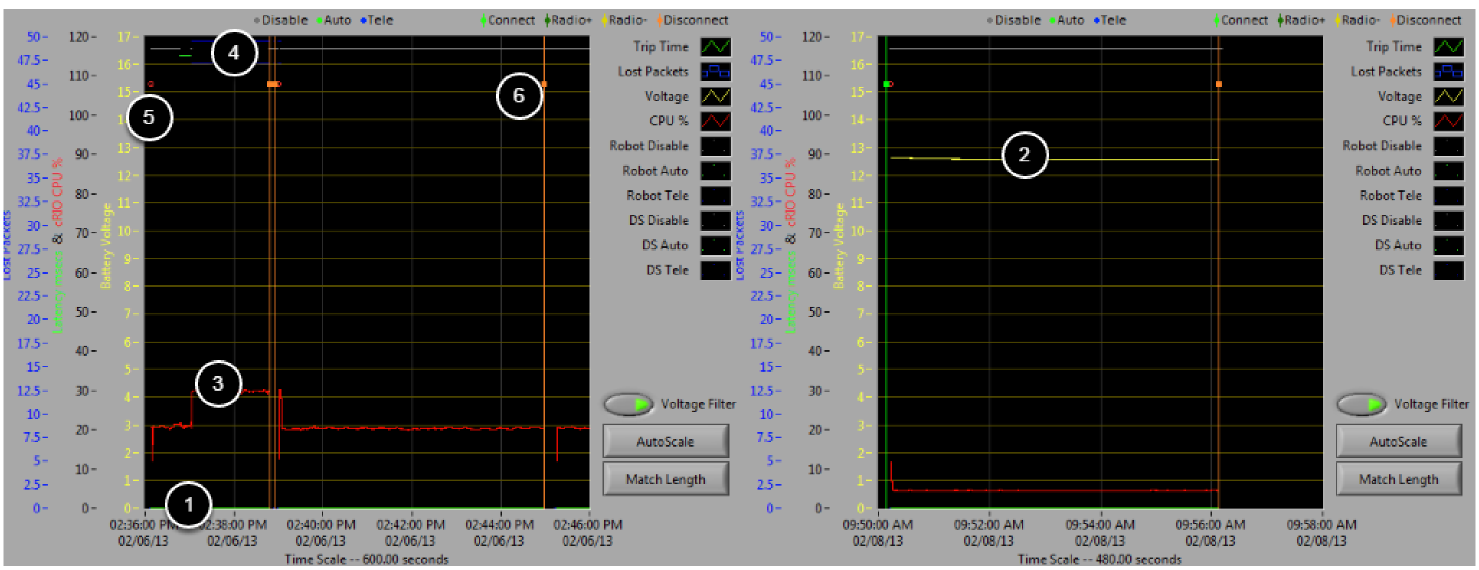
The Log Viewer contains a number of controls and displays to aid in the analysis of the Driver Station log files:

1. File Selection Box - This window displays all available log files in the currently selected folder. Click on a log file in the list to select it.
2. Path to Log Files - This box displays the current folder the viewer is looking in for log files. This defaults to the folder that the Driver Station stores log files in. Click the folder icon to browse to a different location.
3. Message Box - This box displays a summary of all messages from the Event Log. When hovering over an event on the graph this box changes to display the information for that event.
4. Scroll Bar - When the graph is zoomed in, this scroll bar allows for horizontal scrolling of the graph.
5. Voltage Filter - This control turns the Voltage Filter on and off (defaults to on). The Voltage Filter filters out data such as CPU %, robot mode and trip time when no Battery Voltage is received (indicating that the DS is not in communication with the roboRIO).
6. AutoScale - This button zooms the graph out to show all data in the log.

Troubleshooting

7. Match Length - This button scales the graph to approximately the length of an FRC match (2 minutes and 30 seconds shown). It does not automatically locate the start of the match, you will have to scroll using the scroll bar to locate the beginning of the Autonomous mode.
8. Graph - This display shows graph data from the DS Log file (voltage, trip time, roboRIO CPU%, Lost Packets, and robot mode) as well as overlaid event data (shown as dots on the graph with select events showing as vertical lines across the entire graph). Hovering over event markers on the graph displays information about the event in the Messages window in the bottom left of the screen.
9. Robot Mode Key - Key for the Robot Mode displayed at the top of the screen
10. Major event key - Key for the major events, displayed as vertical lines on the graph
11. Graph key - Key for the graph data
12. Filter Control - Drop-down to select the filter mode (filter modes explained below)
13. Tab Control - Control to switch between the Graph (Data and Events vs. Time) and Event List displays.

Using the Graph Display



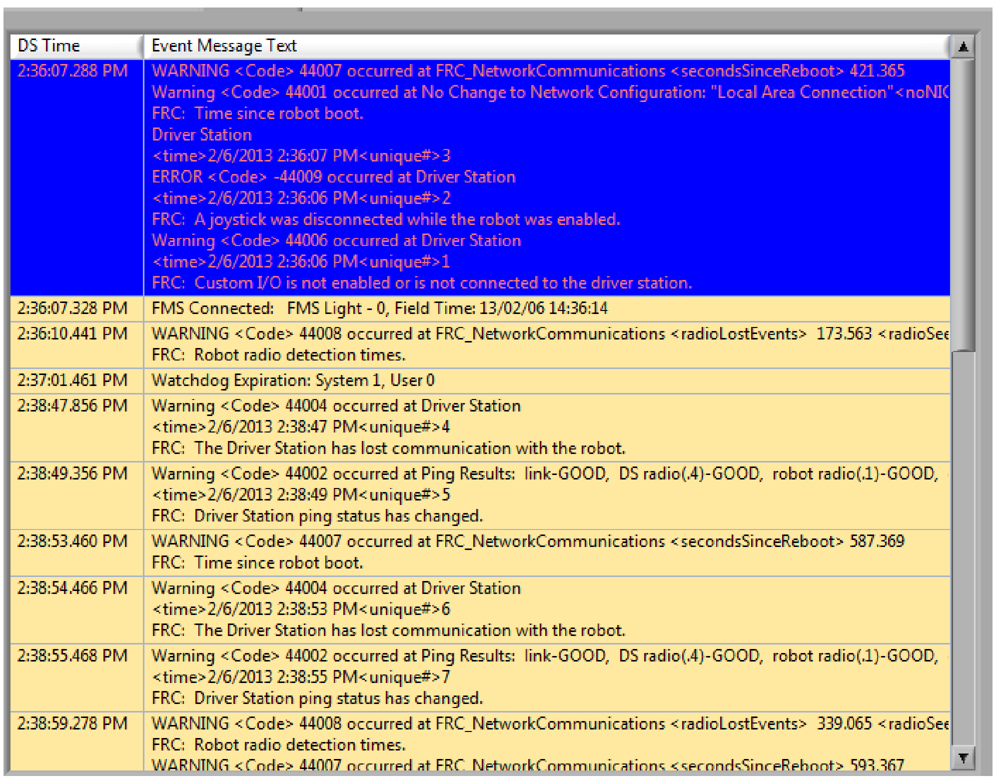
The Graph Display contains the following information:

1. Graphs of Trip Time in ms (green line) and Lost Packets per second (displayed as blue vertical bars). In these example images Trip Time is a flat green line at the bottom of the graph and there are no lost packets
2. Graph of Battery voltage displayed as a yellow line.
3. Graph of roboRIO CPU % as a red line

4. Graph of robot mode and DS mode. The top set of the display shows the mode commanded by the Driver Station. The bottom set shows the mode reported by the robot code. In this example the robot is not reporting it's mode during the disabled and autonomous modes, but is reported during Teleop.
5. Event markers will be displayed on the graph indicating the time the event occurred. Errors will display in red; warnings will display in yellow. Hovering over an event marker will display information about the event in the Messages box at the bottom left of the screen.
6. Major events are shown as vertical lines across the graph display.

To zoom in on a portion of the graph, click and drag around the desired viewing area. You can only zoom the time axis, you cannot zoom vertically.

Event List



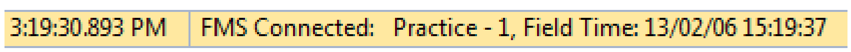
The Event List tab displays a list of events (warnings and errors) recorded by the Driver Station. The events and detail displayed are determined by the currently active filter (images shows "All Events, All Info" filter active).

Filters

Three filters are currently available in the Log Viewer:

1. Default: This filter filters out many of the errors and warnings produced by the Driver Station. This filter is useful for identifying errors thrown by the code on the Robot.
2. All Events and Time: This filter shows all events and the time they occured.
3. All Events, All Info: This filter shows all events and all recorded info. At this time the primary difference between this filter and "All Events and Time" is that this option shows the "unique" designator for the first occurrence of a particular message.

Identifying Logs from Matches



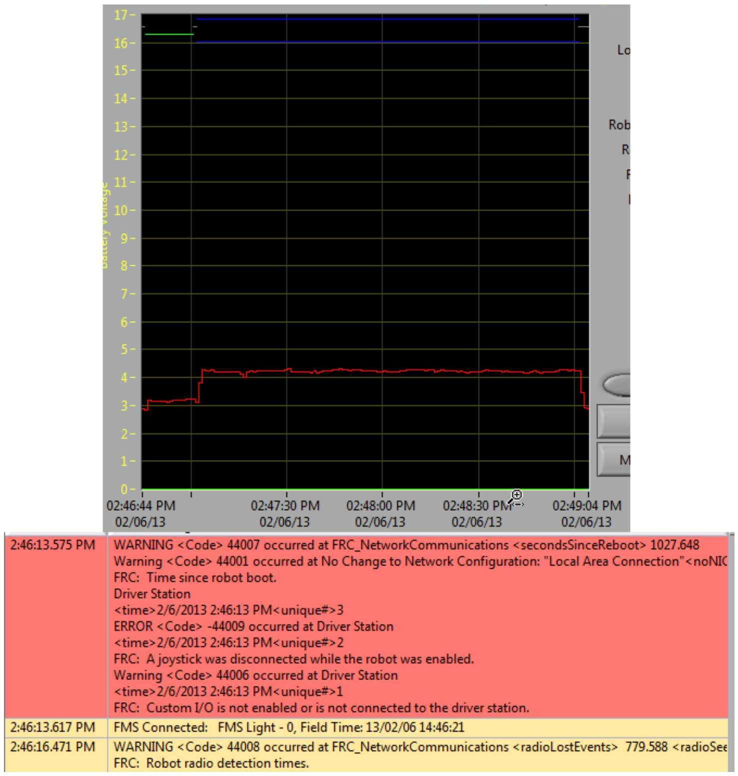
A common task when working with the Driver Station Logs is to identify which logs came from competition matches. Logs which were taken during a match can now be identified using the FMS Connected event which will display the match type (Practice, Qualification or Elimination), match number, and the current time according to the FMS server. In this example, you can see that the FMS server time and the time of the Driver Station computer are fairly close, approximately 7 seconds apart.

Identifying Common Connection Failures with the Log Viewer

When diagnosing robot issues, there is no substitute for thorough knowledge of the system and a methodical debugging approach. If you need assistance diagnosing a connection problem at your events it is strongly recommended to seek assistance from your FTA and/or CSA. The goal of this section is to familiarize teams with how some common failures can manifest themselves in the DS Log files. Please note that depending on a variety of conditions a particular failure show slightly differently in a log file.

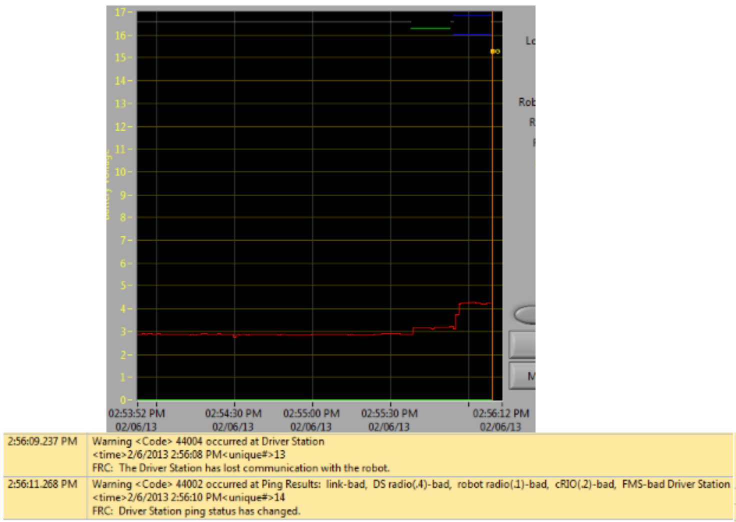
Note that all log files shown in this section have been scaled to match length using the Match Length button and then scrolling to the beginning of the autonomous mode. Also, many of the logs do not contain battery voltage information, the platform used for log capture was not properly wired for reporting the battery voltage.

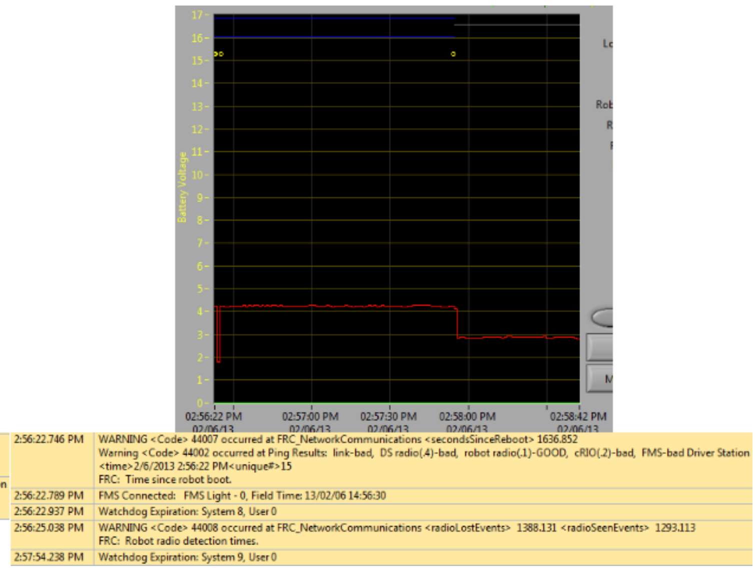
"Normal" Log



This is an example of a normal match log. The errors and warnings contained in the first box are from when the DS first started and can be ignored. This is confirmed by observing that these events occurred prior to the "FMS Connected:" event. The last event shown can also be ignored, it is also from the robot first connecting to the DS (it occurs 3 seconds after connecting to FMS) and occurs roughly 30 seconds before the match started.

