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Team 358
Hauppauge High School
Electrical Workshop

October 2010

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Robotics Subsystems

- **Major Subsystems**
  - Mechanical
  - Pneumatic
  - Electrical ✓
  - Software

*This workshop will cover the **Electrical** Subsystem*

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Electrical Subsystem Topics

- **Presentation**
  - Electrical Theory
  - Block Diagram and Major Components
  - Wiring Basics
  - Safety
  - Electrical Tools
- **Hands-On Demonstrations**
  - Wire Stripping and Crimping
  - Soldering
  - PWM Motor Speed Control
  - Parts Identification

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Electrical Theory

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Basic Electrical Theory

- **Ohm's Law**
  - **E = Voltage (Volts)** **Symbol: V**
  - **I = Current (Amps)** **Symbol: A**
  - **R = Resistance (Ohms)** **Symbol: Ω**

$$I = E / R$$

- **P = Power (Watts)** **Symbol: W**

$$P = E * I$$

We use a Positive Current convention (Current flows from + to -)

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The Water Analogy

Battery ≈ Pump **+ is the High Pressure Side**
- is the Low Pressure Side

E = Voltage (Volts) **≈ Water Pressure**
I = Current (Amps) **≈ Water Volume Flowrate**
R = Resistance (Ohms) **≈ Flow Restriction**

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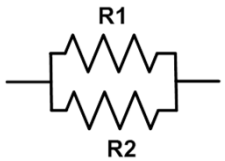
Resistance Rules

- **Resistor Symbol**

- **Series Resistance**
  R = R1 + R2

- **Parallel Resistance**
  R = (R1 * R2) / (R1 + R2)



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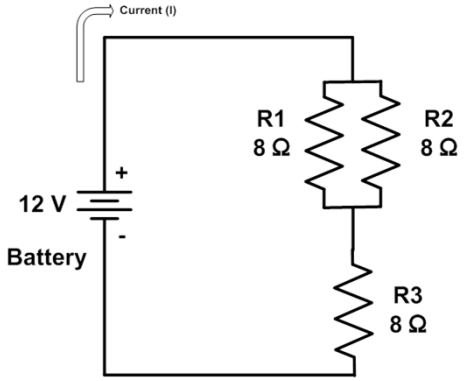
Electrical Circuit Example

- **What is the combined resistance of R1, R2 and R3?**
- **What is the current being supplied by the battery?**
- **What is the voltage across R3?**
- **What is the power dissipated by R3?**



Kirchhoff's Voltage Law
The sum of voltage sources and voltage drops in a circuit must equal zero

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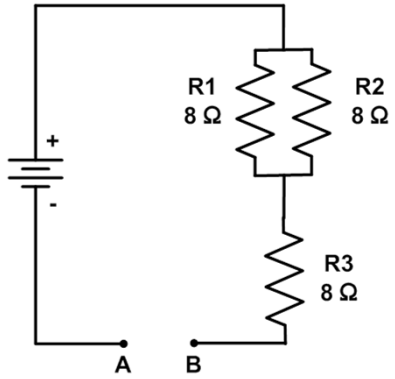
Electrical Circuit Challenge

- **What is the polarity and magnitude of the voltage that would be measured between points A and B?**



Hint: Kirchhoff's Voltage Law
The sum of voltage sources and voltage drops in a circuit must equal zero

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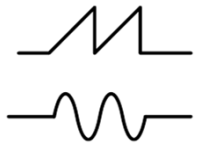
Digital vs. Analog

- **Digital Signal**
  - **Binary values (0 or 1)**
  - **Each value represented by a specific voltage**

- **Analog Signal**
  - **Continually variable**
  - **Random or waveform (sawtooth, sine, etc)**



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Electrical Block Diagram and Major Components

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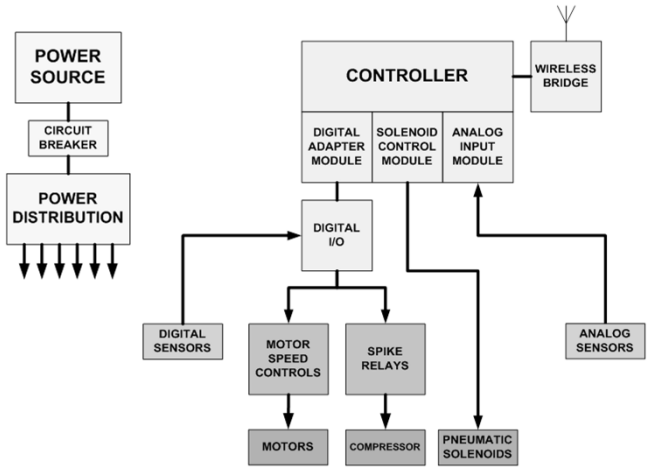
Robot Electrical Block Diagram



