The Compass Alliance Pathways: Electrical

In order for your robot to become functional, you will need electronics! While designing your robot, you'll want to leave room for electrical components. Then, after fabrication and assembly of the robot, it will be time for wiring! This Pathway will review places to learn the fundamentals of theoretical and practical electronics, as well as discuss topics related directly to FRC electronics.

Level 0: Stepping Stones

In order to wire a functional robot, you will need to know the basics of electricity and be able to crimp and solder. Here are some places to start with the basics:

- A useful resource to begin learning about electricity can be found here.
- A multimeter is a tool that is used to measure electric current, voltage, resistance, and sometimes other values. The multimeter is useful for troubleshooting robots, electric circuits, and devices. A video on how to use a multimeter is linked here. In addition to watching this video, refer to your multimeter's user manual.
- Wiring a robot involves dealing with different wire gauges. Wire gauge is the measurement of a wire's diameter or cross-sectional area. Each wire gauge has different characteristics, like current capacity and resistance. Learn more about wire gauges here.
- Electronic devices and machines, such as robots, are controlled with electrical signals. There are two types of electrical signals: analog and digital. Learn about them here.
- Wires are often color coded: red for power (+), and black for ground (-). This is done to make it easy to know where each wire is supposed to connect to. Wires for sending and receiving data will have more than just a power and ground wire. Sometimes data cables have many wires that are all a different color so they can be easily identified and connected in the correct order.

Crimping

Crimping wires creates a strong mechanical and electrical connection between wires and robot components that can be easily connected or disconnected. Here are a few common FRC crimping methods

- **Anderson Powerpole**
  - This is a type of crimp commonly used to connect motors and motor controllers together. A video on how to install these connectors can be found here.
- **Data/Servo Connectors**
  - These are used to crimp signal wires, like PWM wire that connect the motor controller to the RoboRIO, sensor signal wire for various sensors, and CAN wire.

A video on how to crimp with this type of connection can be found here. A great supplier for these crimps is linked here.

- **Terminal Connectors**
  - There are many different varieties of terminal crimps that are used to connect wires to screw terminals, mating connectors, or to join two wires together. A video showing the different types of terminal crimps and how to use them is linked here. A written document about these crimps can be found here.

Soldering

Soldering is a more permanent way to connect wires together. A video on how to solder wires together is linked here. Soldering can be dangerous, and precautions must be taken to ensure the safety of yourself and others around you. Here are some basic soldering safety tips:

- **Solder in well ventilated areas**
  - **Rosin Exposure -** Solder often has a core made of flux. Flux is a chemical agent that is used to prevent and remove metal oxidation, which aids in the adhesion of the melted solder to the wire or metal surface that you are soldering to. This improves the electrical and mechanical connection. Flux creates the fumes seen during soldering. It is crucial to have proper ventilation because exposure to a resin contained in flux, called rosin, can cause eye and respiratory irritation.
- **Wash your hands**
  - **Lead Exposure -** Solder comes in many forms. There are two main types of solder: lead-based and lead-free. Lead-based solder is made of an alloy of tin and lead, and has a lower melting temperature than lead-free solder, and is usually easier to work with. However, exposure to lead can cause damage to your health over time, so make sure to wash your hands after handling lead-based solder.
- **Eye protection**
  - When soldering and cutting wire, wear eye protection to prevent hot flux splatter and flying wire offcuts from hitting your eyes.
- **Heat**
  - Never touch the heating element and tip of the soldering iron, as they get extremely hot. Let a soldered surface cool before touching, and always turn off or unplug the soldering iron when not in use.
- A document on soldering safety written by the Oregon State University Environmental Health and Safety Department can be found here.
- An article on the types of solder, and how to select the correct solder, is linked here.

Level 1: Venturing Onwards

- FIRST provides an overview of all of the electronic components that are required to make a robot functional in a FRC event. The overview is linked here.
- FIRST also provides step-by-step instructions and a schematic diagram for wiring robots. This guide along with good wiring practices are linked below.
  - [Wiring FRC Control System](#)
  - [Best practices for wiring FRC control system](#)
- It is a good idea to read the current FRC game manual to make sure that your system conforms to the electrical rules and regulations.

