Basic FRC Electronics

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FRC 2036 Black Knights

Electricity

- Electricity is the movement of charged particles (usually e^-).
- Charge is measured in Coulombs (C). 1C is equivalent to the charge of $6.24*10^{18}$ e^-.
- Current: The rate of flow of electron charge
  - Measured in Amperes, or “Amps” (A). 1A = 1C/s
- Voltage: The difference in electric potential per charge (C)
  - Measured in Volts (V). 1V = 1J/C
- Power: The rate of flow of energy (work)
  - Measured in Watts (W). Equivalent to Voltage*Current. 1W = 1J/s

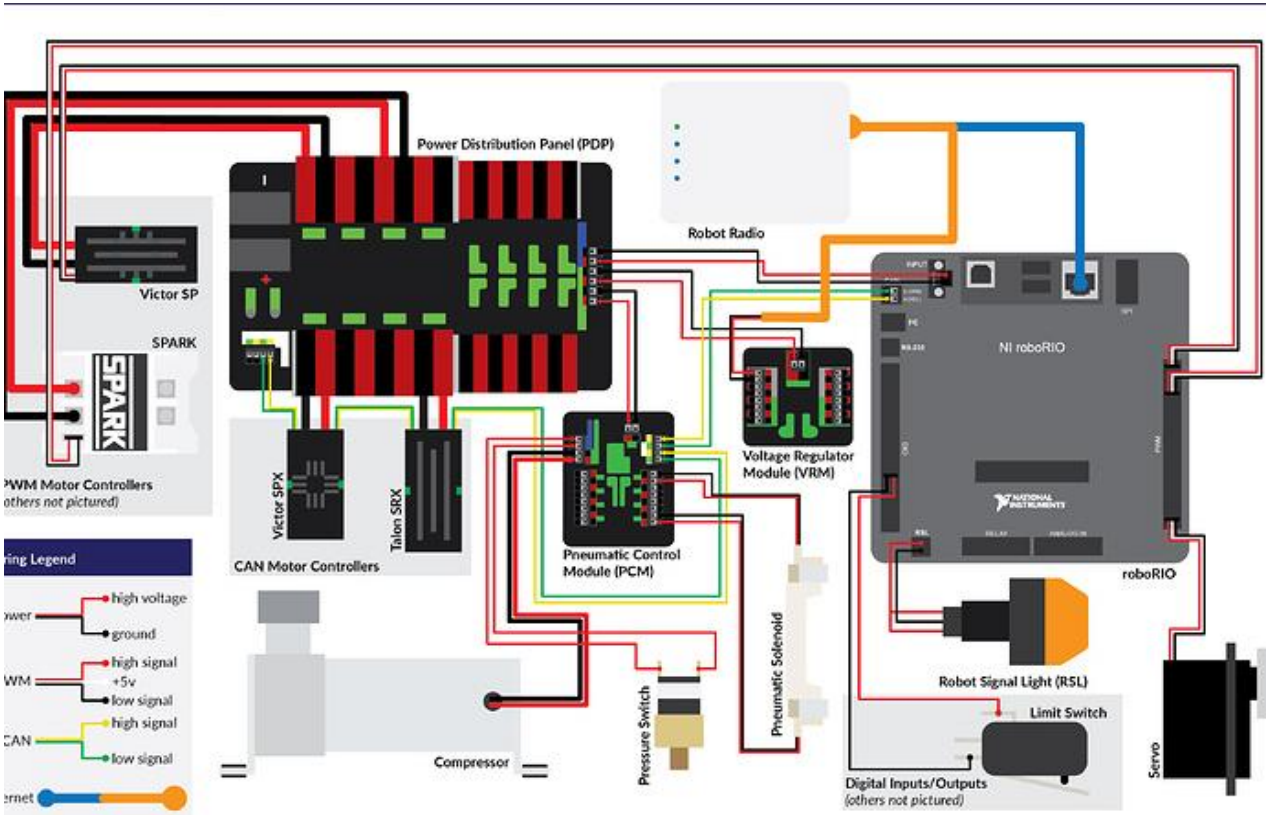
Electricity

- Power sources supply a (relatively) fixed voltage
- Electric components attached to a power source “pull” current
- Important: Power sources don’t have a fixed current. They supply the current pulled by components
- Exercises:

1. How much power is used by a LED pulling 20mA attached to a 5V battery?
2. How many electrons flow through a motor pulling 2.00A at 12.0V in one second?