Disconnected from FMS



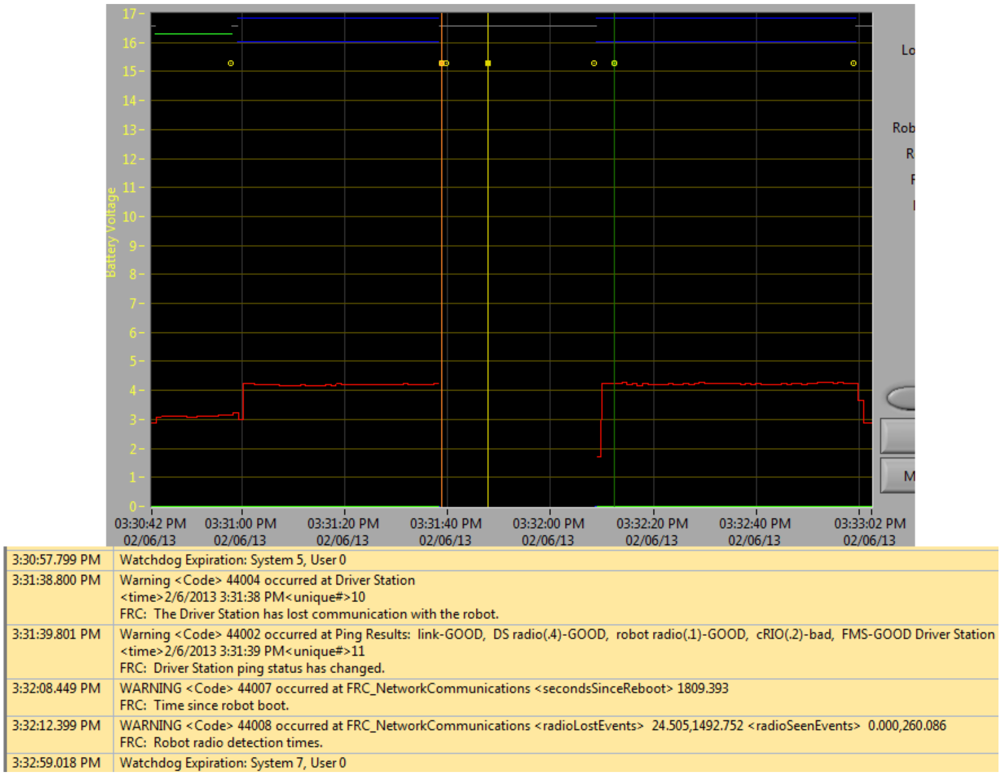


When the DS disconnects from FMS, and therefore the robot, during the match it may segment the log into pieces. The key indicators to this failure are the last event of the first log, indicating that the connection to FMS is now "bad" and the second event from the 2nd log which is a new FMS connected message followed by the DS immediately transitioning into Teleop Enabled. The most common cause of this type of failure is an ethernet cable with no latching tab or a damaged ethernet port on the DS computer.

roboRIO Reboot

The "Time since robot boot" message is the primary indicator in a connection failure caused by the roboRIO rebooting. In this log the DS loses connection with the roboRIO at 3:01:36 as indicated by the first event. The second event indicates that the ping initiated after the connection failed was successful to all devices other than the roboRIO. At 3:01:47 the roboRIO begins responding to pings again, one additional ping fails at 3:01:52. At 3:02:02 the Driver Station connects to the roboRIO and the roboRIO reports that it has been up for 3.682 seconds. This is a clear indicator that the roboRIO has rebooted. The code continues to load and at 3:02:24 the code reports an error communicating with the camera. A warning is also reported indicating that no robot code is running right before the code finishes starting up.

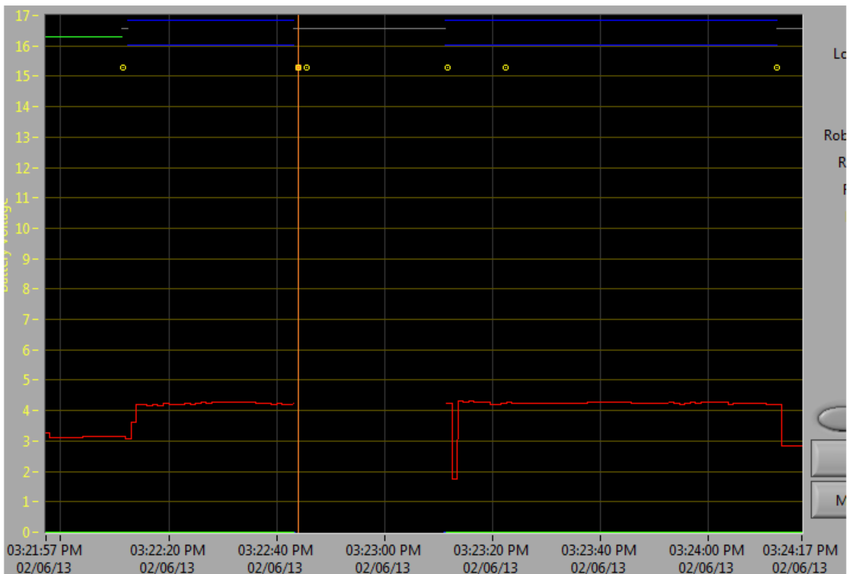
Ethernet cable issue on robot



An issue with the ethernet cable on the robot is primarily indicated by the ping to the roboRIO going to bad and Radio Lost and Radio Seen events when the roboRIO reconnects. The "Time since robot boot" message when the roboRIO reconnects will also indicate that the roboRIO has not rebooted. In this example, the robot Ethernet cable was disconnected at 3:31:38. The ping status indicates that the D-Link radio is still connected. When the robot reconnects at 3:32:08 the "Tim since robot boot" is 1809 seconds indicating that the roboRIO clearly did not reboot. At 3:32:12 the robot indicates that it lost the radio 24.505 seconds ago and it returned 0.000 seconds ago. These points are plotted as vertical lines on the graph, yellow for radio lost and green for radio seen. Note that the times are slightly offset from the actual events as shown via the disconnection and connection, but help to provide additional information about what is occurring.

Troubleshooting

Radio reboot



3:22:11.489 PM	Watchdog Expiration: System 2, User 0
3:22:44.030 PM	Warning <Code> 44004 occurred at Driver Station <time>2/6/2013 3:22:43 PM<unique#>6 FRC: The Driver Station has lost communication with the robot.
3:22:45.531 PM	Warning <Code> 44002 occurred at Ping Results: link-GOOD, DS radio(.4)-GOOD, robot radio(.1)-bad, cRIO(.2)-bad, FMS-GOOD Driver Station <time>2/6/2013 3:22:45 PM<unique#>7 FRC: Driver Station ping status has changed.
3:23:11.620 PM	WARNING <Code> 44007 occurred at FRC_NetworkCommunications <secondsSinceReboot> 1272.775 FRC: Time since robot boot.
3:23:11.690 PM	Watchdog Expiration: System 3, User 0

A reboot of the robot radio is typically characterized by a loss of connection to the radio for ~25-30 seconds. In this example, the radio briefly lost power at 3:22:44, causing it to start rebooting. The event at 3:22:45 indicates that the ping to the radio failed. At 3:23:11, the DS regains communication with the roboRIO and the roboRIO indicates it gas been up for 1272.775 seconds, ruling out a roboRIO reboot. Note that the network switch on the radio comes back up very quickly so a momentary power loss may not result in a "radio lost"/"radio seen" event pair. A longer disturbance may result in radio events being logged by the DS. In that case, the distinguishing factor which points towards a radio reboot is the ping status of the radio from the DS. If the radio resets, the radio will be unreachable. If the issue is a cabling or connection issue on the robot, the radio ping should remain "GOOD".

RoboRIO Brownout and Understanding Current Draw

In order to help maintain battery voltage to preserve itself and other control system components such as the radio during high current draw events, the roboRIO contains a staged brownout protection scheme. This article describes this scheme, provides information about proactively planning for system current draw, and describes how to use the new functionality of the PDP as well as the DS Log File Viewer to understand brownout events if they do happen on your robot.

roboRIO Brownout Protection

The roboRIO uses a staged brownout protection scheme to attempt to preserve the input voltage to itself and other control system components in order to prevent device resets in the event of large current draws pulling the battery voltage dangerously low.

Stage 1 - Output Disable

Voltage Trigger - 6.8V

When the voltage drops below 6.8V, the controller will enter the brownout protection state. The following indicators will show that this condition has occurred:

- Power LED on the roboRIO will turn Amber
- Background of the voltage display on the Driver Station will turn red
- Mode display on the Driver Station will change to Voltage Brownout
- The CAN\Power tab of the DS will increment the 12V fault counter by 1.
- The DS will record a brownout event in the DS log.

The controller will take the following steps to attempt to preserve the battery voltage:

- PWM outputs will be disabled. For PWM outputs which have set their neutral value (all speed controllers in WPILib) a single neutral pulse will be sent before the output is disabled.
- 6V User Rail disabled (this is the rail that powers servos on the PWM header bank)

- GPIO configured as outputs go to High-Z
- Relay Outputs are disabled (driven low)
- CAN-based motor controllers are sent an explicit disable command

The controller will remain in this state until the voltage rises to greater than 7.5V or drops below the trigger for the next stage of the brownout

Stage 2 - User Voltage Rail Disable

Voltage Trigger - 6.3V

When the voltage drops below 6.3V, the User Voltage Rails are disabled. This includes the 5V pins (or 3.3V is the jumper has been set) in the DIO connector bank, the 5V pins in the Analog bank, the 3.3V pins in the SPI and I2C bank and the 5V and 3.3V pins in the MXP bank.

The controller will remain in this state until the voltage rises above 6.3V (return to Stage 2) or drops below the trigger for the next stage of the brownout

Stage 3 - Device Blackout

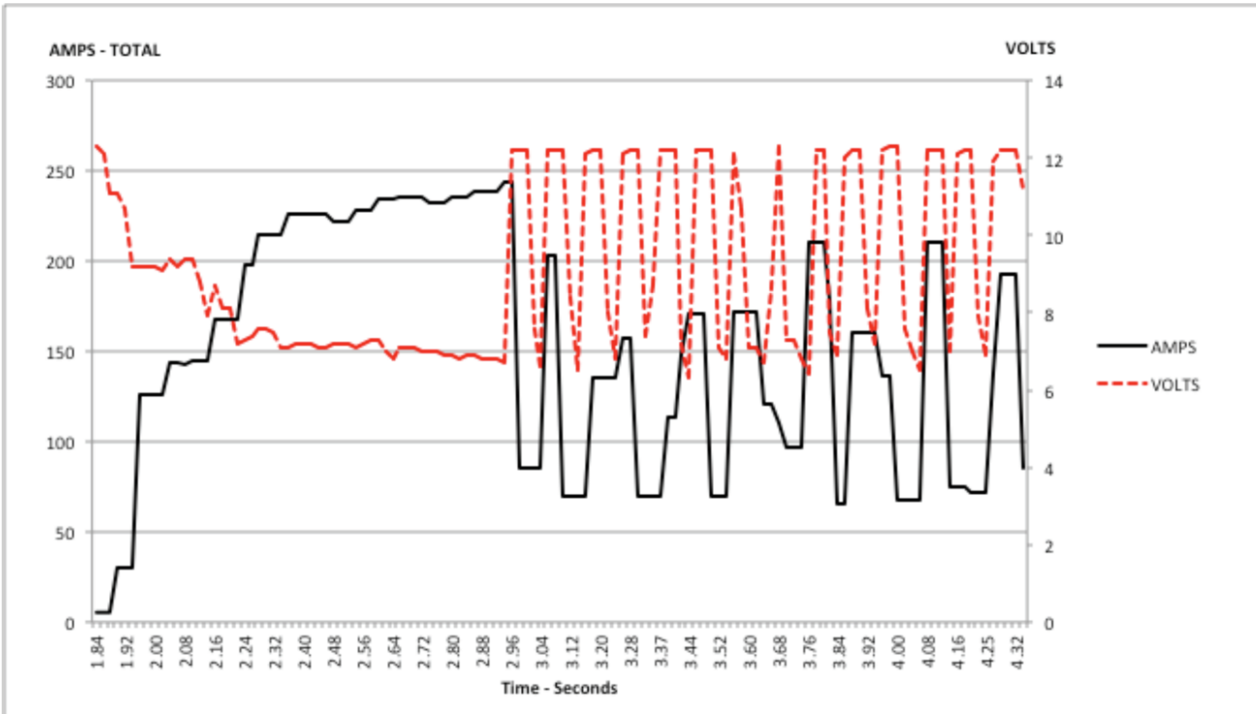
Voltage Trigger - 4.5V

Below 4.5V the device may blackout. The exact voltage may be lower than this and depends on the load on the device.

The controller will remain in this state until the voltage rises above 4.65V when the device will begin the normal boot sequence.

Avoiding Brownout - Proactive Current Draw planning

PLOT 1 – AMPS and VOLTS v. Time – 2.5 Second Window



The key to avoiding a brownout condition is to proactively plan for the current draw of your robot. The best way to do this is to create some form of power budget. This can be a complex document that attempts to quantify both estimated current draw and time in an effort to most completely understand power usage and therefore battery state at the end of a match, or it can be a simple inventory of current usage. To do this:

1. Establish the max "sustained" current draw (with sustained being loosely defined here as not momentary). This is probably the most difficult part of creating the power budget. The exact current draw a battery can sustain while maintaining a voltage of 7+ volts is dependent on a variety of factors such as battery health and state of charge. As shown in the NP18-12 data sheet, the terminal voltage chart gets very steep as state of charge decreases, especially as current draw increases. This datasheet shows that at 3CA continuous load (54A) a brand new battery can be continuously run for over 6 minutes while maintaining a terminal voltage of over 7V. As shown in the image above (used with permission from Team 234's Drive System Testing document), even with a fresh battery, drawing 240A for more than a second or two is likely to

cause an issue. This gives us some bounds on setting our sustained current draw. For the purposes of this exercise, we'll set our limit at 180A.
2. List out the different functions of your robot such as drivetrain, manipulator, main game mechanism, etc.
3. Start assigning your available current to these functions. You will likely find that you run out pretty quickly. Many teams gear their drivetrain to have enough torque to slip their wheels at 40-50A of current draw per motor. If we have 4 motors on the drivetrain, that eats up most, or even exceeds, our power budget! This means that we may need to put together a few scenarios and understand what functions can (and need to be) be used at the same time. In many cases, this will mean that you really need to limit the current draw of the other functions if/while your robot is maxing out the drivetrain (such as trying to push something). Benchmarking the "driving" current requirements of a drivetrain for some of these alternative scenarios is a little more complex, as it depends on many factors such as number of motors, robot weight, gearing, and efficiency. Current numbers for other functions can be done by calculating the power required to complete the function and estimating efficiency (if the mechanism has not been designed) or by determining the torque load on the motor and using the torque-current curve to determine the current draw of the motos.
4. If you have determined mutually exclusive functions in your analysis, consider enforcing the exclusion in software. You may also use the current monitoring of the PDP (covered in more detail below) in your robot program to provide output limits or exclusions dynamically (such as don't run a mechanism motor when the drivetrain current is over X or only let the motor run up to half output when the drivetrain current is over Y).

