FIRST TECH CHALLENGE

Training and Support

2018-2019 *FIRST*® Tech Challenge

Robot Wiring Guide

ROVER RUCKUS

Presented By Qualcomm

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200 BEDFORD STREET ■ MANCHESTER, NH 03101

FIRST

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Revision History		
Revision	**Date**	**Description**
1	9/17/2018	Initial Release

Contents

Introduction

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

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We express the *FIRST*® philosophies of *Gracious Professionalism*® and *Coopertition*® through our Core Values:

- **Discovery:** *We explore new skills and ideas.*
- **Innovation:** *We use creativity and persistence to solve problems.*
- **Impact:** *We apply what we learn to improve our world.*
- **Inclusion:** *We respect each other and embrace our differences.*
- **Teamwork:** *We are stronger when we work together.*
- **Fun:** *We enjoy and celebrate what we do!*

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FIRST® uses this term to describe our programs' intent and *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 the end, *Gracious Professionalism*® is part of everyday life. When professionals use their knowledge graciously and individuals act with integrity and sensitivity, everyone wins, and society benefits.

Watch Dr. Woodie Flowers explain *Gracious Professionalism* in this short video.

Thank you

FIRST Tech Challenge owes a debt of gratitude to the volunteers and teams in AZ who helped us test and evaluate the Electrostatic Disruption mitigation techniques. Thank you to Dave Thompson, Christine Sapio, Rich Gomez, Matt Rainey, Susan Garduno and Robert Garduno. Special thanks also go out to Team 2844, Team 10523, Team 8081, and Team 10984. Our efforts, and these strategies, would not have been possible without their help and testing.

Introduction to Robot Wiring

Wiring is one of the most important parts of a robot. However, wiring often does not receive the same care and attention as the rest of the robot. Good wiring improves robot performance, allows teams to better troubleshoot problems when they occur, and helps to eliminate intermittent electrical problems. Such wiring takes a lot of patience and practice, and teams should budget time accordingly.

Figure 1: REV Robotics Expansion Hub

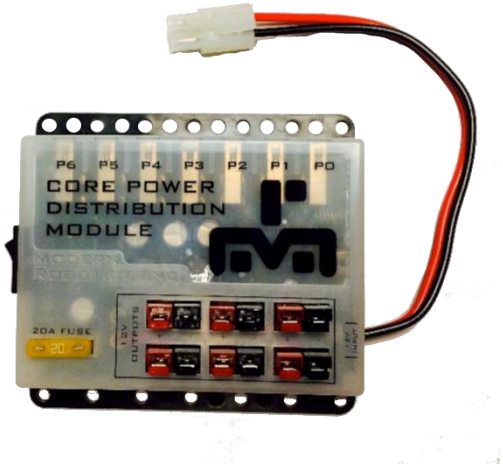

Figure 2: Power Distribution Module

Figure 3: REV Robotics Color Sensor

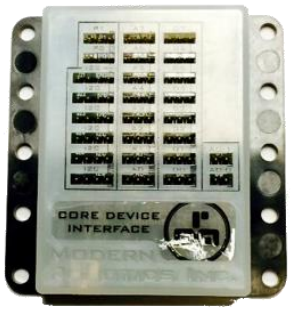

Figure 4: Core Device Interface Module

In this guide, teams will learn how to properly wire their robot, how to improve wiring reliability, and how to handle hardware issues associated with wiring.

- Section 1 of this document covers the allowed control systems that teams may use and recommended additions/modifications for each system.
- Section 2 of this document discusses common wiring problems and mitigations for them.
- Section 3 provides tips for wire management.

- Section 4 explains the phenomena of Electro Static Discharge (ESD) and examines ways to mitigate disruptions caused by ESD.
- Section 5 contains links to additional resources and wiring fundamentals

Section 1

This guide is not a step-by-step tutorial on how to set up any of the electronics systems. For step-by-step instructions, please visit the REV Robotics or Modern Robotics sites, or watch one of the videos that *FIRST* has created on the subject. This section will cover best practices for basic robot wiring. It will also cover changes and additions that teams may wish to make as they wire their robot.

Note: *It is required that teams follow the rules detailed in the Game Manuals. See Game Manual Part 1 for a list of rules about robot wiring.*

Mounting the Android Phone

When attaching the Android Phone to the robot, there are many things to keep in mind.

1. It is important to protect the phone from robot-to-robot contact.
2. The robot controller phone uses a wireless radio to communicate with the driver station. It should be mounted in a location that is protected from physical impact, but that is free from metallic structures that could block the wireless radio signals that are broadcast to/from the phone. Burying a phone deep in the center of a robot's metallic frame could result in diminished wireless performance.
3. To minimize the risk of an electrostatic shock between the phone and the metallic frame of the robot, mount the phone so that its back face is not flush against the frame. Electrical tape can be used to insulate the metallic frame from the back face of the phone.
4. Make sure the phone is easily accessible for charging, programming, and emergencies.
5. Make sure the phone sits so the camera is available for Vuforia, if needed.
6. Make sure that wires connected to the phone are not in danger of being bumped, damaged, or disconnected. It is essential there is no chance of stress placed on the wire that connects to the phone because stressing this wire could ruin the phone port. Wires should be properly strain relieved (see Section 3). Phone mounts are available from various sources for *FIRST* Tech Challenge teams.

Figure 5: The cable is secured in place. It is still easy to unplug it for charging, but it will be difficult to accidentally unplug. If the phone moves around, there is enough slack to avoid damaging the USB connector

Figure 6: The cable is not supported and is easily damaged or disconnected. The phone is also in direct contact with metal.

Note: Every wire connection is a possible point of failure. This applies to all electronics, not only the phone. In general, all connections should be properly secured and strain relieved. Wires should be tied down/secured near their ends to prevent them from moving or shaking loose during a match. If you notice the robot controller phone is having connection problems with the USB devices during a match, it could be because the cables are not properly secured and are momentarily being shaken loose during the match. In particular, the USB connection to the Micro USB port tends to be more susceptible to being shaken or jolted loose if the USB cable is not properly secured.

Battery Connections

There are various battery connectors available to teams, depending on where they order their batteries. Anderson PowerPoles are one of the most reliable types of battery connectors. These connectors have proven to stand up to the rigors of the *FIRST* Tech Challenge season well. Other styles of connectors, like the Tamiya connectors (Figure 7), are only reliable for a few dozen cycles and may wear out during a season.

