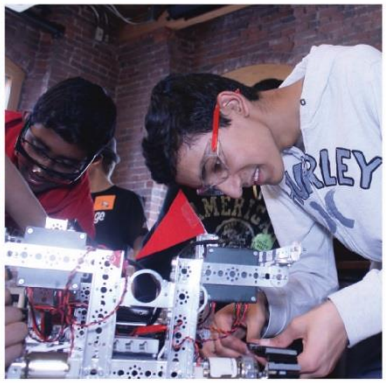
Training and Support

FIRST TECH CHALLENGE

2017-2018 *FIRST*® Tech Challenge
Robot Wiring Guide



www.firstinspires.org

200 BEDFORD STREET ■ MANCHESTER, NH 03101

FIRST
FOR INSPIRATION & RECOGNITION OF SCIENCE & TECHNOLOGY

Sponsor Thank You

Thank you to our generous sponsors for your continued support of the *FIRST* Tech Challenge!

***FIRST*® Tech Challenge**
Season Presenting Sponsor

Qualcomm

***FIRST*® Tech Challenge**
Official Program Sponsor

Rockwell Collins

***FIRST*® Tech Challenge**
Official 3D Augmented Reality/
Virtual Reality Sponsor

ptc

Volunteer Thank You

Please take the time to thank *FIRST*® Tech Challenge volunteers. *FIRST*® and *FIRST*® Tech Challenge rely heavily on volunteers to ensure events run smoothly and are a fun experience for teams and their families, which could not happen without volunteers. With over 4,600 teams competing yearly, their dedication and commitment are essential to the success of each event and the *FIRST* Tech Challenge program.

Revision History		
Revision	**Date**	**Description**
1	09/19/2017	Initial Release
1.1	10/3/2017	Formatting Update
1.2	01/09/2018	Updated sponsor thank you image

Contents

What is the *FIRST*® Tech Challenge Robot Wiring Guide?

The purpose of the *FIRST* Tech Challenge Robot Wiring Guide is to:

- Provide teams with information, tips, and tricks to improve their wiring for better and more reliable robot performance.
- Help teams and mentors troubleshoot their robot wiring.

  The goals of this guide are as follows:
  - Equip teams with a complete list of robot wiring tools and methods.
  - Provide clear instructions for improving basic robot wiring.
  - Present instructions on troubleshooting wiring issues.

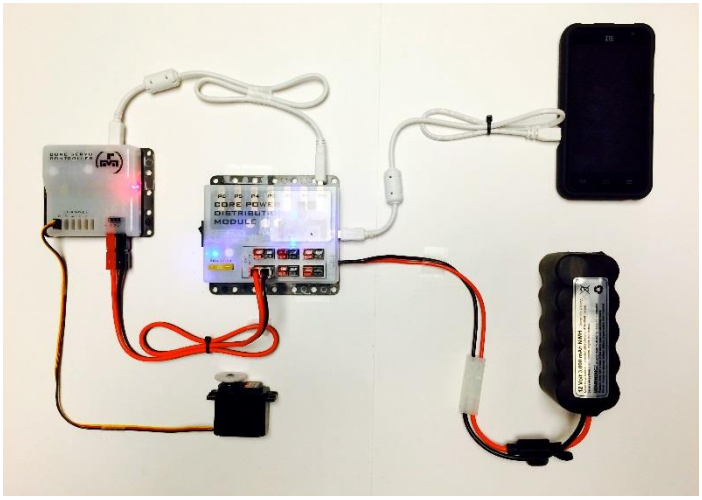


Figure 1: Modern Robotics Electronics, Phone, Battery Cell

This guide would not be possible without the contributions of time, ideas, and resources provided by the 2015 World Championship Inspire Award winning team, #3595 Schrödinger's Hat.

Introduction to Robot Wiring

Wiring is one of the most important components 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.

