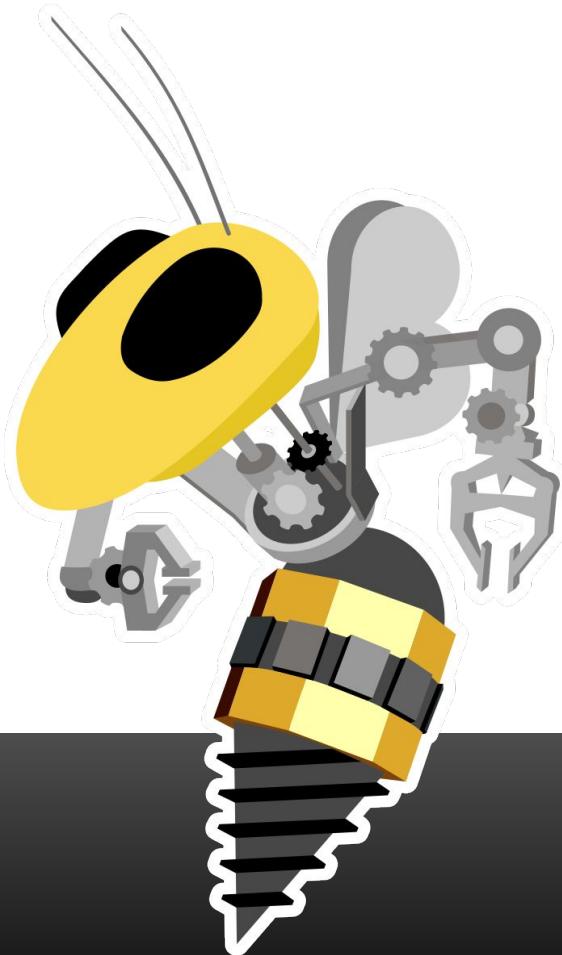


Welcome!

Electrical/Firmware Training Week 0



ROBOJACKETS
COMPETITIVE ROBOTICS AT GEORGIA TECH

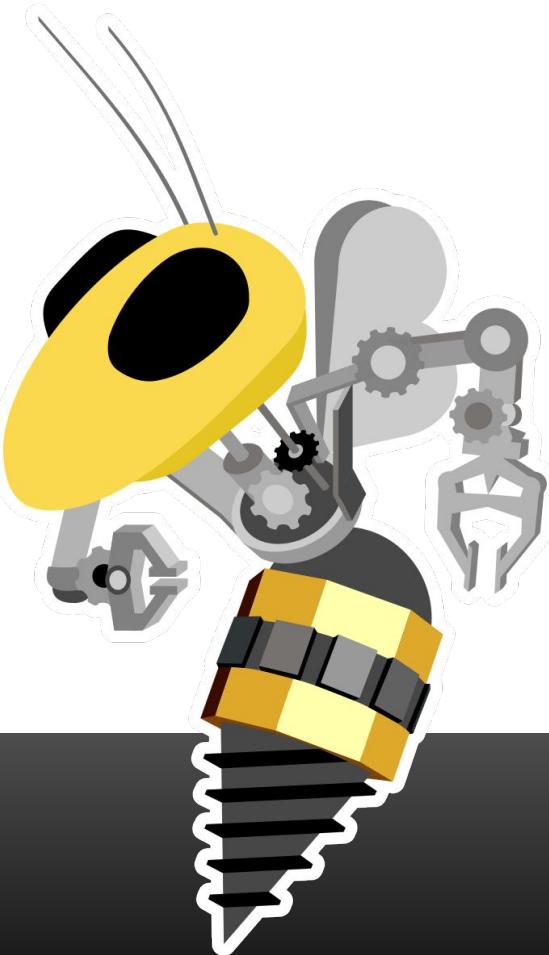
www.robojackets.org

BUT FIRST

SCC Training Level 0
Join: sccgt.slack.com

ROBOJACKETS
COMPETITIVE ROBOTICS AT GEORGIA TECH

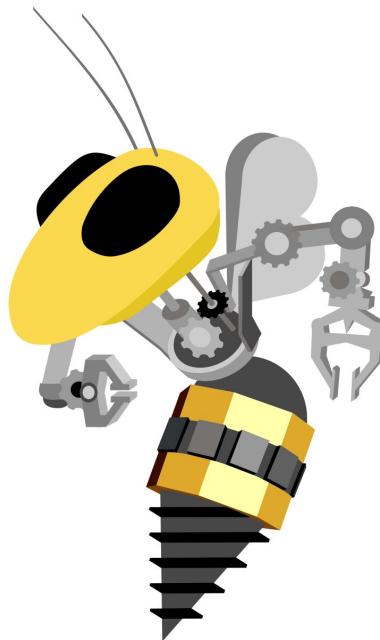
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SCC Training Document



[SCC Level 0 Training](#)

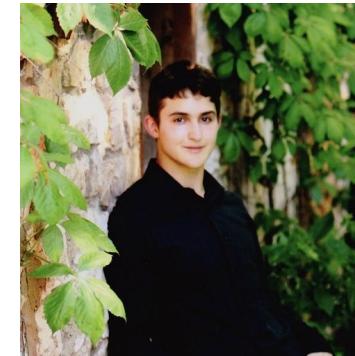


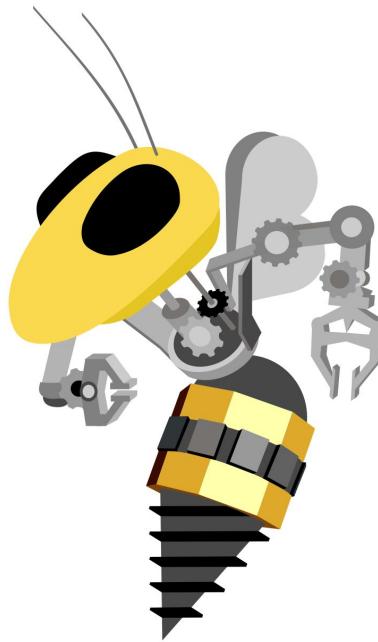
Instructor Introductions

Who are we?

