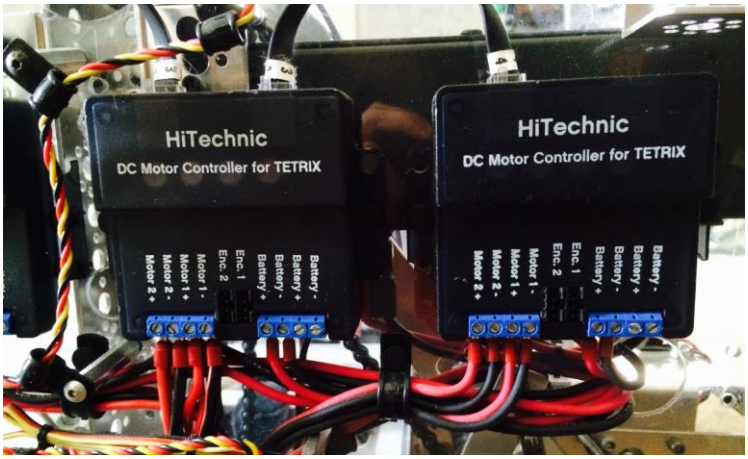
FTC®

FIRST® Tech Challenge

FIRST Tech Challenge®

Robot Wiring Guide



Volunteer Thank You

Thank you for taking the time to volunteer for a *FIRST* Tech Challenge Event. *FIRST* and FTC rely heavily on Volunteers to ensure Events run smoothly and are a fun experience for Teams and their families, which could not happen without people like you. With over 4,000 Teams competing annually, your dedication and commitment are paramount to the success of each Event and the FTC program. Thank you for your time and effort in supporting the mission of *FIRST*!

Sponsor Thank You

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

Rockwell Collins

Official Program Sponsor

PTC®

CAD and Collaboration Sponsor

Revision History		
Revision	**Date**	**Description**
1	9/3/2014	Initial Release

Contents

Images

Introduction

What is the FIRST Tech Challenge?

FIRST® Tech Challenge is a student-centered activity that focuses on giving students a unique and stimulating experience. Each year, Teams participate in a new Game that requires them to design, build, test, and program autonomous and driver-operated Robots that must perform a series of tasks.

The Playing Field for the Game consists of the *FIRST* Tech Challenge Game Pieces set up on a foam-mat surface, surrounded by a metal and Lexan Field frame. Each Tournament features Alliances, which are comprised of two Teams, competing against one another on the Playing Field. Teams work to overcome obstacles and meet challenges, while learning from and interacting with their peers and adult Mentors. Students develop a greater appreciation of science and technology and how they might use that knowledge to impact the world around them in a positive manner. They also cultivate life skills such as:

Details about setting up a Playing Field can be found on the FTC website after the yearly Game challenge Kickoff.

- Planning, brainstorming, and creative problem-solving.
- Research and technical skills.
- Collaboration and Teamwork.
- Appreciation of differences and respect for the ideas and contributions of others.

To learn more about FTC and other *FIRST* Robotics Competitions, visit www.usfirst.org.

FIRST Tech Challenge (FTC) Core Values

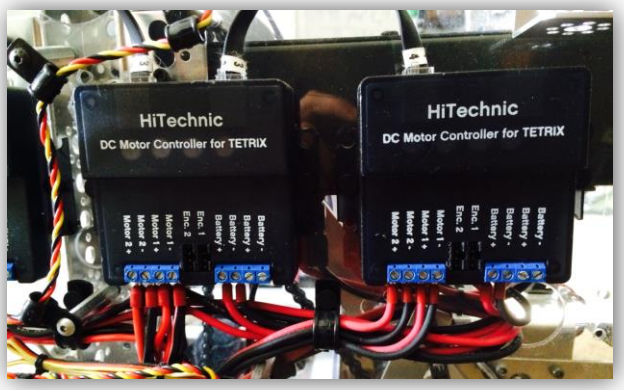
Volunteers are integral to the *FIRST* community. The *FIRST* Tech Challenge relies on Volunteers to run the program at many levels, from managing a region to Mentoring an individual Team. FTC Affiliate Partners coordinate the program in each region or state. These FTC Partners fundraise, run Tournaments, hold workshops and demonstrations, market FTC locally, handle public relations, and recruit Volunteers and Teams. They are a tremendous resource for Mentors and FTC would not exist without them.