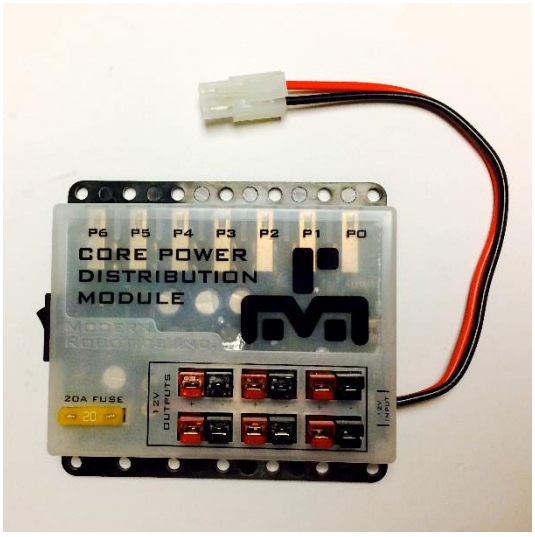


Figure 2: Power Distribution Module

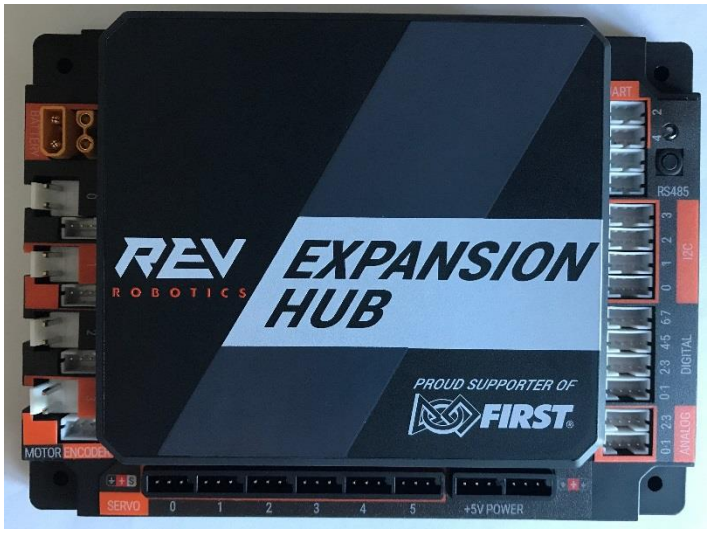


Figure 3: REV Expansion

Figure 4: Core Device Interface

Figure 5: REV Touch Sensor

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 contains links to additional resources and wiring fundamentals.

Section 1

This guide is not intended to be a step-by-step tutorial on how to set up any of the electronics systems. For step-by-step instructions, please visit the REV 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 alterations 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 regarding 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 imperative that the phone is protected from robot-to-robot contact.
2. The phone should be mounted such that it is not in contact with any metal components on the robot. If it is in contact with metal, the phone becomes susceptible to electrostatic discharge (ESD).
3. Similarly, teams should avoid surrounding the phone in metal. If it is mounted at the bottom of a robot and surrounded by metal, the metal can interfere with the phone's Wi-Fi connection.
4. Make sure that the phone is easily accessible for charging, programming, and emergencies.
5. Make sure that the phone is mounted such that the camera is available for Vuforia, if desired.

6. Make sure that all wires connected to the phone are securely mounted and are not in danger of being bumped, damaged, or disconnected. It is essential that there is no chance of stress being placed on the wire that connects to the phone. If the wire is stressed, the phone port could be ruined. Wires should be tied down, and there should be no movement around the port. Phone mounts are available from a variety of different sources for *FIRST* Tech Challenge teams.

Figure 6: The cable is supported and secured in place. It is still easy to unplug it for charging, but it will be difficult to accidentally unplug it.

Figure 7: 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 not only to the phone, but also to all electronics. 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 that 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 these cables are momentarily being shaken/jolted loose during the match. In particular, the USB connection to the Micro USB port on the phone should be properly secured. This Micro USB connection tends to be more susceptible to being shaken or jolted loose if the USB cable is not properly secured.

Battery Connections

There are a variety of 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 be able to stand up to the rigors of the *FIRST* Tech Challenge season. Other styles of connectors, like the Tamiya connectors (Figure 8), are only reliable for a few dozen cycles and may wear out during a *FIRST* Tech Challenge season.

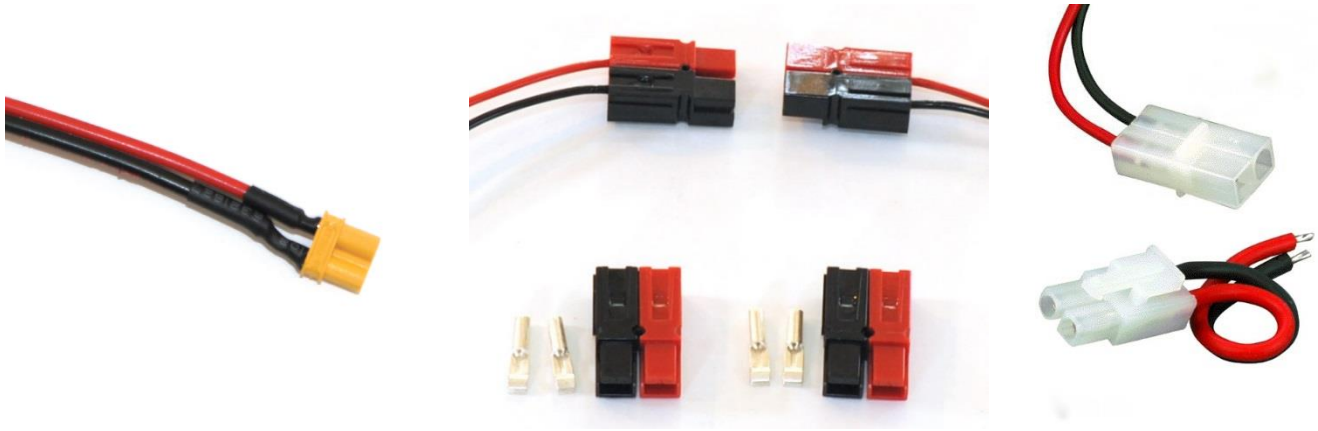


Figure 8: Tamiya connector.

