HyTech Racing Circuits Training

2019-2020

Dues

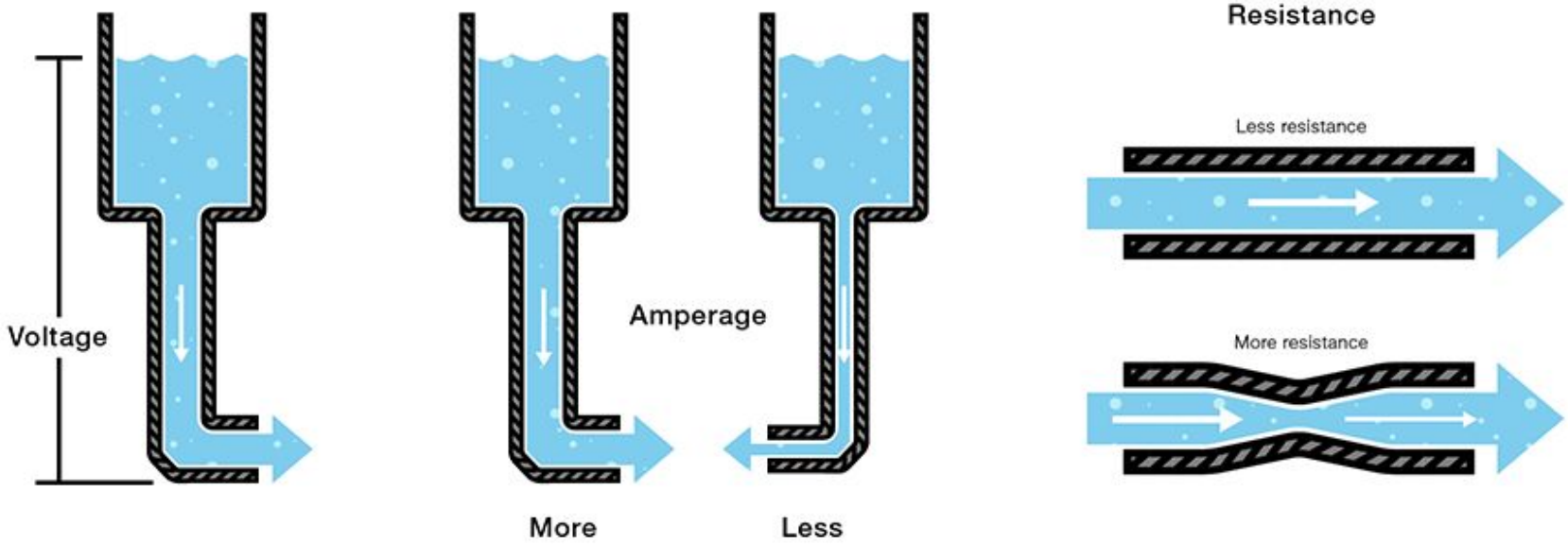
- If you would like to officially join HyTech Racing, you can pay dues using **Venmo**, **PayPal**, **Square**, or **Cash**.
  - Venmo: **@hytechracing**
  - PayPal: **gthytech@gmail.com**
  - Square: **https://squareup.com/store/hytech-racing**
  - Cash: **See an Officer**
- Paying dues gets you access to our Slack, Trello, Github, and Google Drive.
- Deadline is 9/15.

Initial Survey

- Fill out this survey here: **https://tinyurl.com/2020CircuitsExperience**.