Trainers

- Jackie Mac Hale, Electrical Trainer
 - (RoboRacing, CmpE)
- Bernardo Perez, Electrical Trainer
 - (RoboCup, EE)
- Andrew Roach, Firmware Trainer
 - (RoboNav, CS+Math)



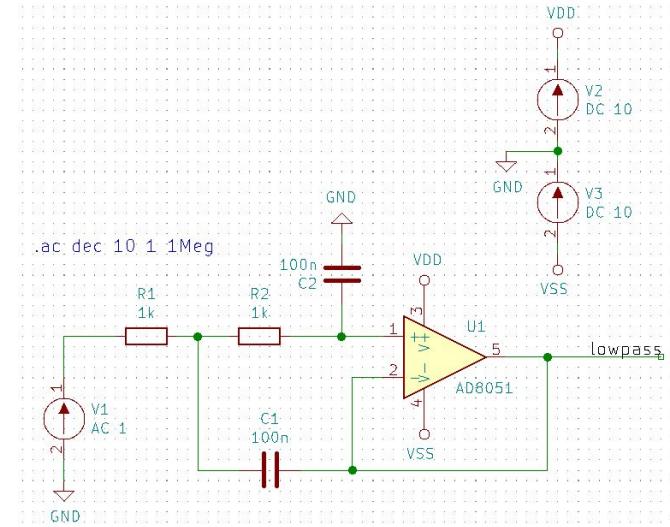


Disciplines

What's the difference?

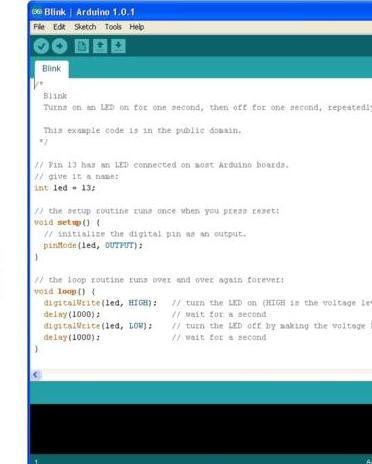
Electrical

- Responsibilities:
 - Develop PCBs
 - Electrical system design
- What you learn:
 - Electrical components
 - Common circuits
 - Prototyping
 - Printed Circuit Board (PCB) design using KiCAD
 - Debugging circuits and soldering



Firmware

- Responsibilities:
 - Writes the code to run on PCBs that electrical designs
 - Implements the low-level functionality for software
- What you learn:
 - Electrical components
 - Common circuits
 - Prototyping
 - Microcontroller programming
 - Communication Protocols
 - Debugging circuits and soldering



```
06 Blink | Arduino 1.0.1
File Edit Sketch Tools Help
Sketch: /Blink
Blink
/*
  Turns on an LED on for one second, then off for one second, repeatedly.

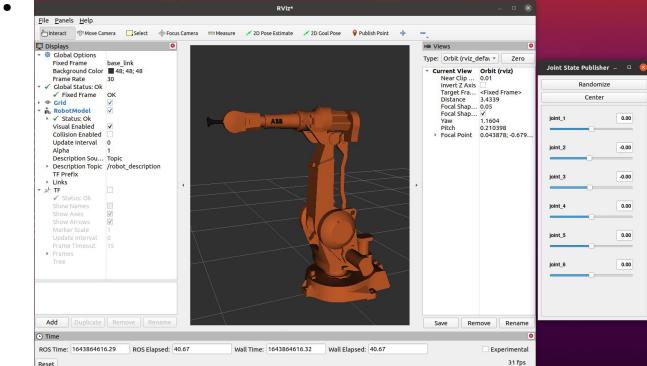
  This example code is in the public domain.
*/
// Pin 13 has an LED connected on most Arduino boards.
// give it a name:
int led = 13;

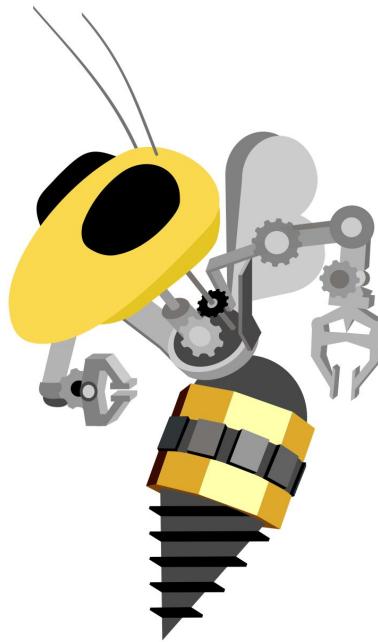
// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output:
  pinMode(led, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
  digitalWrite(led, HIGH); // turn the LED on (HIGH is the voltage level)
  delay(1000); // wait for a second
  digitalWrite(led, LOW); // turn the LED off by making the voltage low
  delay(1000); // wait for a second
}
```

Software

- Responsibilities:
 - Write code that runs (mostly) on “regular” computers
 - “Autonomy”: Vision, motion planning, decision making, etc.
 - A little bit of motion control (split between SW/FW teams)
- What you learn in Software Training:
 - Basics of C++ and ROS
 - Robotics concepts for autonomy





Logistics

How will this work?

Electrical/Firmware Training

- Two sessions a week
 - Monday and Wednesday 6:30pm - 8:00pm
 - Only need to come to one a week

Weekly Plan

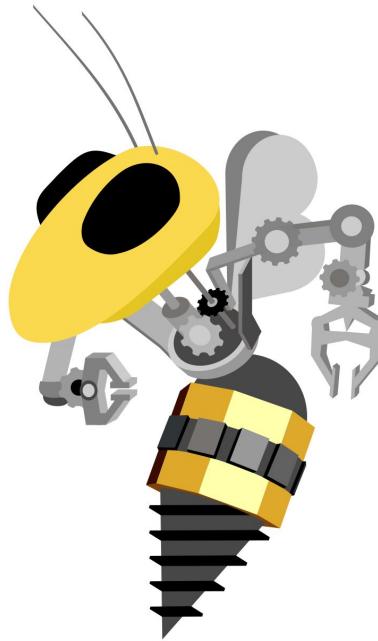
Week	Electrical Training	Firmware Training
0	Introductions, Electrical Basics	
1	Introduction to Prototyping and Arduino	
2	KiCAD Parts and Libraries	More C and Interrupts
3	KiCAD Schematics	PWM and Bitwise Operations
4	KiCAD Board Layout	Communication Protocols
5	Debugging and Soldering	