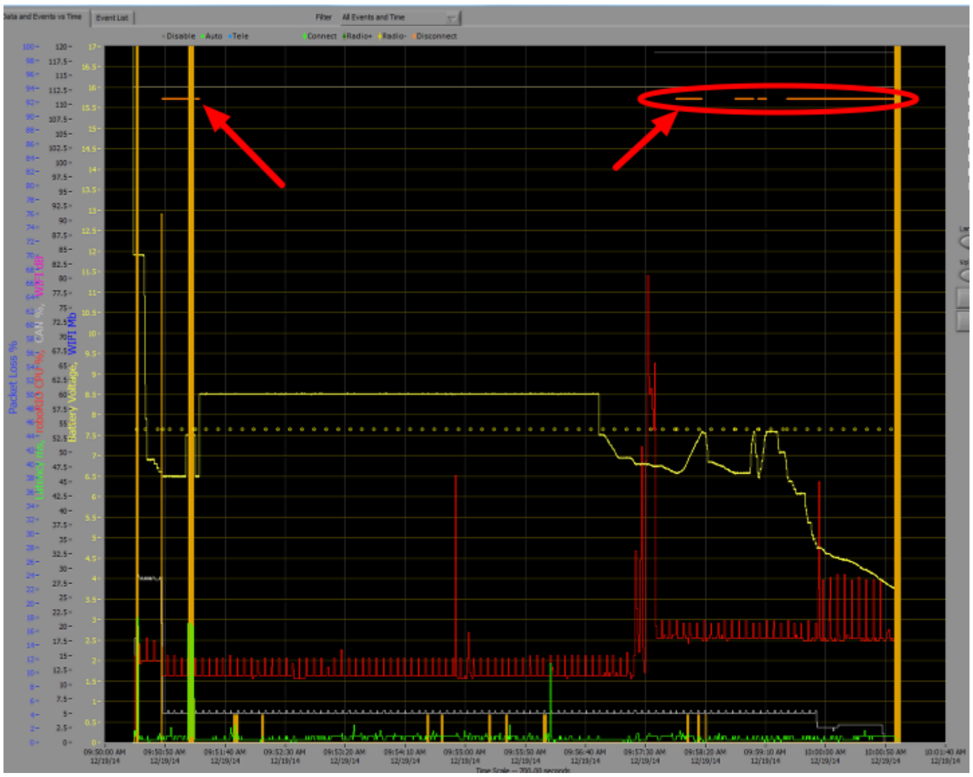
Measuring Current Draw using the PDP

The FRC Driver Station works in conjunction with the roboRIO and PDP to extract logged data from the PDP and log it on your DS PC. A viewer for this data is still under development.

In the meantime, teams can use their robot code and manual logging, a LabVIEW front panel or the SmartDashboard to visualize current draw on their robot as mechanisms are developed. In LabVIEW, you can read the current on a PDP channel using the PDP Channel Current VI found on the Power pallete. For C++ and Java teams, use the PowerDistributionPanel class as described in the Power Distribution Panel article. Plotting this information over time (easiest with a LV Front Panel or with the SmartDashboard by using a Graph indicator can provide information to compare against and update your power budget or can locate mechanisms which do not seem to be performing as expected (due to incorrect load calculation, incorrect efficiency assumptions, or mechanism issues such as binding).

Troubleshooting

Identifying Brownouts



The easiest way to identify a brownout is by clicking on the CAN\Power tab of the DS and checking the 12V fault count. Alternately, you can review the Driver Station Log after the fact using the Driver Station Log Viewer. The log will identify brownouts with a bright orange line, such as in the image above (note that these brownouts were induced with a benchtop supply and may not reflect the duration and behavior of brownouts on a typical FRC robot).

Support Resources

In addition to the documentation here, there are a variety of other resources available to FRC teams to help understand the Control System and software.

Other Documentation

In addition to this site there are a few other places teams may check for documentation:

- NI FRC Community Documents Section
- USFIRST.org Technical Resources Page
- VEXPro Jaguar Page
- CTRE Product Pages

Forums

Stuck? Have a question not answered by the documentation? Official Support is provided on these forums:

- NI FRC Community Discussion Section (roboRIO, LabVIEW and Driver Station software questions)
- USFIRST.org Control System Forum (wiring, hardware and Driver Station questions)
- USFIRST.org Programming Forum (programming questions for C++, Java, or LabVIEW)

NI Phone Support

Have a LabVIEW, roboRIO, or Driver Station question? NI provides phone support for FRC teams during the build season at 866-511-6285 1:00-7:00 PM CST Monday - Friday.

Troubleshooting

CTRE Support

Support for Cross The Road Electronics components (Pneumatics Control Module, Power Distribution Panel, Talon SRX, and Voltage Regulator Module) is provided via the e-mail address support@crosstheroadelectronics.com

Bug Reporting

Found a bug? Let us know by reporting it in the Issues section of the appropriate WPILibSuite project on Github: https://github.com/wpilibsuite

Specific Issues

Measuring Bandwidth Usage

On the 2013 FRC Field (and at home when the DAP-1522 is configured using the FRC Bridge Configuration Utility) each team is limited to 7Mb/s of network traffic (see the [FMS Whitepaper] for more details). The FMS Whitepaper provides information on determining the bandwidth usage of the Axis camera, but some teams may wish to measure their overall bandwidth consumption. This document details how to make that measurement.

Measuring Bandwidth Using the Perfomance Monitor (Win 7 only)

Windows 7 contains a built-in tool called the Performance Monitor that can be used to monitor the bandwidth usage over a network interface.

Launching the Performance Monitor

Launching the Performance Monitor

Click **Start** and in the search box, type **perfmon.msc** and press Enter.

Open Real-Time Monitor

Open Real-Time Monitor

In the left pane, click Performance Monitor to display the real-time monitor.

Add Network Counter

Add Network Counter

Troubleshooting

1. Click the green plus near the top of the screen to add a counter
2. In the top left pane, locate and click on **Network Interface** to select it
3. In the bottom left pane, locate the desired network interface (or use All instances to monitor all interfaces)
4. Click **Add>>** to add the counter to the right pane.
5. Click **OK** to add the counters to the graph.

Remove extra counters

Remove extra counters

In the bottom pane, select each counter other than **Bytes Total/sec** and press the **Delete** key. The **Bytes Total/sec** entry should be the only entry remaining in the pane.

Configure Data Properties

Configure Data Properties

Press **Ctrl+Q** to bring up the Properties window. Click on the dropdown next to **Scale** and select **1.0**. Then click on the **Graph** tab.

Configure Graph Properties

Configure Graph Properties

In the **Maximum Box** under **Vertical Scale** enter 917504 (this is 7Megabits converted to Bytes). If desired, turn on the horizontal grid by checking the box. The click **OK** to close the dialog.

Viewing Bandwidth Usage

Viewing Bandwidth Usage

You may now connect to your robot as normal over the selected interface (if you haven't done so already). The graph will show the total bandwidth usage of the connection, with the bandwidth cap at the top of the graph. The Last, Average, Min and Max values are also displayed at the bottom of the graph. Note that these values are in Bytes/Second meaning the cap is 917,504. With just the Driver Station open you should see a flat line at ~100000 Bytes/Second.

Measuring Bandwidth Usage using Wireshark

If you are not using Windows 7, you will need to install a 3rd party program to monitor bandwidth usage. One program that can be used for this purpose is Wireshark. Download and install the latest version of Wireshark for your version of Windows. After installation is complete, locate and open Wireshark. Connect your computer to your robot, open the Driver Station and any Dashboard or custom programs you may be using.

Select the interface and Start capture

Select the interface and Start capture

In the Wireshark program on the left side, select the interface you are using to connect to the robot and click **Start.**

Open Statistics Summary

Open Statistics Summary

Let the capture run for at least 1 minute, then click **Statistics>>Summary**.

View Bandwidth Usage

View Bandwidth Usage

Average bandwidth usage, in Megabits/Second is displayed near the bottom of the summary window. The bandwidth cap on the field is 7 Megabits/second.

RoboRIO Network Troubleshooting

The roboRIO and the 2015 FRC tools use dynamic IP addresses (DHCP) for network connectivity. This article describes steps for troubleshooting networking connectivity between your PC and your roboRIO

Ping roboRIO

The first step to identifying roboRIO networking issues is to isolate if it is an application issue or a general network issue. To do this, click Start->type **cmd**->press Enter to open the command prompt. Type **ping roboRIO-####-FRC.local** where #### is your team number (with no leading zeroes) and press enter. If the ping succeeds, the issue is likely with the specific application, verify your team number configuration in the application, and check your firewall configuration.

USB Connection Troubleshooting

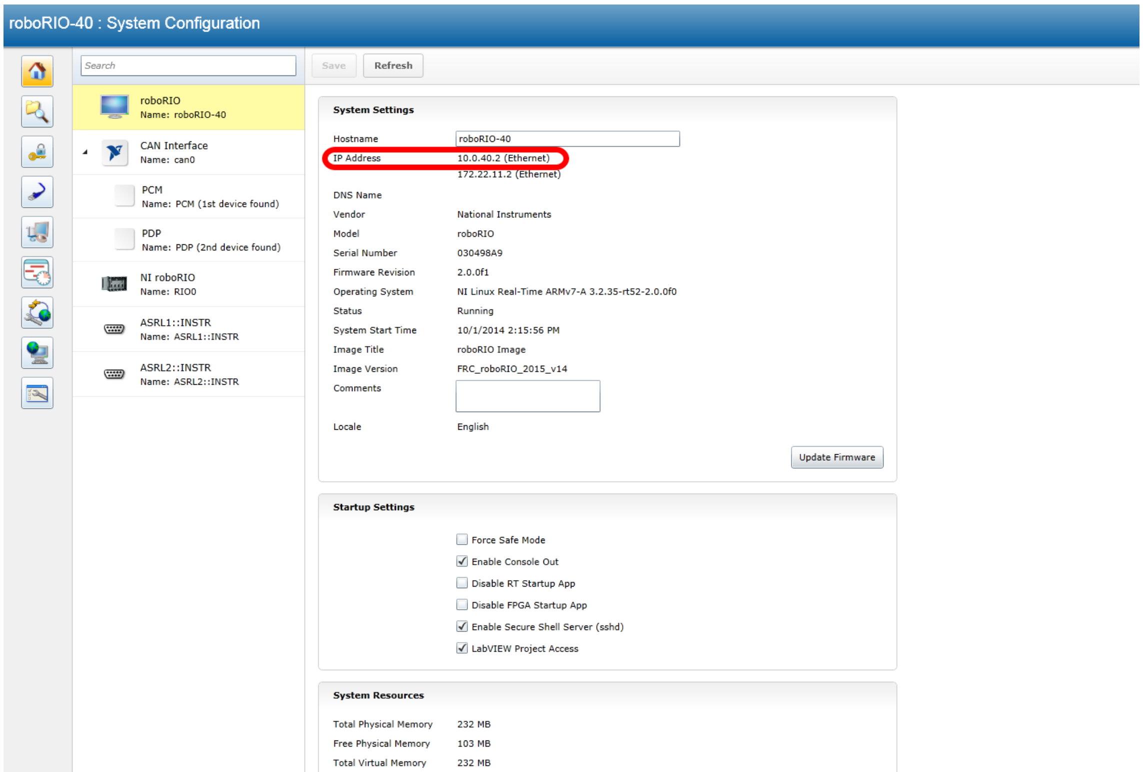
If you are attempting to troubleshoot the USB connection, try pinging the roboRIO's IP address. As long as there is only one roboRIO connected to the PC, it should be configured as 172.22.11.2. If this ping fails, make sure you have the roboRIO connected and powered, and that you have installed the NI FRC Update Suite. This update installs the roboRIO drivers needed for the USB connection.

If this ping suceeds, but the .local ping fails, it is likely that either the roboRIO hostname is configured incorrectly,, or you are connected to a DNS server which is attempting to resolve the .local address.

- Verify that your roboRIO has been imaged for your team number. This sets the hostname used by mDNS.
- Disconnect your computer from all other networks including Ethernet and WiFi. It is possible that one of these networks contains a DNS server that is attempting to resolve the .local address.

Troubleshooting

Ethernet Connection



If you are troubleshooting an Ethernet connection, it may be helpful to first make sure that you can connect to the roboRIO using the USB connection. Using the USB connection, open the roboRIO webdashboard and verify that the roboRIO has an IP address on the ethernet interface. If you are tethering to the roboRIO directly this should be a self-assigned 169.*.*.* address, if you are connected to the OM5P-AN radio, it should be an address of the form 10.TE.AM.XX where TEAM is your four digit FRC team number. If the only IP address here is the USB address, verify the physical roboRIO ethernet connection.

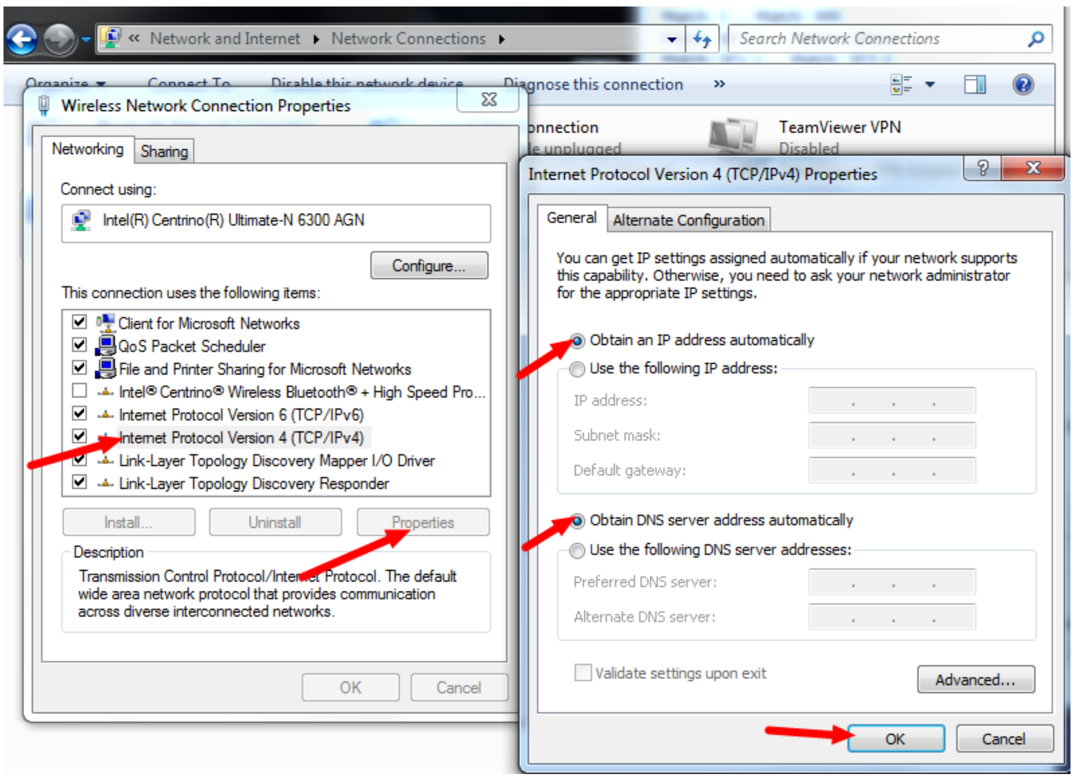
Ping the roboRIO IP address

If there is an IP address in the step above, try pinging this IP address using the command prompt as described above. If this works, you have an issue resolving the mDNS address on your PC. The two most common causes are not having an mDNS resolver installed on the system and a DNS server on the network that is trying to resolve the .local address using regular DNS.

Troubleshooting

- Verify that you have an mDNS resolver installed on your system. On Windows, this is typically fulfilled by the NI FRC Update Suite. For more information on mDNS resolvers, see the RoboRIO Networking article.
- Disconnect your computer from any other networks and make sure you have the OM5P-AN configured as an access point, using the FRC Bridge Configuration Utility. Removing any other routers from the system will help verify that there is not a DNS server causing the issue.

Ping fails



If pinging the IP address directly fails, you may have an issue with the network configuration of the PC. The PC should be configured to Obtain an Address Automatically (also known as DHCP). To check this, click Start->Control Panel->Network Connections->Change adapter settings, then right click on the appropriate interface (usually Local Area Connection for Ethernet or Wireless Network Connection for wireless) and select Properties. Click Internet Protocol Version 4, then click Properties. Make sure both radio buttons are set to Obtain automatically.

Other things to check

Other possibilities that may cause issues include:

- Proxies. Having a proxy enabled may cause issues with the roboRIO networking.