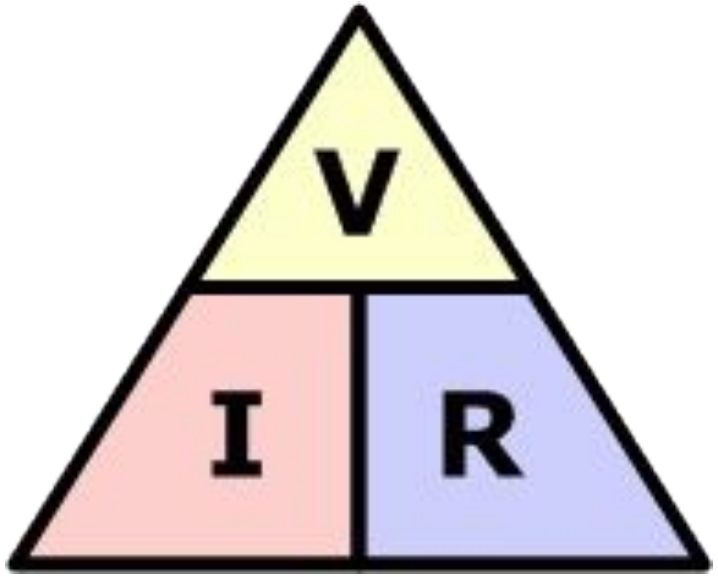
Voltage, Current, and Resistance

- Electricity is the flow of electrons.
- Three basic terms are **voltage**, **current**, and **resistance**.
- Imagine electrons as water:
  - Voltage: “Force behind electrons or pressure”.
  - Current: “Number of electrons per second or flow rate”.
  - Resistance: “Opposition to electron movement or flow constrictions”.



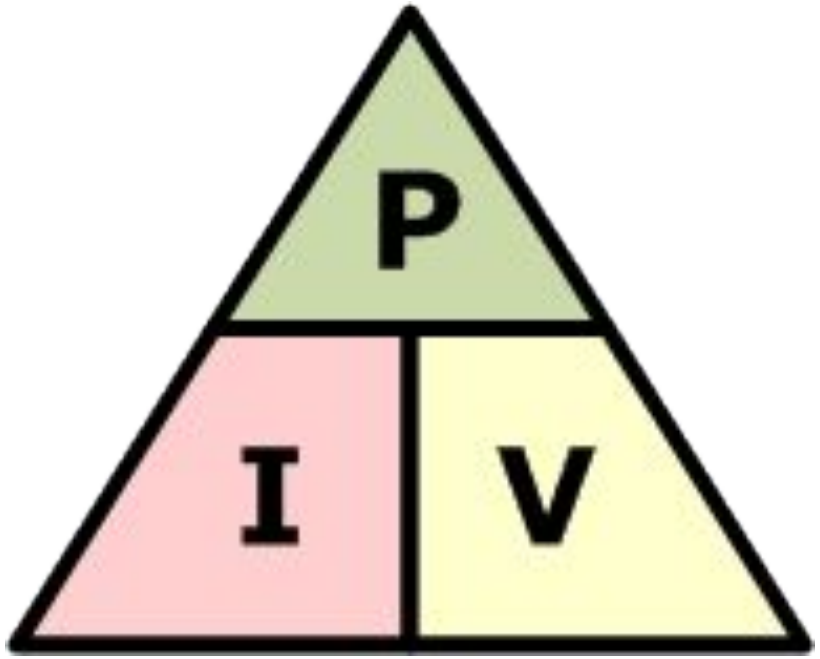
Ohm's Law

- **Ohm's Law** is the fundamental relationship between voltage, current, and resistance.
- Three Basic Units:
  - Voltage: **Volts (V)**
  - Current: **Amps (A)**
  - Resistance: **Ohms (Ω)**
- It is defined as $Voltage = Current \cdot Resistance$