Online Platforms

- GitHub - Slides and Labs
 - github.com/robojackets/electrical-training
 - github.com/robojackets/firmware-training
- Slack - RoboJackets Team Communication
 - channel: **#electrical-firmware-training-helpdesk**

Important Slack Channels

- Important channels:
 - #<team> (i.e. #robocup)
 - #<team>-electrical (i.e. #robocup-electrical)
 - #electrical-core (electrical/firmware collaboration)
 - #electrical-ama (electrical/firmware questions)
- TODO: Set up your Slack profile!
 - Set profile picture / “What I do” (<team> Electrical)
- Fun channels:
 - #random #rj-girl-gang #research #lets-meet-up

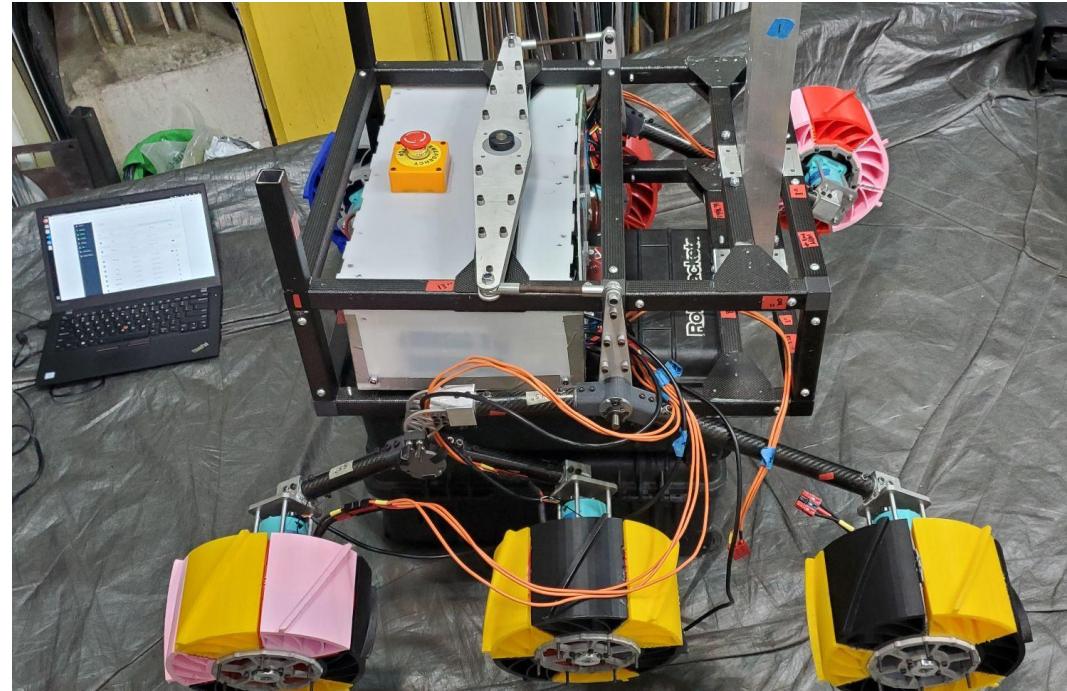


Team Introductions

We build robots!

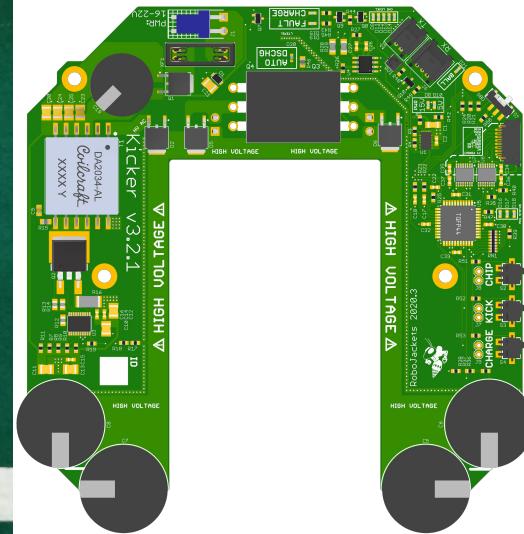
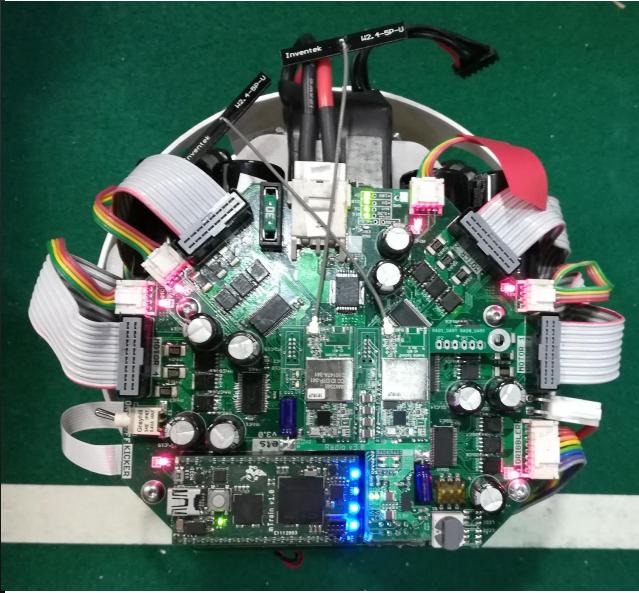
RoboNav