FIRST asks everyone who participates in FTC to uphold the following values:

- We act with integrity.
- We are a Team.
- We do the work to get the job done with guidance from our Coaches and Mentors.
- We respect each other in the best spirit of Teamwork.
- We honor the spirit of friendly Competition.
- What we learn is more important than what we win.
- We behave with courtesy and compassion for others at all times.
- We share our experiences with others.
- We display Gracious Professionalism in everything we do.
- We have fun.
- We encourage others to adopt these values.

What is the FIRST Tech Challenge Robot Wiring Guide?

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



- Provide Teams detailed instructions for properly wiring their Robot for reliable performance.
- Provide Teams with tips and tricks to improve their wiring for improved Robot performance.
- Help Teams and mentors with troubleshooting their Robot wiring.

The guide focuses on the skills and concepts needed for the development of the following general goals:

- 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, including ESD-related issues.

This guide would not be possible without the contributions of time, ideas, and resources provided by the following people:

- Content written by Tom Viars, FTC Washington, and **Colleen Johnson *(pictured right),*** Team #3595 Schrödinger's Hat, Alaska, who also provided the step-by-step instructions and images.
- Wiring tips provided by Dave and Lydean Spangler, FTC Maryland.
- Electrostatic Discharge recommendations provided by Dale Jordan, FTC Oregon.
- Anderson Powerpole instructions provided by Lauren Keeling, Team #2901, North Carolina.
- Editing by Michael Coleman, Florida *FIRST*.

Gracious Professionalism™

FIRST uses this term to describe the program's intent. This is one of the most important concepts that can be taught to a young person who is learning to get along in the work world. At *FIRST*, Team members help other Team members, but they also help other Teams.

Gracious Professionalism is not clearly defined for a reason. It can and should mean different things 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.
- Professionals possess special knowledge and are trusted by society to use that knowledge responsibly.
- Gracious Professionals make a valued contribution in a manner pleasing to others and to themselves.

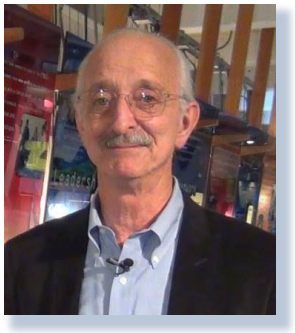
An example of Gracious Professionalism is a Team loaning a spare Motor to a competitor Team.

In the context of *FIRST*, this means that all Teams and participants should:

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

In the end, Gracious Professionalism is part of pursuing a meaningful life. When professionals use knowledge in a gracious manner and individuals act with integrity and sensitivity, everyone wins, and society benefits.

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



"The FIRST spirit encourages doing high-quality, well-informed work in a manner that leaves everyone feeling valued. Gracious Professionalism seems to be a good descriptor for part of the ethos of FIRST. It is part of what makes FIRST different and wonderful."

- Dr. Woodie Flowers, National Advisor for ***FIRST***

Youth Protection Program

FIRST requires all youth Team members to register in support of our enhanced Youth Protection Program.

FIRST understands that an important component of protecting children is knowing who the children are on our Teams. In addition, having parent/guardian contact information increases our ability to communicate important information, and also provides us with a better understanding of who our programs serve.

Coaches and Mentors are expected to read the Youth Protection Program Guide, available here: http://www.usfirst.org/aboutus/youth-protection-program

Forms are available here: http://www.usfirst.org/aboutus/youth-protection-program

Information on the US Screening process is available here: http://www.usfirst.org/sites/default/files/uploadedFiles/About_Us/US-Youth-Protection-Clearance-Process.pdf

All adults working closely with the Team and Event Volunteers must be registered and screened.