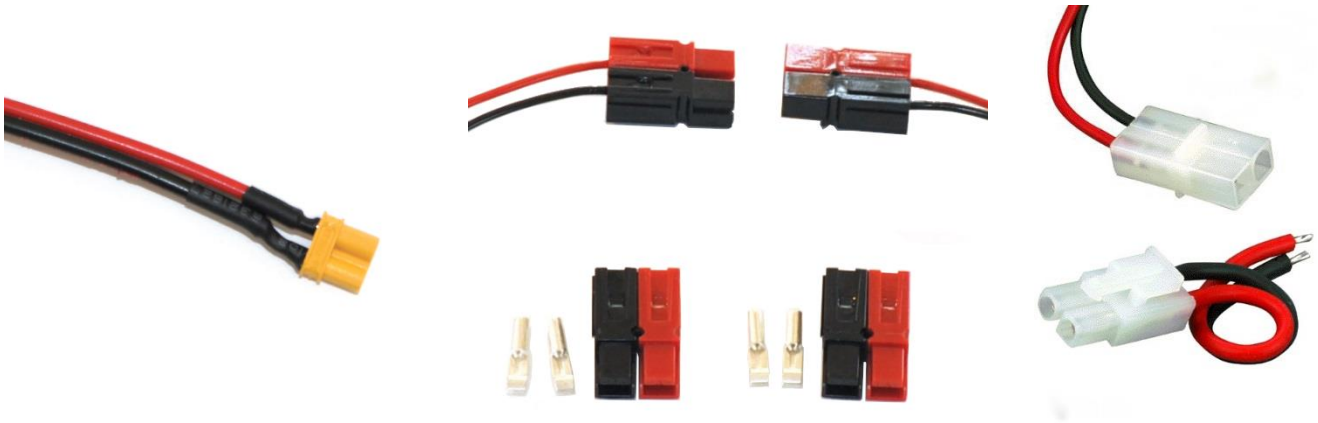

Figure 7: XT30, Anderson PowerPole and Tamiya connectors.

REV Robotics: The REV system uses XT30 style connectors for the power wires. These connectors are used in the RC vehicle industry and are designed to withstand repeated connect and disconnect cycles. It is not necessary to replace these connectors with Anderson PowerPoles. However, there have been credible reports of occasional disconnects between the XT30 connectors provided with the REV Robotics hardware, possibly because of slight variations in manufacturing tolerances for the XT30 style connectors used.

If you suspect that you might have a loose XT30 connection, then conduct a careful physical inspection of the connection. Check to make sure the connectors fit snuggly together and there is a slight amount of retention between the connectors when you try to pull them apart. Also check to make sure that power is not disrupted when the ends of the power cables that connect through the XT30 connectors are jiggled. If you do find a loose connection, replace the bad cable or contact REV Robotics if the bad connector is mounted on the Expansion Hub.

If you prefer to use Anderson PowerPoles as your primary connectors, then you can attach an XT30/Anderson PowerPole converter cable to your Expansion Hub and strain relieve it properly (see Section 3). Once this converter is plugged into the Expansion Hub, it can be left in place, and the battery can connect or disconnect using the Anderson PowerPole connection. This will reduce wear experienced by the XT30 connectors.

Warning: Do not reverse the polarity of the input DC power. *Although the REV Robotics Expansion Hub has built in reverse polarity protection, there have been credible reports of damaged Hubs when reverse*

polarity power is applied in certain scenarios. If the wires are reversed (red to black, black to red) (Figure 8), the Expansion Hub could potentially be damaged.

Modern Robotics: The Modern Robotics system uses Tamiya style connectors for the battery wires. Over the course of a season these connectors will fatigue, and the battery connection will become less reliable. To address this, it is recommended that teams zip-tie or otherwise attach a Tamiya/Anderson PowerPole converter cable to their Core Power Distribution Module. Once this connector is plugged into the hub, it should be left in place, and the battery should always be disconnected using the Anderson PowerPole connection. This will preserve the Tamiya connection and keep the connections reliable throughout the season.

Warning: Early Versions of the Modern Robotics Core Power Distribution Module are not reverse-polarity protected. *If the wires are reversed (red to black, black to red) (Figure 8), a Core Power Distribution Module could be damaged. Additionally, the battery should never be plugged into the distribution ports (Figure 9).*

Figure 8: Reversed power wires.

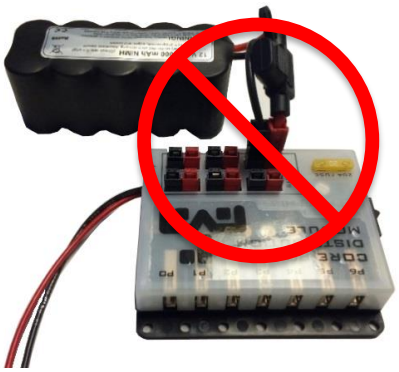

Figure 9: Battery plugged into wrong port.

Making an Adapter

Teams may wish to replace the connectors on their batteries and install more reliable connectors in their place. If teams choose to do this, the old connectors can be useful.

1. When removing the unwanted connectors from the battery, do not cut the wires flush with the end of the connector. Instead, leave a 1/2” length of wire attached to the connector.
2. Install Anderson PowerPoles on the free end of the 1/2” length of wire.

Figure 10: Anderson PowerPole to XT30 adaptor.

Figure 11: Anderson PowerPole to Tamiya adaptor.

Installing Anderson PowerPoles

The following steps explain how to install Anderson PowerPoles on a battery. The same steps can be modified to install Anderson PowerPoles on any wire.

Note: Under no circumstances should there be exposed ends on both battery wires. Early MATRIX batteries have no built-in fuse. Bare wires that touch will short out and damage the battery and may create a fire hazard.

1. With TETRIX, REV, and current MATRIX batteries, remove the fuse from the battery. This step is not applicable to early MATRIX batteries.

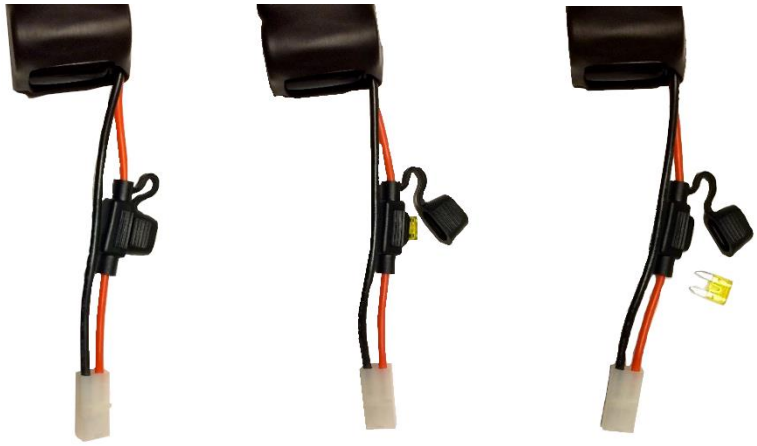

Figure 12: Remove the fuse.

2. Cut one of the wires close to the attached Tamiya connector. Do not cut too close to the battery or the fuse housing, as that will make installation difficult or impossible.
3. Strip the wire to the Anderson PowerPole specs (Figure 13).