Windows Firewall Configuration

Many of the programming tools used in FRC need network access for various reasons. Depending on the exact configuration, the Windows Firewall may potentially interfere with this access for one or more of these programs. This document describes procedures for Windows 7, but Windows 8 should be similar.

Disabling Windows Firewall

The easiest solution is to disable the Windows Firewall. Teams should beware that this does make the PC potentially more vulnerable to malware attacks if connecting to the internet.

Control Panel

Control Panel

Click Start->Control Panel to open the Control Panel. Click the dropdown next to **View by:** and select **Small icons** then click **Windows Firewall.**

Turn Windows Firewall on or off

Turn Windows Firewall on or off

In the left pane, click **Turn Windows Firewall on or off,** and click yes or enter your Administrator password if a dialog appears.

Disable the Firewall

Disable the Firewall

For each category, select the radio button to **Turn off Windows Firewall**. Then click **OK.**

Configure the firewall

Alternatively, you can add exceptions to the Firewall for any FRC programs you are having issues with.

Control Panel

Control Panel

Click Start->Control Panel to open the Control Panel. Click the dropdown next to **View by:** and select **Small icons** then click **Windows Firewall**.

Allow a program...

Allow a program...

In the left pane, click **Allow a program or feature through Windows Firewall**

Allowed Programs

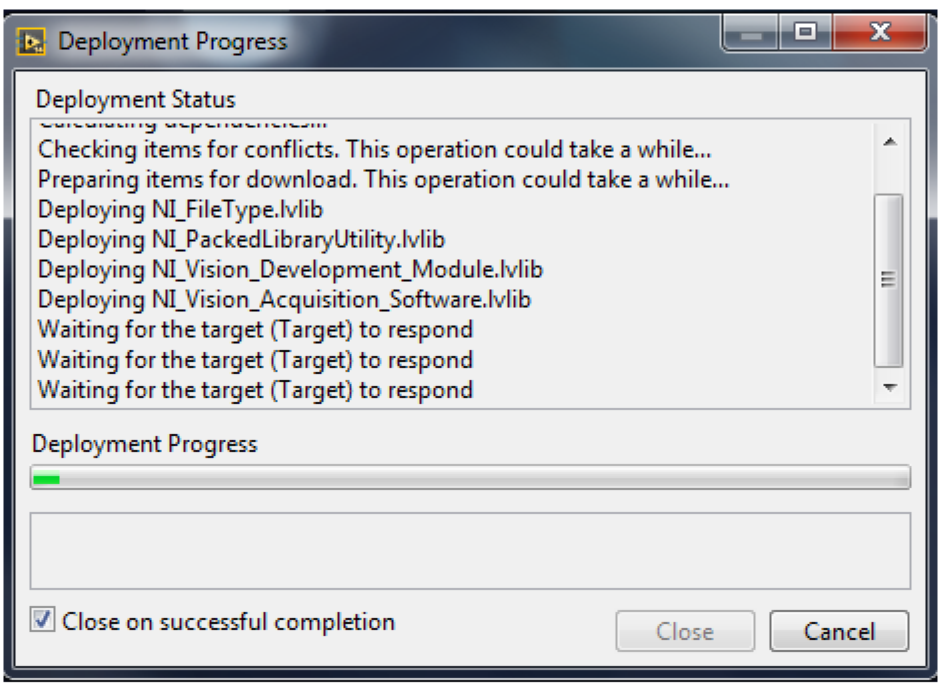
Allowed Programs

For each FRC program you are having an issue with, make sure that it appears in the list and that it has a check in each of the 3 columns. If you need to change a setting, you made need to click the **Change settings** button in the top right before changing the settings. If the program is not in the list at all, click the **Allow another program...** button and browse to the location of the program to add it.

Waiting for Target to Respond - Recovering from bad loops

If you download LabVIEW code which contains an unconstrained loop (a loop with no delay) it is possible to get the roboRIO into a state where LabVIEW is unable to connect to download new code. This document explains the process required to load new, fixed, code to recover from this state.

The Symptom

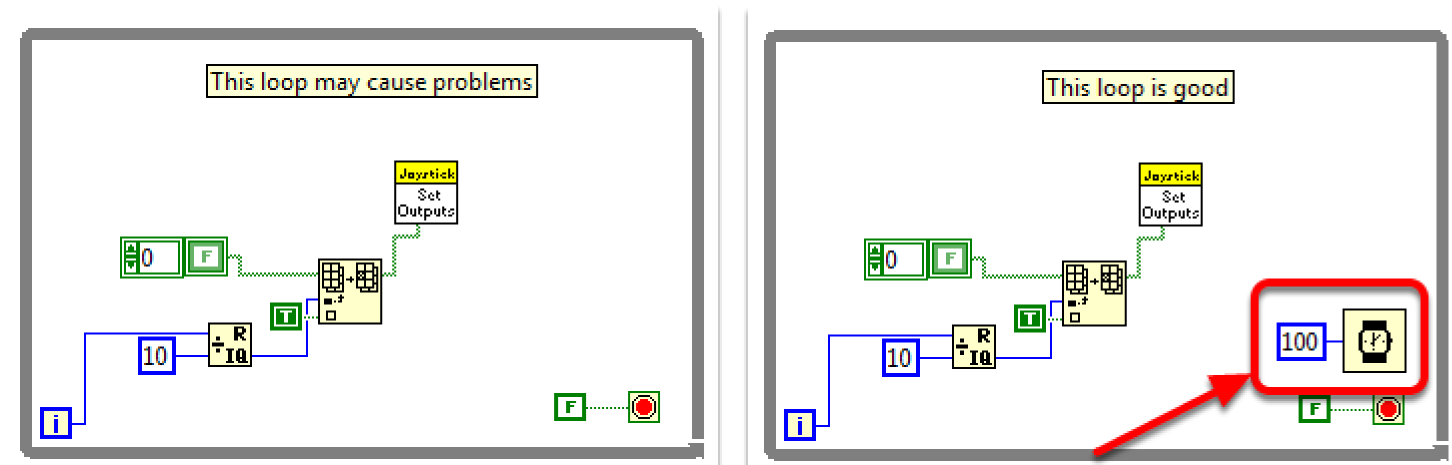


Troubleshooting

The primary symptom of this issue is attempts to download new robot code hang at the "Waiting for the target (Target) to respond" step as shown above. Note that there are other possible causes of this symptom (such as switching from a C++\Java program to LabVIEW program) but the steps described here should resolve most or all of them.

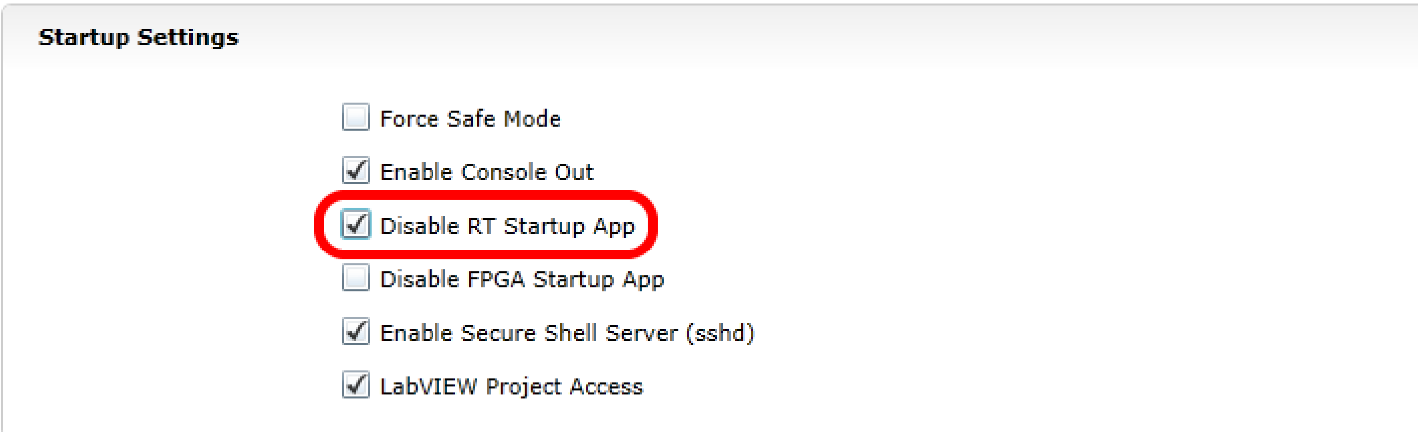
Click Cancel to close the download dialog.

The Problem



One common source of this issue is unconstrained loops in your LabVIEW code. An unconstrained loop is a loop which does not contain any delay element (such as the one on the left). If you are unsure where to begin looking, Disabled.VI, Periodic Tasks.VI and Vision Processing.VI are the common locations for this type of loop. To fix the issue with the code, add a delay element such as the Wait (ms) VI from the Timing palette, found in the right loop.

Set No App

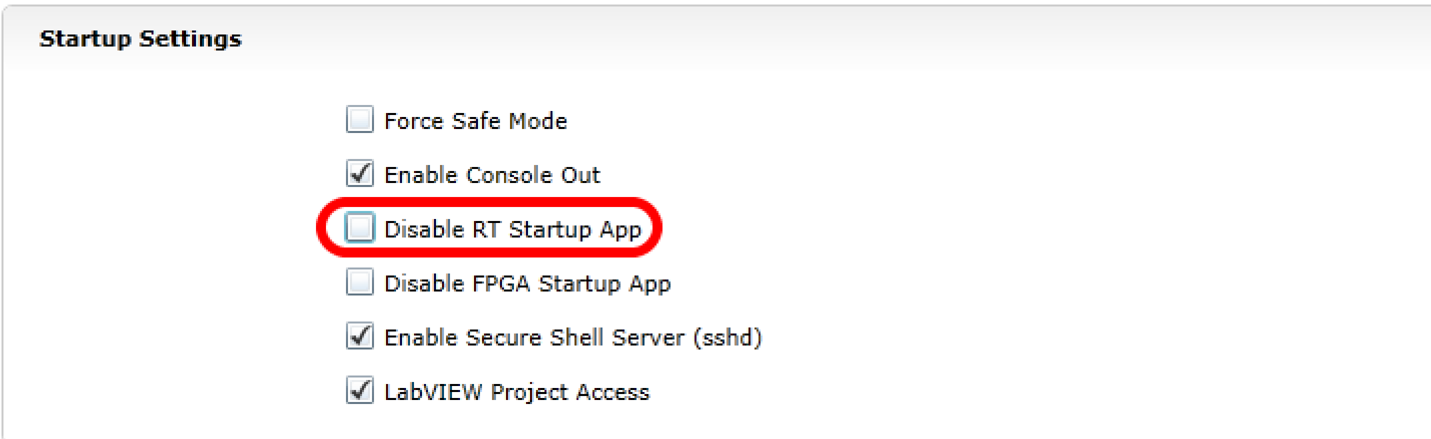


Using the roboRIO webserver (see the article RoboRIO Webdashboard for more details). Check the box to "Disable RT Startup App".

Reboot

Reboot the roboRIO, either using the Reset button on the device or by click Restart in the top right corner of the webpage.

Clear No App



Using the roboRIO webserver (see the article RoboRIO Webdashboard for more details). Uncheck the box to "Disable RT Startup App".

Load LabVIEW Code

Load LabVIEW code (either using the Run button or Run as Startup). Make sure to set LabVIEW code to Run as Startup before rebooting the roboRIO or you will need to follow the instructions above again.

Recovering a roboRIO using Safe Mode

Occasionally a roboRIO may become corrupted to the point that it cannot be recovered using the normal boot and imaging process. Booting the roboRIO into Safe Mode may allow the device to be successfully re-imaged.

Booting into Safe Mode

Booting into Safe Mode

To boot the roboRIO into Safe Mode:

1. Apply power to the roboRIO
2. Press and hold the Reset button until the Status LED lights up (~5 seconds) then release the Reset button
3. The roboRIO will boot in Safe Mode (indicated by the Status LED flashing in groups of 3)

Recovering the roboRIO

The roboRIO can now be imaged by using the roboRIO Imaging Tool as described in Imaging your roboRIO.

About Safe Mode

In Safe Mode, the roboRIO boots a separate copy of the operating system into a RAM Disk. This allows you to recover the roboRIO even if the normal copy of the OS is corrupted. While in Safe Mode, any changes made to the OS (such as changes made by accessing the device via SSH or Serial) will not persist to the normal copy of the OS stored on disk.

OM5P-AC Radio Modification

The intended use case for the OM5P-AC radio does not subject it to the same shocks and forces as it sees in the FRC environment. If the radio is subjected to significant pressure on the bottom of the case, it is possible to cause a radio reboot by shorting a metal shield at the bottom of the radio to some exposed metal leads on the bottom of the board. This article details a modification to the radio to prevent this scenario.

Note: It takes significant pressure applied to the bottom of the case to cause a reboot in this manner. Most FRC radio reboot issues can be traced to the power path in some form. We recommend mitigating this risk via strategic mounting of the radio rather than opening and modifying the radio (and risk damaging delicate internal components):

- Avoid using the "mounting tab" features on the bottom of the radio)
- You may wish to mount the radio to allow for some shock absorption. A little can go a long way, mounting the radio using hook and loop fastener or to a robot surface with a small amount of flex (plastic or sheet metal sheet, etc.) can significantly reduce the forces experienced by the radio.

Opening the Radio

The OpenMesh OM5P-AC is not designed to be a user serviceable device. Users perform this modification at their own risk. Make sure to work slowly and carefully to avoid damaging internal components such as radio antenna cables.

Troubleshooting

Case Screws

Locate the two rubber feet on the front side of the radio then pry them off the radio using fingernails, small flat screwdriver, etc. Using a small Phillips screwdriver, remove the two screws under the feet.

Side Latches

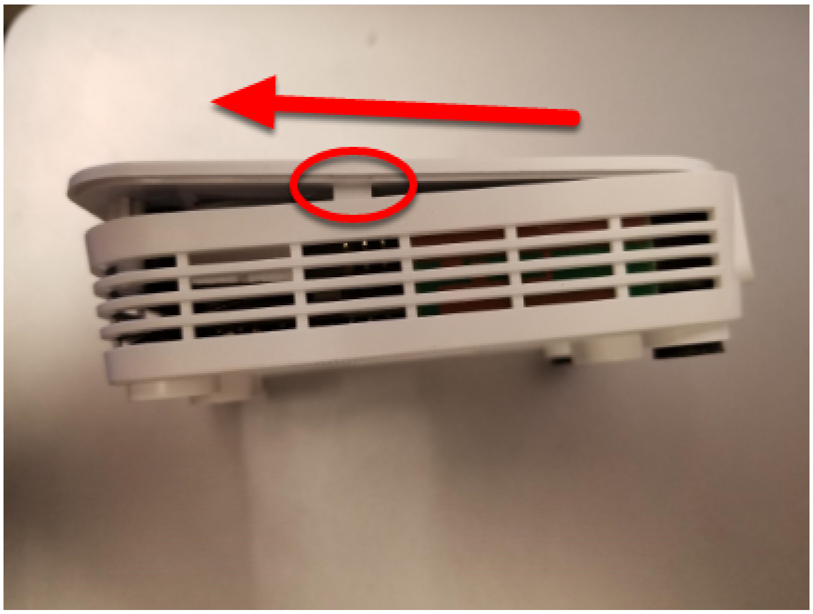
There is a small latch on the lid of the radio near the middle of each long edge (you can see these latches more clearly in the next picture). Using a fingernail or very thin tool, slide along the gap between the lid and case from front to back towards the middle of the radio, you should hear a small pop as you near the middle of radio. Repeat on the other side (note: it's not hard to accidentally re-latch the first side while doing this, make sure both sides are unlatched before proceeding). The radio lid should now be slightly open on the front side as shown in the image above.