REV: The REV system uses XT30 style connectors for the power wires. Over the course of a season these connectors will fatigue, and the battery connection will become less reliable. In order to address this, it is recommended that teams zip-tie or otherwise attach an XT30/Anderson PowerPole converter cable to their expansion hub. 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 XT30 connection and keep the connections reliable throughout the season.

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. In order 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: The Modern Robotics Core Power Distribution Module is not reverse-polarity protected. *If the wires are inadvertently reversed (red to black, black to red) (Figure 9), the Core Power Distribution Module will be damaged. Additionally, the battery should never be plugged into the distribution ports (Figure 10).*

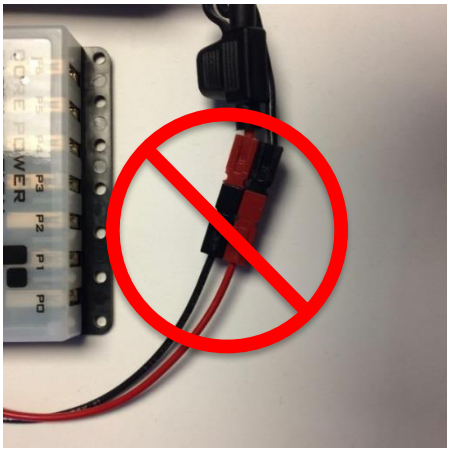


Figure 9: Reversed power wires.

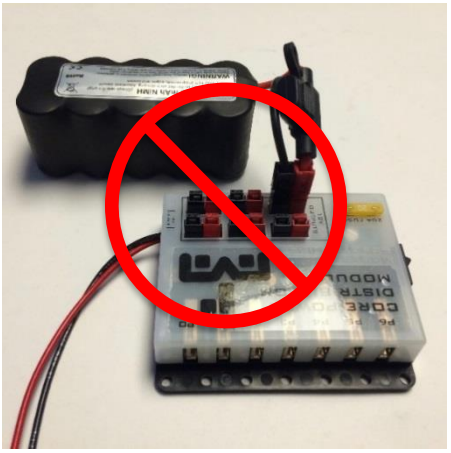


Figure 10: Battery plugged into wrong port.

Legacy: Legacy hardware needs a Modern Robotics Core Power Distribution Module to function. As such, the Modern Robotics requirements, mentioned earlier, apply to the legacy hardware.

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 very 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 11: Anderson PowerPole to XT30 adaptor.

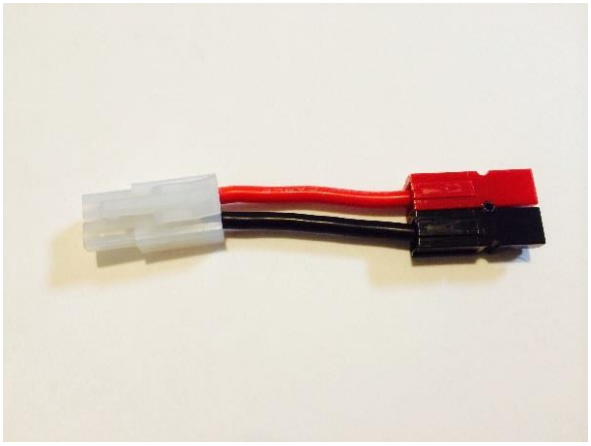


Figure 12: Anderson PowerPole to Tamiya adaptor.

Installing Anderson PowerPoles

The following sequence of steps explains 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 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.

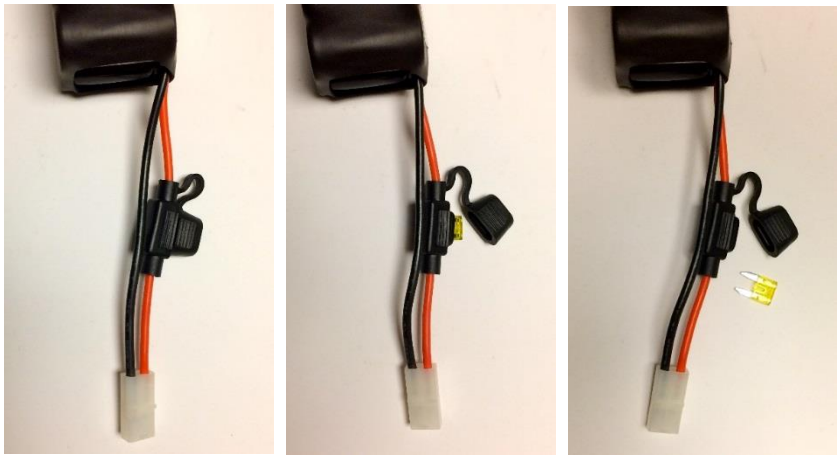


Figure 13: Remove the fuse.