FRC Components

- The FRC control system uses a number of different components
- [Wiring directions]
- Comprehensive documentation: [docs.wpilib.org]



Battery

- FRC uses rechargeable 12v lead-acid batteries (motorcycle battery)
- Typically 18Ah (Ah = Amp*hour, the amount of current the battery can supply for one hour before being depleted)
- The voltage supplied by the battery decreases as it gets depleted (and during high current usage)
- A battery beak is used to check the voltage and charge of batteries

120A Circuit Breaker

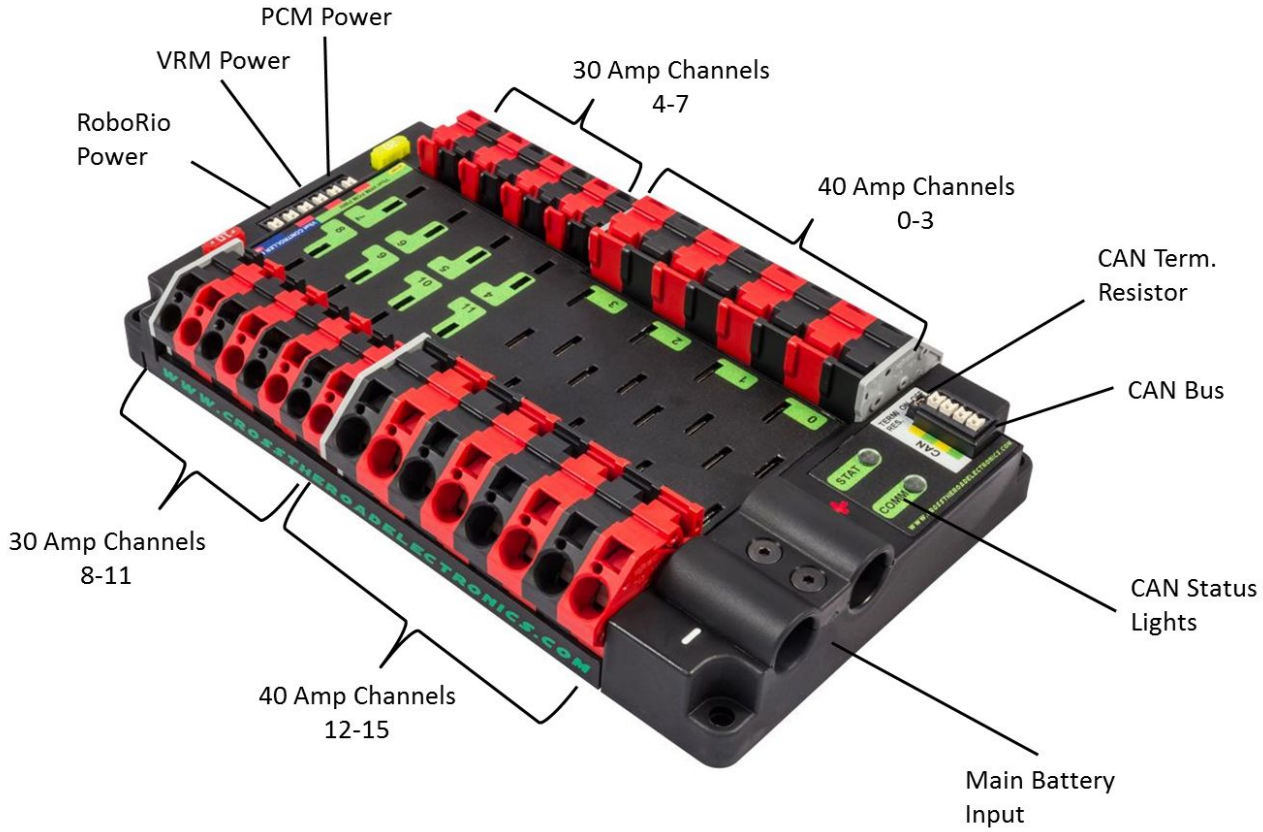
- The 120A breaker is wired directly to the battery
- The breaker “pops” if more than 120A is betting pulled (safety)
- Pressing the red button pops the breaker (off), flipping the black switch turns it on

