Section 9: Electrical

By Team 1718 – The Fighting Pi
www.fightingpi.org

The range of controls components FIRST teams are allowed to use are, quite literally, infinite. As long as the component is not a power source and is not a motor of some type, it is usually legal to use on a robot. This allows the controls systems on FIRST robots to range from the simplistic to the complex. Listed here are some of the most commonly used FIRST electrical components.

Main Circuit Breaker

The main circuit breaker is the primary "On/Off" switch on a FIRST robot. The red button on the top of the breaker turns it off and the black switch turns it on.

The switch is rated at 120 amps continuous current, and can actually carry far more than that for short periods of time. It is necessary to take motor-loading into account when a robot is being designed. Some of the motors used in first can draw 70-90 amps by themselves.

The main circuit breaker also has another handy use. It can be used to measure current draw using only an inexpensive multimeter. The internal resistance of the circuit breaker is .96 milliohm. Placing the probe tips of a multimeter across the opposite lugs of the circuit breaker will give you the voltage drop across the switch. Using Ohm's law, V (voltage) =I (current in amps) * R (resistance in ohms), one can easily determine how much current is being used by the robot. This will allow useful tests like running one side of a drive train and comparing it the other to check for mechanical or electrical problems.

Jaguar

The Jaguar is a variable speed controller, which is a device that controls the motors on a robot. The Jaguar has a very linear response and can be controlled through two methods: pulse width modulation (PWM) or CAN Bus (CAN). PWM signals come from the digital side car, and are the most commonly used control method. CAN Bus control is relatively new to FIRST teams. It allows additional information to be known about the motor controller: output amperage, exact output voltage, and temperature are just a few. The Jaguar has an on-board

processor that, when used with CAN, can allow closed-loop control. Teams can learn more about CAN on the FIRST website. A Jaguar should be wired to a 40 or 30 amp breaker in the power distribution board. It has a 12 volt input and the output can range from -12 volts to +12 volts. The Jaguar also has a physical jumper that can set either break or coast mode. In break mode, the leads of the motor are shorted together when power is removed from the jaguar. This results in a resistance to rotation that acts as a (minimal) type of braking. Coast mode lets the motor's momentum spin down on it's own with no resistance.

Victor

The Victor is the warhorse of FIRST. Purportedly more robust than the Jaguars, the victor usually 'just works'. The physical footprint of the Victor is smaller than a Jaguar. The Victor can only be controlled through a PWM input from the digital side car. A Victor should be wired to a 40 or 30 amp breaker in the power distribution board. It has a 12 volt input and the output can range from -12 volts to +12 volts. The Jaguar also has a physical jumper that can set either break or coast mode. In break mode, the leads of the motor are shorted together when power is removed from the jaguar. This results in a resistance to rotation that acts as a (minimal) type of braking. Coast mode lets the motor's momentum spin down on it's own with no resistance.

Teams have found that the PWM connection on the Victor tends to be hit-or-miss. It is difficult to connect and there is no self-locking feature that holds it in place. It has become common practice to use tape, hot-glue, or some other method of securely holding the PWM in place.

Spike

The Spike is a relay that controls motors or other devices. It has 4 states: forward, backward, on and off. The Spike connects to the digital sidecar where there is a "Relay" section. A spike is significantly different than a Victor or Jaguar in that it only allows full-voltage output. That means that the output is either forward, on, off, or reversed. When the output is turned "on", both pins are set to +12 volts. A spike should be wired to a 20 amp breaker on the power distribution board. It also has an internal fuse that is 20 amps.

Pneumatic Solenoid

A pneumatic solenoid is a device that blocks or releases air supplied from the compressor and pneumatic reservoirs. Solenoids have several types – single acting where the tube sockets are connected to an air compressor with pneumatic tubing. The solenoid pictured is a FESTO brand solenoid. Solenoid input voltage requirements vary between models: most are either 24 volts or 12 volts. 24 volt solenoids are supplied with the KOP. This requires 24 volt power to be fed to the solenoid break-out board that mounts in the top of the solenoid bumper in the CRio. Other less-expensive solenoids that function off 12 volts are available to FIRST teams. One such valve manufacturer is SMC.

Air Compressor

The air compressor pressurizes air for pneumatic devices. The air compressors allowed for FIRST are generally small and have low flow rates. In order to provide enough air for the robot, pneumatic reservoirs are used in the form of Clippard Tanks (aluminum pressure vessels). In addition, some teams have located plastic pressure vessels that save a significant amount of weight on the robot.