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 14).

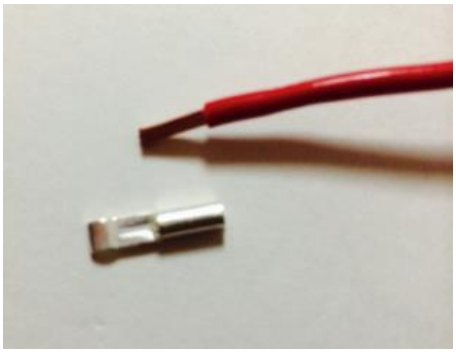


Figure 14: Strip the wires.

4. Crimp the connector on. Make sure that the wire is in the proper orientation before doing this -- the PowerPoles need to be able to connect properly. (Figure 15).

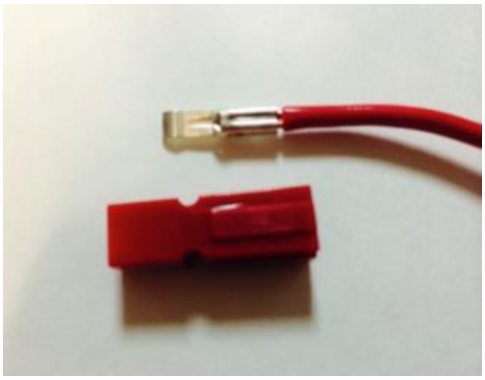


Figure 15: Crimp connector onto wire.

5. Snap on the plastic housing. (Note colors, making sure that the red housing 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 interface with the existing PowerPoles on the modules or adaptors.
8. If applicable, re-insert the fuse.
9. Repeat the procedure on the battery charger.

A video demonstration of this process can be seen in the *Gear Up with FTC!* Robot Wiring Troubleshooting Video. (Skip to 10:10 in the video.) Additional details can be found athttp://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.

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 16: Blade connectors and power switch.

REV: REV provides a power switch to pair with the 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).

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 the built-in switch is protected from robot to robot contact.

Legacy: Legacy hardware needs a Modern Robotics Core Power Distribution Module to function. As such, the Modern Robotics requirements, mentioned earlier, apply to the legacy hardware.

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 (Figures 17-19).

Replacing Tinned Wire

1. Cut the blade connector off of the wire, as close to the edge of the connector as possible, so as not to waste wire (Figure 18).
2. Strip the end of the wire to the required length (Figure 19).
3. Insert the stripped wire into a replacement connector. Make sure that all of the strands of the wire make it inside the connector. They should not bend or otherwise miss the opening.
4. Crimp the necessary section of the connector onto the wire (Figure 20).
5. Attach the connector to the switch (Figure 21).
6. Repeat as necessary.

Figure 17: The original wire.

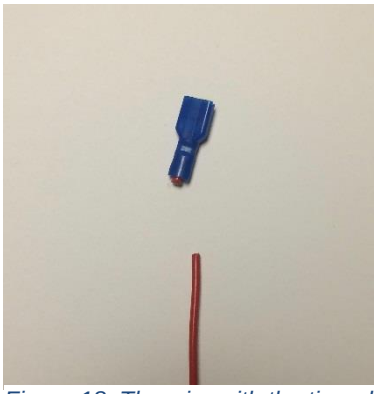


Figure 18: The wire with the tinned end removed.

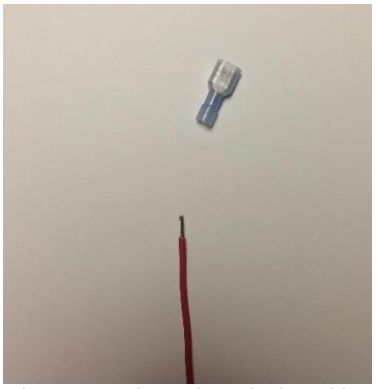


Figure 19: The stripped wire with a new connector.

Figure 20: The wire with the connector crimped on

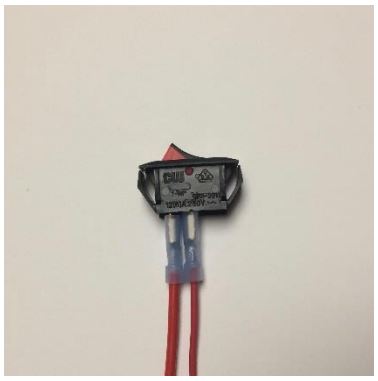


Figure 21: The switch with the new connectors.