^ Closed (On) configuration

^Open/Popped (Off) configuration

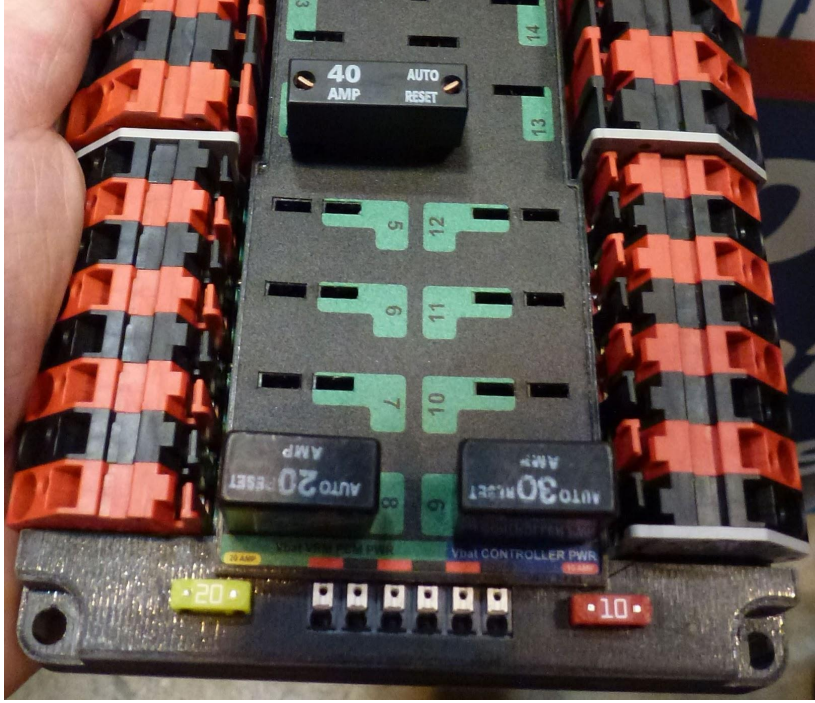
Power Distribution Panel (PDP)

- The PDP regulates and distributes power to most components
- Input from battery
- 16 output channels (motor controllers)
- RoboRio, VRM power outputs

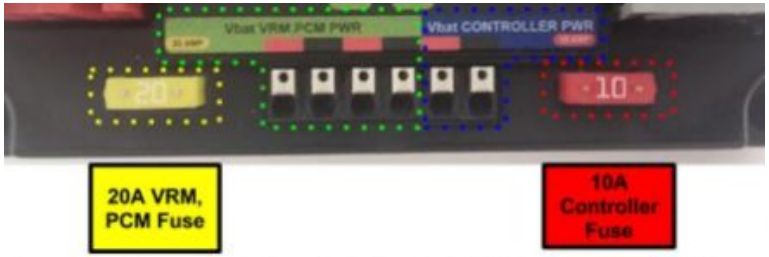


PDP Breakers + Fuses

- Breakers on channels 0-15
- Channels 0-3, 12-15: 40 Amp Breakers
- Channels 4-11: 20 or 30 Amp Breakers
- 10 Amp fuse on roboRio output
- 20 Amp fuse on VRM output
- Breakers can be reset
- Fuses can’t be reset