- *Fast Prototyping*
- *Lots of actuators!*
*(Arm, drivetrain,
science)*



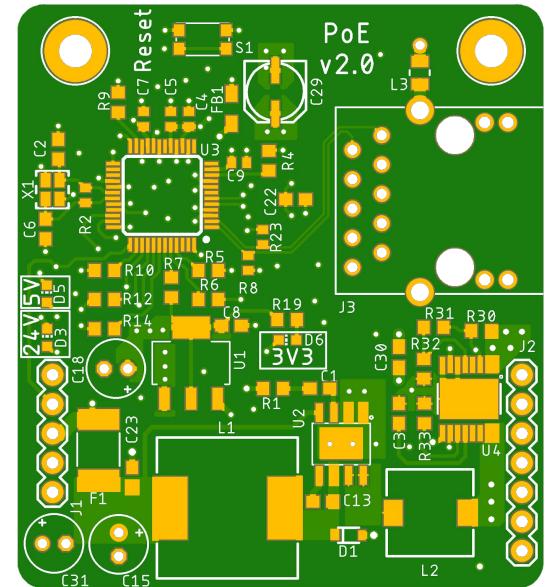
RoboCup

- *Power Electronics*
- *FPGA-based Motor Control*



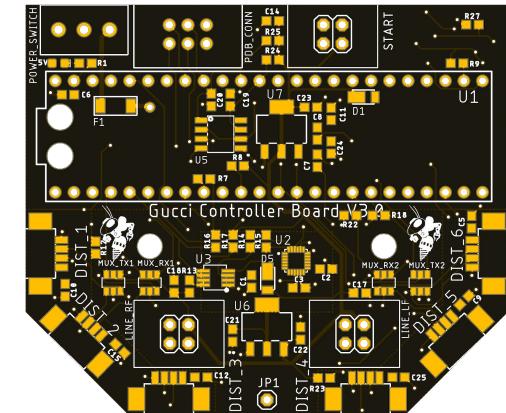
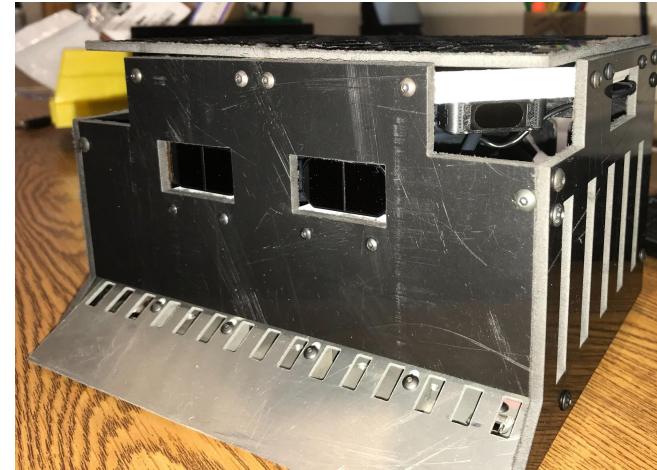
RoboRacing

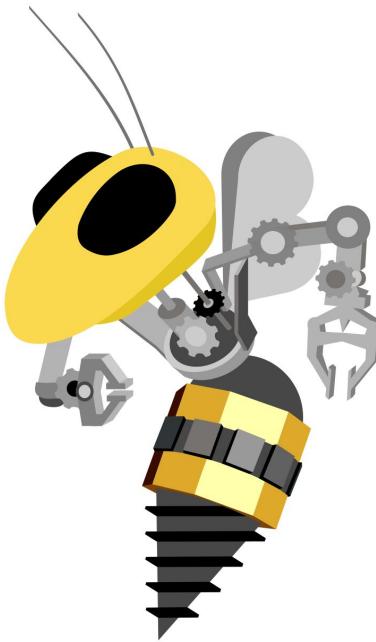
- *Distributed Network Systems*
- *High Speed and Power*



RoboWrestling

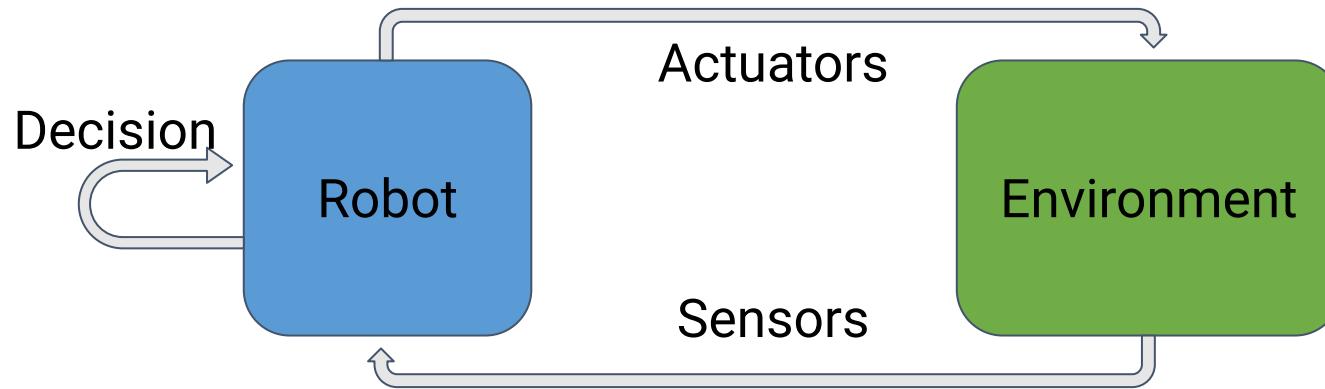
- *Real-Time Strategy*
- *Small Packaging*