The air compressor functions off a Spike. Also note that the start-up current required by the compressor commonly exceeds the 20-amp limit of the internal fuse in a spike. It is good practice to replace the fuse in the spike itself with a self-resetting breaker to prevent the start up current from blowing the fuse on the Spike.

Pressure Gage

Pressure gauges are required in two locations on the robot. The first location is directly in line with the pneumatic storage tanks. This allows FIRST to confirm that your storage tanks are at no more than 125 psi. The other pressure gauge should be mounted on the working-pressure side of the pneumatics system. This pressure should not exceed 60 psi.

Pressure Regulator

A pressure regulator is required between the high pressure storage system and the low pressure 'working' side of the pneumatics. Working

pressure should be set to 60 psi by rotating the handle. Generally teams mount their second pressure regulator directly in the pressure port of the regulator. In addition, teams should note that the regulator has a direction-of-flow arrow on it. This arrow points from the high pressure side of the pneumatic system to the low pressure side: this is the direction air will flow through the system.

cRio

The cRio is the primary processor of the robot. It has on board flash memory to store programs written by FIRST teams. Bumpers are plugged into the ports on a cRio to give it capabilities like analog input. It has an ethernet port which is plugged into an external wireless adapter to allow wireless communication to and from the robot. It has a serial port as well, which is used to diagnose problems through a terminal output, and also serves as the CAN Bus connection if CAN is used.

Digital Bumper

This device is plugged into the cRio and connects to the digital side-car. It controls digital (I/O) information.

Analog Bumper

The Analog bumper plugs into the CRio. A small breakout board plugs into the top of the analog bumper and handles analog (I/O) information.

Analog Breakout Board

This board mounts onto the top of the analog bumper. It is capable of receiving analog signals, and has a 5V supply voltage for each analog input. It can connect to sensors like potentiometers.

Solenoid Bumper (Digital Sourcing Module)

This device connects to the cRio and has a solenoid breakout board that mates to its top. The solenoid bumper can directly be plugged in to pneumatic solenoids to control them.

Power Distribution Board

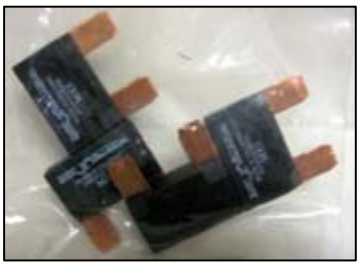
This device distributes the power to all devices. It has inputs (seen at the top) that come from the main breaker and battery

On the sides of the power distribution board are outputs that supplier 12V that can have 40, 30, or 20 amp snap-action breakers inserted.

Digital Side Car

The digital side car handles pulse width modulation (PWM) outputs that connect to Victors or Jaguars, relay outputs that connect to spikes, and digital inputs/outputs that connect to sensors like encoders.

Snap Action Breakers



40, 30, and 20 amp Breakers are inserted into ports on the power distribution board. Breakers are used instead of fuses because of the high stresses an FRC robot is routinely placed under. These breakers take approximately 3 seconds to reset once they have tripped.

Solenoid Breakout Board

The solenoid breakout allows direct control of pneumatic solenoids. It plugs into the top of the solenoid bumper, and then is wired into the solenoids that are used on the robot.

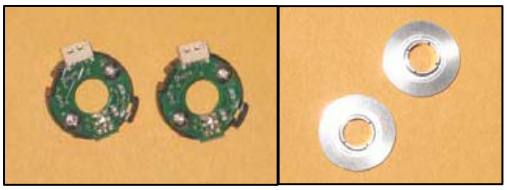
Wireless Bridge

The wireless bridge allows the cRio on the robot (the robot brain) to talk back to the driver station (the netbook). It connects to the cRio's #1 ethernet port. Any port can be used on the wireless bridge. At each competition, teams will take the wireless bridge to the administration table to have encryption enabled and a passkey added so that outside parties cannot tamper with the robot systems. The wireless bridge can also be connected directly to the camera to allow full-speed playback on the driver station of video with no processing slowdown from the CRio. Finally, the wireless bridge is supplied by a small transformer (on the 2011 robots) to modify the output voltage of the power distribution board to the correct voltage for the input on the bridge.

Servo

Servos are small self-contained motors with positional feedback. They connect directly to the digital side-car. The side car provides the power to the servo when a jumper is plugged in on the digital sidecar next to the PWM port that the servo is connected to. The servos can be commanded in several means through the controls system, either by degree travel or PWM level (-1 to 1). Servos may sometimes experience 'jitter' when there is a power cable in close proximity to the servo PWM cable.