Remove Lid

⚠ Warning: the board may stick to the lid as you remove it due to the heatsink pads. Look through the vents of the radio as you remove the lid to see if the board is coming with it, if it is you may need to insert a small tool to hold the board down to separate it from the lid. We recommend a small screwdriver or similar tool that fits through the vents, applied

Troubleshooting

through the front corner on the barrel jack side, right above the screw hole. You can scroll down to the picture with the lid removed to see what the board looks like in this area.



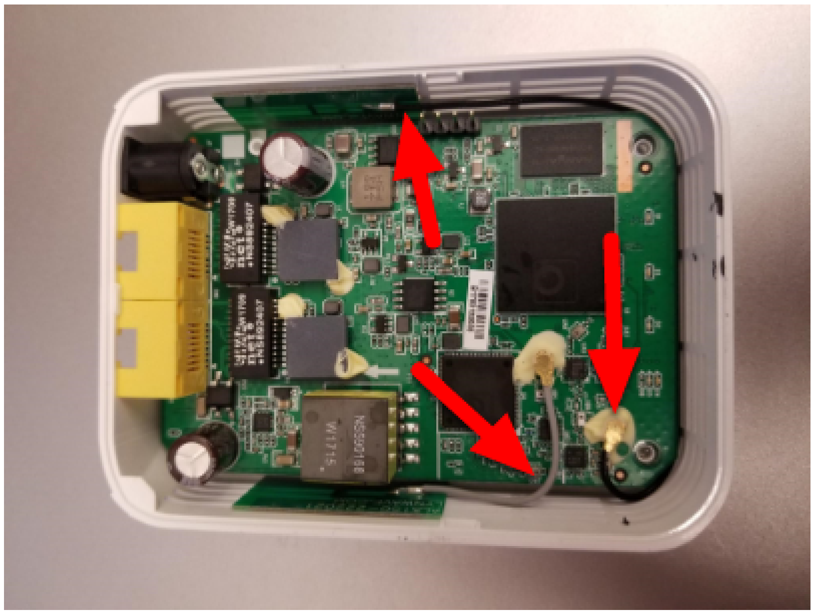
To begin removing the lid, slide it forward (lifting slightly) until the screw holders hit the case front (you may need to apply pressure on the latch areas while doing this.

Troubleshooting

Next, begin rotating the lid slightly away from the barrel jack side, as shown while continuing to lift. This will unhook the lid from the small triangle visible in the top right corner. Continue to rotate slightly in this direction while pushing the top left corner towards the barrel jack (don't try to lift further in this step) to unhook a similar feature in the top left corner. Then lift the lid completely away from the body.

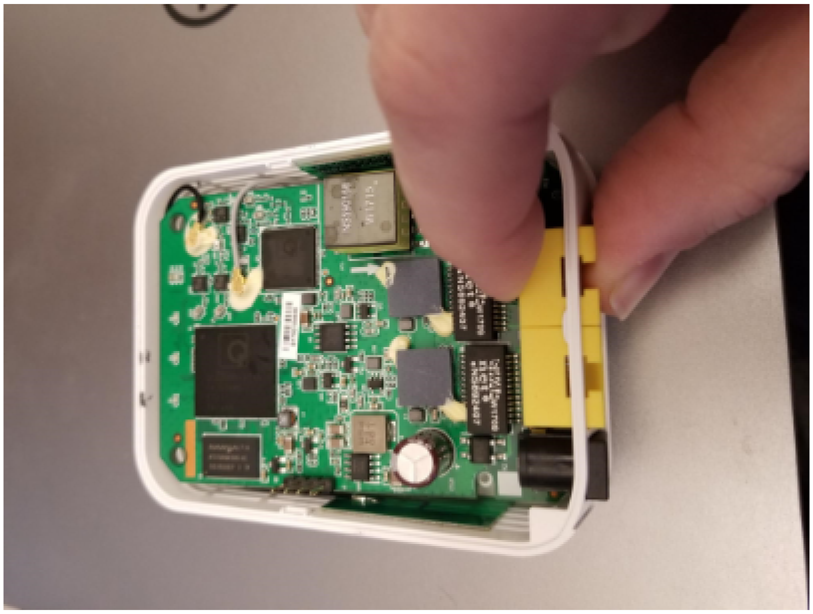
Troubleshooting

Remove Board



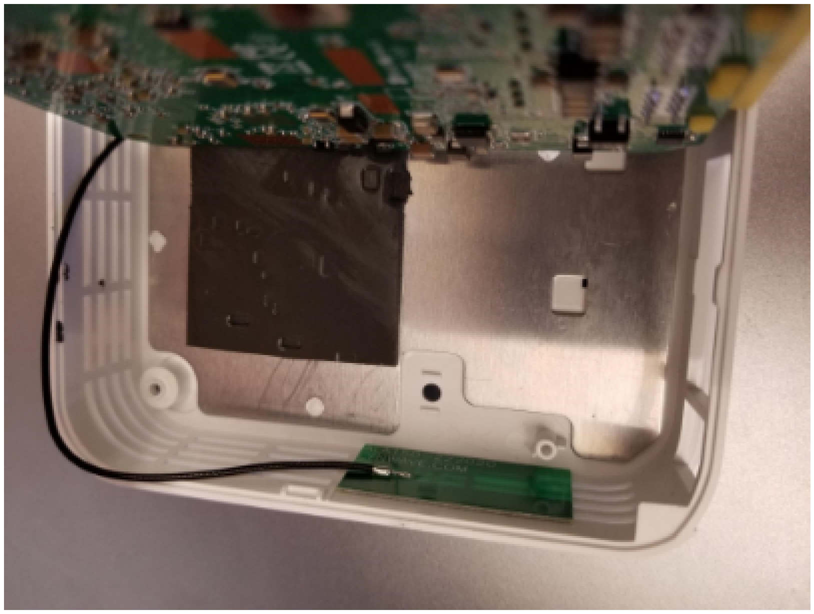
⚠ Note the antenna wires shown in the image above. These wires, and their connectors, are fragile, take care not to damage them while performing the next steps.

Troubleshooting



To remove the board, we recommend grasping one or both network ports with your fingers (as shown) and pushing inward (toward the front of the radio) and upward until the network ports and barrel jack are free from the case.

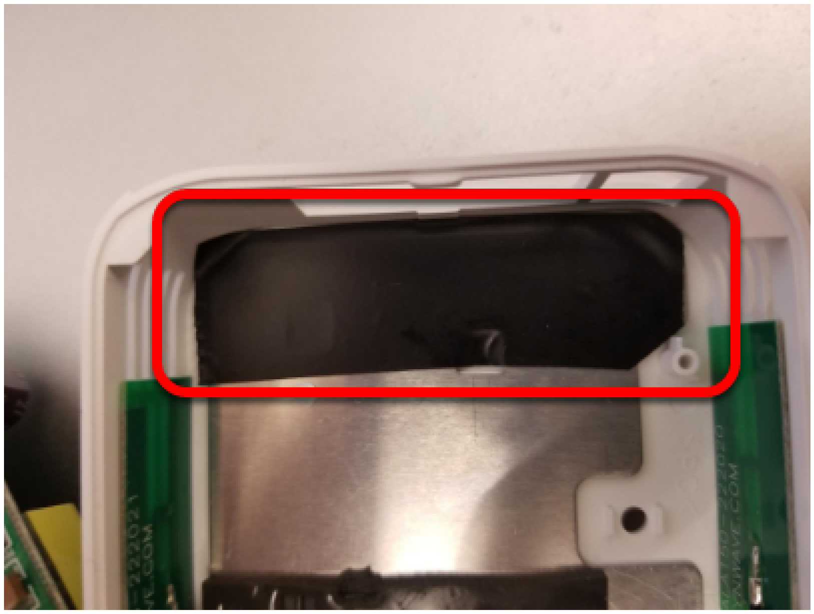
Troubleshooting



Tilt the board up (towards the short grey antenna cable) to expose the metal shield underneath.

When you perform this step, you may notice that there is a small reset button on the underside of the board that is larger than the hole in the case. Note that pressing the reset button with the FRC firmware installed has no effect and that drilling the case of the radio is not a permitted modification.

Apply Tape



Apply a piece of electrical tape to the metal shield in the area just inside of the network port/barrel jack openings. This will prevent the exposed leads on the underside of the board from short circuiting on this plate.

Re-assemble Radio

Re-assemble the radio by reversing the instructions to open it:

- Lay the board back down, making sure it aligns with the screw holes near the front and seats securely
- Slide the lid onto the back left retaining feature by moving it in from right to left. Take care of the capacitor in this area
- Rotate the lid, press downwards and slide the back right retaining feature in.
- Press down firmly on the front/middle of the lid to seat the latches.
- Replace 2 screws in front feet
- Replace front feet.

At The Event

IP Networking at the Event

This document describes the IP configuration used at events, both on the fields and in the pits, potential issues and workaround configurations.

TE.AM IP Notation

The notation TE.AM is used as part of IPs in numerous places in this document. This notation refers to splitting your four digit team number into two digit pairs for the IP address octets.

Example: 10.TE.AM.2

Team 12 - 10.0.12.2

Team 122 - 10.1.22.2

Team 1212 - 10.12.12.2

Team 3456 - 10.34.56.2

On the Field

This section describes networking when connected to the Field Network for match play

DHCP (typical configuration)

The Field Network runs a DHCP server with pools for each team that will hand our addresses in the range of 10.TE.AM.20 and up with subnet masks of 255.0.0.0

- OpenMesh OM5P-AN or OM5P-AC radio - Static 10.TE.AM.1 programmed by Kiosk
- roboRIO - DHCP 10.TE.AM.2 assigned by the Robot Radio
- Driver Station - DHCP ("Obtain an IP address automatically") 10.TE.AM.X assigned by field
- IP camera (if used) - DHCP 10.TE.AM.Y assigned by Robot Radio
- Other devices (if used) - DHCP 10.TE.AM.Z assigned by Robot Radio

Static (workaround configuration)

It is also possible to configure static IPs on your devices to accommodate devices or software which do not support mDNS. When doing so you want to make sure to avoid addresses that will be in use when the robot is on the field network. These addresses are 10.TE.AM.1 and 10.TE.AM.4 for the OpenMesh radio and the field access point and anything 10.TE.AM.20 and up which may be assigned to a device still configured for DHCP. The roboRIO network configuration can be set from the webdashboard.

- OpenMesh radio - Static 10.TE.AM.1 programmed by Kiosk
- roboRIO - Static 10.TE.AM.2 would be a reasonable choice, subnet mask of 255.255.255.0 (default)
- Driver Station - Static 10.TE.AM.5 would be a reasonable choice, subnet mask must be 255.0.0.0
- IP Camera (if used) - Static 10.TE.AM.11 would be a reasonable choice, subnet 255.255.255.0 should be fine
- Other devices - Static 10.TE.AM.6-.10 or .12-.19 (.11 if camera not present) subnet 255.255.255.0

In the Pits

New for 2018: There is now a DHCP server running on the wired side of the Robot Radio in the event configuration.

DHCP (typical configuration)

- OpenMesh radio - Static 10.TE.AM.1 programmed by Kiosk.
- roboRIO - 10.TE.AM.2, assigned by Robot Radio
- Driver Station - DHCP ("Obtain an IP address automatically"), 10.TE.AM.X, assigned by Robot Radio
- IP camera (if used) - DHCP, 10.TE.AM.Y, assigned by Robot Radio
- Other devices (if used) - DHCP, 10.TE.AM.Z, assigned by Robot Radio

Static (workaround configuration)

It is also possible to configure static IPs on your devices to accommodate devices or software which do not support mDNS. When doing so you want to make sure to avoid addresses that will be in use when the robot is on the field network. These addresses are 10.TE.AM.1 and 10.TE.AM.4 for the OpenMesh radio and the field access point and anything 10.TE.AM.20 and up which may be assigned to a device still configured for DHCP. The roboRIO network configuration can be set from the webdashboard.

- OpenMesh radio - Static 10.TE.AM.1 programmed by Kiosk
- roboRIO - Static 10.TE.AM.2 would be a reasonable choice, subnet mask of 255.255.255.0 (default)
- Driver Station - Static 10.TE.AM.5 would be a reasonable choice, **subnet mask must be 255.0.0.0**
- IP Camera (if used) - Static 10.TE.AM.11 would be a reasonable choice, subnet 255.255.255.0 should be fine
- Other devices - Static 10.TE.AM.6-.10 or .12-.19 (.11 if camera not present) subnet 255.255.255.0

Troubleshooting

The most common issue is to have a mix of static and DHCP configured devices. This should be less problematic with the 2018 configuration, but should still be avoided.

Another common issue is using a subnet mask of 255.255.255.0 on the DS PC. This configuration will not communicate with the FMS system which is on a 10.0.100 address.

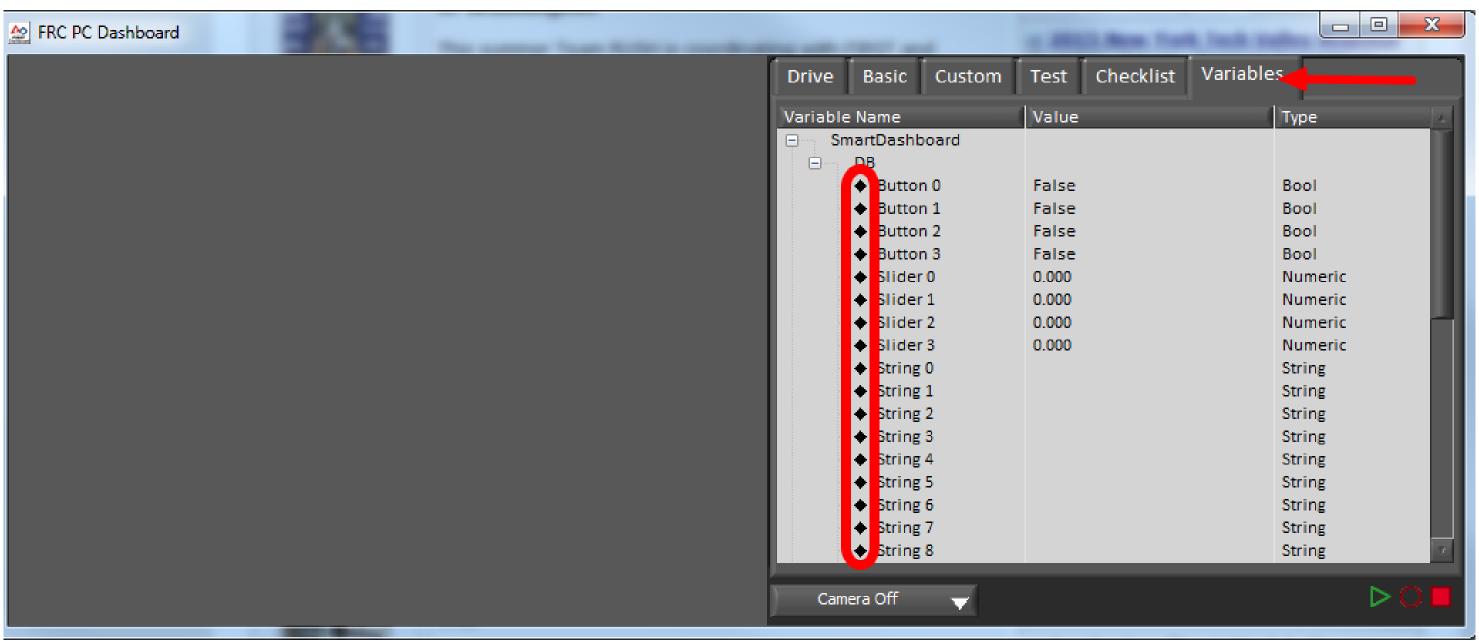
Troubleshooting Dashboard Connectivity

We have received a number of reports of Dashboard connectivity issues from events. This document will help explain how to recognize if the Dashboard is not connected to your robot, steps to troubleshoot this condition and a code modification you can make

LabVIEW Dashboard

This section discusses connectivity between the robot and LabVIEW dashboard

Recognizing Connectivity



If you have an indicator on your dashboard that you expect to be changing it may be fairly trivial to recognize if the Dashboard is connected. If not, there is a way to check without making any changes to your robot code. On the Variables tab of the Dashboard, the variables are shown with a black diamond when they are not synced with the robot. Once the Dashboard connects to the robot and these variables are synced, the diamond will disappear.