PWM and CAN Bus Wiring Setup

- **PWM -** Pulse Width Modulation (PWM) is a way of using a digital signal to achieve analog results. A PWM signal is a series of on (5v) and off (0v) pulses. Varying the amount of time a signal is on simulates voltages in between 5v and 0v. The duration a signal is on is called the "pulse width". More information about PWM can be found here.
  - **Wiring Concept:** A FRC robot can use motor controllers that are controlled by PWM signal. In a wiring setup that uses PWM motor controllers, each controller is individually routed to the roboRIO. This involves a lot of wire and can be messy. Alternatively, a CAN Bus wiring setup can be used.
- **CAN Bus -** The Controller Area Network (CAN Bus) is a communications network standard that allows microcontrollers, devices, and sensors to communicate with each other without relying on a host computer, which creates an efficient and flexible system that is easy to wire and program. A resource about CAN, and how data is sent in a CAN bus, can be found here.
  - **Wiring Concept:** The components on a CAN bus are "daisy chained" in a loop. A CAN bus reduces the amount of connections and wires, which allows for a neater and more efficient wiring system.
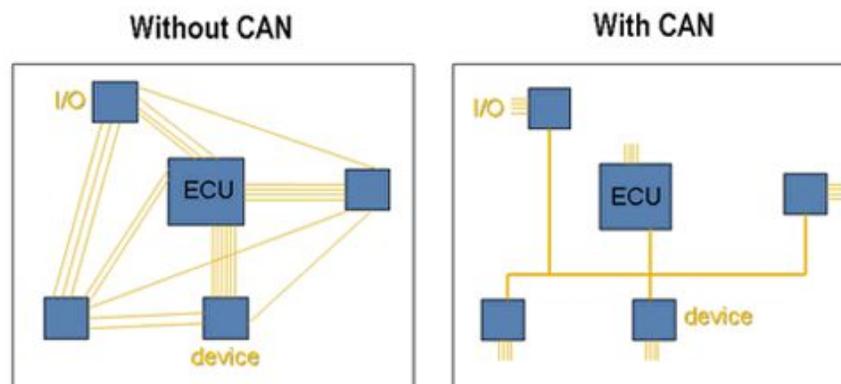
- The FRC components that are required to be connected by CAN are the roboRIO, PCM, and PDP.
- FRC robots use the High Speed CAN system, which requires that the CAN bus is terminated at each end with a 120Ω resistor.
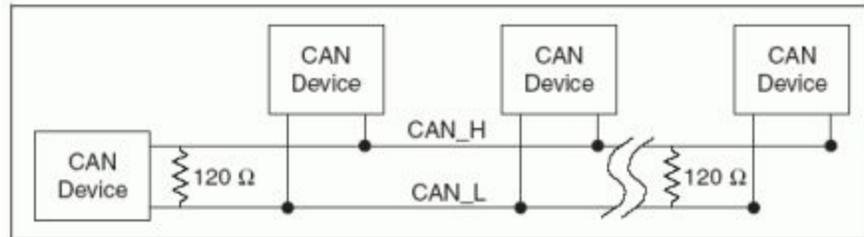
- The terminating resistors are used to maximize efficiency by preventing impedance mismatching, which minimizes signal reflection. A document on impedance and signal reflection can be found here. A document that further explains the High Speed CAN system and CAN termination is linked here.
- The main CAN loop (which includes the roboRIO, PCM, and PDP) starts at the roboRIO and can end with the PDP. Both the roboRIO and the PDP include terminating resistors. If the CAN bus ends with the PDP, the jumper labeled "TERM/RES." needs to be set to the "ON" position.
- In addition to these three FRC robot components, motor controllers and sensors can be added to the CAN bus. The motor controllers that are compatible with CAN are the Talon SRX and the Victor SPX. A document that compares the features of the Talon SRX and Victor SPX can be found here.
- The Talon SRX has a data port where sensors like the SRX Mag Encoder can be easily powered and integrated into the CAN bus.
- A useful component that can be used in a CAN wiring setup is the CANifier. The CANifier is a CAN controlled device that can be used to control LEDs and interface sensors into the bus. The use of a CANifier eliminates the need for sensors to be directly wired to the roboRIO's DIO ports.

Level 2: Forging New Paths

MXP Expansion and Sensor Boards

- The MyRIO Expansion Port (MXP) on the roboRIO is a group of signal input/output and power pins that can be used as a multi-purpose extension of the UART transmitting/receiving lines, DIO, I^{2}C, and PWM. Information on the MXP pins and signals can be found in the roboRIO User Manual.
- FRC regulations allow for teams to use passive circuits to extend the signal pins. Premade circuits can be used, such as the REV Robotics More Board. A guide on developing a MXP board can be found here.

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- A passive circuit is one that does not control electrical current with external signals. Information about passive and active circuits can be found [here](#).
- The active devices that are approved by FIRST for use with the MXP in FRC events are:
  - [Kauai Labs navX MXP](#)
  - [RCAL Daughter MXP Daughter Board](#)
  - [REV Robotics RIOduino](#)
  - [Rev Robotics Digit Board](#)
  - [West Coast Products Spartan Sensor Board](#)
  - [Huskie Robotics HUSKIE 2.0 Board](#)
    - In addition to expanding signal ports, these approved active MXP devices can have features such as data logging, driver control and status, field orientation, and can provide additional GPIO and Analog inputs.

Sensor Boards

- Additional sensor boards can be added to your robot, such as the [FRC Gyro board](#) from AndyMark, and the [Gadgeteer Pigeon IMU](#).
  - The use of sensor boards can expand your robot's capabilities and improve performance in a competition.

Onboard Coprocessors

- Processors, such as the [NVIDIA Jetson](#), [Kangaroo computer](#), and [Raspberry PI](#), can be added to your robot for applications such as vision streaming and processing.
- Coprocessors can be powered from the PDP 12 Volt load terminals. If the coprocessor requires more than 12 Volts, it can be powered through a DC-DC voltage converter, as long as it does not produce voltages exceeding 24 Volts. Information about DC-DC converters can be found [here](#).

Appendix A - Revision History

Revision #	Revision Date	Revision Notes
1.0	Sept. 2018	Initial Release

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