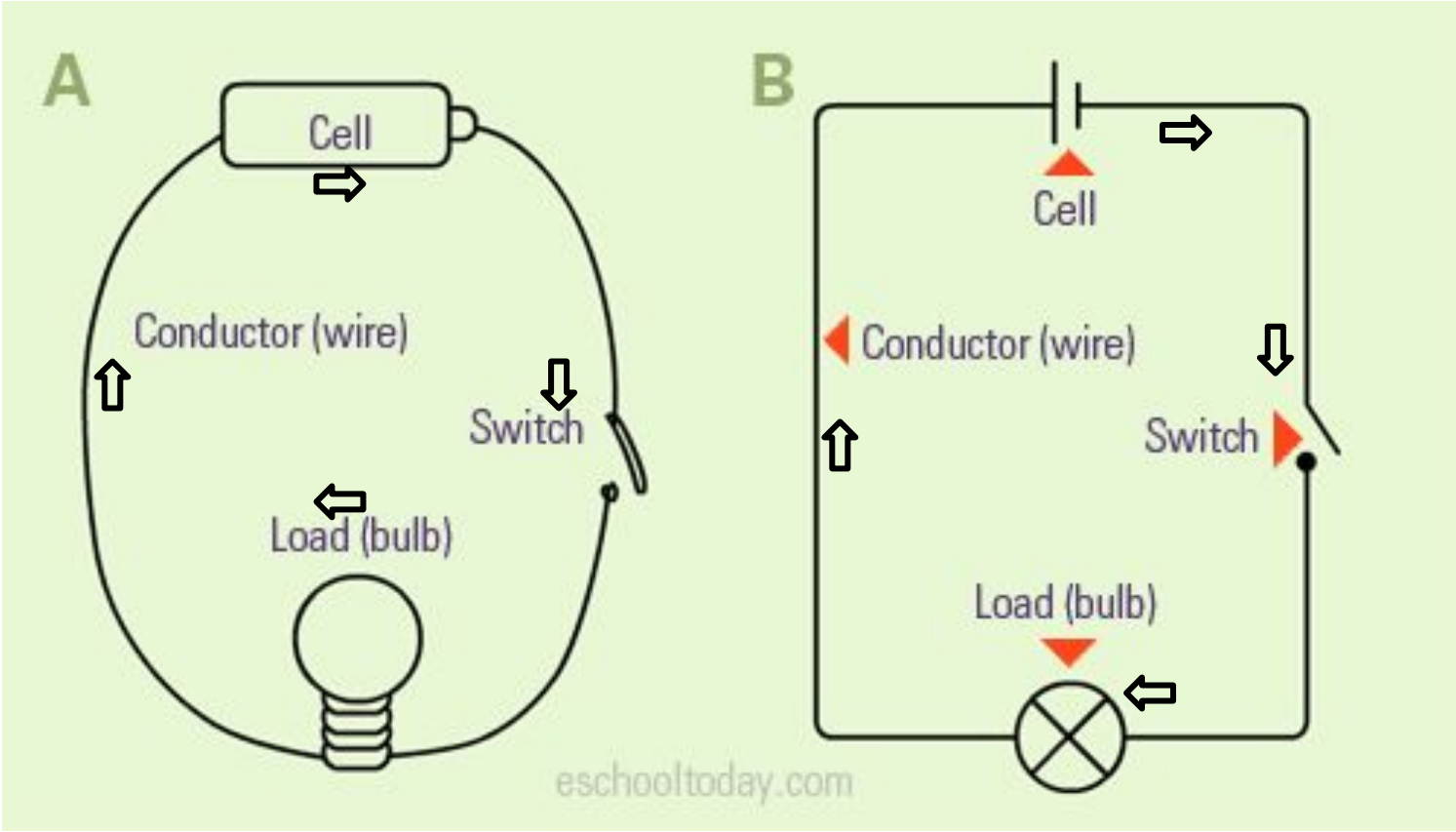
Power

- One more aspect of electronics is **power**.
- Represents the work done by the electron movement.
- Usually can be considered as the heat output.
- Basic unit for power is **Watt (W)**.
- It is defined as $Power = Voltage \cdot Current$.