Information on the Canadian Screening process is available here: http://www.usfirst.org/sites/default/files/uploadedFiles/About_Us/Canadian-Youth-Protection-Clearance.pdf

You can find FAQ and additional information about the *FIRST* Youth Protection Program on the FIRST website at: http://www.usfirst.org/aboutus/youth-protection-program

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. Even the briefest of power interruptions can cause the Samantha Module to reboot, which in turn can cause a Robot to disconnect from the Field Control System. Good wiring allows Teams to create tight connections and to better troubleshoot problems as they occur. Such wiring takes a lot of patience and practice, and Teams should budget time accordingly.

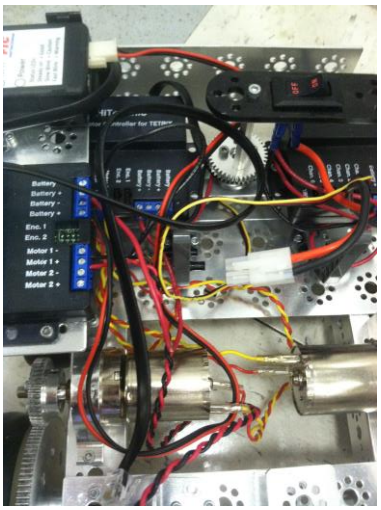


Figure 1: Haphazard Wiring.

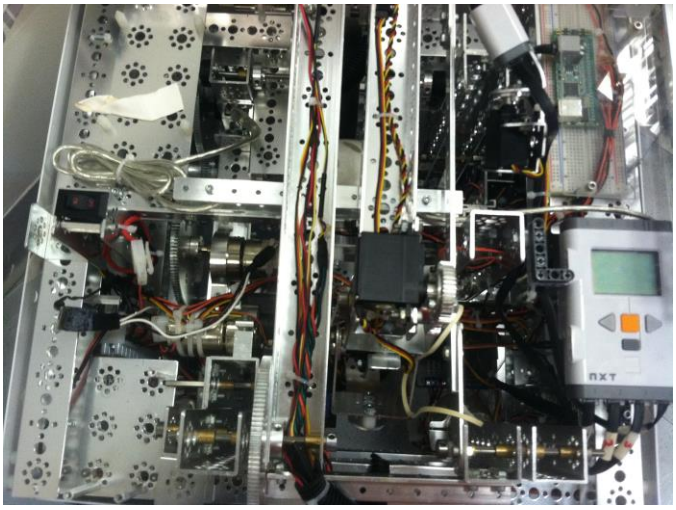


Figure 2: Organized Wiring.

In this Guide, Teams will learn how to properly wire their Robot, tips to improve wiring reliability, and troubleshooting techniques.

- Section 1 of this document discusses common wiring problems and their solutions.
- Section 2 provides several tips for proper wire management.
- Links to additional resources and wiring fundamentals can be found in Section 3.

Section 1: Common Wiring Problems & Their Solutions

Hardware Problems and Their Solutions

There are several potential issues that can arise with the wiring hardware included in the original kits. This section will detail these issues.

Battery Connections

Problem: The plug on the TETRIX battery (Figure 3) is called a Tamiya connector. Tamiya connectors provide a quick and easy way to change a battery. Unfortunately, Tamiya connectors are not well-suited for the type of wear encountered during an FTC season. The connectors are only reliable for a few dozen cycles -- after additional cycles, the internal contacts can become deformed and cause the Robot to suffer from intermittent disconnects.

Figure 3: Tamiya connector.

Solution: Replacement is the only reliable option for solving the problems caused by Tamiya connectors. The connectors can be removed and replaced with a quick-disconnect option, such as an Anderson Powerpole (Figure 4). Anderson Powerpoles are designed for the sort of conditions FTC Robots experience.