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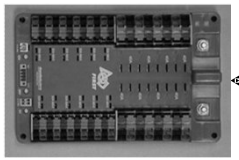
Power Source and Power Distribution



POWER SOURCE

CIRCUIT BREAKER

POWER DISTRIBUTION

12 Volt Battery
Lead Acid
18 Ah

Power Distribution Panel
12 Volt Power Distribution
Circuit Breaker protection
24 Volt source
5 Volt source

Circuit Breaker
High Current (120A)
Used to enable and disable Robot Power

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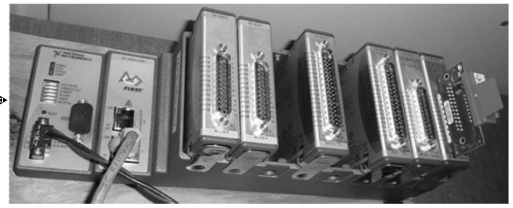
cRIO Controller

cRIO with Interface Modules
Analog Digital Solenoid



CONTROLLER

DIGITAL ADAPTER MODULE | SOLENOID CONTROL MODULE | ANALOG INPUT MODULE

Contains an industrial 400 MHz Freescale MPC5200 processor that supports the execution of code on the Wind River VxWorks real-time operating system

Interface Modules can be added or removed depending on the application
Shown with Analog Input, Digital I/O and Solenoid Control Modules

Wiring can be via Bumper (blue/red card on Solenoid Module)
or Cable & Sidecar Expansion Module

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Controller and Digital I/O

NI-9403 Digital I/O
Interface to Digital Sidecar

cRIO
Controller

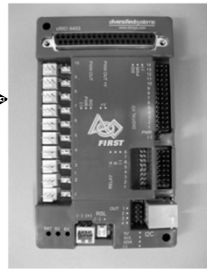
CONTROLLER

WIRELESS BRIDGE

DIGITAL ADAPTER MODULE | SOLENOID CONTROL MODULE | ANALOG INPUT MODULE

DIGITAL I/O

Inter-connecting Cable



NI-9403 Digital Sidecar
Handles PWMs, Digital I/O, Relays w/standard 3-pin connectors

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Controller and Analog Input

cRIO
Controller

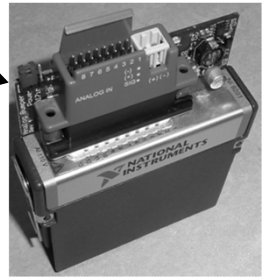
CONTROLLER

WIRELESS BRIDGE

DIGITAL ADAPTER MODULE | SOLENOID CONTROL MODULE | ANALOG INPUT MODULE

DIGITAL I/O

NI-9201 Analog Input
(w/Analog Bumper)
Analog inputs also w/standard 3-pin connectors



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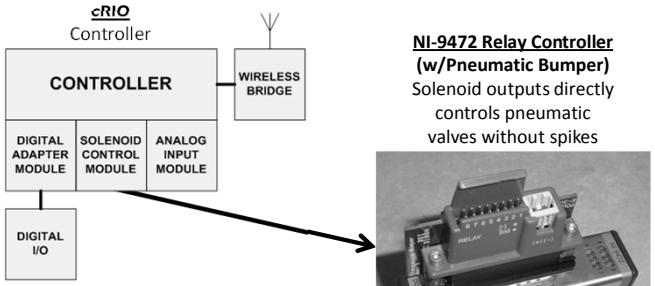
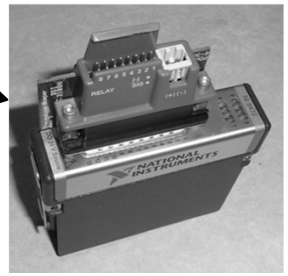
Controller and Solenoid Control



NI-9472 Relay Controller
(w/Pneumatic Bumper)
Solenoid outputs directly controls pneumatic valves without spikes



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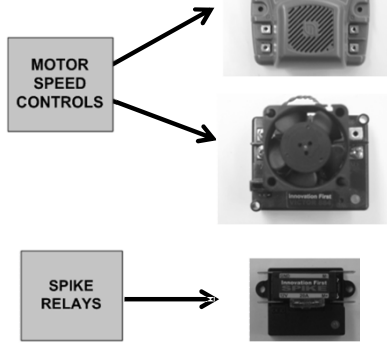
Motor Speed Controllers and Spikes



Jaguar Motor Controller
PWM Motor speed control
Bi-directional, variable speed
40 Amp load