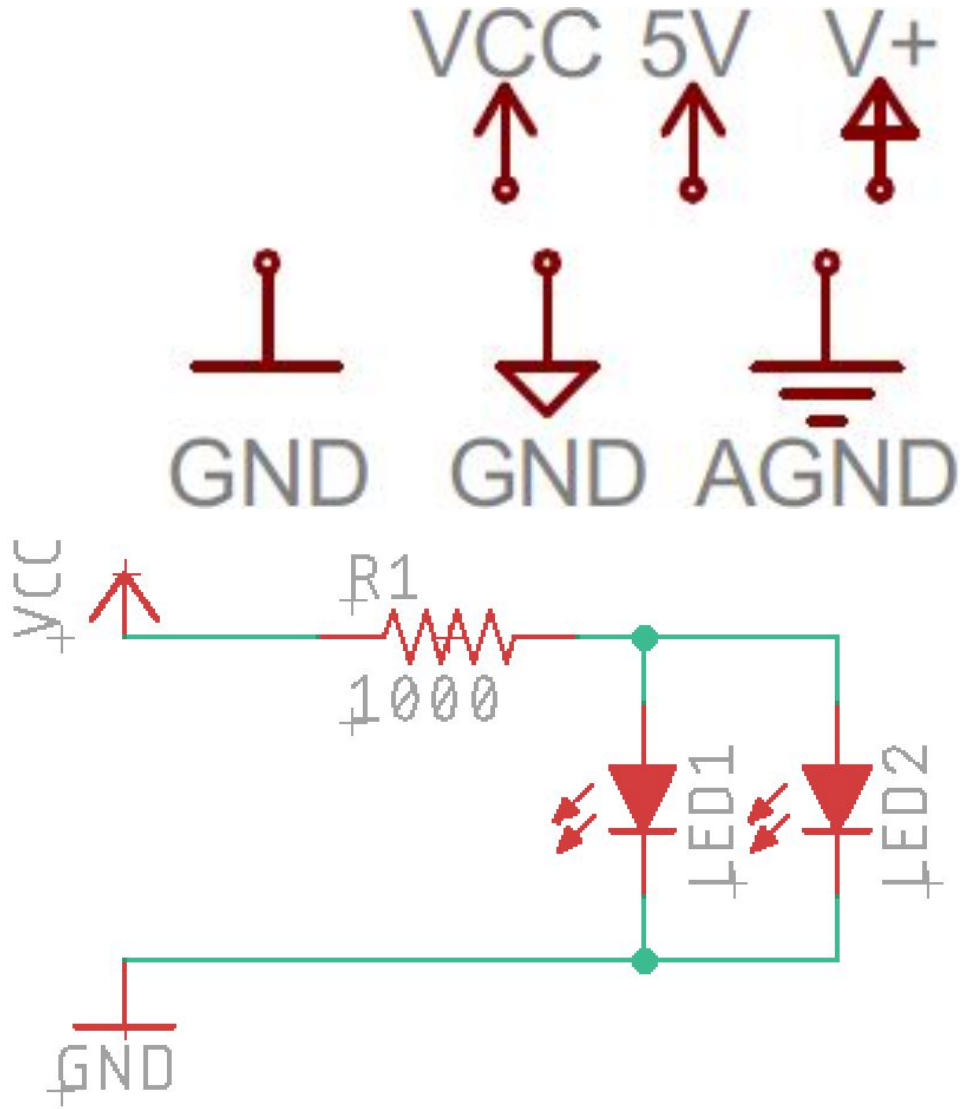
Electrical Circuits

- An **electric circuit** is a path in which electrons from a voltage or current source flow.
- Electrons enter a circuit at the **source** (the right side of the battery below).
- Electrons leave a circuit at the **return** or **earth ground** (the left side of the battery below).