^ Note: Channels incorrectly labelled

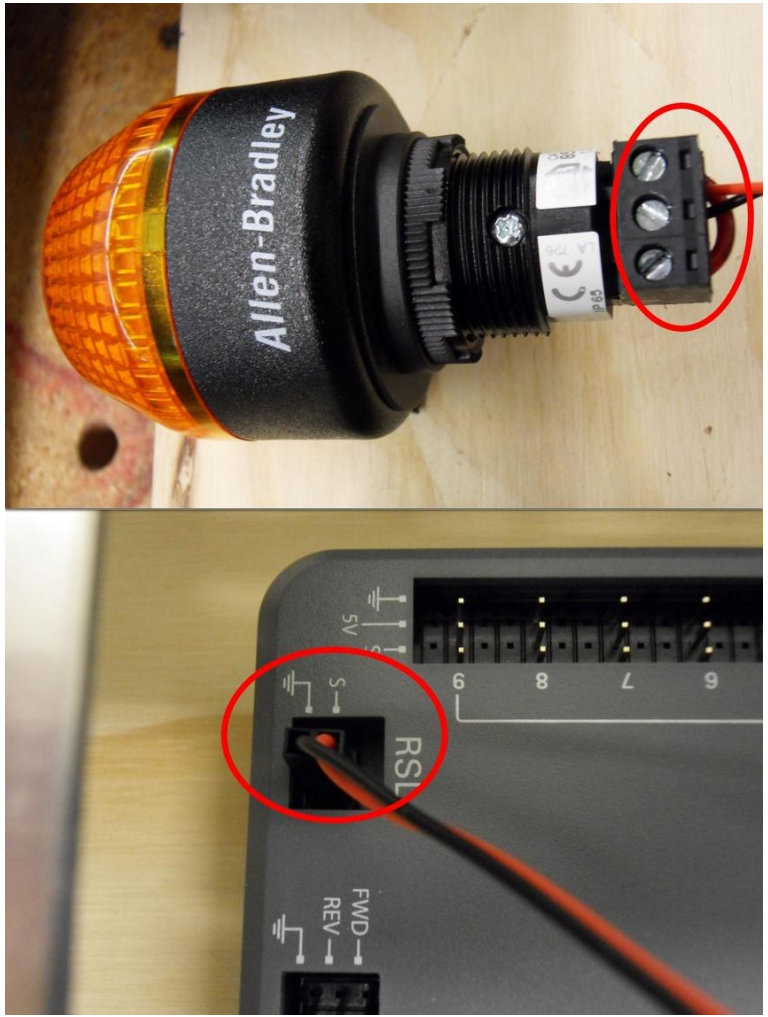


roboRio

- The roboRio is the primary computer on the robot
- Inputs/Outputs go to sensors, motor controllers, radio
- The roboRio runs FRC's control/safety software + team written software
- Contains an ARM Cortex-A9 microprocessor and Xilinx Z-7020 FPGA