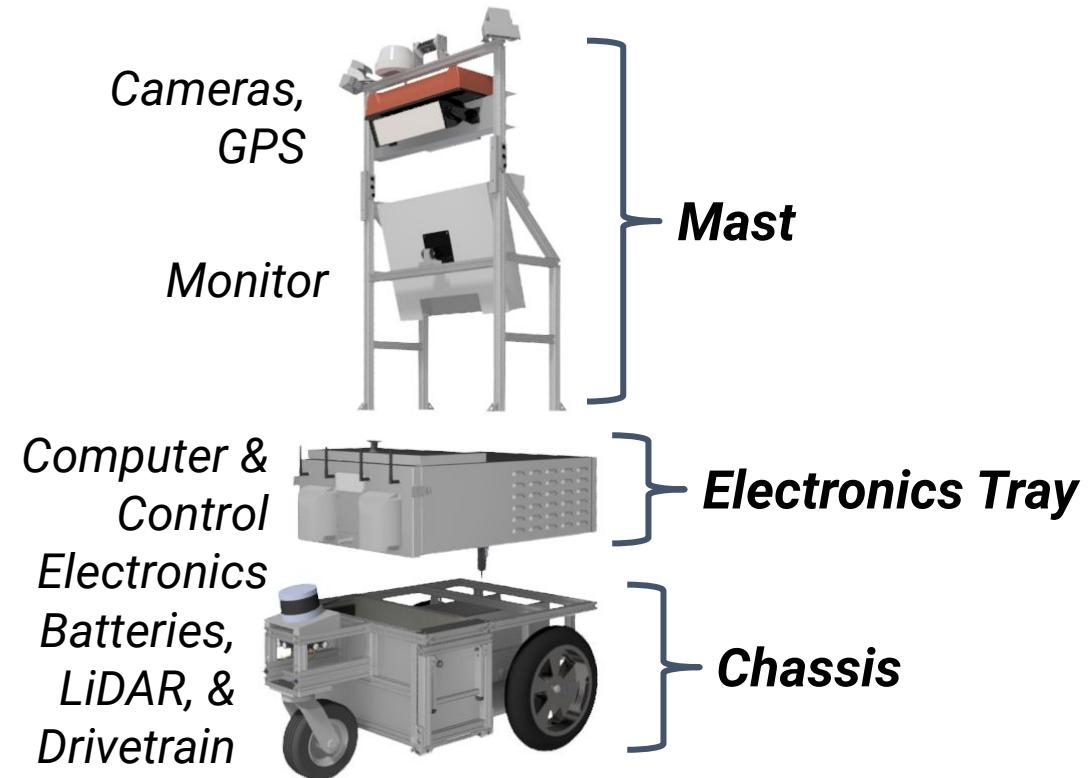




Robotics

What is a Robot?



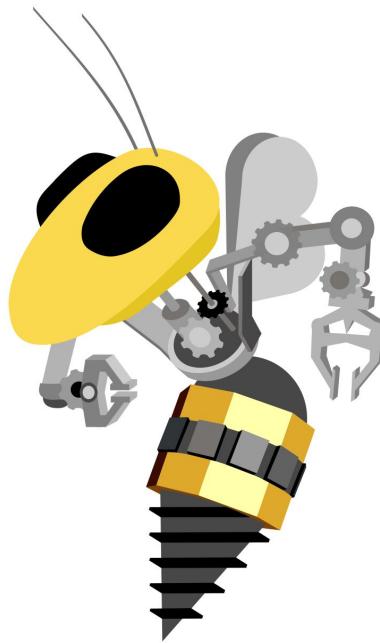




- LiDAR
- Inertial Measurement Unit
- Cameras
- Wheel Encoders

- Computer
- Mbed Microcontroller

- 2x Brushed DC Motors

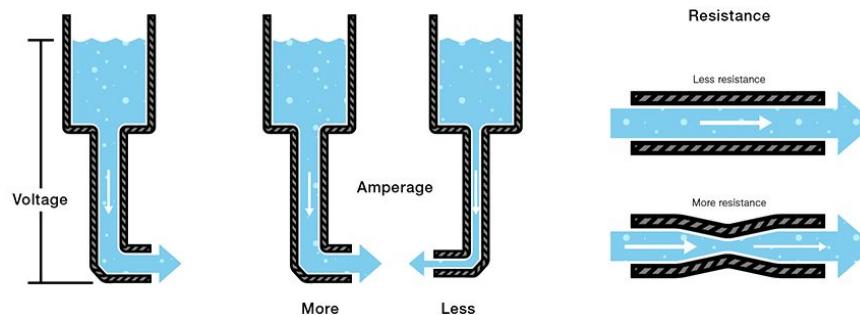


Electricity Basics

Electrons go brrrr

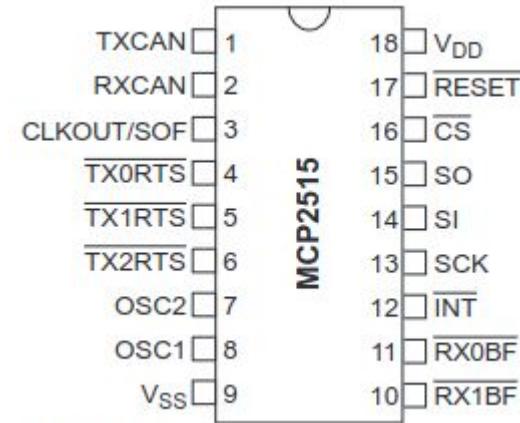
What is electricity?

- Movement of charged particles (electrons)
- Voltage: Amount of potential energy in electrons (J/C)
- Current: Rate at which electrons flow (C/s)
- Current flows from high potential to low potential, releasing energy



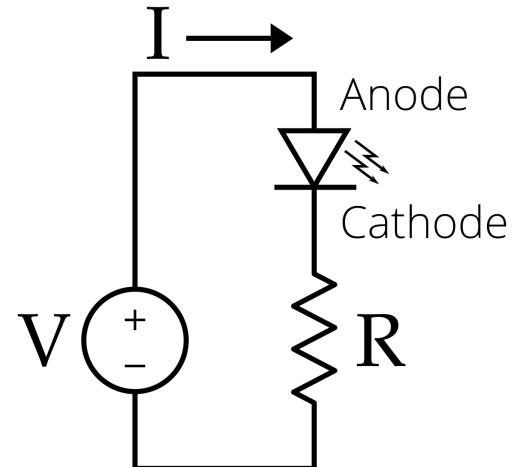
Notation

- Symbols
 - V: voltage, measured in volts (V)
 - I: current, measured in amps (A)
 - R: resistance, measured in ohms (Ω)
- Power and Ground
 - Power: VCC, VDD, +5V
 - Ground: VEE, VSS, GND, 0V