Troubleshooting

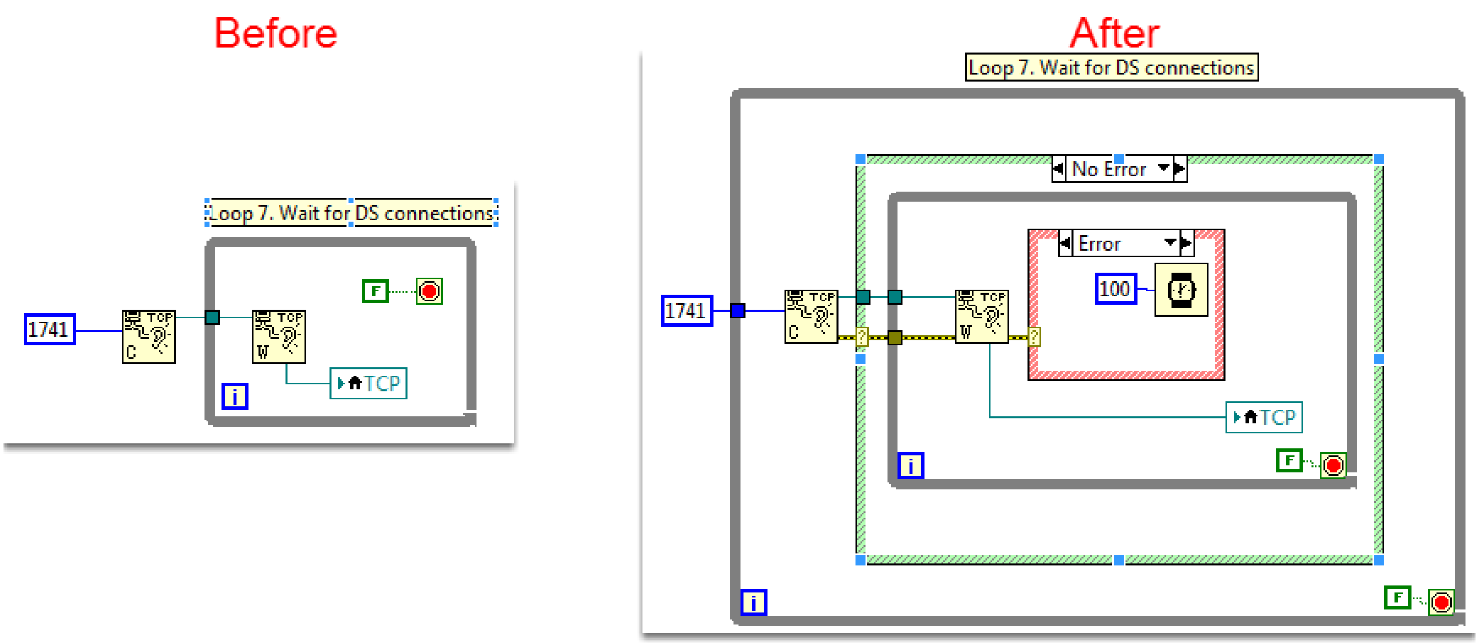
Troubleshooting Connectivity

If the Dashboard does not connect to the Robot (after the Driver Station has connected to the robot) the recommended troubleshooting steps are:

1. Close the Driver Station and Dashboard, then re-open the Driver Station (which should launch the Dashboard).

2. If that doesn't work, restart the Robot Code using the Restart Robot Code button on the Diagnostics tab of the Driver Station

Improving Reliability of a Custom Dashboard



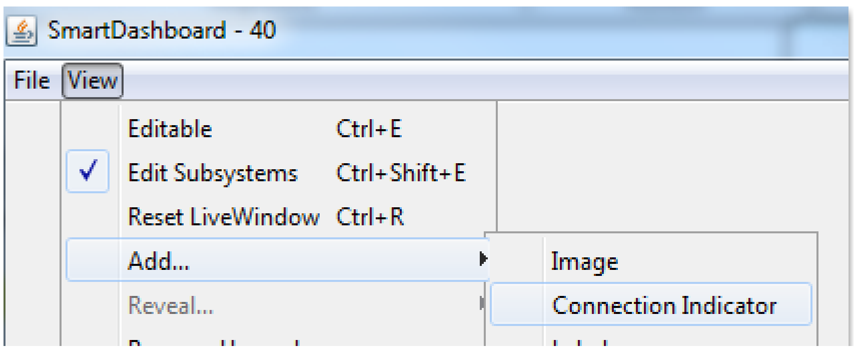
If you have created a custom LabVIEW dashboard there is a tweak you can make to the code to improve reliability of the initial connection. Locate the loop labeled Loop 7 in the Dashboard Main VI. Modify the loop according to the image above by adding a loop around the listener, 2 case statements, a Wait block and error wiring.

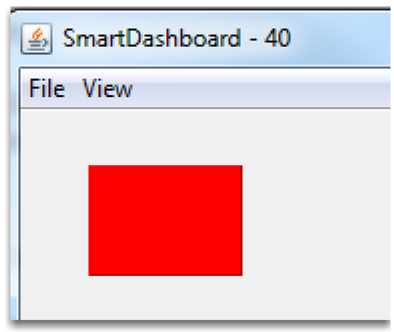
Troubleshooting

SmartDashboard

This section discusses connectivity between the robot and Java SmartDashboard

Recognizing Connectivity





The typical way to recognize connectivity with the Java SmartDashboard is to add a Connection Indicator widget and to make sure your code is writing at least one key during initialization or disabled to trigger the connection indicator. The connection indicator can be moved or re-sized if the Editable checkbox is checked.

Troubleshooting Connectivity

If the Dashboard does not connect to the Robot (after the Driver Station has connected to the robot) the recommended troubleshooting steps are:

1. Restart the SmartDashboard (there is no need to restart the Driver Station software for the Java SmartDashboard)

2. If that doesn't work, restart the Robot Code using the Restart Robot Code button on the Diagnostics tab of the Driver Station

3. If it still doesn't connect verify that the Team Number is set properly in the Dashboard and that your Robot Code writes a SmartDashboard value during initialization or disabled

Programming Radios for FMS Offseason

When using the FMS Offseason software, the typical networking setup is to use a single access point with a single SSID and WPA key. This means that the radios should all be programmed to connect to this network, but with different IPs for each team. The Team version of the FRC Bridge Configuration Utility has an FMS-Lite mode that can be used to do this configuration.

Before you begin using the software:

1. Disable WiFi connections on your computer, as it may prevent the configuration utility from properly communicating with the bridge
2. Make sure no devices are connected to your computer via ethernet, other than the wireless bridge.

The steps below describe installing and using the FRC Bridge Configuration Utility to program radios for this network configuration. If you have a machine where you have already used this tool to program a radio for FRC 2016, skip to "Launch the Software".

Pre-Requisites

The 2016 FRC Radio Configuration Utility requires the Java Runtime Engine (JRE). If you do not have Java installed, you can download the JRE from here: https://www.java.com/en/download/

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

Application Notes

The 2016 Radio Kiosk will program the radio to enforce the 7Mbps bandwidth limit on traffic exiting the radio over the wireless interface. In the home configuration (AP mode) this is a total, not a per client limit. This means that streaming video to multiple clients is not recommended.

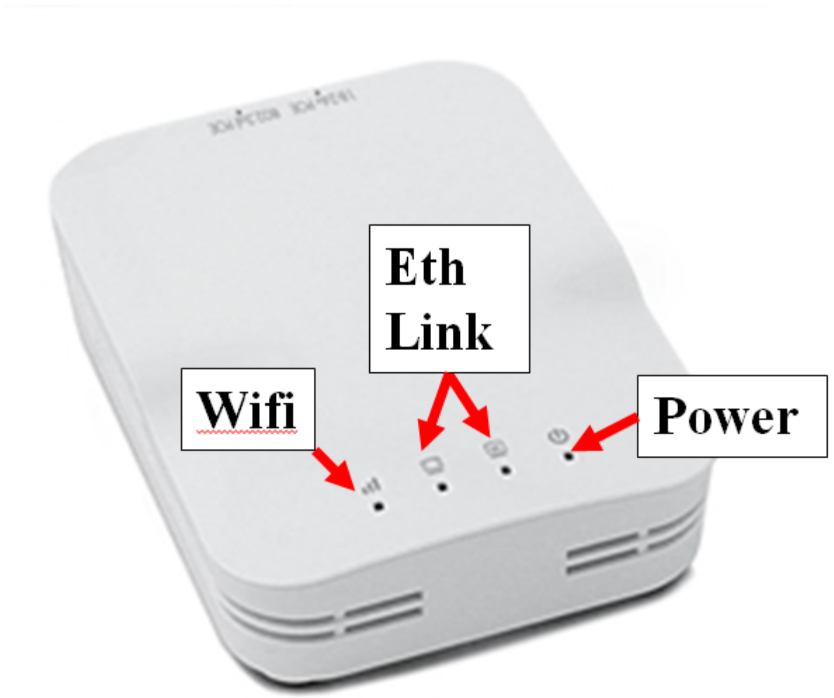
Troubleshooting

The 2016 Kiosk has been tested on Windows 7, 8 and 10. It may work on other operating systems, but has not been tested.

Programmed Configuration

Power	
Blue	On or Powering up
Blue Blinking	Powering up
Eth Link	
Blue	Link Up
Blue Blinking	Traffic present
WiFi	
Red	Bridge Mode, unlinked
Yellow\Orange	Bridge Mode, Linked
Green	AP Mode
Off	Unprogrammed

WiFi light only works after radio has been power cycled.



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

- Set a static IP of 10.TE.AM.1
- Set an alternate IP on the wired side of 192.168.1.1 for future programming
- Bridge the wired ports so they may be used interchangeably
- The LED configuration noted in the graphic above
- 7Mb/s bandwidth limit on the outbound side of the wireless interface
- QoS rules for internal packet prioritization (affects internal buffer and which packets to discard if bandwidth limit is reached). These rules are Robot Control and Status (UDP 1110, 1115, 1150) >> Robot TCP & Network Tables (TCP 1735, 1740) >> Bulk (All other traffic).

When programmed with the team version of the Radio Configuration Utility, the user accounts will be left at (or set to) the firmware defaults:

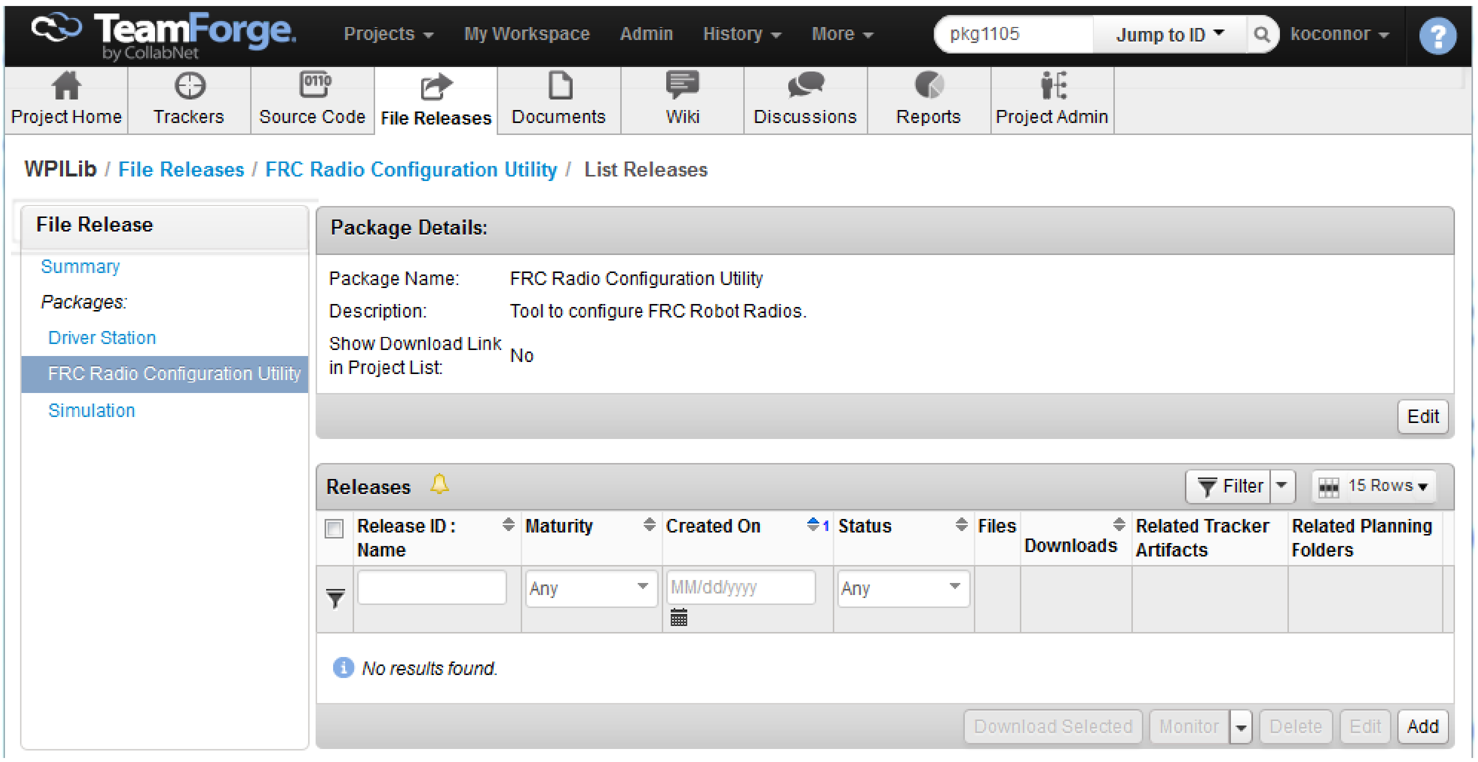
- Username: root

Troubleshooting

- Password: root

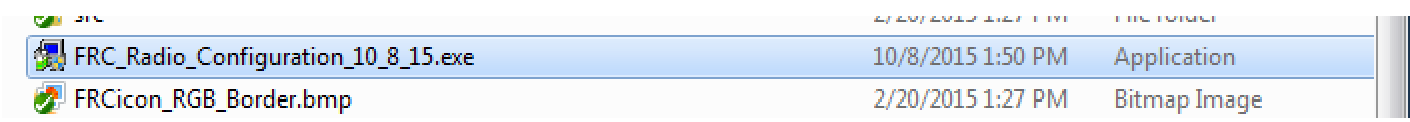
Note: It is not recommended to modify the configuration manually

Download the software



Download the latest FRC Radio Configuration Utility Installer from the [WPILib project File Releases].