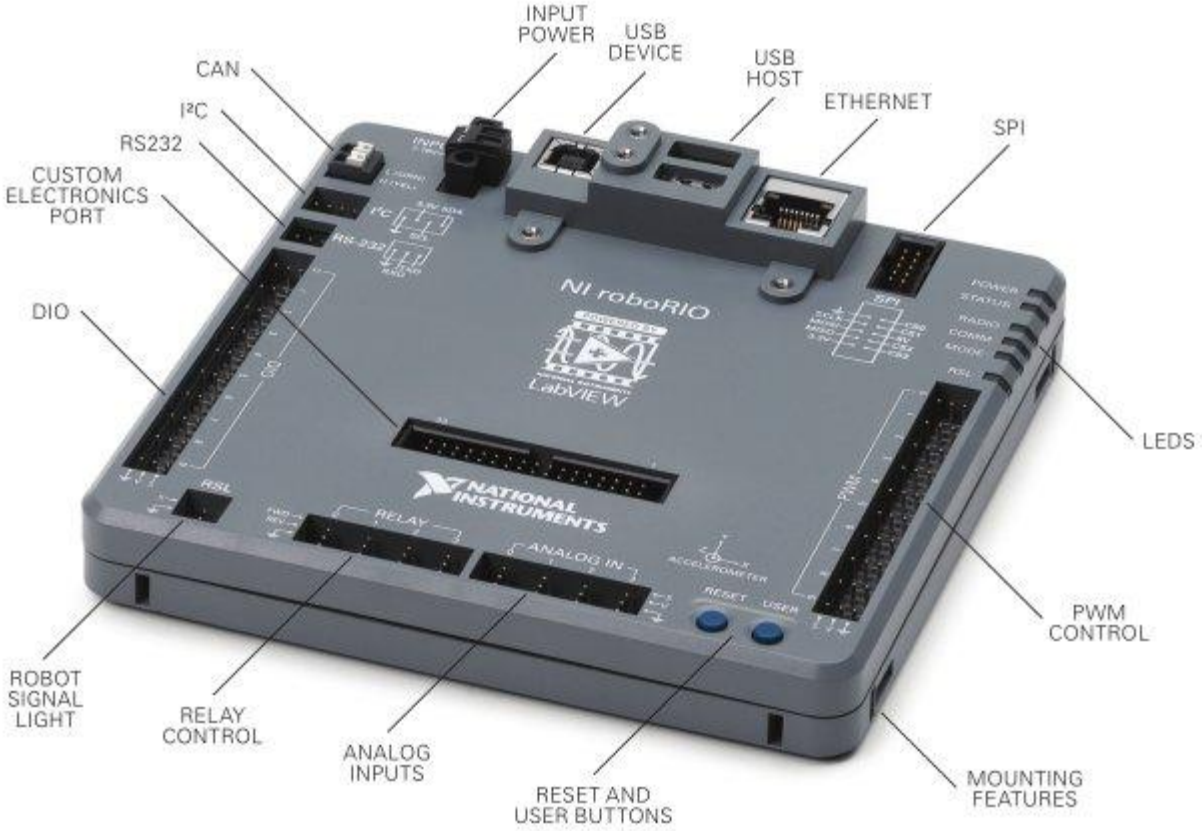
Robot Signal Light

- Wired into the RSL port on the roboRio
- Used as a safety feature:
  - Off: robot is not powered
  - Solid On: robot is powered + disabled
  - Blinking: robot is powered + enabled



roboRio IO

- Ethernet to radio
- CAN bus to motor controllers, PDP
- PWM to older motor controllers/servos
- DIO (digital IO) to some digital sensors
- Analog In to analog sensors
- I2C, SPI, RS232 to certain digital devices

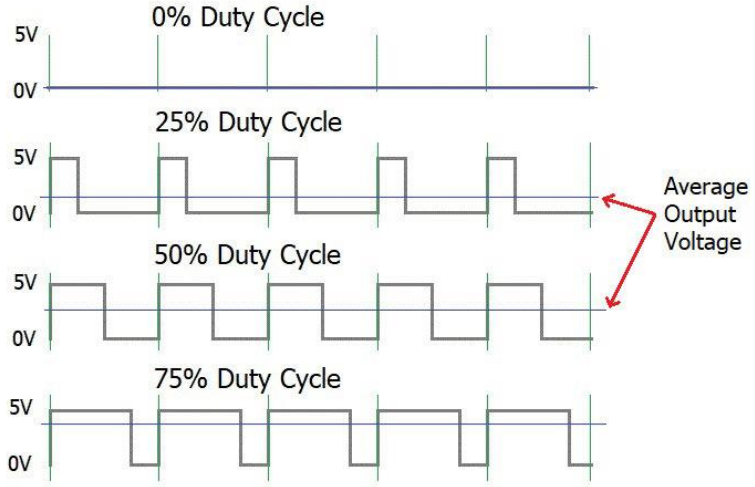


Control Area Network (CAN)

- CAN is a protocol that allows for two-way communication between devices
- The CAN bus consists of two wires, low (green wire), and high (yellow wire)
- The roboRio communicates with motor controllers and the PDP over CAN
    - Controls motors + get status, gets current info from PDP
- CAN devices are daisy chained

Pulse Width Modulation (PWM)