A note on Logic Level Converters (Rev):

Logic Level Converters (also known as Level Shifters) are for use with 5V electronics (such as some encoders, Modern Robotics sensors, etc.). These converters must be used to convert 5V electronics to 3.3V, thus making them usable with the Rev electronics. A complete explanation can be found in the Rev Electronics Guide (linked in Section 4).

Figure 22: Logic Level Converter.

Section 2

Common Problems

Hardware Problems and Their Mitigations
There are several potential issues that can arise with the expansion hub, the Modern Robotics electronics, and legacy 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 of the modules. It is possible for the pins in the module ports to be damaged. **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 each type of technology. There are a number of tricks teams can implement to reduce these issues.

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

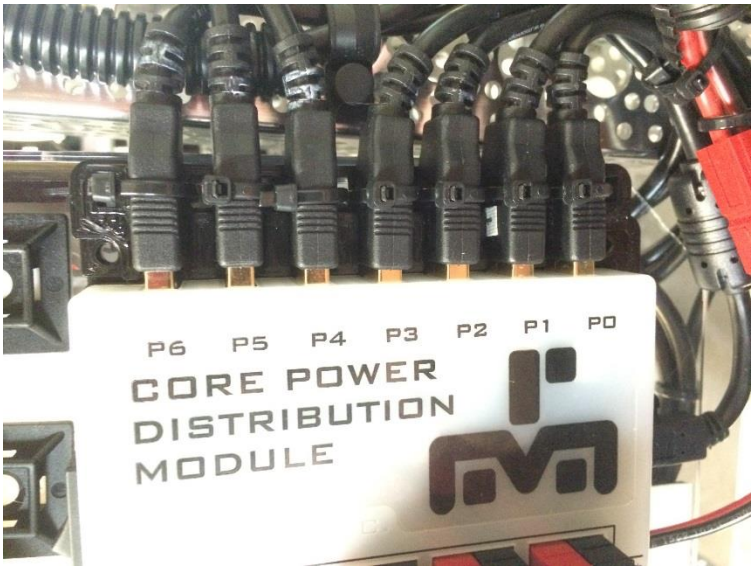


Figure 23: Make sure every connection to and from the modules are supported.

Mitigation 2: Isolating electronics from metal components on the robot also cuts down on connection issues. Mounting the electronic components on plastic areas of the robot helps to isolate them and cuts down on the effect of electrostatic discharge.

Mitigation 3: Make sure that 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, 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 due to electrostatic discharge. Before making a decision on wheels, teams should research the pros and cons of the particular model, and make a decision accordingly.

Legacy Controller Connections

Problem: Legacy motor and servo controllers use screw terminals for the power and motor connection wires. These terminals hold onto the wires using compression. The wires that come with some kits are tinned, and because the solder creeps when compressed, the grip on the wires can loosen over time and cause the robot to experience intermittent failures.

Additionally, stripping a wire and inserting it into the legacy motor controller often results in stray strands of wire (Figure 24). These loose strands of wire are problematic and make it easy to inadvertently create a short circuit.

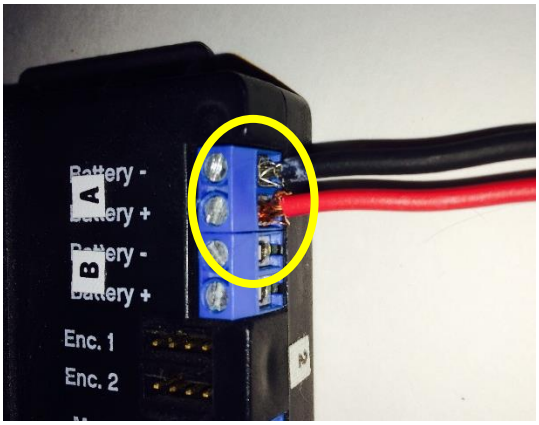


Figure 24: Try to avoid stray strands of wire when connecting to the Motor Controller.

Mitigation: Ferrules, also called “end sleeves”, are a simple way to avoid many of the potential problems with the motor and servo controller connections (Figure 25). Ferrules are the industry standard for providing a robust connection in a screw terminal, and they are inexpensive and easy to install.