884 Victor Motor Controller
PWM Motor speed control
Bi-directional, variable speed
40 Amp load

Spike Relay Controller
High current power switching
Compressor, Motor Control
On/Off only
40 Amp load

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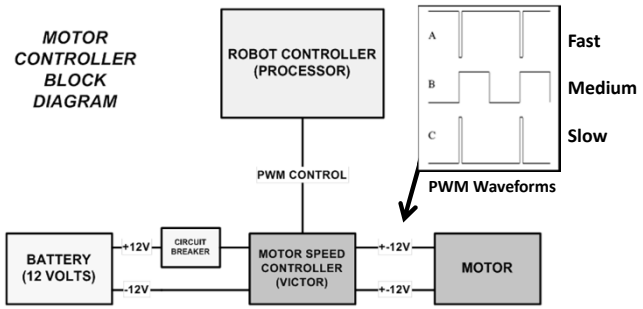
Pulse Width Modulation (PWM)



PWM Motor Drive
Switches the motor on and off with a series of pulses of different duty cycles
Provides high torque at low speeds
Pulses are always 0 to 12 volts
The polarity can be changed to reverse motor direction

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Analog and Digital Sensors

DIGITAL SENSORS

Examples
Limit switches
IR sensors
Digital Encoders
Digital Accelerometers

ANALOG SENSORS

Examples
Potentiometers (variable resistors)
Analog Encoders
Analog Multi-position Switches
Gyroscopes

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Wiring Basics

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Wire Characteristics

- **Basic types**
  - **Solid (single wire)**
  - **Stranded (multiple smaller wires twisted together)**
  - **Jacketed (multiple insulated wires with an outer cover)**
- **The size (diameter) of a wire is referred to as the "gauge" of the wire**
  - **The smaller the gauge, the larger the wire**
  - **The larger the wire, the lower the resistance per foot**
  - **The larger the wire, the more current it can handle**
  - **Undersized wire can produce excess heat**

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Wire Gauge Table

AWG Stranded Wire Table

Size		Resistance ohm/1000'	6 feet Resistance (Ohms)	Voltage Drop (Volts)	Maximum Current Capacity
AWG	Diameter inch				
20	0.0369	10.360	0.0622	6.22	5 A
18	0.0465	6.520	0.0391	3.91	7 A
16	0.0587	4.080	0.0245	2.45	12 A
14	0.0740	2.580	0.0155	1.55	20 A
12	0.0933	1.620	0.0097	0.97	30 A
10	0.1177	1.020	0.0061	0.61	50 A
8	0.1484	0.640	0.0038	0.38	80 A
6	0.1871	0.402	0.0024	0.24	125 A
4	0.2360	0.253	0.0015	0.15	200 A

Calculation shown for 6 feet of wire @ 100 Amps @ 12Vdc
Max Current rating based on allowable 2.5% voltage drop

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Wire Gauge Rules

Typical First Robotics Wiring Rules

F. Each primary power connection between the battery and Power Distribution Board must be made with 6 AWG red and black wire or larger.

A. ***12 AWG or larger*** diameter wire must be used for all circuits protected by a 40A circuit breaker.

B. ***14 AWG or larger*** diameter wire must be used for all circuits protected by a 30A circuit breaker.

C. ***18 AWG or larger*** diameter wire must be used for all circuits protected by a 20A circuit breaker.

D. ***20 AWG or larger*** diameter wire must be used for the power connection between the Power Distribution Board and the cRIO Mobile Device Controller.

E. ***20 AWG or larger*** diameter wire must be used for the power connection between the Power Distribution Board and the Linksys Wireless Bridge

F. ***20 AWG or larger*** diameter wire must be used for the power connections between the Power Distribution Board and the Analog Breakouts and/or Solenoid Breakout if individual power feeds are used. ***18 AWG or larger*** diameter wire must be used if a common power feed is used for multiple breakouts.

G. ***24 AWG or larger*** diameter wire must be used for providing power to pneumatic valves.

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Wire Color Codes

- Wire Insulation Colors
  - Colors are used to indicate the use
  - Typical (past First Robotics rules):

Constant + Voltage :	red, white, brown
Constant - Voltage:	black, blue
Signal wires:	user selectable

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Safety

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Electrical Safety
Voltage Levels

- Voltage Levels
  - Robot components operate at a maximum voltage of 24 Volts
  - Most circuits operate at 12 Volts
  - Safe to the touch, but the power sources can generate sufficient current to damage the robot or cause fires if shorted

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Electrical Safety
Robot Construction

- Circuit Breakers & Fuses
  - Limit current by interrupting (opening) the electrical circuit
  - Circuit breakers can be reset, fuses must be replaced
- Appropriate Wire Size (wire guage)
  - Wire must be of the appropriate size to handle the current in the circuit
  - Undersized wire generates excess heat

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Electrical Safety
Robot Construction (continued)

Typical First Robotics Wiring Rules

A. Each speed controller branch circuit must be protected by one and only one 20-amp, 30-amp, or 40-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

B. Each relay module branch circuit must be protected with one and only one 20-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

C. Each Digital Sidecar branch circuit must be protected with one and only one 20-amp circuit breaker on the Power Distribution Board. No other electrical load can be connected to the breaker supplying this circuit.