Figure 13: Strip the wires.

4. Crimp the connector on. Make sure the wire is in the proper orientation before doing this -- the PowerPoles need to connect properly. (Figure 14).

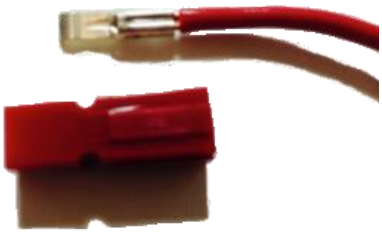

Figure 14: Crimp connector onto wire.

5. Snap on the plastic housing. (Note colors, making sure that using is attached to the positive wire, and the black housing is attached to the negative wire.)
6. Repeat steps 2 through 5 on the remaining wire.
7. Slide the red and black housing pieces together in such a way that they link with existing PowerPoles on the modules or adaptors (i.e., red connector to red connector and black connector to black connector).
8. If applicable, reinsert the fuse.
9. Repeat the procedure on the battery charger.

A video demonstration of this can be seen in the *Gear Up with FTC!* Robot Wiring Troubleshooting Video (skip to 10:10 in the video). More details can be found at http://www.powerwerx.com/assembly.asp

Teams using motors from earlier seasons may need to install PowerPoles on their motors. When using PowerPoles on motor wires, make sure that they properly interface with the connectors on the motor controllers (i.e., red connector to red connector and black connector to black connector).

Power Switch

The Game Manual Part 1 requires that teams use a TETRIX, MATRIX, or REV power switch. Teams should be aware of switch placement when building and wiring the robot. Mounting points will differ depending on which control system a team is using, and it is important that teams take this into consideration.

Figure 15: REV Robotics Power Switch and Tamiya to XT30 cable adapter.

REV Robotics: REV Robotics provides a power switch to connect the Expansion Hub and battery. This switch should be mounted in compliance with Game Manual Part 1 rules and should be easily accessible for teams and Field Technical Advisors (FTAs). Note that if you have a battery with a Tamiya style connector (instead of

the XT30 style connector) you will also need the REV Robotics Tamiya to XT30 cable adapter to connect to the switch to the battery.

Modern Robotics: Although the Core Power Distribution Module has a built-in switch, teams are required to use an external switch. Teams should take care to mount the Core Power Distribution Module in such a way that its built-in switch is protected from robot-to-robot contact.

Note: Teams should be aware that TETRIX power switches come with blade connectors that are crimped onto tinned wire. Over time this solder will creep (or flow), leading to a poor connection that may cause intermittent power interruptions. The simplest way to fix this problem is to cut off the tinned section of the wire and replace it with a new blade connector (Figure 16 - Figure 18).

Replacing Tinned Wire

1. Cut the blade connector off the wire as close to the edge of the connector as possible, so you don't waste wire (Figure 17).
2. Strip the end of the wire to the length needed (Figure 18).
3. Insert the stripped wire into a replacement connector. Make sure that all the strands of the wire make it inside the connector. They should not bend or miss the opening.
4. Crimp the necessary section of the connector onto the wire (Figure 19).
5. Attach the connector to the switch (Figure 20).
6. Repeat as necessary.

Figure 16: The original wire.

Figure 17: The wire with the tinned end removed.

Figure 18: The stripped wire with a new connector.

Figure 19: The wire with the connector crimped on

Figure 20: The switch with the new connectors.

A note on Logic Level Shifters (REV):

There are two voltage levels commonly used for logic on integrated circuits (like the chips in a REV Robotics Expansion Hub): 5V and 3.3V. The REV Expansion Hub works using 3.3V logic levels, but Modern Robotics devices work using 5V logic levels. If you'd like to use 5V Modern Robotics I^2C sensors with the REV Robotics Expansion Hub, then you will need to use Logic Level Converters (also known as Level Shifters) to convert the signals to and from the sensor. You will also need a REV Robotics Sensor Adapter Cable (REV-31-1384) to connect the 5V sensor to the Logic Level Converter. A complete explanation can be found in the REV Robotics Expansion Hub Getting Started Guide (linked in Section 5).

Figure 21: Logic Level Converter.

Section 2

Common Problems

Hardware Problems and Their Mitigations

There are several potential issues that can arise with the REV Robotics Expansion Hub and the Modern Robotics electronics. This section will detail these issues and offer solutions.

Connection Issues

Note: Before wiring a robot, make sure to inspect the ports on all the modules. It is possible to damage the pins in the module ports. **If this is the case, do not use the module**. It should be sent back to the manufacturer for repairs.

Problem: It is common for teams to experience connection issues with both control systems. There are several tricks to reduce these issues.

Mitigation 1: The most important solution is to take great care to strain relieve all wiring connections. Using 3D-printed supports for the USB connections where they plug into the Modern Robotics core modules has proven to reduce connection issues. Zip-tying the USB cords to these supports adds even more strain relief. There are various designs already available for teams online.

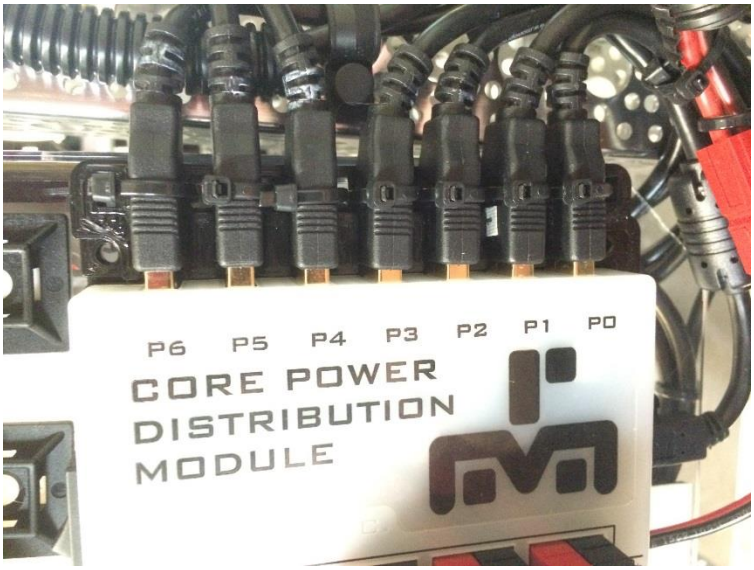

Figure 22: Make sure every connection to and from the modules are supported.

The connectors used to attach sensors, motors, and servos to the REV Robotics Expansion Hub have good retention and provide a secure connection between the externally connected device. However, the USB mini cable used to connect the robot controller phone to the Expansion Hub should be secured and strain-relieved to ensure a reliable connection during competition. Figure 23 is an example of an available 3D printable mini USB strain relief device for the REV Robotics Expansion Hub.