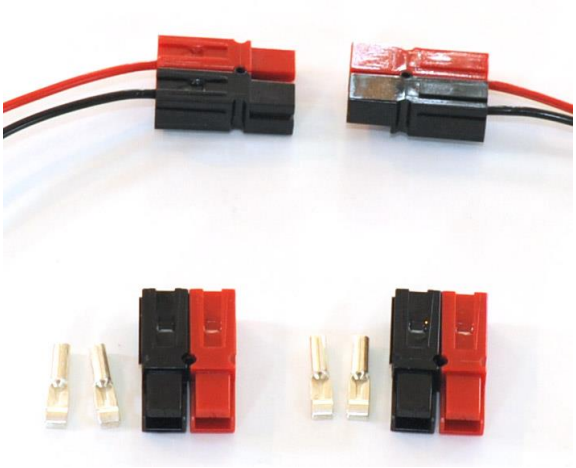
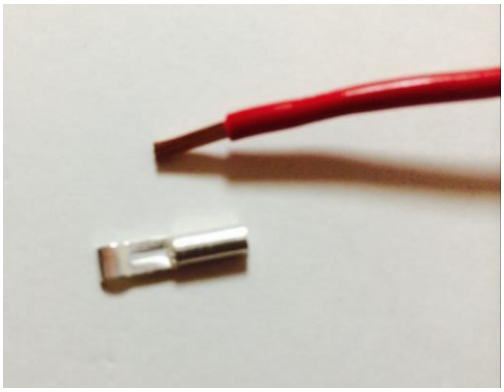


Figure 4: Anderson Powerpoles.

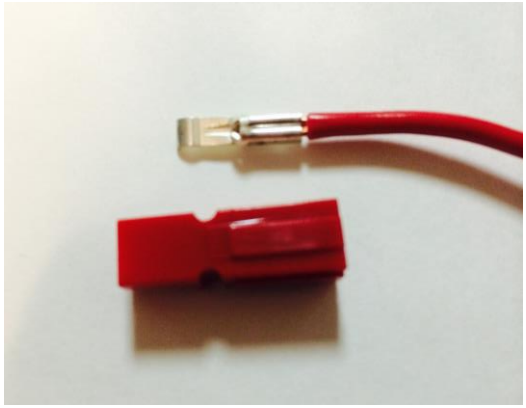
Installing Anderson Powerpoles

The following sequence of steps explains how to install Anderson Powerpoles on a Robot:

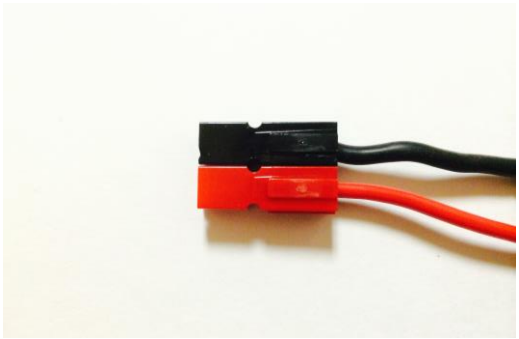
1. Remove the fuse from the battery.
2. Cut the Tamiya connectors off the end of the wire.
3. Strip the wires to the Anderson Powerpole specs:



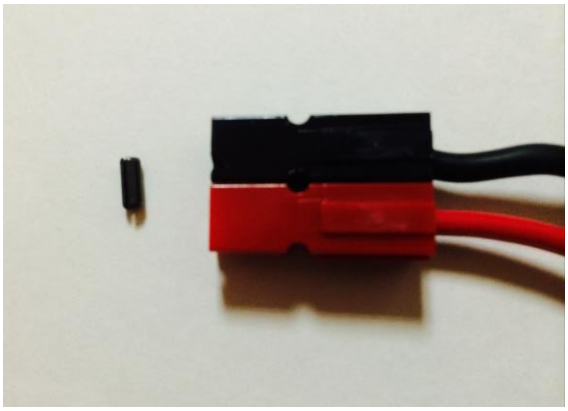
4. Crimp the connectors on. (Make sure that the wires are in the proper orientation before doing this -- the Powerpoles need to be able to interface.)
5. Snap the plastic housing on. (Note colors, making sure that the red housing is attached to the red wire and the black housing is attached to the black wire:



6. Snap the red and black housing pieces together:



7. Insert the pin:



8. Re-insert the fuse.
9. Repeat the procedure on the Robot end of the Tamiya connector.
10. 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.)