- PWM is a technique where a digital signal is used to convey analog information
- The signal is flipped between high + low, and the width of the high period is varied
- Used to control older motor controllers + servos
- Uses a three wire connector (ground - power - signal)



Digital IO (DIO), I2C, SPI, RS232, USB

- The DIO ports can be wired to digital encoders, LED’s, limit switches, etc
- The I2C, SPI, RS232, and USB ports are digital ports that can be wired to devices using those protocols
  - Ex: USB Camera
  - Ex: I2C + SPI sensors (color sensors, ultrasonic, etc)

RoboRio Brownout

- If a large amount of current is being pulled, the battery voltage may begin to drop (running a lot of motors at once, etc)
- If the roboRio's input voltage drops below certain thresholds, it begins a staged brownout protection scheme:
  - 6.8V — 6V PWM outputs are disabled
  - 6.3V — All outputs (motors, etc) are disabled, power led turns amber, battery
  - 4.5V — roboRio turns off, will reset if voltage above 4.5V is restored
- A brownout is often responsible for intermittent motor operation

Voltage Regulation Module (VRM)

- Wired to the VRM output on the PDP
- Provides regulated (constant) 12V and 5V power supplies
- The radio is wired to the 12V output
- Other components, such as the raspberry pi, etc, can be wired to the VRM

Radio (Router)

- The radio provides wireless communication for the robot
- Power is wired to VRM, ethernet is wired to roboRio
- Typically placed higher up, away from motors on robot (to limit interference)
- Connects to Driver Station laptop during practice
- Connects to the Field Management System during matches

Motor Controllers

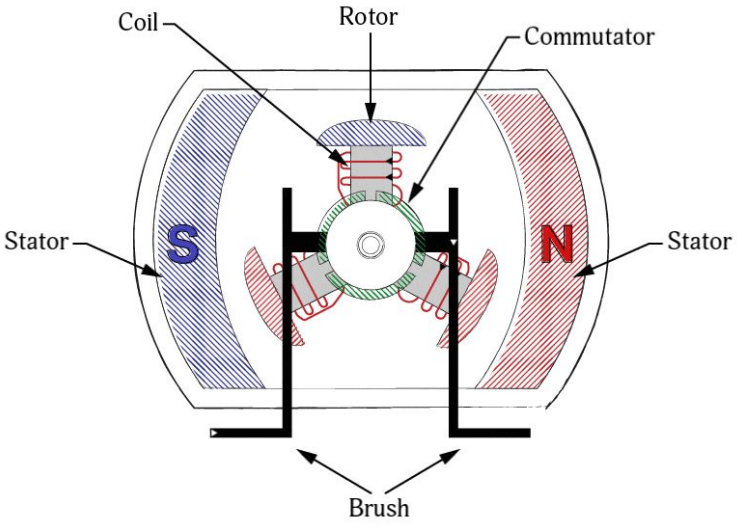
- Motor controllers allow the roboRio to control the speed of motors
- 2036 primarily uses Talon SRX’s
  - On the Talon, the red and black wires are wired to a pdp channel, the green and white wires to a motor, and the green/yellow to the CAN bus
- 2036 uses the Spark Max for brushless motors
  - The red + black wires go to a pdp channel, the red+black+white to the motor, and the green/yellow to the CAN Bus

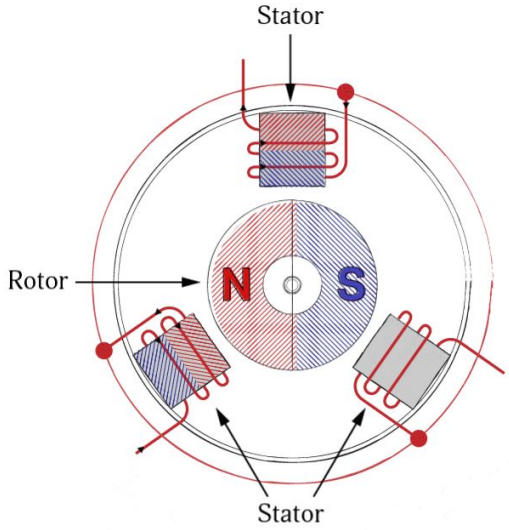
Encoders

- Encoders are placed on the rotating shaft of a motor, and provide precise information on the motor’s rotation, distance, speed, etc
- Wired to either two DIO ports or directly to motor controllers
- Some newer motors have integrated encoders
- Encoders allow software to maintain precise information about the robot’s position and state