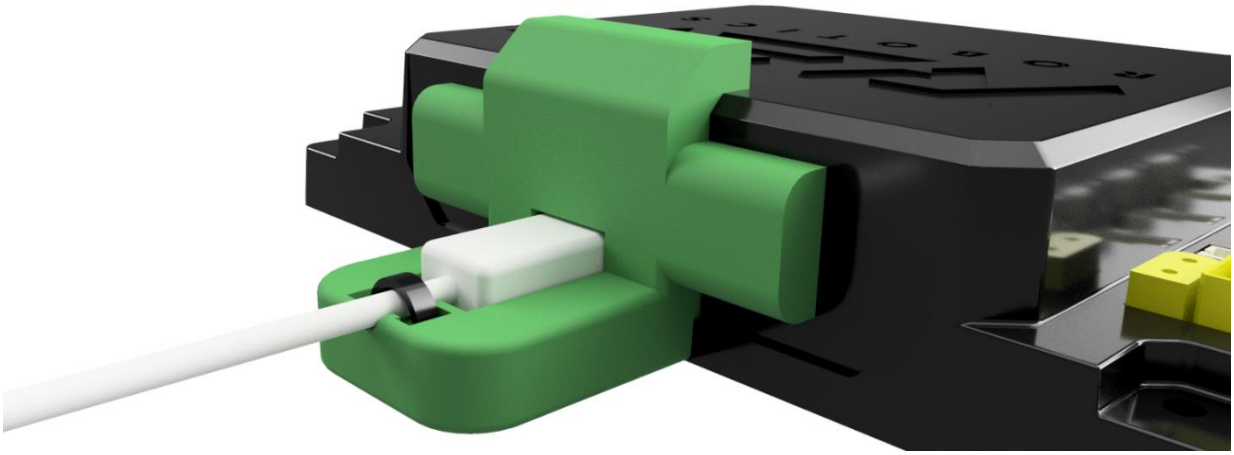

Figure 23: 3D printable Mini USB strain relief

Rev Robotics also sells a commercially manufactured retention mount for the Expansion Hub that creates a very secure connection to the USB mini port.

Figure 24: REV Robotics USB Retention Mount.

Mitigation 2: Isolating electronics from metal parts on the robot also cuts down on connection issues. Mounting the electronic parts on electrically insulated areas of the robot helps to isolate them and cuts down on the risk of an electrostatic discharge between the metal parts of the robot and the electronic parts. Such electrostatic discharges can disrupt or in rare cases damage the electronics of a robot.

Mitigation 3: Make sure the cords are high quality and plug snuggly into the modules. Cords that allow the plug to wobble at the connection to the module can contribute to connection issues. Cords with built-in ferrite chokes should be used whenever possible, as they decrease the effects of electrostatic discharge. Flexible cords also allow for ease in routing and cut down on wear and tear.

Mitigation 4: The wheels used on the robot can play a big part in connection issues because they can increase the buildup of static. Before deciding on wheels, teams should research the pros and cons of the model and decide accordingly. Certain materials used in the construction of a wheel could promote the buildup of electrostatic charge on a robot. Similarly, wheel construction can have a large effect. Mecanum wheels, for example, may produce more static than other types of wheels.

Mitigation 5: Using a *FIRST*-approved, commercially manufactured cable (with built-in resistor) to ground the control system electronics to the metallic frame of a robot will help reduce the risk that a shock between electronics and the frame will disrupt the robot.

Common Pitfalls and Their Solutions

The following pitfalls are common when wiring. Being able to recognize and avoid them will lead to much more reliable and resilient wiring.

Haphazard Wiring

Pitfall: It is not unusual to quickly wire a robot for testing purposes and then let that “temporary” wiring become permanent. When all the wires in a robot jumble together and are not properly tied down, a variety of problems can arise, including:

- Faulty Connections
- Broken Wires
- Signal Interference between Wires
- Difficulties with Troubleshooting
- Maintenance Issues

Solution: If enough time is allotted for wiring, this should not be an issue. Wire management techniques that are described in Section 3 of this document also help prevent this "rat's nest" wiring.

Loose Cables
Pitfall: If the cables connecting the devices are not properly secured and strain relieved, it is common for a temporary disconnection to occur. If certain cables come loose, the robot can disconnect for the rest of the match.

Solution: Make sure your wires are properly secured so they do not vibrate or jolt loose during a match. Securing the wires to the frame, or some rigid structure near the ends of the cable, helps prevent them from shaking loose during normal operation.

Reversed Servo Wires
Pitfall: The Expansion Hub has three color-coded symbols and the Core Servo Controllers are marked with "WRB". WRB stands for "White Red Black," and the colors of the symbols on the Expansion Hub align with the colors on the servo wires. These all show orientation of the Servo cable, which has three wires: ground, positive, and signal. The black ground wire must line up with the "B," or the black symbol. The other wires are in a standard order and will be in the correct spots if you align the ground wire properly. It is easy to reverse the connection and then misidentify the problem as a software issue. This same mistake can be made if using servo extensions or splitters.

Solution: Be mindful of this common problem and you can easily avoid it (Figure 25).

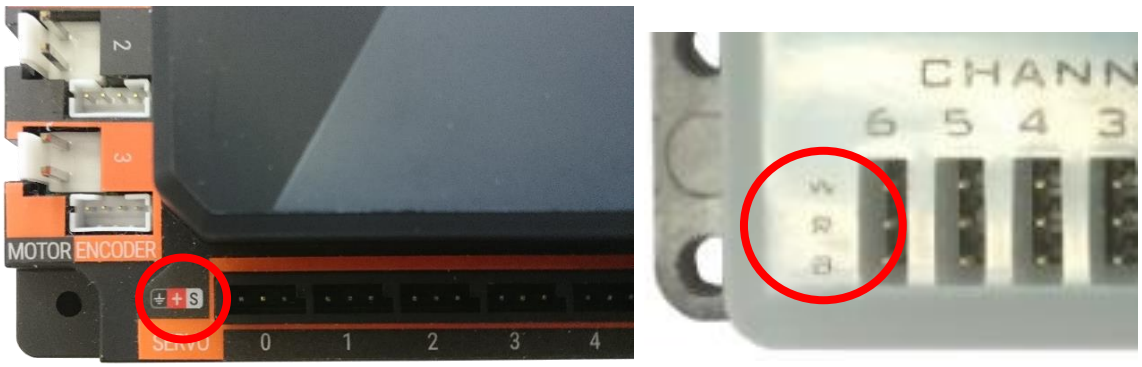

Figure 25: Markings on the Servo Controllers.

Daisy Chaining Electronic Parts
Pitfall: Daisy chaining is one way of powering several different units. Multiple parts are wired together, with each unit being powered by the one before it in the chain. Both the REV Robotics Expansion Hub and the Modern Robotics parts can be daisy chained. It is common for teams to daisy chain the power terminals on these controllers. In a haphazardly-wired robot, daisy chaining can cause many issues. If one connection in the middle of the chain comes loose, the power to the remaining controllers will be lost.