Install the software

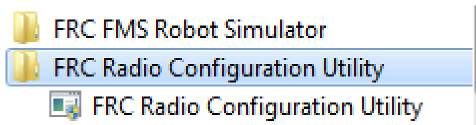


Double click on FRC_Radio_Configuration_MM_DD_YY.exe to launch the installer. Follow the prompts to complete the installation.

Troubleshooting

Part of the installation prompts will include installing WinPCap if it is not already present. The WinPCap installer contains a checkbox (checked by default) to start the WinPCap driver on boot. You should leave this box checked.

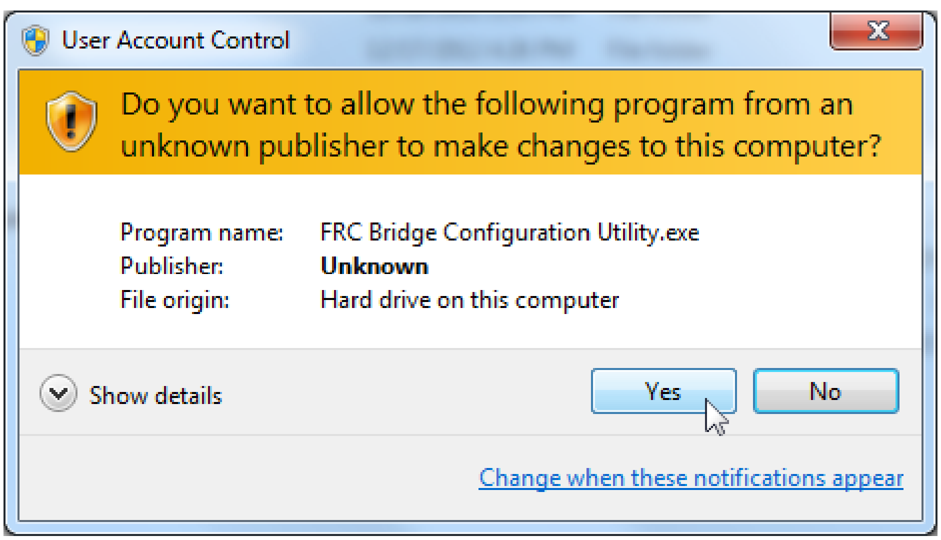
Launch the software



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

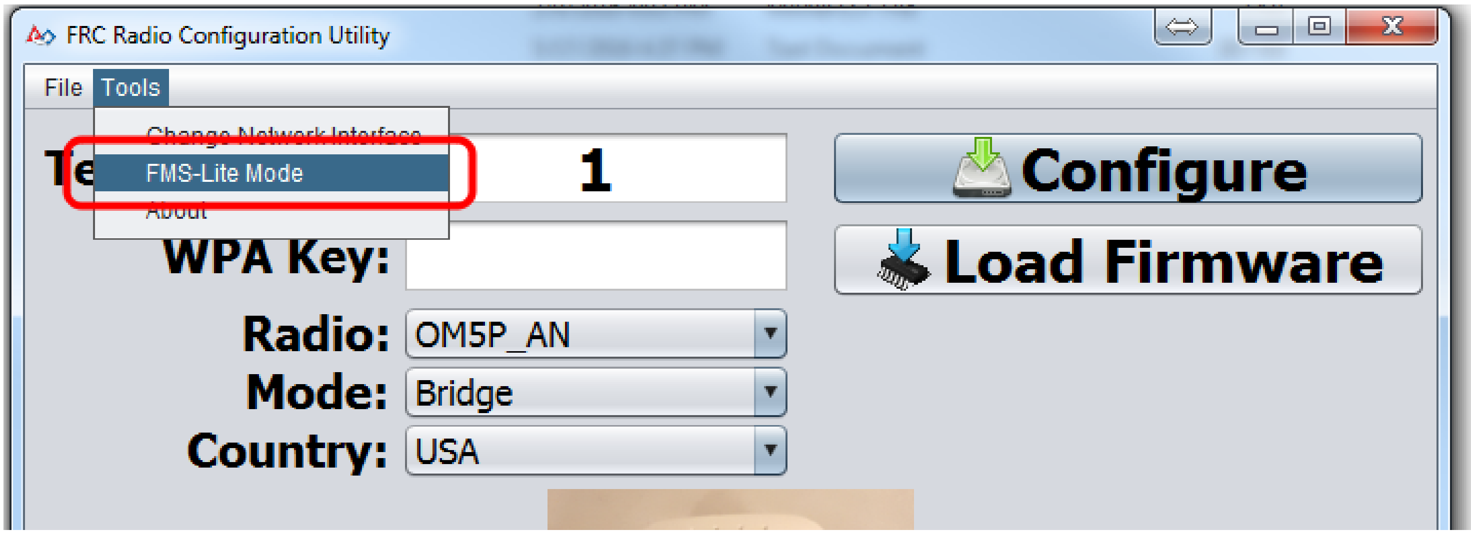
Note: If you need to locate the program it is installed to C:\Program Files (x86)\FRC Radio Configuration Utility. For 32-bit machines the path is C:\Program Files\FRC Radio Configuration Utility\

Allow the program to make changes, if prompted



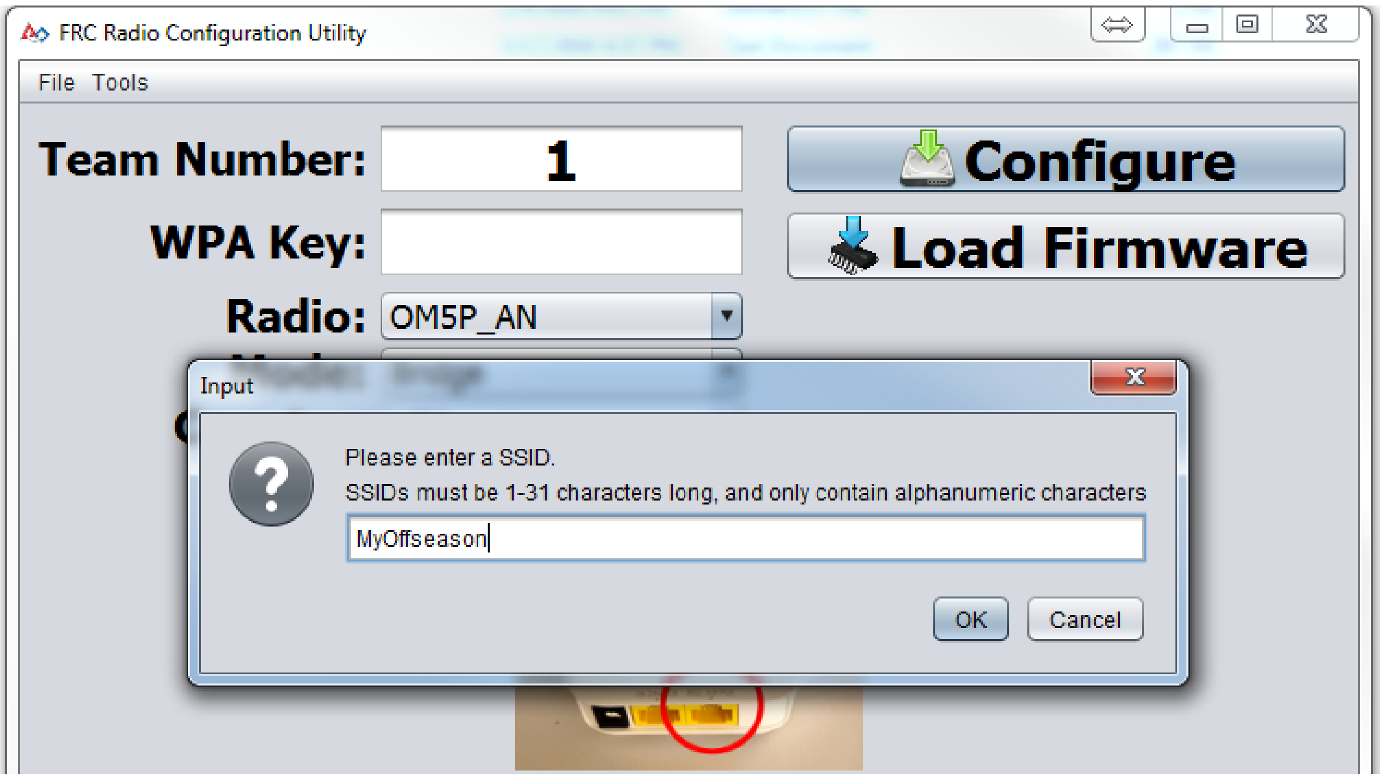
If the your computer is running Windows Vista or Windows 7, a prompt may appear about allowing the configuration utility to make changes to the computer. Click "Yes" if the prompt appears.

Enter FMS-Lite Mode



Click **Tools->FMS-Lite Mode** to enter FMS-Lite Mode.

Enter SSID



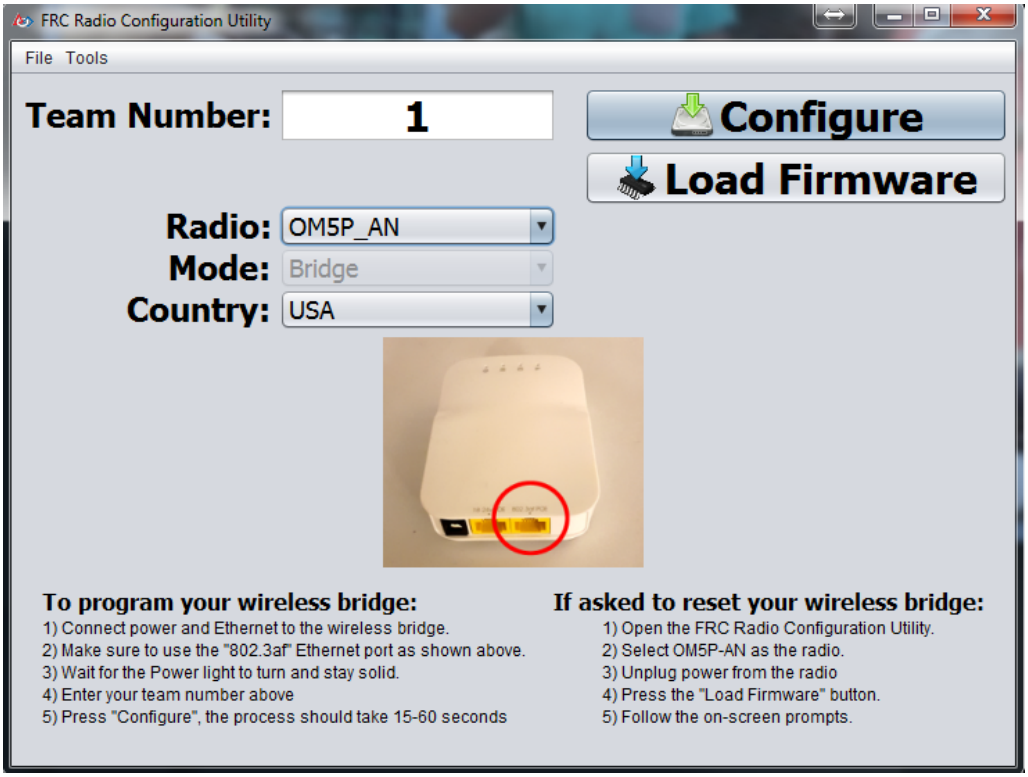
Enter the SSID (name) of your wireless network in the box and click OK.

Enter WPA Key

Enter the WPA key for your network in the box and click OK. Leave the box blank if you are using an unsecured network.

Troubleshooting

Program Radios



The Kiosk is now ready to program any number of radios to connect to the network entered. To program each radio, connect the radio to the Kiosk, set the Team Number in the box, and click Configure.

The kiosk will program D-Link Rev A or Rev B radios to work on an offseason FMS network by selecting the appropriate option from the "Radio" dropdown. **Note: Bandwidth limitations and QoS will not be configured on the D-Link radios in this mode.**

Changing SSID or Key

If you enter something incorrectly or need to change the SSID or WPA Key, go to the Tools menu and click FMS-Lite Mode to take the kiosk out of FMS-Lite Mode. When you click again to put the Kiosk back in FMS-Lite Mode, you will be re-prompted for the SSID and Key.

FMS Whitepaper

The purpose of this document is to provide an insight to the functional structure and method by which the FIELD MANAGEMENT SYSTEM (FMS) is implemented on a typical FRC field. All rules information should be directed to the season-specific FRC Game Manual, as that is the authoritative source for rules and regulations. This document is purely for informational purposes.

Role of the Field Management System (FMS)

The FIELD MANAGEMENT SYSTEM (FMS) is the electronics core responsible for controlling the *FIRST* Robotics Competition (FRC) playing field. The FMS encompasses all field electronics, including the Field Management server, Referee Panels, Field Access Point, Team Stack Lights, Emergency Stops, etc. Additional hardware and software components may be added to the FMS for each years' challenges.

The FMS is also responsible for coordinating control of the Driver Stations and robots during a match, as well as providing the pipeline for them to communicate. The FMS also provides the infrastructure for real-time score-keeping, and logs diagnostic data during the event. Finally, the FMS provides data to the Audience and Pit Displays.

The FMS is based on Ethernet architecture. End devices such as the Driver Station, Referee Panels and other field components communicate over a wired Ethernet interface. Numerous other field electronics (such as Stack Lights and Emergency Stops) also connect to devices that, in the end, communicate over Ethernet to the rest of the network. Wireless communications (WIFI) is only used to communicate with the robots during a match.

Although the FMS Field Network is all on one physical network, this physical network is split into Virtual Networks (VLANs), to ensure each team's communications are independent from other teams, as well as the rest of the field electronics.

The goal of the FMS is to provide a unified, secure and robust solution to running FRC matches in a fair and consistent manner. Many protocols and procedures are put in place to ensure the FMS is operational and running to full capacity.

Troubleshooting

The Field Network

Components

The FMS is made of many components, all working together in unison to provide the full functionality of an FRC field. This section contains most, but not all, of the field electronic components and has been generalized to be season-agnostic.

The Field Router

The Field Router is located inside the FMS roadcase, and is used to provide the FMS network with an internet uplink to the venue connection, route all cross-network traffic, and establish routing rules and VLAN configurations. The Field Router does not directly connect to any other member of the network other than the Score Switch. All active interfaces on the Field Router are 10/100/1000 Gigabit Ethernet.

The Score Switch

The Score Switch is located inside the FMS roadcase, and is the central point for all communications on the Field network. The Score Switch connects the Station Control Cabinets (SCCs), Field Access Point, FMS server and a secondary, unmanaged 10/100 Fast Ethernet switch, which connects to the Arena Stack Light and Programmable Logic Controller (PLC). All interfaces on the Score Switch are 10/100/1000 Gigabit Ethernet.

Another 10/100/1000 Switch is located external to the FMS roadcase, usually located on the scoring table. This switch connects to the Score Switch and is used to interconnect Referee Panels, Pit/Audience Displays and the *FIRST* Technical Advisor (FTA) Field Monitor.