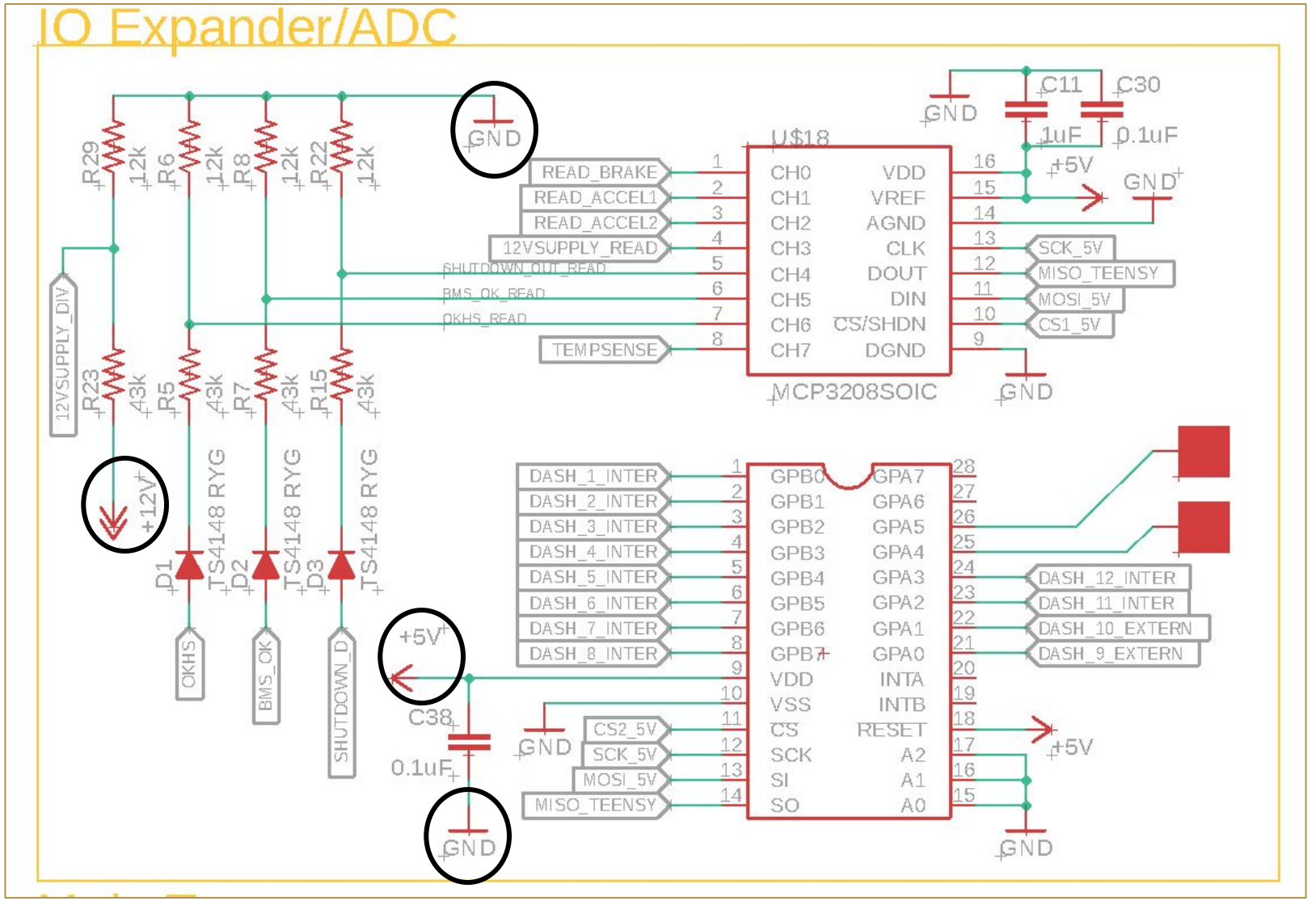


Power and Ground Symbols

- Instead of drawing circuits as a big loop, we use **power** and **ground** symbols.
- Labeling is important for readability:
  - We label power symbols with specific voltages.
  - We label ground symbols with types of grounds.

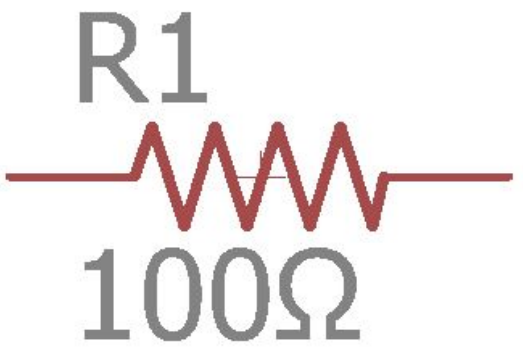


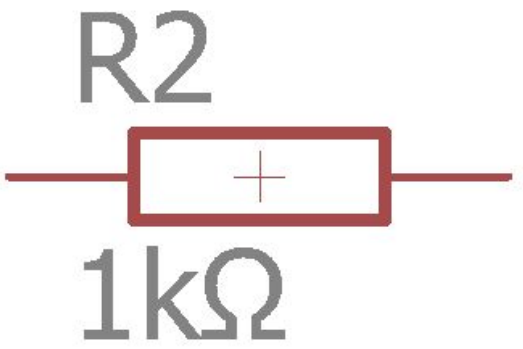
Power and Ground Symbols (Schematic Example)