Solution: For REV Robotics users, periodically inspect the XT30 power and the JST PH 3-wire signal cables that are used to daisy chain one Expansion Hub to another. Verify that these cables are in good condition and that they keep secure connections between the two Hubs. For Modern Robotics users, rather than daisy chaining parts, plug each one into the Core Power Distribution Module.

Haphazard Battery and Controller Placement
Pitfall: When the placement of the battery and controllers is not incorporated into the early robot design, the parts may be attached to the robot as an afterthought. The controllers may then be placed in locations that are

difficult to reach and/or that can be damaged by other robots during competition. The battery may be attached towards the top of the robot, leading to a high center of gravity and an unstable robot.

Solution: Take the battery and controllers into consideration while building.

- Ensure there are no sharp edges that can cut into the battery.
- Ensure the battery and controllers will be protected during matches.
- Ensure all connections are secure and cannot be shaken loose or pulled out during matches.
- Ensure the battery is properly secured to the robot and cannot disconnect during a match.
- If zip ties or a similar fastener are used to secure the battery to the robot, make sure the ties are not over tightened. If the ties are pulled excessively tight, the internal connections of the battery could be damaged, causing problems (including short circuits) within the battery.
- The battery is often one of the heaviest parts on the robot and its placement can have a dramatic effect on drivability and stability. A good rule of thumb is to place the battery as low as possible.

Problem: The signals that pass between the Android phone and the controllers are sensitive to interference. If a motor power wire or servo wire is routed next to a USB cable, it is possible to induce a stray signal that can lead to intermittent problems.

Solutions:

Wiring Placement

Try to keep power wires away from motor wires and motor wires away from USB cables and signal wires. Always use the shortest possible. Coiling a 6' USB cable inside a robot may cause data errors on the USB bus. 12" or 18" cables are an inexpensive alternative.

Ferrite Chokes

Ferrite chokes help filter high frequency interference. It is best to use high-quality shielded USB cables with built-in or external Ferrite chokes to help reduce interference on the line from the motors and to help reduce the effects of electrostatic discharges. The cords included with the Modern Robotics electronics come with built-in ferrite chokes. Signal wires, like the I2C cables and servo cables should also have ferrite chokes added. Clip on ferrite chokes are available online from many sources.

Figure 26: Ferrite choke on a signal wire

Ferrite chokes are one of the ***easiest-to-implement and most effective ways to mitigate disruption from electrostatic discharges***. These devices help to block current spikes that can be generated by an ESD event.

Clip-on ferrite chokes can be installed on cables that do not already have them to reduce the risk of disruption:

- Sensor wires (analogue, digital and I2C)

- Encoder cables
- USB cables

Teams should make sure they secure the ferrite chokes if they install them onto cables of their robot.

Section 3

Wire Management Tips

Besides building a great robot and wiring it using the recommendations made in Sections 1 and 2, there are some general wiring best practices. These best practices are good habits to start as soon as possible and then uphold every season.

Use Proper Strain Relief

It is important to use proper strain relief techniques at connectors to prevent them from being damaged or coming loose. When adding strain relief, it is best to immobilize the wire an inch or two before the connection and leave a little slack on the connector side. This prevents unintended tension on the wire from damaging the connector and allows the connector to move if the part it is attached to moves. This can easily be done with a few cable ties. In some situations, it may be acceptable to mount the connector more rigidly, but only if all parts involved are also mounted solidly on a rigid panel. Mounting the electronics on a nonconductive (plywood, PVC type A, etc.), rigid panel can also help with mitigating the effects of ESD (see Section 4).

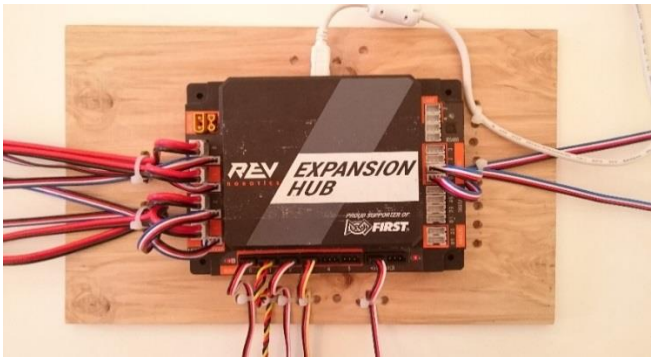

Figure 27: REV Robotics Expansion Hub with strain relief.

When using PowerPole connectors, it is advisable to use clips to prevent them from pulling apart. These can be bought online from various sources. For other wire to wire connections, it is good practice to tape or zip tie connectors together (this can also be done with PowerPole connectors).

Figure 28: Retention clips for PowerPole connectors are available from vendors such as AndyMark and Powerwerx.[1]

[1] Image from https://powerwerx.com/powerpole-connector-retention-clip?gclid=CjwKCAjwma3ZBRBwEiwA-CsblHcL_wgDG62t9kNjSztPjW8HuRPbb9t_NkLjLk3N1GGjrjoNDq9UfxoCtDYQAvD_BwE (accessed on 6/21/18).

Conduct Proper Maintenance

To help a robot perform better during a competition, teams should:

- Double-check the wiring is tightened down;
- Check battery voltages and connections; and
- Check wiring insulation for flaws.

Using a checklist with written reminders to conduct maintenance between matches can ensure that these details are attended to throughout the tournament.

Keep It Neat

There are many parts on a competition robot, and a neatly-wired robot is less likely to run into problems. A robot with disorganized wiring is more likely to have connection issues.

Neat wiring will be:

- Easier to follow when troubleshooting;
- Easier to fix;
- Less likely to get caught in moving parts; and
- Less likely to become entangled with other robots.

Use Proper Wire Management

Perhaps the most important step towards neat wiring is the implementation of proper wire management. Wire management involves bundling and routing wires along a defined path to the various electrical parts. Keeping the following tips in mind will ensure neater, more robust wiring:

- Keep the wiring stationary.
- Protect the wiring.
- Make sure all cables are the correct length.
- Use wire management hardware (Figure 29).
    - Zip ties allow teams to quickly tie down wiring.
    - Wire loom allows teams to quickly protect at-risk wiring.
    - Self-adhesive cable tie mounts allow teams to attach wires to surfaces without holes.
    - Grommets protect wire from damage when it is passed through a hole with sharp edges.

Figure 29: From left to right: zip ties, wire loom, self-adhesive cable tie mounts, grommets.