Power-Switch Connectors

Problem: Crimp-on connectors should never be used on solid core wire or on wire that has been tinned. Crimp-on connectors rely on the deformation of multi-stranded wire to make a permanent connection. Unfortunately, the TETRIX power switch comes with blade connectors that are crimped onto already tinned wire. Over time this solder will creep (or flow), leading to a poor connection that will cause intermittent disconnects.

Solution: 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 5).

Figure 5: Blade connectors.

Samantha Module Placement

Problem: Wiring to the Samantha Module unit must be well-supported in order to prevent disconnects and physical damage to the unit.

Solution: The proper way to support the Samantha Module unit wiring (Figure 6) is detailed in the "Samantha Module User Guide:

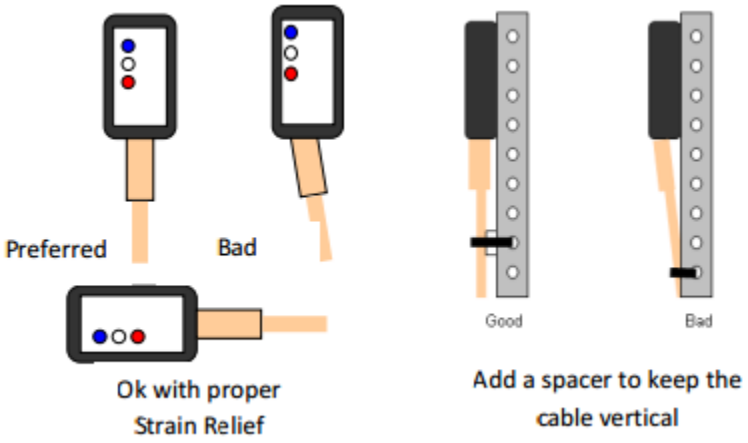


Figure 6: Samantha Module placement tips.

- A vertical placement of the Module is best; while Teams might see a marginal improvement in signal if the Module is mounted horizontally, the Samantha Module **will not** receive a signal if the cable becomes dislodged. Therefore vertical placement is recommended, because it is easier to support the cable and keep a constant physical connection.
- Mount the Samantha Module as high on the Robot as possible.
- Avoid burying the Module inside the Robot Chassis, as the metal will interfere with signal strength.

Controller Connections

Problem: Motor and Servo Controllers use screw terminals for the power and Motor connection wires. These terminals hold onto the wires using compression. Unfortunately, the wires that come with 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 Motor Controller often results in stray strands of wire, as shown in Figure 7. These loose strands of wire are problematic and make it easy to inadvertently create a short circuit.

Figure 7: Try to avoid stray strands of wire when connecting to the Motor Controller.

Solution: Ferrules, also called "End Sleeves", are a simple way to avoid many of the potential problems with the Motor and Servo Controller connections (Figure 8). Ferrules are the industry standard for providing a robust connection in a screw terminal, and they are inexpensive and easy to install.

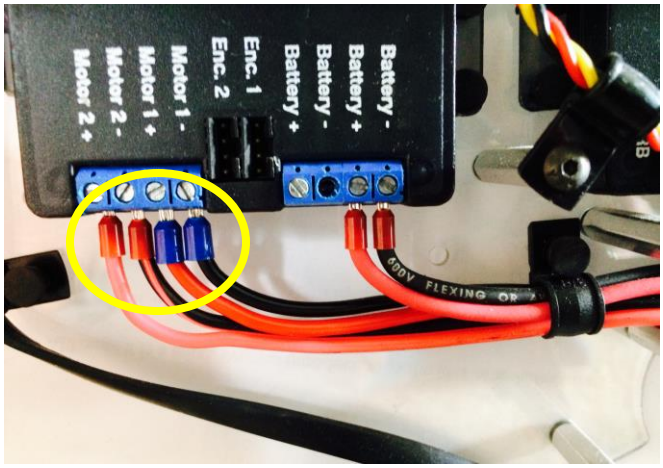
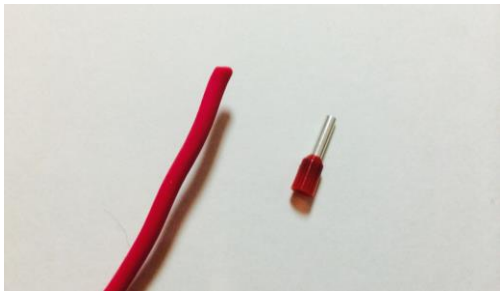