Encoder



Encoders are mounted on a flat surface with a shaft protruding through the center hole. The counter-disc (the shiny disk pictured) is then

slide down the shaft until it is just above the encoder surface. Usually a tool is provided from the manufacturer to do this. The counter-disc has hundreds of tiny grooves on its surface that the encoder counts as the shaft rotates. This allows relative positioning (where the shaft is located when the robot is turned on is the 'zero' position). These are most popular in drive trains to measure distance traveled.

Potentiometer

Potentiometers are a component that allows the measurement of rotational motion. Unlike encoders, potentiometers are relative. A voltage of 5V is applied across the potentiometer's leads, and the internal resistance of the potentiometer changes as it's shaft is rotated. The analog breakout board is capable of reading the voltage as it changes, and this can be referenced to a position. Potentiometers are sold at varying resistances and varying numbers of turns (as well as varying power dissipation). They usually come in 1 turn, 3 turn, and 10 turn varieties. The analog breakout board works best with potentiometers that have a 10k maximum resistance. They can usually be purchased from a local Radio Shack store. www.digikey.com also has a large variety.

Gyro

A gyro is an electrical component that can give the robot directional feedback. By wiring a gyro into the cRio system correctly and using the appropriate programming (in the FIRST library) gyros can provide feedback accurate to the tenth of a degree. Gyros come in different varieties, based on the supply voltage, resolution, and rotational speed. The gyro that is supplied in the Kit of Parts is usually sufficient for most robot applications. Gyros are most often used to determine robot heading in autonomous mode.

Ultrasonic Sensor

Ultrasonic sensors are an easy way of gathering information about the robot's surroundings. There are a number of sensors that function well with the cRio's system. Team 1718 prefers the Maxbotix sensor (www.maxbotix.com) as it comes in a wide range of offerings, is accurate to over 30 feet, and is very inexpensive. These sensors can be used in autonomous mode to see walls, locate other robots, and get the robot's range from potential targets.

Limit Switches

Limit switches are commonly used on robots to cut off power to motors once they have reached a physical position. Switches can be normally open (when the switch is not pushed down, no current flows) and normally closed (when the switch is not pushed down, current flows).

Big Flashing Light

The "Big Flashing Light" is supplied by FIRST and plugs in directly to the digital side car. The light blinks in different patterns to describe the mode the robot is in. It can be used as a trouble shooting tool as well if you are familiar with the blink-patterns. These are usually provided on the FIRST website.

Axis Camera

The axis camera is a web-cam that is used to provide vision functionality to the robot. FIRST usually supplies default camera code that provides basic functionality for the given year's challenge. Robotic Vision can be extremely frustrating and takes enormous amounts of development time. In most cases, the task involved can be completed in another manner more easily. Vision systems also pose a challenge in that they must be calibrated to differing light conditions at each venue. What works in the team's practice area will most likely not work at the competition.

Anderson Battery Connectors

Anderson battery connectors are provided to the team in the Kit of Parts. They are used to attach the battery to the main circuit breaker of the robot. A word of caution is needed: because these connections are constantly plugged and unplugged, it is important to strain-relieve the wiring. Strain-relieving is the act of physically attaching the wiring to the structure of the robot (and battery!) so that the force of plugging and unplugging never transmits itself to the fasteners that connect the wires to the control system. Zip-Ties work well in this regard.

Battery Charger

The battery charger supplied by FIRST should be modified before use. The alligator clips on the charger should be removed and replaced by an Anderson Battery Connector

for safety. Never allow open wiring to be energized: build spaces and competition pits are very crowded places and free electricity doesn't equate with safety!

DB37 Cable

The DB37 cable connects the Digital Bumper from the cRIO to the Digital Sidecar. This transmits all the signals for such things as PWM connections and Digital I/O connections.

Ethernet and Ethernet Crossover Cable

The ethernet cable connects the cRIO to the wireless bridge to allow the cRio to communicate. However, be careful! There is a cross-over cable that has two wires switched also provided in the KOP. This cross-over cable is specifically to plug the Axis webcam into the cRio. In the past, cross-over cables have been colored orange.

Y-Shaped PWM Cable

PWM (Pulse Width Modulation) cables are 3 pin cables that send signals to from the digital side car to the Victors, Spikes, and Jaguars to control motors and other components. In many situations, teams want 2 motors to act in tandem. In that case, a team can use a Y cable. It plugs into 1 PWM port on the digital side car, then splits and can be plugged into 2 motor controllers so that they are controlled at the same time. Because PWM is digital (on/off), the reduction in voltage as a result of splitting the cable will not have any effect on the response of the motors.