Tie Down All Wiring

It is best to run wires along stationary parts of a robot as much as possible. Properly tying down wiring will:

- Minimize connection errors with the Android phone
- Prevent wires from moving into pinch points (e.g., between two gears or into a movable mechanism);
- Prevent entanglement with other robots;

- Prevent strain on wiring components; and
- Provide easier access for maintenance.

Teams should keep the end cap securely attached to the TETRIX DC Motor. One method is to use electrical tape to fasten the end cap (Figure 30).

Figure 30: Securely fastened end cap

Dealing with Moving Parts

In some cases, teams will need to run wires over and around moving parts. When doing this, teams should be careful to avoid pinch points and make sure there is always enough slack that wires are never stressed. Teams should protect wires that will be prone to chaffing and rubbing with wire loom and routinely check them over the course of the season. It is important to make sure that wires will not end up twisted around any moving parts, which could cause damage both to the wiring and to the part.

Make Wiring Diagrams

Wiring diagrams show what parts are wired together at a glance (Figure 31). These diagrams are relatively simple to create and are useful for the following reasons:

- They ease troubleshooting;
- They ease programming; and
- They become a valuable reference when included in the Engineering Notebook.

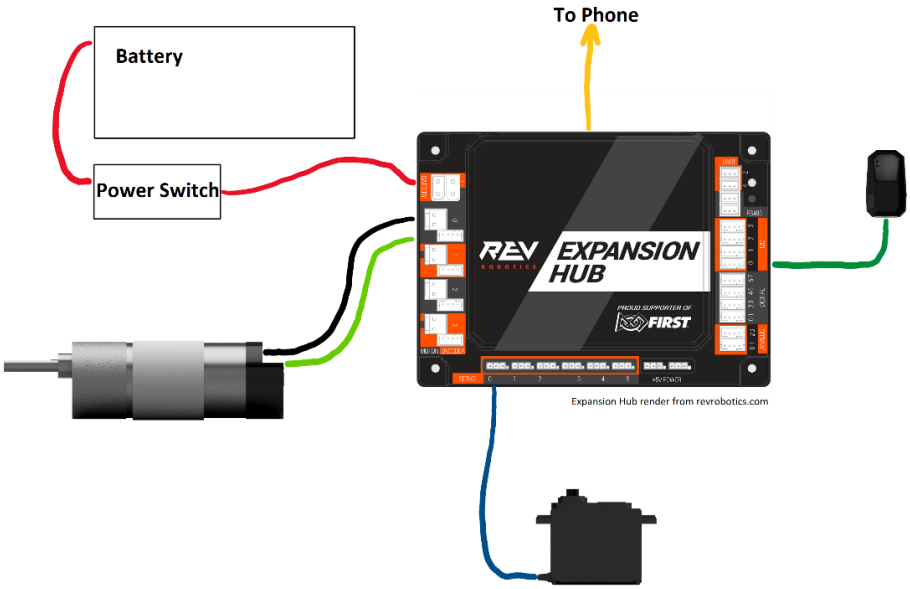

Figure 31: A simple wiring diagram

Use the Proper Tools

Proper tools ease the implementation of wiring (see Figure 32 to Figure 37). Tools like the Anderson PowerPole crimping tool and small nippers will aid in clean wiring.

Figure 32: Wire strippers.

Figure 33: Small nippers for cutting zip ties.

Figure 34: Ferrule crimpers.

Figure 35: Anderson PowerPole crimpers.

Label Wires

Proper wire labeling quickly solves many problems (Figure 36). It helps in the creation of a wiring document and cuts down on time devoted to maintenance and troubleshooting.

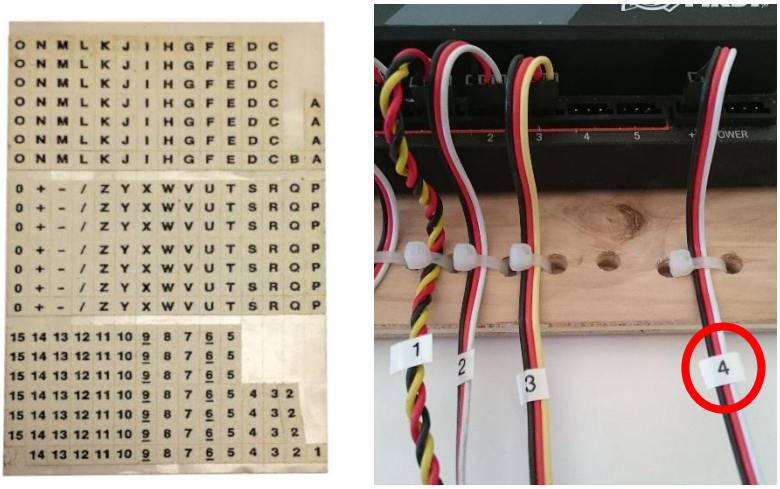

Figure 36: Wire labels.

Build Structure to Route Wires

If necessary, it can be helpful to build structures on the robot purely to aid in wire management. Creating a safe path for wires can ease wire routing trouble and decrease strain.

Section 4

Reducing the Effects of Electrostatic Discharges (ESD)

What is an Electrostatic Discharge Event?

An electrostatic discharge (ESD) event is when a charged object (like a robot) discharges to a neutral (no charge) or oppositely charged object. Because of the high voltages involved (up to tens of kilovolts), ESD events produce extremely high electrical currents.

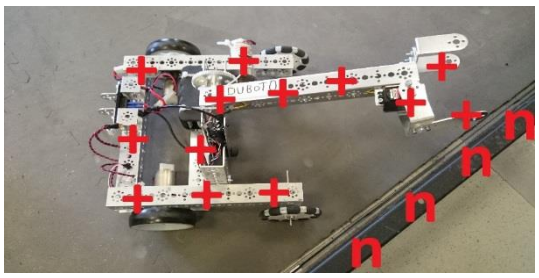

Figure 37: Positively charged robot next to neutral

How Does an ESD Event Disrupt a Robot?

ESD induced currents can flow through the sensitive electronics of a robot. Although ESD current spikes are extremely brief, they can easily damage or disrupt these devices. Communication wires between control system components are particularly vulnerable to ESD events. If the current during an ESD event is large enough, it can even destroy chips whose inputs are not well protected.

How Robots Become Charged

Consider what happens when you shuffle your feet on a carpet in wool socks and then touch a door knob. You'll almost certainly get a shock. What causes this phenomenon? When two surfaces interact, there is a small amount of adhesion. This means that they share electrons and if they are made from different materials the electron sharing may be uneven. When the surfaces are taken apart, they can become charged. This is called the *triboelectric effect*.