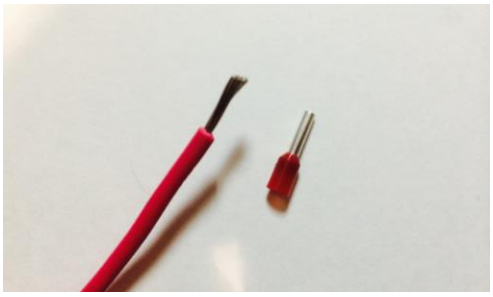
Figure 8: Ferrules or End Sleeves.

Installing Ferrules

1. Cut wire to proper length:

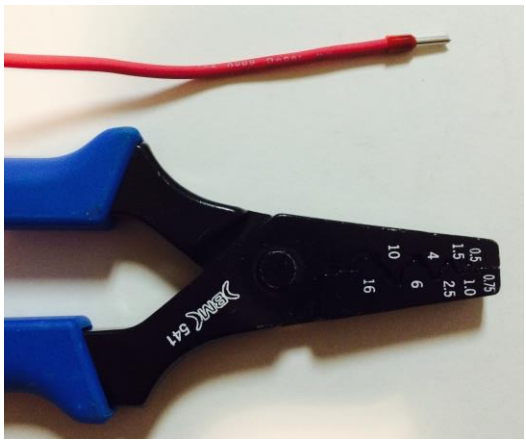


2. Strip off the end of the wire insulation:

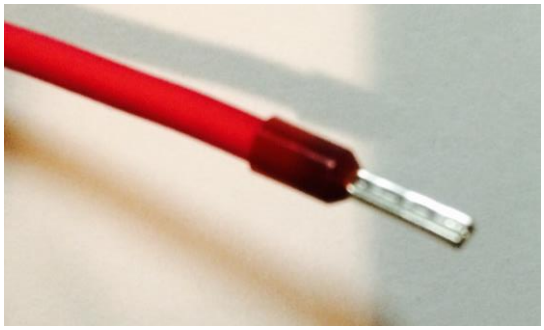


3. Slide the Ferrule over the end of the wire. Be sure that the ends of the wire are flush with the end of the Ferrule.

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



5. Crimp:



Signal Wires and Power Wires

Problem: The signals that pass between the NXT and the Motor Controllers are sensitive to interference, and Motors are electronically noisy devices. The NXT and USB cables are designed to carry electrical signals while the remaining wires on the Robot are designed to carry power. If a power wire is routed adjacent to a signal wire, it is possible to induce a stray signal that can lead to intermittent disconnects, a frozen NXT, or locked up Motor and Servo Controllers.

Solutions:

There are multiple solutions to this problem: correct wiring placement; using Ferrite Chokes; or use a USB surge protector (new allowable part for 2014).

Wiring Placement

Try to keep power cables and Motor cables away from the black LEGO data 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. The most important wire to protect is the USB cable running between the Samantha Module and the NXT. Teams may also wish to protect the NXT cables coming out of the NXT to the Motor Controller.

Ferrite Chokes

Ferrite chokes electronically isolate signal cables from the power network. Using 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 (Figure 9).

Figure 9: Ferrite choke in use on a USB cable

USB Surge Protectors

A USB surge protector is a newly-allowed element in 2014 (Figure 10). Adding a surge protector to the NXT's USB cable seems to work very well for reducing the effects of electro-static discharge. One recommended model is available here: http://www.l-com.com/usb-usb-surge-protector-ecf-style-panel-mountable-type-a-type-b

Figure 10: USB Surge protector.