Important Formulas

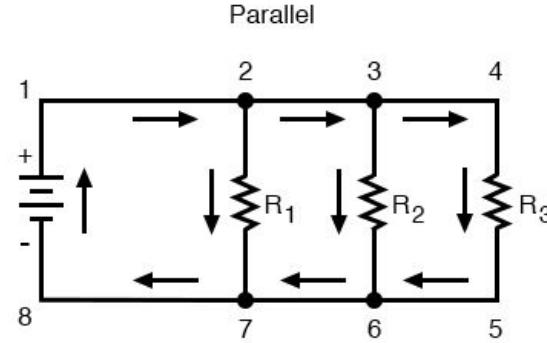
- Ohm's Law: $V = I \cdot R$
- Power: $P = V \cdot I = I^2 \cdot R = V^2/R$



Parallel and Series Circuits

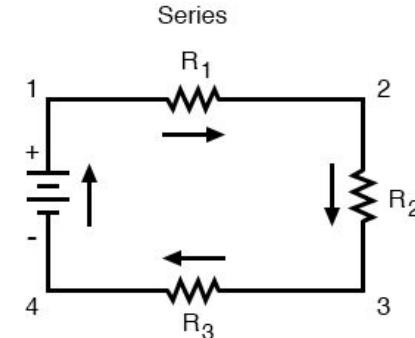
Parallel

- Constant voltage drop for each path



Series

- Current is the same everywhere in the circuit



Takeaway: mind the current!

$$P = I^2 \cdot R$$

$$Q = I^2 \cdot R \cdot t$$

Temp Rise	10°C			20°C			30°C		
Copper	1/2oz.	1oz.	2oz.	1/2oz.	1oz.	2oz.	1/2oz.	1oz.	2oz.
Trace Width (inch)	Maximum Current Amps								
0.01	0.5	1	1.4	0.6	1.2	1.6	0.7	1.5	2.2
0.015	0.7	1.2	1.6	0.8	1.3	2.4	1	1.6	3
0.02	0.7	1.3	2.1	1	1.7	3	1.2	2.4	3.6
0.025	0.9	1.7	2.5	1.2	2.2	3.3	1.5	2.8	4
0.03	1.1	1.9	3	1.4	2.5	4	1.7	3.2	5
0.05	1.5	2.6	4	2	3.6	6	2.6	4.4	7.3
0.075	2	3.5	5.7	2.8	4.5	7.8	3.5	6	10
0.1	2.6	4.2	6.9	3.5	6	9.9	4.3	7.5	12.5
0.2	4.2	7	11.5	6	10	11	7.5	13	20.5
0.25	5	8.3	12.3	7.2	12.3	20	9	15	24

Table 1 Carrying Capacity per mil std 275

More current
=
Thicker wire

More current
=
Thicker PCB
trace!

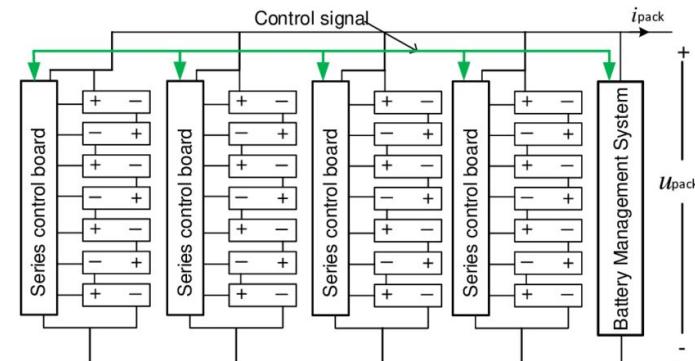
Wire Gauges Size & Wire Ampacity Table	
3/0 Gauge	200 AMPS Service Entrance - From Utility Pole to Energy Meter
1/0 Gauge	150 AMPS Service Entrance & Feeder Wire - To Panel Box
3 Gauge	100 AMPS Service Entrance & Feeder Wire - To Panel Box
6 Gauge	55 AMPS Feeder & Large Appliance Wire
8 Gauge	40 AMPS Feeder & Large Appliance Wire
10 Gauge	30 AMPS Appliances e.g. Dryer, Air-conditioning, Water Heater
12 Gauge	20 AMPS Appliances like Laundry, Bathroom & Kitchen Circuits
14 Gauge	15 AMPS General Lighting, Fans & Outlet / Receptacle Circuits

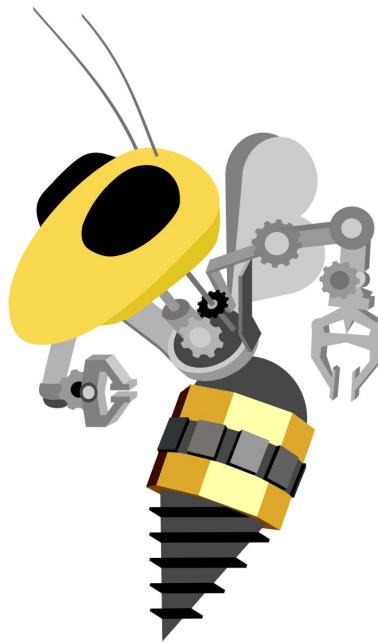
Takeaway: Series & Parallel

Series = voltage adds
Parallel = current adds



Power distribution: in parallel!





Electronic Components & Tools

Multimeter

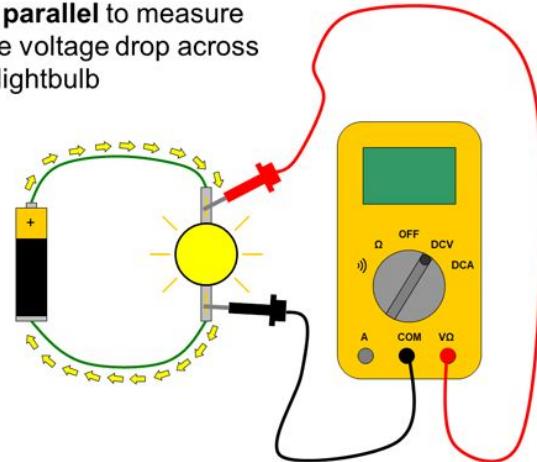
An electrician's best friend!