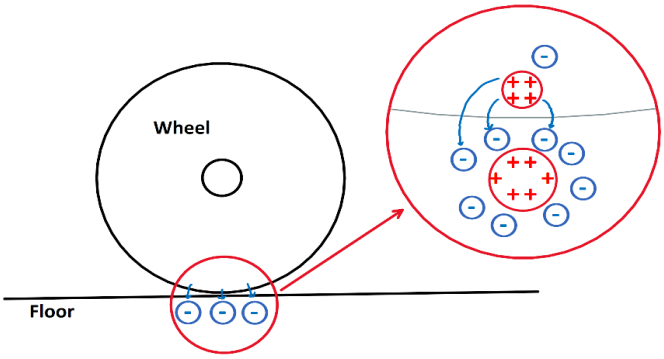

Figure 38: The triboelectric effect

A robot's wheels moving on field tiles build charge on the robot frame just like your wool socks moving on carpet build charge on your body. Many other plastic and rubber materials behave similarly. It is important to note that triboelectric charging **takes** charge from one object and **gives** it to another, so the charges are mirrored. In the case of an FTC robot, positive charge accumulates on the wheels and negative charge accumulates on the tiles.

Note that a robot with wheels that slide across the soft tiles of a competition field will build electrostatic charge on its frame more rapidly than a robot with wheels that roll across the tiles.

Discharging a Robot

Current "wants" to flow from objects at higher potential to the objects at lower potential to equalize the voltage difference between them and it will if given a conductive path to do so (like an uninsulated wire). In the case of a robotics competition, if a robot is at a higher potential than another metallic object (such as a portion of the game field), an ESD event will occur if the frame of the charged robot contacts the other object.

If the potential difference is high enough, it is also possible for current to flow through the air in the form of an *electrical arc*. Arcing occurs when the air between two differently charged conductors becomes ionized and allows current to flow from one conductor to the other. Arcs at voltages seen on *FIRST* Tech Challenge robots can jump air gaps of more than 3/8" (1 cm). Arcs behave almost like direct contact, so they can carry a

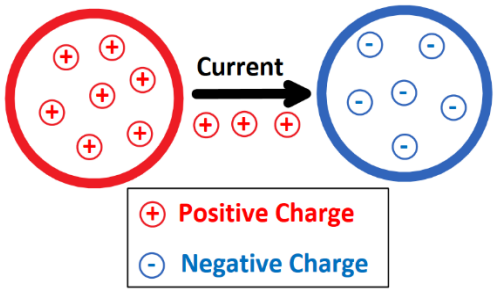

Figure 39: Electric arc between two spheres of opposite charge.

significant amount of current. Visible sparks go with large electrostatic arcs.

Best Practices for Mitigating the Effects of ESD

Add ferrite chokes to signal wires

Ferrite chokes block large changes in current like those seen during an ESD event. This can reduce the risk of damage to or disruption of electrical components when a sensor or other peripheral device receives a shock.

Figure 40: Clip-on ferrite choke

To reduce the risk of ESD disruption, use USB cables that have built-in or snap-on ferrite chokes. Also, install snap-on ferrite chokes onto your sensor cables, encoder cables, and servo cables. Using ferrite chokes is an *effective method* for mitigating the effects of ESD.

Electrically Isolating the Control System Electronics from the Metal Frame of the Robot

As a robot moves back and forth across the tile floor during a *FIRST* Tech Challenge match, charge can accumulate on the metallic frame of the robot due to the *triboelectric effect*. If a charge builds up on the frame

of the robot, but the Control System is at a different voltage, then a shock can occur if an exposed or poorly insulated portion of the Control System gets close (less than 3/8” or 10mm) to the metal frame.

Electrically isolating or insulating the electronics from the frame can help avoid disruptions due to this type of shock.

Mounting Electronics on a Non-Conductive Material

Mounting the Control System Electronics on a non-conductive material, such as a thin sheet of plywood or a sheet of PVC type A, can help reduce the risk of an ESD event between the frame and the electronics (see Figure 27, page 18). Using a non-conductive, rigid panel can also help with wire management and strain relieving.

Isolate Exposed or Poorly Insulated Parts of the Electronics

Certain parts of the Control System’s electronics have exposed metal or are poorly insulated. If these parts are placed too close to the metal frame, a shock can occur if a charge accumulates on the frame.

Figure 41 – Electrostatic shocks can occur at poorly insulated or exposed portions of the electronics.

For example, the 4-wire sensor cables that are used by the REV Robotics Expansion Hub have plastic connectors that are poorly insulated. If a charge accumulates on the metal frame of the robot, and the end of sensor cable is placed close to the frame, a shock can occur and this shock can disrupt or even damage the I2C port of an Expansion Hub.

Similarly, some servo extension cables (see Figure 41) have exposed portions of metal that could be vulnerable to ESD unless properly isolated or insulated.

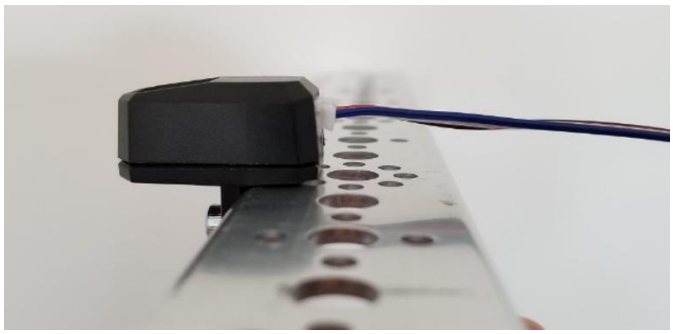

Figure 42 - Keeping exposed or thinly insulated portions of the electronics more than 3/8" (10mm) away from the frame can help.

Moving these vulnerable areas of the electronics system away from the frame (with an air gap greater than 3/8” or 10mm) can help reduce the risk of an ESD disruption. Using electrical tape to insulate these areas can be equally effective and may be easier.

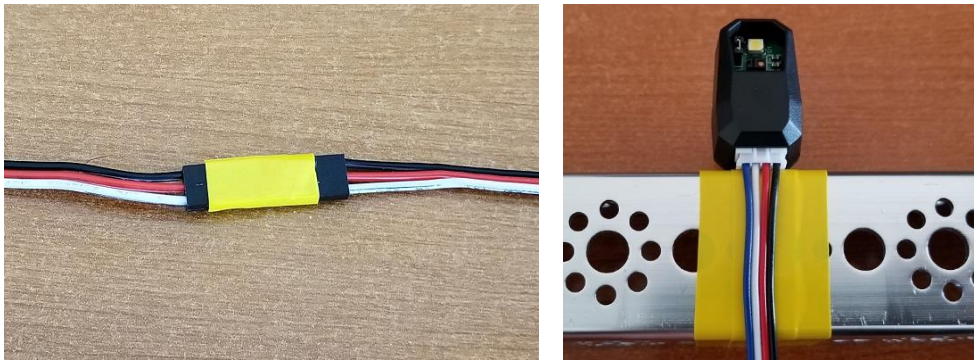

Figure 43- Electrical tape (colored yellow in the image above) can be used to insulate exposed or poorly insulated metal.