Common Team 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
- Difficulty 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 2 of this document also prevent this "rat's nest" wiring.

Reversed Servo Wire

Pitfall: The Servo Controllers are marked with "YRB," as shown in Figure 11. YRB stands for "Yellow Red Black" and indicates the orientation of the Servo wire. 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 (see Figure 11).

Figure 11: YRB Marking on the Servo Controller.

Daisy Chaining 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 drop.

Solution: Rather than daisy chaining, a better way to design a power distribution network is to use a power distribution terminal, such as the Anderson Powerpole splitter (Figure 12). With this method, if any one Controller disconnects, the other Controllers will continue working.

Figure 12: Anderson Powerpole Splitter.

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 the battery is properly secured to the Robot, and cannot disconnect during a Match.
- The battery is one of the heaviest components on the Robot and its placement can have a dramatic effect on drivability and stability. A good rule is to place the battery as low as possible.

Section 2: Wire Management Tips

In addition to building a great Robot and wiring it using the recommendations made in Section 1, 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 not only aesthetically pleasing but also 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 proper wire management hardware (Figure 13).
  - 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 13: 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:

- 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.

In order to keep the end cap securely attached to the TETRIX DC Motor, use electrical tape to fasten the end cap as demonstrated in Figure 14.

Figure 14: Securely fastened end cap.

Be Careful with Power Switch Placement

Mount the power switch so it is easy for the FTA to locate and reach, but difficult for another Robot to trigger (Figure 15).

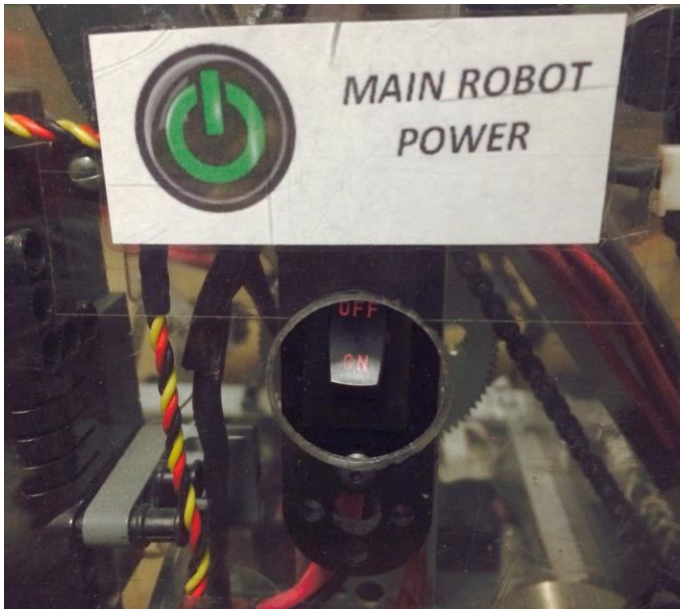


Figure 15: Power switch placement (behind plastic sheeting with an access hole).

Make Wiring Diagrams

Wiring diagrams show what components are wired together at a glance (Figure 16). 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.

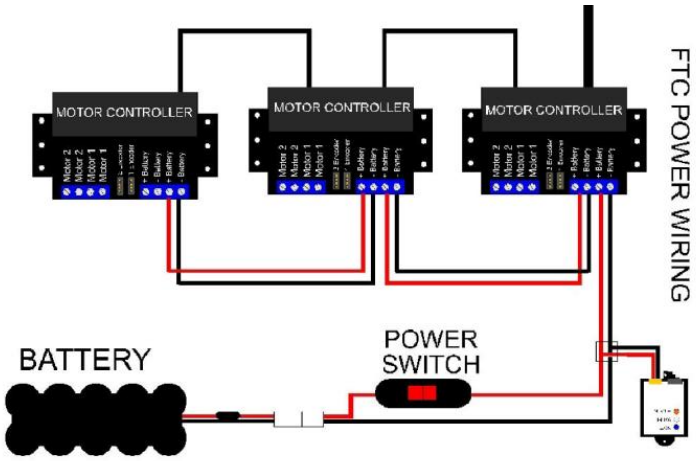


Figure 16: A simple wiring diagram.