D. If the compressor is used, the relay module branch circuit supplying the compressor must be protected with a 20-amp circuit breaker. No other electrical load can be connected to the breaker supplying this circuit.

Each power-regulating device (speed controller or relay module) shall control one and only one electrical load (motor, actuator or compressor).

A. Exception: Multiple low-load, pneumatic solenoid valves may be connected to a single relay module. This would allow one relay module to drive multiple pneumatic actions. No other electrical load can be connected to a relay module used in this manner.

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Electrical Safety
ESD

- **Electro-Static Discharge (ESD)**
  - **The human body can generate static charge on the order of several thousand volts**
  - **This can damage electronic circuits and components (semiconductors)**
  - **Failure may be immediate or at some time in the future**
- **Prevention**
  - **Anti-Static mats**
  - **Wrist straps**

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Electrical Tools and Instrumentation

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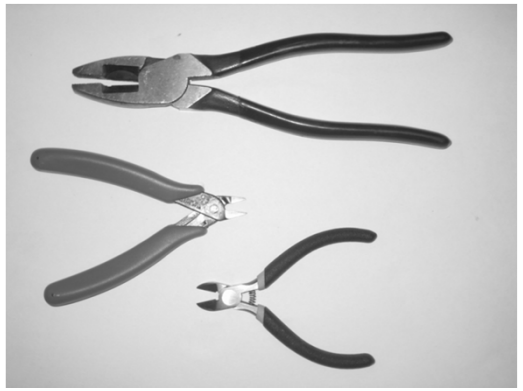
Electrical Tools

Wire Cutters



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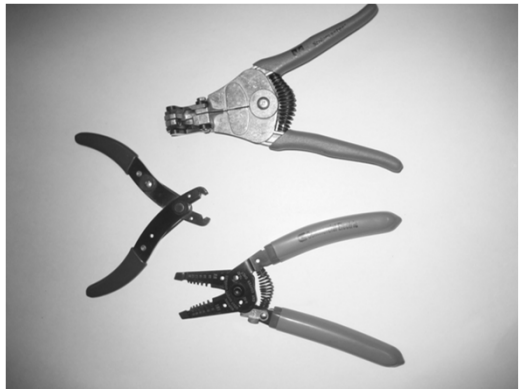
Electrical Tools

Wire Strippers



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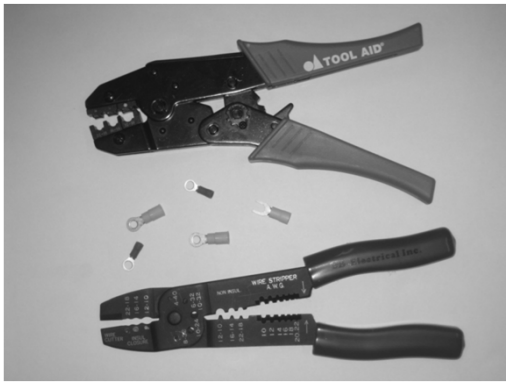
Electrical Tools

Wire Terminals and Crimping Tools



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Electrical Tools

Tie Wrap Gun and Tie Wraps

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Electrical Tools

Soldering Iron

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Electrical Tools

Digital Multi-Meter or Digital Volt Meter (DVM)

Measures:
Voltage
Resistance
Current
Continuity

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Electrical Tools

Clamp-On Current Meter (Amprobe)

Measures:
Current

(Also Resistance & Voltage with probes)

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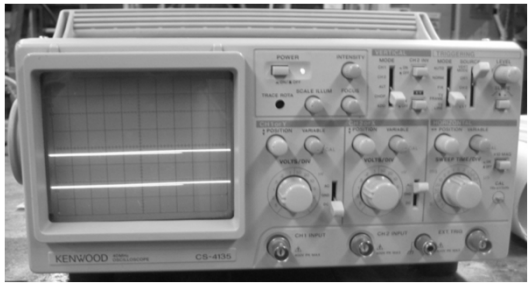
Electrical Tools

Oscilloscope



Measures:
Voltage
Vs.
Time

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Demonstrations

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Hands-On Demonstrations

- **Wire Stripping and Crimping**
- **Soldering**
- **PWM Motor Speed Control**
- **Parts Identification using an existing Robot**

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