Brushed vs Brushless Motors

- Brushed Motors:
  - The shaft of the motor contains electromagnets, which uses a brush to reverse their polarity as the shaft rotates
- Brushless Motors:
  - The shaft of the motor contains permanent magnets, while electromagnets on the outside create rotation
- Brushless motors are more efficient, run cooler, last longer, and can often be smaller and lighter than brushed motors

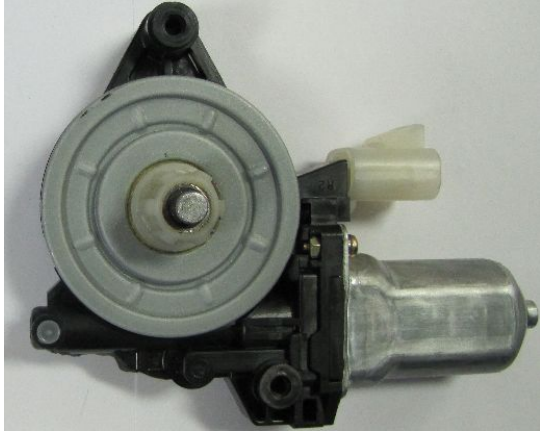




Brushed Motors

- There are a huge variety of brushed motors that can be used in FRC
  - Different power requirements
  - Different torques + speeds

^ BAG motor



^ Window motor

^ Mini CIM Motor

^ CIM motor

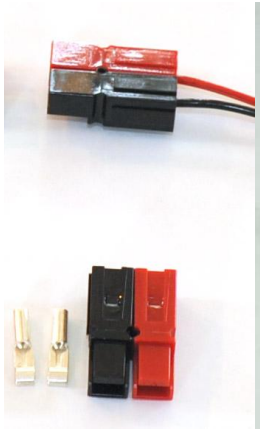
Brushless Motors

- Brushless motors are relatively new to FRC (2018)
- The major brushless motors are the NEO, the NEO 550, and the Falcon 500
- 2036 used a NEO in 2019

Servos

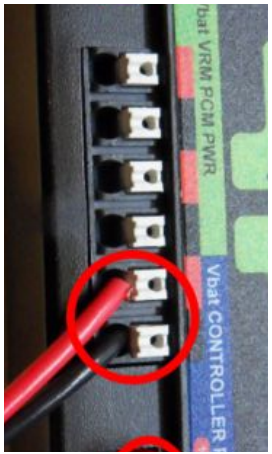
- Servos allow for fairly precise angular control
- Typically have a 180 degree range (they can’t continuously rotate)
- Wired to the PWM ports on the roboRio

Common FRC Connector Types



< Anderson Connectors:

- Used for motors + battery
- Contacts crimped onto wire



< Weidmuller LSF Connectors:

- Used on VRM, PDP
- To insert or remove wire, connector is depressed with small screwdriver

< PWM/Jumper cables

- 0.1” pitch connectors
- Contacts crimped onto wire
- Used for PWM, DIO, etc

< Screw Terminals

- Used for roboRio power + PDP to battery connection

Safety

- Battery Safety:
  - Visibly damaged batteries should not be used
  - FRC Batteries contain sulfuric acid, which is highly corrosive
  - If a battery does leak acid, it should be handled with gloves and neutralized with baking soda
- Robot Safety
  - When ANY work is being done on the robot, the battery should be unplugged (or at least the breaker off)
  - Before the robot is enabled, the robot operator should call “Clear!” and the test supervisor should call “Good!”

Exercise

Identify and explain the function of the components seen in this image.

(There are some pneumatics you may not recognize)