The FMS Server

The FMS server runs the FMS software, and is connected directly to the Score Switch. The FMS server is responsible for managing field play, scoring, field control, as well as the Audience and Pit displays. It also provides the FMS graphic overlay used on the video displays at the event. The FMS also manages the Driver Stations of each alliance.

Troubleshooting

The FMS server does not communicate directly with the robots. All communication is between the FMS server and the Driver Station, including states (Enabled, Disabled, Teleop, Auto, etc), Emergency Stop status, Match Time, and more. If the Driver Station loses connection with the FMS software, the watchdog function onboard the robot halts control and disables the robot.

The FMS server also collects diagnostic status from Driver Stations, field electronics, robot radios, and the National Instruments roboRIO to diagnose issues and log match play. This data includes, but is not limited to, ping status, robot code status, packet trip time, bandwidth utilization and battery voltage. All robot data is first communicated from the robot to the driver station, and then from the driver station to the FMS server.

There is a second FMS server included with the field that can be swapped out as a spare at any time. The configurations for both are identical.

The Programmable Logic Controller (PLC)

The Rockwell Automation Programmable Logic Controller (PLC) is located inside of the FMS roadcase, and is responsible for keeping track of the field scoring equipment. Over Ethernet, the PLC communicates with other field electronics (many of which are season-specific) to keep score count, and update the FMS server. This offloads some of the work done by the FMS server and allows much more advanced control over other season-specific field electronics.

Station Control Cabinet (SCC)

Each alliance on the field, red and blue, has its own Station Control Cabinet (SCC). A 3rd, spare SCC is included with the field. There are 2 versions of the SCCs in use at FRC events, but the functionality is the same.

Version 1 contains a primary Ethernet switch connected to the Score Switch with a 10/100/1000 Gigabit Ethernet trunk line, and one secondary Power over Ethernet (PoE) 10/100 Fast Ethernet switch.

Version 2 contains one 10/100/1000 Gigabit Ethernet Switch capable of Power over Ethernet (PoE), connecting to the Score Switch with a 10/100/1000 Gigabit Ethernet trunk line. There is no secondary switch. Version 2 was introduced at the start of the 2017 season.

All switches in the SCC are managed switches.

Each Driver Station connects to a dedicated a port on the “main” switch. Each of these ports is assigned its own VLAN interface. In Version 1, this is a 10/100 Fast Ethernet connection, in Version 2 the connection is 10/100/1000 Gigabit Ethernet.

On each SCC, a port on the primary switch is dedicated to the LED Team Signs (+ Timer LED Sign), as well as to the Rockwell Automation Armorpoint I/O device used to connect the Driver Station Stack Lights and Emergency Stop buttons.

Ports on the secondary switch (or main switch in version 2) are dedicated to other miscellaneous equipment, such as Referee Panels, lighting controllers, or MiniSCCs, used to control other field devices, such as scoring devices located in the Alliance Stations. Devices outside the core infrastructure of the playing field network are not discussed in this whitepaper.

The Field Wireless Access Point

The Field Wireless Access Point (WAP) broadcasts and receives wireless data from robots on the playing field. The Field WAP hosts a hidden SSID for each robot scheduled to play on the field, all of which are multiplexed over a single wireless interface. Each SSID is allocated a VLAN to the corresponding Driver Station.

The Field WAP connects to the Score Switch through a 10/100/1000 Gigabit Ethernet trunk line. The switch ports on the Field WAP are unused and unallocated, only the WAN (trunk) line is used.

The Field WAP uses the 802.11n Wi-Fi standard, and the 5GHz band is reserved exclusively for robots. The standard configuration employs a 20MHz channel, with the option for 40MHz, and employs WPA2/AES encryption with a unique key per team, per event.

Referee Panels

There are typically multiple Referee Panels located around the field. There is no standard configuration or location for these panels as it dictated by the season’s game. It is common for there to be at least 5; 3 on one side, and 2 on the other. The panels are used to input fouls, tech fouls, yellow and red cards during the match, as well to award points that are not scored automatically.

The Head Referee panel includes controls for the LED light strings on the playing field, declaring when it is safe for field staff and team members to enter the field, and to initiate a referee review of the match.

Troubleshooting

Robots

Each robot contains, at minimum, a wireless radio and robot controller (roboRIO). The wireless radio is configured in bridge mode to communicate to the Field WAP using an assigned SSID and WPA Key, which then communicates with the robot controller and any other devices on the robot at the discretion of the team. At each event, each team is assigned a unique encryption key.

The robot radio is responsible for connecting to the field, as well as implementing the bandwidth limit. Each team must configure their radio at the event before it will successfully link with the Field WAP. Radio configuration kiosks are provided for this purpose.

Additional Non-Field Components

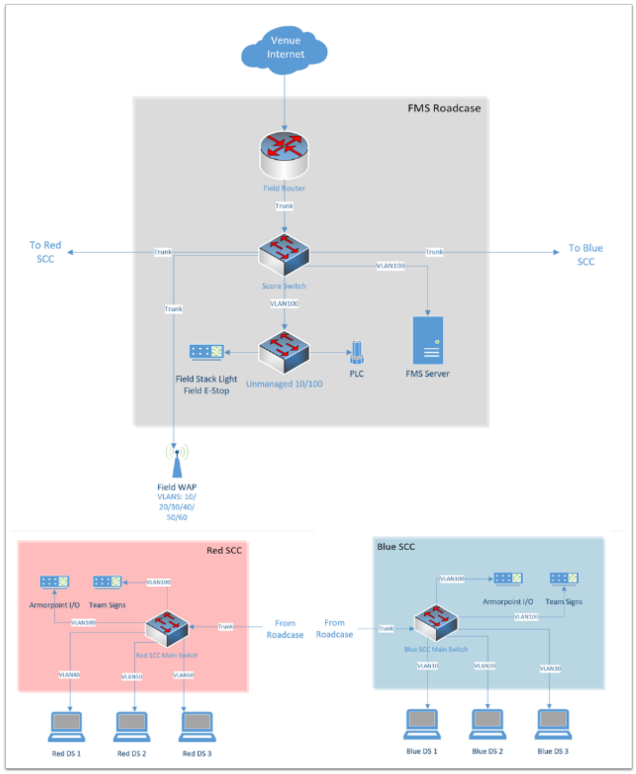
Additional devices may be introduced to the Field Network at the FTA's discretion, such as a tablet or mobile device used by the FTA to view diagnostic information, logs, etc. while on the field prior to the start of a match. This is commonly used to monitor a robot's connection state, and is often used when troubleshooting a robot that does not connect to the field. It is also used during matches if a robot suddenly loses connection or experiences problems. The Game Announcer may also connect to the Field Network to access and provide up-to-the-minute team statistics to relay during the match.

These wireless devices operate only on the 2.4GHz wireless network and do not overlap with robot communications.

Field Network

The figure below shows a basic network diagram of the FMS field network setup. VLANs have been labelled to indicate how networks are separated. Robots and other equipment are excluded from this diagram.

Troubleshooting



VLANs and Network Policy

The FMS field network is split into multiple networks using VLANs, a method by which data is encapsulated on the trunk lines, and then distributed at the switch based on its configuration. This is employed on the field to ensure each teams' connection to their respective robot is private from other teams on the field.

The Field Router sets up the VLANs 10, 20, 30 (Blue), 40, 50, 60 (Red) and 100 (Admin). The switches (and Field WAP) then assign specific ports (or SSIDs, in the case of the Field WAP) to each VLAN, allowing that port to become isolated form the rest of the network. Each VLAN consists only of the Robot, the Driver Station, and the FMS server. The FMS server is a part of the Admin VLAN, but the Field Router is configured to permit it communication with the Driver Station of each VLAN.

The Admin VLAN is the only VLAN capable of reaching the venue Internet. This allows the FMS server to upload match results and awards information to *FIRST* servers, as well as download team information. The Admin VLAN is not accessible to robots and driver stations.

Troubleshooting

Addressing

The Field Router does not provide a DHCP server to the rest of the Field Network. Instead, this is handled by the FMS server, with 7 DHCP pools being allocated (one for each VLAN). The 6 team DHCP pools change depending on what teams are scheduled for that match (10.TE.AM.xx). The Admin VLAN has mostly statically addressed devices, with some, such as Referee Panels, running on DHCP.

Team IP addresses follow the 10.TE.AM.xx scheme, and are dynamically addressed with DHCP unless otherwise configured by the team. Prior to the beginning of the match, the FMS server sends new configuration parameters to the switches on the field, to reconfigure their VLAN settings to accept the new IP addresses. The Field Router and Field WAP are also reconfigured using this process. The Prestart process is described at length later in this paper.

Network Bandwidth

The FMS Field Network has limited bandwidth available. There is an imposed 4Mbit/s limit for each team via the robot radios to ensure no one team overloads the system, causing packets to drop for other teams. Given that each wireless SSID that the Field WAP handles is multiplexed, this adds up to a total of 4x6=24Mbit/s for the Field WAP. All other traffic on the FMS Field Network is not limited by bandwidth.

The Robot Radio prioritizes certain communications over others. Driver Station control and status packets are the highest priority, followed by Network Tables, then all other traffic (e.g. video).

Driver Station and Robot Communications

The Driver Station to Robot Communication is identical to that of a system without the FMS in terms of packets. The only difference is that on an FMS network, the packets are routed through the FMS Field Network, then to the Robot. These packets include control data for your robot, telling it what state it should be in and what the values of the joysticks are. The FMS **does not** send any packets to your robot.

The following ports are opened for communication between your Robot and Driver Station. All other ports are blocked. All ports are bidirectional unless otherwise stated.

- UDP/TCP 1180 - 1190: Camera Data

- TCP 1735: SmartDashboard
- UDP 1130: DS-to-Robot control data
- UDP 1140: Robot-to-DS status data
- HTTP 80: Camera/web interface
- HTTP 443: Camera/web interface (secure)
- UDP/TCP 554: Real-Time Streaming Protocol for h.264 camera streaming
- UDP/TCP 5800-5810: Team Use

Teams are permitted to utilize ports 5800-5810 for their own purposes, or any other open ports (other than 1130 and 1140) if not already allocated.

Your robot will report data about itself to the Driver Station, which is then, in turn, forwarded to the FMS. This includes data about your robot including what motors are being used, what language it was programmed in, and other metadata. This is then forwarded to *FIRST* for statistical purposes. This process is known as “Usage Reporting”, and is discussed at length later in this whitepaper.

The FMS server communicates to the Driver Station through the Field Router, with a routing exception, allowing the FMS server to send data to the team VLAN. This includes critical data, such as what state the robot should be in, match time, and other details. The Driver Station also sends data back, such as battery voltage. Logging of data is discussed at length later in this whitepaper.

Logging and Data Collection

Robot and Driver Station Logging

During the match, the Robot forwards data about itself to the Driver Station, such as battery voltage. The Driver Station combines this with its own log data and forwards it to the FMS server. All this log information, along with diagnostic data from the field, is combined to produce a log that can be read by the FTA during, or after, a match in order to diagnose potential issues. Below is a list of all data that is logged by the FMS.

- Timestamp (local time)
- Match Number
- Team Number
- Match Time
- Alliance
- Mode (Auto/Teleop)
- DS in FMS Mode (yes/no)

- Robot Mode (enable/disable)
- Estop state (on/off)
- Robot Link (yes/no)
- Bandwidth consumption over the wireless link
- Strength of the signal transmitted by the robot radio
- Signal-to-Noise Ratio of the wireless link
- Average packet trip time between DS and Robot
- Number of missed packets between DS and Robot
- Total number of packets sent by DS to Robot
- Robot Battery Voltage

Usage Reporting

At the beginning of the match, the Robot forwards some Usage Reporting data to the Driver Station, which in turn reports it to the FMS server, which in turn reports that to *FIRST* HQ's servers. This data is collected throughout the season and usually released at the end of the season to give some statistics and insight into what teams are using. The data included in Usage Reporting is, but not limited to, the following:

- Motor Controllers used
- Programming Language
- Accelerometers / Gyros used
- Joysticks Used
- RobotDrive class used
- Smart Dashboard used
- Ultrasonic devices used
- I2C/SPI used

Field Status Indicators

Team Stack Lights

On the field are located 6 stack lights, one per team. Each stack light contains two LED sections equal to the alliance color (red or blue), and an additional amber LED used to indicate Emergency Stop status. Below is a table representing the state of the stack lights and what they indicate.

Troubleshooting

	Alliance Color	Amber Color
Flashing	No connection to robot or station bypassed	N/A
Solid	Robot Enabled	Estop pressed/enabled
Off	Connection Established to Robot	Estop not pressed/disabled

Field Stack Light

The field has its own stack light that is typically used by the FTA and Field Staff to determine what state the field is in. There are 4 LEDs on the stack light, and a buzzer. Below is a table representing the state of the stack lights and what they indicate.

	Green LED	Red LED	Blue LED	Amber LED	Buzzer
Flashing	Match Ready	N/A	N/A	*During Match:* Scoring malfunction (e.g. jammed, sensor blocked) *Post Match:* Waiting for Referee	Match Ready (single chime, coincides with green LED beginning to flash)
Solid	Match running/ Field enabled	Red Alliance not ready (e.g. not all robots connected)	Blue Alliance not ready (e.g. not all robots connected)	N/A	N/A
Off	Match not Ready	Red Alliance ready (all robots connected)	Blue Alliance ready (all robots connected)	*Pre-Match Start:* Referee Ready *Post-Match:* Referee Done	Waiting for Match Ready

Troubleshooting

The Match Play Process

Match Prestart

During Prestart, configurations are deployed to the networking systems that comprise the FMS to setup team-specific VLANs, IP addresses, security settings, etc. During this time, the LED signs on each Player Station are updated to reflect the teams configured to play in the upcoming match.

After Prestart, each Driver Station connected to the FMS displays “FMS Connected” on the dashboard software. If a team is located in the wrong Player Station, the dashboard software indicates the correct Player Station to which the team should move.

A match cannot start until the state of all Player Stations is known. The two states which permit a match to start are:

1. The Driver Station configured for the Player Station is connected and linked with the FMS and the corresponding robot is linked with the Driver Station
2. The Player Station is bypassed. The *FIRST* Robotics Game Manual outlines the specific rules outlining when a team is eligible to participate in a match. For the sake of this whitepaper, we are using the lower-case term bypass to define only the state of the Player Station from a software perspective.

Match Play

During Match Play robots are enabled, scoring mechanisms activated, Referee panels enabled, and the FMS audience screen is displayed. The scoring mechanisms communicate with the FMS server directly, or with the PLC located in the FMS roadcase, which in turn communicates with the FMS server.

A match is stopped by cancelling it via the FMS software interface or by pressing the Field Emergency Stop button located on the Scoring Table. When stopped, all robots are immediately disabled, scoring mechanisms stopped, and the foghorn sound played.

Troubleshooting

Match Scoring

Matches are scored via Rockwell Automation sensors and counters that link back into the PLC, which tells the FMS the counts and different game states. Other sensors may be used depending on the season's field configuration.

Once the FMS has received the final penalties/scoring, the scorekeeper waits for the head referee for any changes to the score last minute, and then submits the score.

Match Publishing

Provided an event has an internet connection available, the FMS server uploads match data upon completion of a match following the Match Scoring process to an Azure MS SQL Database.

If the event does not have Internet available, event data is backed up to a USB drive. The FTA at the event then uploads the event database as possible to HQ for posting to Azure.

The database is queried via the FMS API (Documentation available here: https://usfirst.collab.net/sf/projects/first_community_developers/) and is available to users who request access.

The data model is year specific, due to game scoring breakdowns being available.