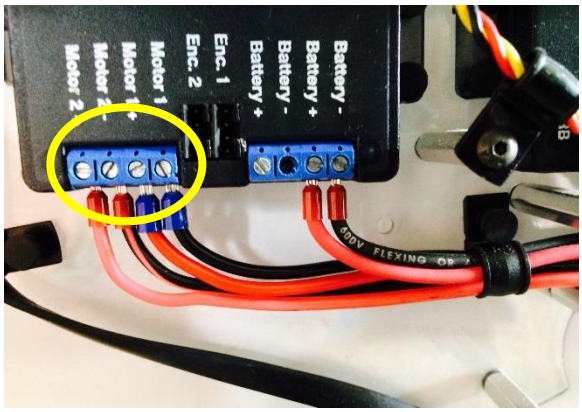


Figure 25: Ferrules or End Sleeves.

Installing Ferrules

1. Cut wire to proper length:

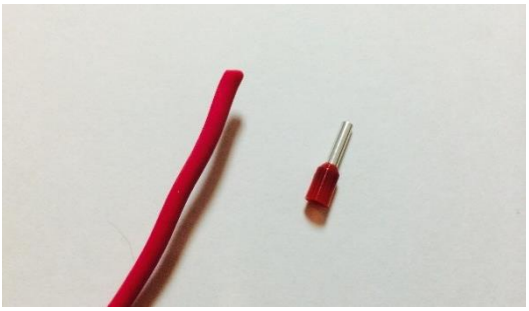


Figure 26: Wire and Ferrule.

2. Strip off the end of the wire insulation:

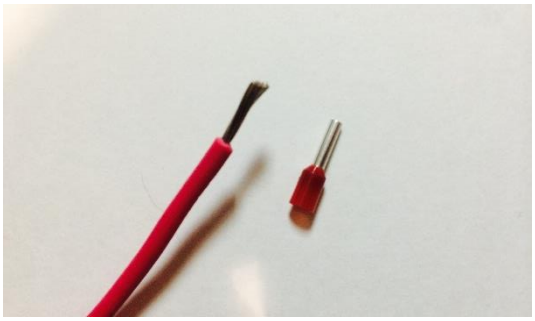


Figure 27: Strip the wire.

3. Slide the Ferrule over the end of the wire. Be sure that the ends of the wire are flush with the end of the Ferrule.

4. Insert the Ferrule/wire combination into the proper slot on the crimping tool:

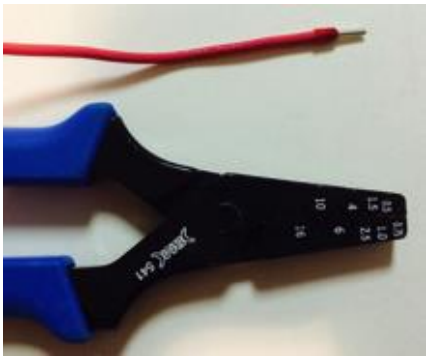


Figure 28: Ferrule crimping tool

5. Crimp:

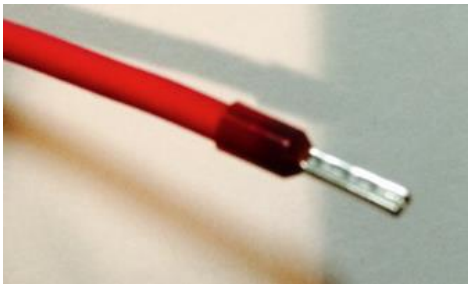


Figure 29: Crimped Ferrule.

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 of the wires in a robot are jumbled together and not properly tied down, a variety of problems can arise, including:

- Faulty Connections
- Broken 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 remainder of the match.

Solution: Make sure your wires are properly secured so that 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 Wire

Pitfall: The Legacy Servo Controllers are marked with "YRB," the Core Servo Controllers are marked with "WRB," and the Expansion Hub has three color-coded symbols. YRB stands for "Yellow Red Black," 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 indicate the orientation of the Servo wire. The black wire must line up with the "B," or the black symbol. The other colors do not matter. 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 30).