Using a Multimeter

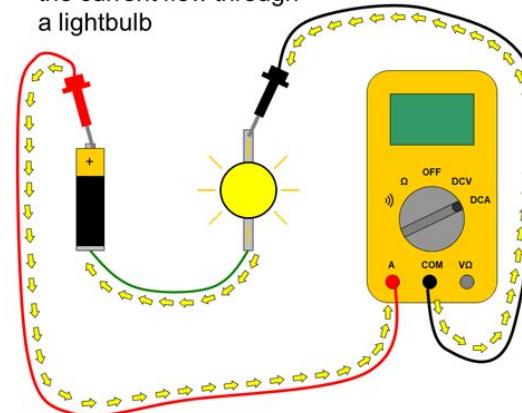
Voltage / Resistance / Continuity

Connect a multimeter in **parallel** to measure the voltage drop across a lightbulb



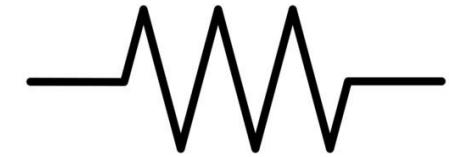
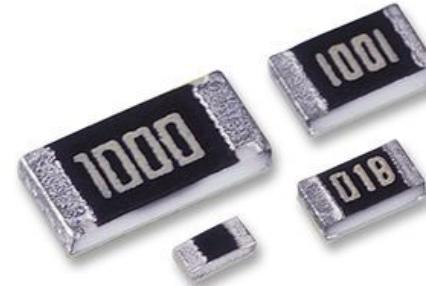
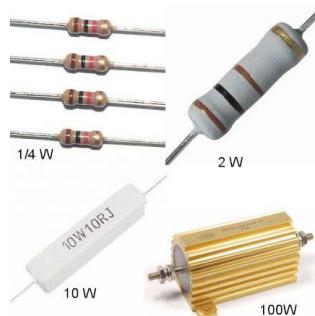
Current

Connect a multimeter in **series** to measure the current flow through a lightbulb



Resistor

- Purpose: reduces current flow
 - Resistance measured in Ohms (Ω)
 - Makes it harder for current to flow
- Converts electrical energy to heat



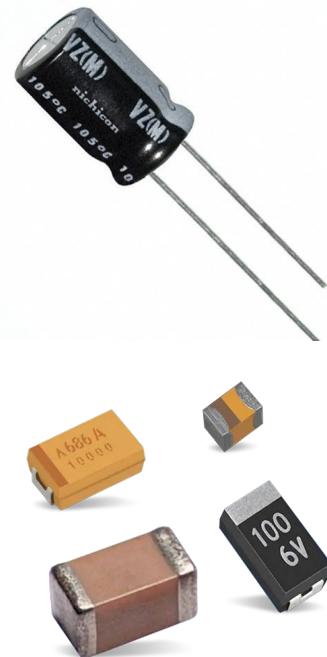
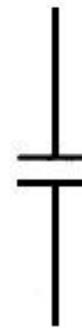
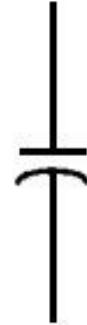
Fuse

- Safety device which blows when too much current flows through it



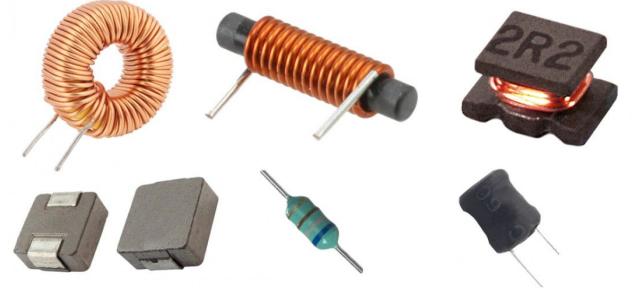
Capacitor

- Purpose: Stores energy as an electric field between two charged plates
 - Measured in Farads (F)
- Uses:
 - Power Source
 - Smoothing voltage signals



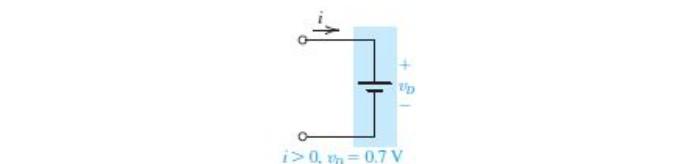
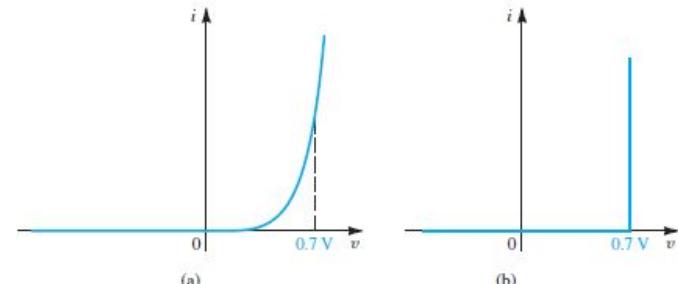
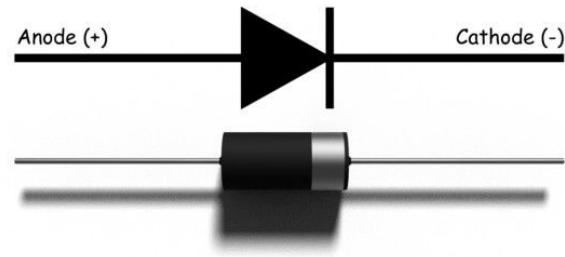
Inductor

- Purpose: Stores energy as a magnetic field in a coil
- Measured in Henry (H)
- Uses:
 - Smoothing current
 - Electromechanical parts (solenoids, relays)