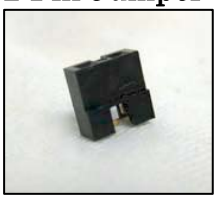
Rotary Encoder Boards

The rotary encoder boards can be mounted in a position that the magnets pass them on a regular basis. For instance, the magnets can be mounted to a wheel, and the encoders mounted to the robot frame. The rotate rate can then be measured.

2 Pin Wago Connector

The 2 pin Wago connector is the power connector for most of the breakout boards. They can be ordered from www.AndyMark.com. They clamp to the wires very securely.

2 Pin Jumper



Two pin jumpers are used in several places. If a servo is connected to a PWM port on the digital sidecar, the corresponding jumper must be installed so that 5V power is supplied to the servo. In addition, if a two pin jumper is not installed per the control system instructions, the dashboard on the driver station computer will not show battery voltage.

Joystick

Many different USB controllers can be used to plug into the driver station. A standard Logitech Attack joystick is provided in the kit of parts. The multitude of buttons and robustness make it versatile, however it has the drawback of requiring mounting onto the driver station board to keep it steady when the drivers are using them. As an alternative, consider purchasing Logitech Dual Action Gamepad. These generally cost about $10.00 - $15.00 a piece. They are similar to other current game controllers and members are usually familiar with using them already. More than 1 controller can be plugged into the driver station (most teams use 2 or 3).

Logitech Dual Action Gamepad

4 Pin Wago Connector

4 pin connectors are similar to two pin. They are used for the cRio power supply.

USB Hub

The driver station has only 2 usb ports to allow external devices like joysticks and gaming controllers to be connected. One USB port must be used for the Stop Button. This forces teams to use unpowered USB hubs that plug into the driver station to add USB ports. The hubs supplied by FIRST are NOT extremely robust, and it is highly recommended that a backup unpowered USB hub is purchased (and tested!) prior to competition.

Stop Button

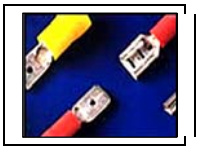
The stop button is required. It is essentially an emergency stop. When (note the use of When, and not "if") the robot starts unexpected motion, the stop button can be pushed to disable it.

Robot Wiring

Wiring a robot is a science unto itself. Components require different fuse sizes and different wire sizes. In addition, specific connectors should be used for different types of connections. Generally speaking, spade, ring, and quick disconnect terminals are most widely used in FIRST.

Spade Terminal

Ring Terminal



Quick Disconnect Terminal

Spade terminals are easy to install and remove, but can detach more easily than ring terminal. However, Some FIRST components require the use of a spade terminal. The Jaguar speed controllers have captured fasteners where the motor and power wires attach. They should not be removed because they can leave metal debris on the internal circuit board of the Jaguar, causing it to fail. Some spade terminals have tabs on the prongs that make them more secure: teams may want to consider using them instead of standard spade terminals.

Ring Terminals can be used to fasten wires to Victor speed controllers, as well as connecting the victor fan wire to the power terminals.

Utilizing quick disconnects can change a 30 minute repair job into a 5 minute one. Specifically, quick disconnects should always be used near an end component like a motor. This allows the motor to be quickly removed and swapped out for a new motor. The female side of the quick disconnect can also connect to the motor leads on window motors and is required to connect to the inputs and outputs of the spike relays. All wire connectors are rated by size. The size of the wiring is determined by the amount of current a wire will carry. Below is brief table describing wiring sizes, fuse sizes, and components:

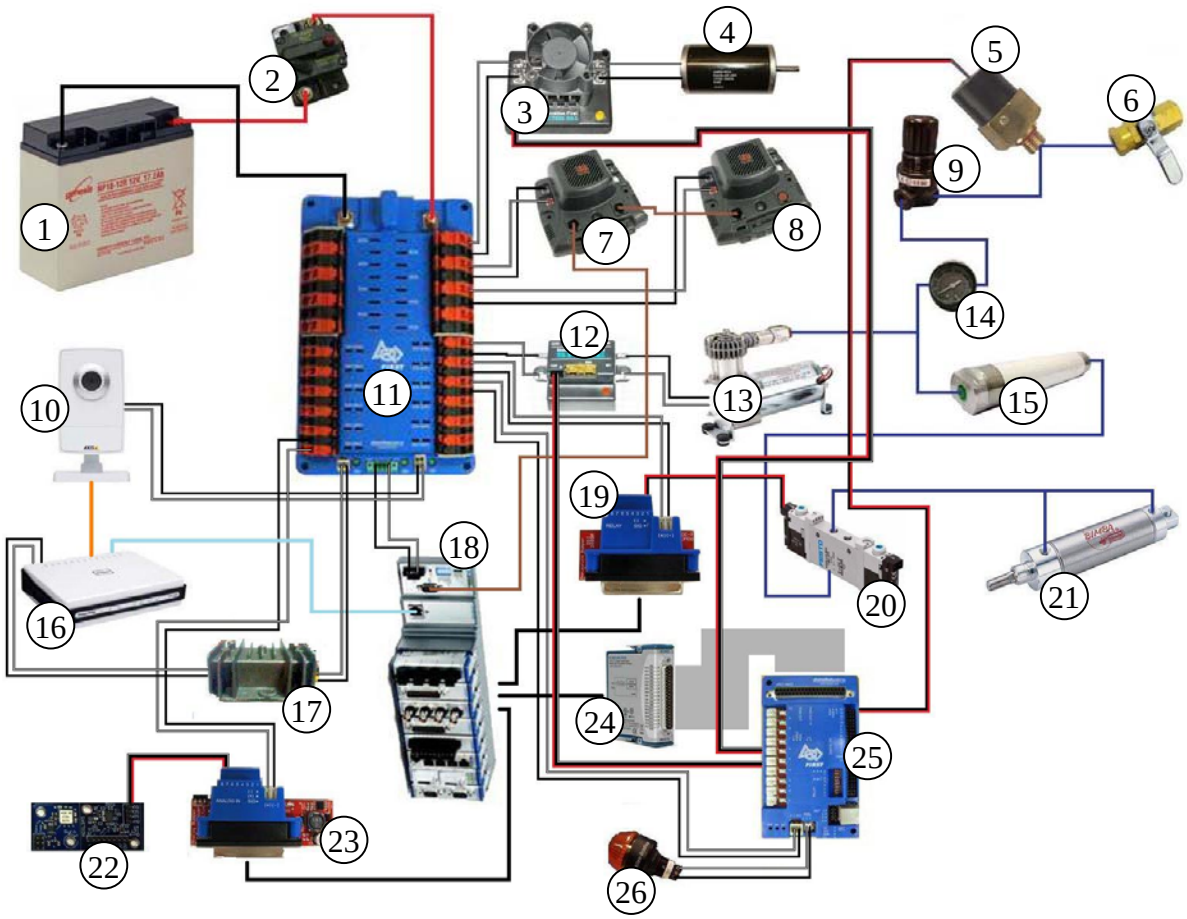
Current Requirement (breaker size)	Wire Gage	Components
40 Amps	12	Victors, Jaguars
30 Amps	14	Victors, Jaguars
20 Amps	18	Victors, Jaguars, Spikes
Power Distribution (common wire) => Analog / Solenoid Breakouts	18	
Power Distribution (separate wires)=> Analog / Solenoid Breakouts	20	
Power Distribution => cRio-FRC	20	
Power Distribution => Radio	20	
Pneumatic Valves	24	

Note: Remember that wire gauge numbers decrease as actual size increases)

A quality wire crimper is necessary to make durable wire connections. Most terminals, even ones intended to be soldered, require a crimp first. Ratcheting crimp tools are among some of the priciest tools but also provide an extremely good crimp.

In addition, a good soldering iron is a must for teams. Radio Shack sells very inexpensive soldering irons. To maintain their function, the tips must be properly maintained. After soldering, wipe them gently on a wet sponge to remove excess solder. Carbon build up over time may require cleaning the tips with sandpaper or emery paper as well.

FIRST Robotics Wiring Diagram



1. 12 Volt Battery
2. Main Breaker
3. Victor Speed Controller
4. CIM Drive Motor
5. Nason Pressure Valve
6. Air Release Valve
7. Jaguar Speed Controller
8. Jaguar Speed Controller
9. Pressure Regulator
10. Axis Camera
11. Power Distribution Board
12. Spike Relay
13. Air Compressor
14. Pressure Gauge
15. Clippard Pneumatic Reservoir
16. Gaming Adapter
17. Gaming Adapter Power Supply
18. cRio
19. Pneumatic Break Out Board
20. Pneumatic Solenoid
21. Pneumatic Cylinder
22. Sensors
23. Analog Break Out Board
24. Digital Bumper
25. Digital Side Car
26. Robot Status Light