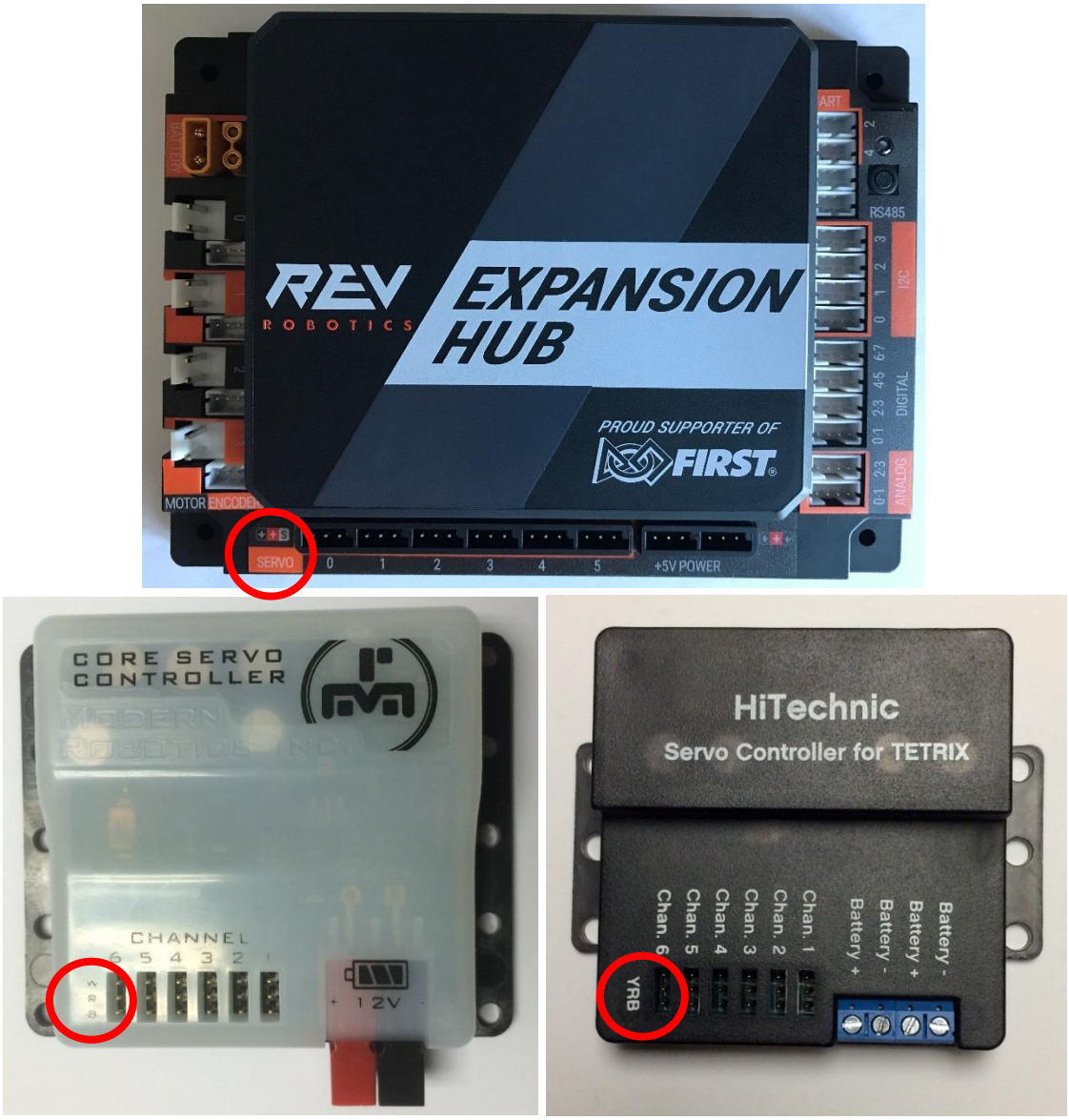


Figure 30: Indicators on the Servo Controllers.

Daisy Chaining Legacy and Modern Robotics Wiring Components

Pitfall: Daisy chaining is one way of powering several different units. Multiple components are wired together, with each unit being powered by the one before it in the chain. It is common for teams to daisy chain the power terminals on the motor and servo 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: Rather than daisy chaining legacy components, plug each one into the core distribution module.

Haphazard Battery and Controller Placement

Pitfall: When the placement of the battery and controllers is not incorporated into the initial robot design, the components 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 that there are no sharp edges that can cut into the battery.
- Ensure that the battery and controllers will be protected during matches.
- Ensure that all connections are secure and cannot be jostled or otherwise disturbed during matches.
- Ensure that the battery is properly secured to the robot, and cannot disconnect during a match.
- The battery is often one of the heaviest components 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 adjacent 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. Use the shortest possible cable at all times. 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 suppress interference from the power network. Use a high-quality shielded USB cable with built-in or external Ferrite chokes to help reduce interference on the line from the motors and to help reduce the effects of electro-static discharge. The cords included with the Modern Robotics electronics come with built-in ferrite chokes.

Section 3

Wire Management Tips

In addition to building a great robot and wiring it using the recommendations made in Sections 1 and 2, there are best practices for general wiring of the robot – good habits to start as soon as possible and then maintain every season.

Conduct Proper Maintenance

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

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

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

Keep It Neat

There are a lot of 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, thus aiding in troubleshooting;
- Easier to fix;
- Less likely to get caught in moving parts; and
- Less likely to become entangled in 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 components. 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 31).
    - 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 31: 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 components 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 32).

Figure 32: Securely fastened end cap

Dealing with Moving Parts

In some cases teams will need to run wires over and around moving pieces to get them to a required location. When doing this, teams should use extreme caution. Avoid pinch points whenever possible, and make sure that there is always enough slack so that wires are never put under unnecessary stress. Protect wires that will be prone to chaffing and rubbing with wire loom and routinely check them during the course of the season. 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 components are wired together at a glance (Figure 33). 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.