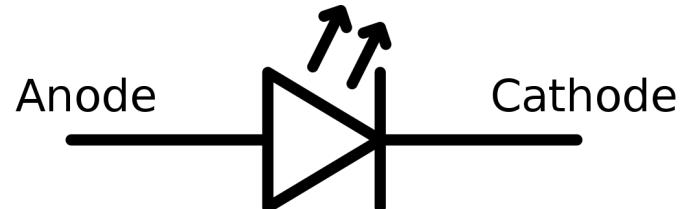
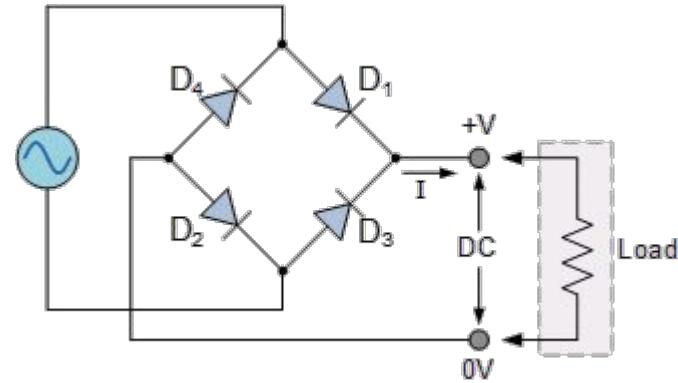
Diode

- Conducts current in one direction
- CVD Model: Assume diode conducts infinite current at constant voltage



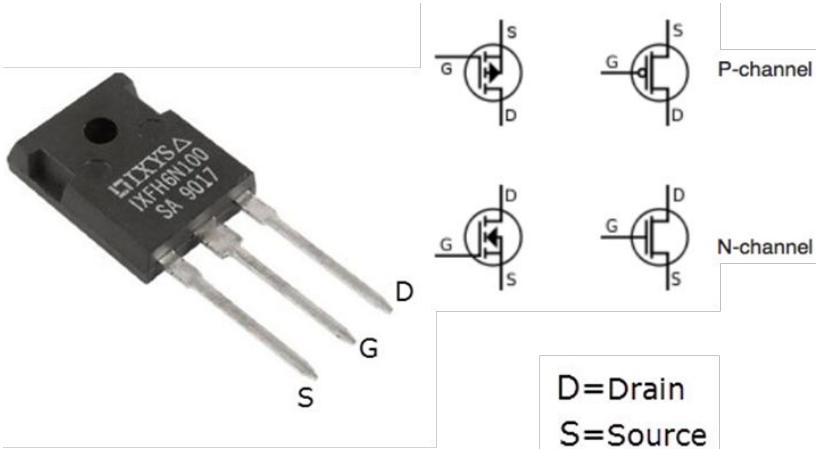
Diode

- Uses:
 - Rectification
 - Reverse Polarity Protection
 - Light Emitting Diode



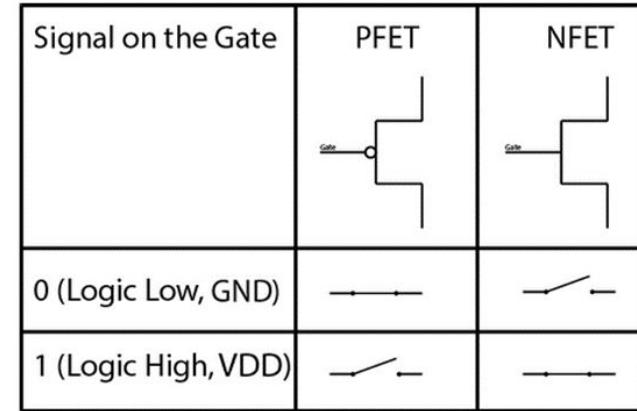
Transistor (MOSFET)

- 3 Terminal Component
 - Gate, Drain, Source
- Voltage signal at gate controls current flow between Source and Drain
- Acts as an electronic switch



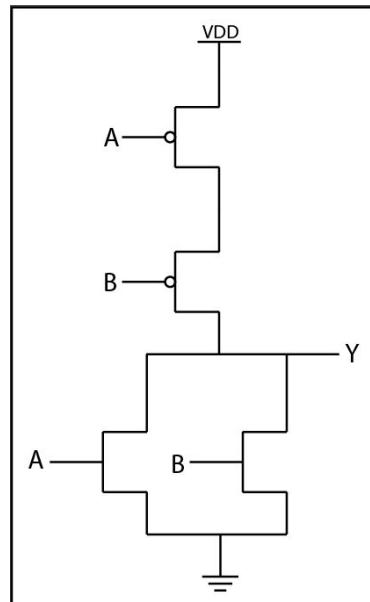
Transistor

- An electrical switch!
 - Transistors “activate” when the gate-source voltage reaches the threshold
- Two types: N- and P-Type
 - N-Type: source kept at GND
 - P-Type: source kept at VCC
- RoboJackets: don’t often use directly
 - Buy integrated circuits (ICs) that contain lots of transistors



Transistor Uses

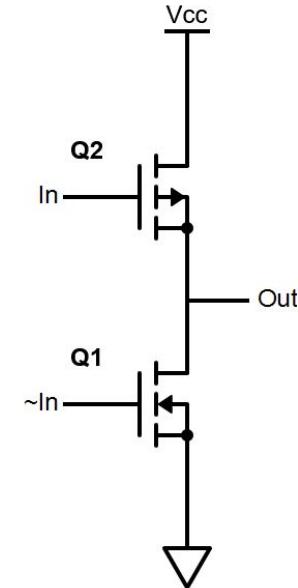
Digital Logic

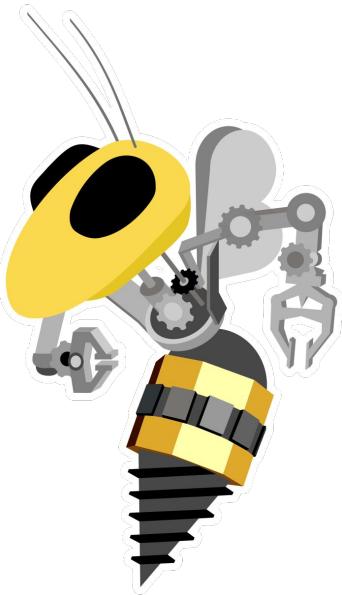


CMOS NOR gate

Power
Amplification

Cascode Amplifier





Kahoot

Test your knowledge



ROBOJACKETS
COMPETITIVE ROBOTICS AT GEORGIA TECH