Use a USB Adapter

A “USB A Female to B Female” adapter can be directly attached to the Robot and is useful when reflashing the Samantha Module (Figure 17). This adapter allows a USB thumb drive to be plugged directly into the NXT-side of the USB cable instead of into the Samantha Module port. This helps prevent mechanical wear on the Samantha Module port and also prevents Teams from needing to disassemble any part of the Robot if the Samantha Module cords are tied down.

Figure 17: USB Adapter for reflashing the Samantha Module.

Use the Proper Tools

Proper tools ease the implementation of wiring (see Figures 18-22). Tools like the Anderson Powerpole crimping tool and small nippers will greatly aid in clean wiring.

Figure 18: Wire strippers.

Figure 19: Small screwdriver for tightening screw terminals.

Figure 20: Small nippers for cutting zip ties.

Figure 21: Ferrule crimpers.

Figure 22: Anderson Powerpole crimpers.

Label Wires

Properly labeling wires quickly solves many problems (Figure 23). It helps in the creation of a wiring document and also cuts down on time devoted to maintenance and troubleshooting.

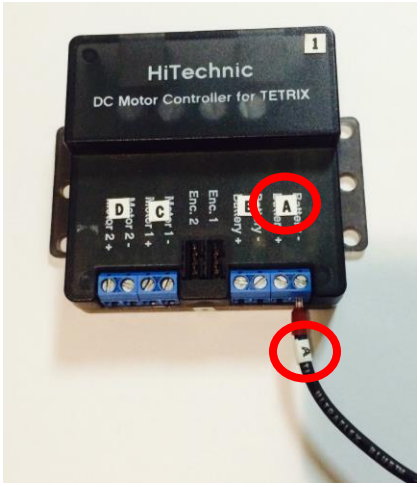


Figure 23: Wire labels.

Make a Tamiya/Powerpole Adapter

Teams that replace Tamiya connectors with Anderson Powerpoles may be concerned that they cannot share battery chargers with other Teams during a Tournament. In order to maintain compatibility with both styles of connectors, Teams can make an adapter (Figure 24).

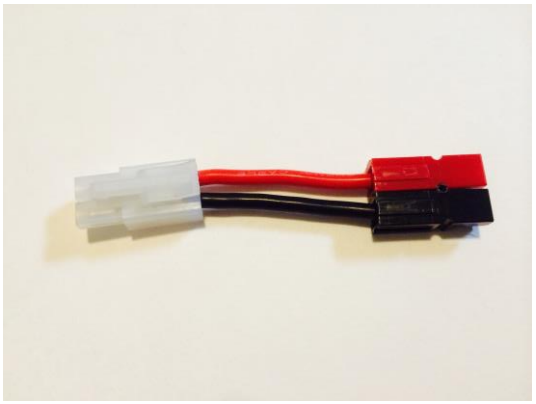


Figure 24: Tamiya/Powerpole Adapter.

Making an Adapter

1. When removing the Tamiya connectors from the battery, do not cut the wires flush with the end of the Tamiya connector. Instead, leave a 1" length of wire attached to the Tamiya connector.
2. Install Anderson Powerpoles on the free end of the 1" length of wire.
3. Velcro or otherwise attach this adapter to the Robot to ensure that it is available when needed.

Section 3: Additional Resources

Careful incorporation of the solutions and wire management tips in the previous two 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
- Electro-Static Discharge (ESD) White Paper – by Dale Jordan, FTC Oregon
- FTC Samantha Module User Guide
- Gear Up With FTC Presentation: Robot Wiring Troubleshooting
- Basic wiring instructions:
    - Provided with TETRIX kits.
    - Provided with MATRIX kits.
    - Provided by Carnegie Mellon Robotics Academy.