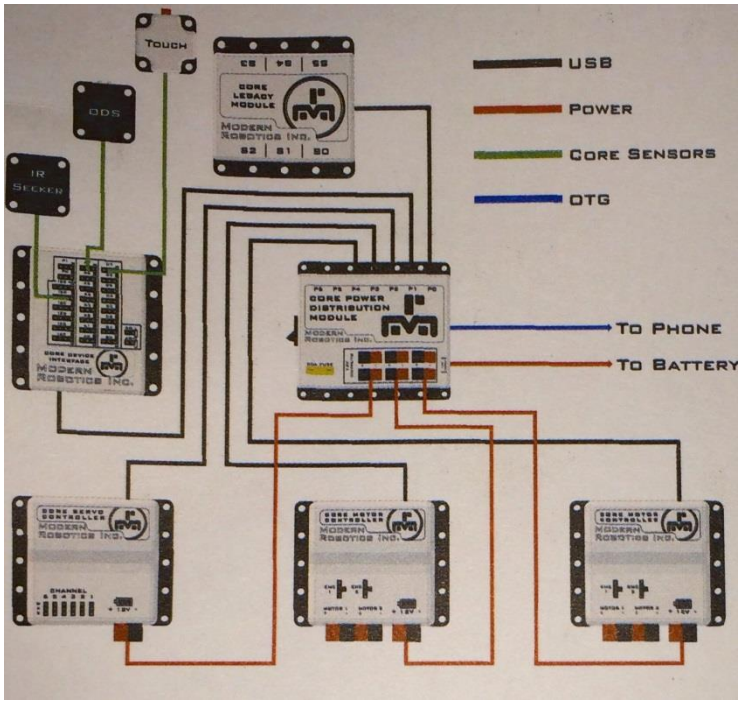


Figure 33: A simple wiring diagram.

Use the Proper Tools

Proper tools ease the implementation of wiring (see Figures 34 - 38). Tools like the Anderson PowerPole crimping tool and small nippers will greatly aid in clean wiring.

Figure 34: Wire strippers.

Figure 35: Small screwdriver for tightening screw terminals on Legacy modules.

Figure 36: Small nippers for cutting zip ties.

Figure 37: Ferrule crimpers.

Figure 38: Anderson PowerPole crimpers.

Label Wires

Proper wire labeling quickly solves many problems (Figure 39). It helps in the creation of a wiring document and also cuts down on time devoted to maintenance and troubleshooting.

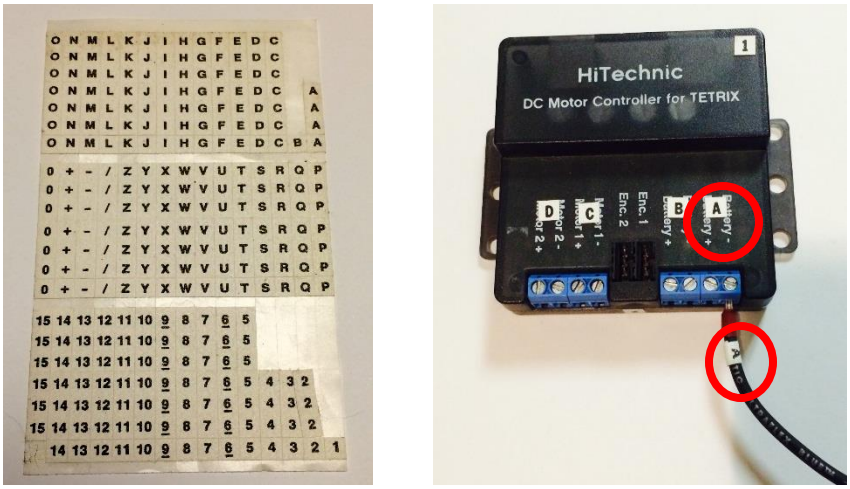


Figure 39: Wire labels.

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

Additional Resources

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

- NASA Guide to Crimping, Interconnecting cables, Harnesses, and Wiring
- Gear Up With FTC Presentation: Robot Wiring Troubleshooting
- Basic wiring instructions:
  - Provided with REV Electronics.
  - Provided with TETRIX kits.
  - Provided with MATRIX kits.

FIRST also has a number of resources for teams looking for more information on the Android based technology: http://www.firstinspires.org/node/5291.

Modern Robotics also has descriptions of their technology: http://www.modernroboticsinc.com

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.

FIRST Tech Challenge Game Manuals

Part 1 and 2 - http://www.firstinspires.org/node/4271

FIRST Headquarters Pre-Event Support

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

FIRST Tech Challenge Google+ community - If you are on Google+, follow the *FIRST* Tech Challenge community for news updates.

Feedback

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