Covering Critical Exterior Metal Features of the Robot with Electrically Insulated Material
Another ESD mitigation strategy is to cover exposed portions of metallic frame pieces with an electrically insulating material. Covering the conductive exterior parts of a robot with a non-conductive material reduces the risk that they will touch a conductive object at a different electrical potential and trigger an ESD event. Wooden bumpers, electrical tape, and other non-conductive coatings are all effective.

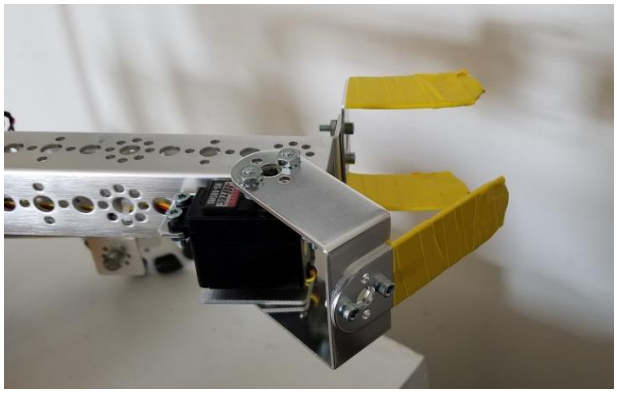

Figure 44 - Insulating portions of the robot that touch other metallic objects on the field can help.

In past seasons, teams who have done this have observed reductions in the frequency and severity of ESD events on their robots.

Ground the Control System Electronics to the Metal Frame using an Approved Cable
Because it is difficult to perfectly isolate the electrical system, it is beneficial to ground the electrical system to the frame of the robot to prevent a potential difference from building up between the frame and the electronics. Doing this can help reduce the risk that a shock can occur between the frame of a robot and the Control System electronics.

Figure 45 - The REV Robotics Resistive Grounding Strap (part # REV-31-1269) is an approved grounding cable.

It is important that the grounding only be done using a *FIRST*-approved, commercially manufactured cable (see Figure 45 above). A *FIRST*-approved cable has an appropriately sized inline resistor. This resistor is critical because it acts as a safeguard to prevent excessive current from flowing through the frame of the robot if a "hot" (positive) wire of the electronics system is inadvertently short circuited to the frame of the robot. Also, the commercially manufactured grounding cable has a keyed connection, which is designed to prevent a user from inadvertently connecting a hot (12V) line to the frame of robot.

To ground the electronics, plug one end of the *FIRST*-approved cable into a spare XT30 port on the Control System electronics. Then bolt the other end using a conductive (i.e., metal) bolt to the frame of the robot.

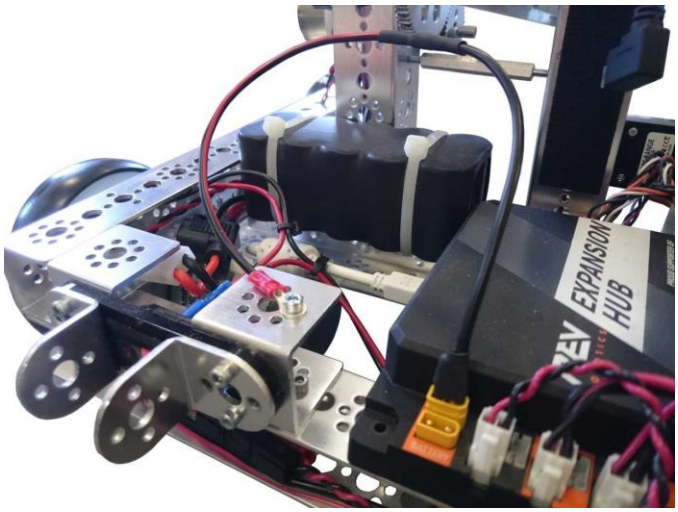

Figure 46 - Ground the electronics to the frame using a FIRST-approved cable.

It might initially seem contradictory to both insulate the electronic components of the control system from the frame and to also ground the electronics to the frame. However, if the electronics are not grounded to the frame, shocks can occur if a charge builds on the robot frame and an exposed or poorly insulated portion of the electronics (such as the base of a REV Robotics color sensor) gets close it. If the electronics are grounded to the frame, the grounding wire helps keep the electronics at the same potential as the frame, preventing arcs between the two systems.

Section 5

Additional Resources

Careful incorporation of the solutions and wire management tips in the previous four sections should ensure more robust electrical system performance and increase robot reliability. For teams looking to further increase their wiring knowledge, the following may be useful:

- NASA Guide to Crimping, Interconnecting cables, Harnesses, and Wiring
- Gear Up With FTC Presentation: Robot Wiring Troubleshooting
- Basic wiring instructions that are provided by REV Robotics for its Expansion Hub Control System.

FIRST also has a number of resources for teams looking for more information on the Android based technology: https://www.firstinspires.org/resource-library/ftc/robot-building-resources

Appendix A – Resources

Game Forum Q&A

http://ftcforum.usfirst.org/forum.php
Anyone may view questions and answers within the *FIRST*® Tech Challenge Game Q&A forum without a password. To submit a new question, you must have a unique Q&A System User Name and Password for your team.

Volunteers that apply for a specific volunteer role will receive an email from FTCTrainingSupport@firstinspires.org with their username and password to the forum. You will receive access to the forum thread specific to your role.

FIRST Tech Challenge Game Manuals

Part 1 and 2 - https://www.firstinspires.org/resource-library/ftc/game-and-season-info

FIRST Headquarters Pre-Event Support

Phone: 603-666-3906
Mon – Fri
8:30am – 5:00pm
Email: Firsttechchallenge@firstinspires.org

FIRST Websites

FIRST homepage – www.firstinspires.org

FIRST Tech Challenge Page – For everything *FIRST* Tech Challenge.

FIRST Tech Challenge Volunteer Resources – To access public Volunteer Manuals.

FIRST Tech Challenge Event Schedule – Find *FIRST* Tech Challenge events in your area.

FIRST Tech Challenge Social Media

FIRST Tech Challenge Twitter Feed - If you are on Twitter, follow the *FIRST* Tech Challenge Twitter feed for news updates.

FIRST Tech Challenge Facebook page - If you are on Facebook, follow the *FIRST* Tech Challenge page for news updates.

FIRST Tech Challenge YouTube Channel – Contains training videos, Game animations, news clips, and more.

FIRST Tech Challenge Blog – Weekly articles for the *FIRST* Tech Challenge community, including Outstanding Volunteer Recognition!

FIRST Tech Challenge Team Email Blasts – contain the most recent *FIRST* Tech Challenge news for Teams.

Feedback

We strive to create support materials that are the best they can be. If you have feedback about this manual, please email firsttechchallenge@firstinspires.org. Thank you!