Resistors

- A **resistor** is a passive two-terminal component that **has electrical resistance**.
- The resistance of a resistor is measured in **Ohms (Ω)**.
- It is used to control current, adjust voltages, and so much more.
- It is the simplest part to use, as it **linearly** relates voltage and current.





Resistor Color Codes and SI Units

	Colour	Band 1 First digit	Band 2 Second digit	Band 3 Multiplier	Band 4 Tolerance
	Black	0	0	x 1 (x 1)	-
	Brown	1	1	x 10 (x 10)	1%
	Red	2	2	x 100 (x 100)	2%
	Orange	3	3	x 1 000 (x 1k)	not used
	Yellow	4	4	x 10 000 (x 10k)	not used
	Green	5	5	x 100 000 (x 100k)	not used
	Blue	6	6	x 1 000 000 (x 1M)	not used
	Violet	7	7	-	not used
	Grey	8	8	-	not used
	White	9	9	-	not used
	Gold	-	-	-	5%
	Silver	-	-	-	10%

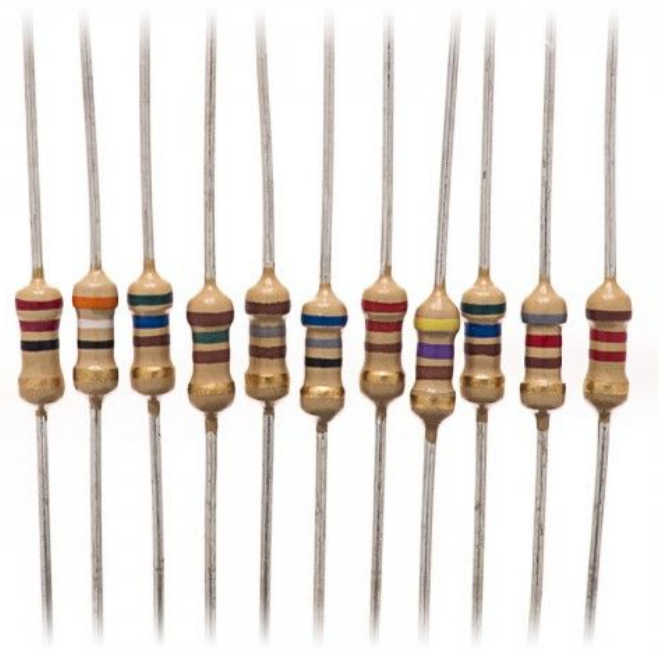
The Prefixes Used with SI Units

Prefix	Symbol	Meaning	Scientific Notation
exa-	E	1,000,000,000,000,000,000	10^{18}
peta-	P	1,000,000,000,000,000	10^{15}
tera-	T	1,000,000,000,000	10^{12}
giga-	G	1,000,000,000	10^{9}
mega-	M	1,000,000	10^{6}
kilo-	k	1,000	10^{3}
hecto-	h	100	10^{2}
deka-	da	10	10^{1}
—	—	1	10^{0}
deci-	d	0.1	10^{-1}
centi-	c	0.01	10^{-2}
milli-	m	0.001	10^{-3}
micro-	μ	0.000 001	10^{-6}
nano-	n	0.000 000 001	10^{-9}
pico-	p	0.000 000 000 001	10^{-12}
femto-	f	0.000 000 000 000 001	10^{-15}
atto-	a	0.000 000 000 000 000 001	10^{-18}

391 = 39 x 10^1 = 390 Ω
270 = 27 x 10^0 = 27 Ω

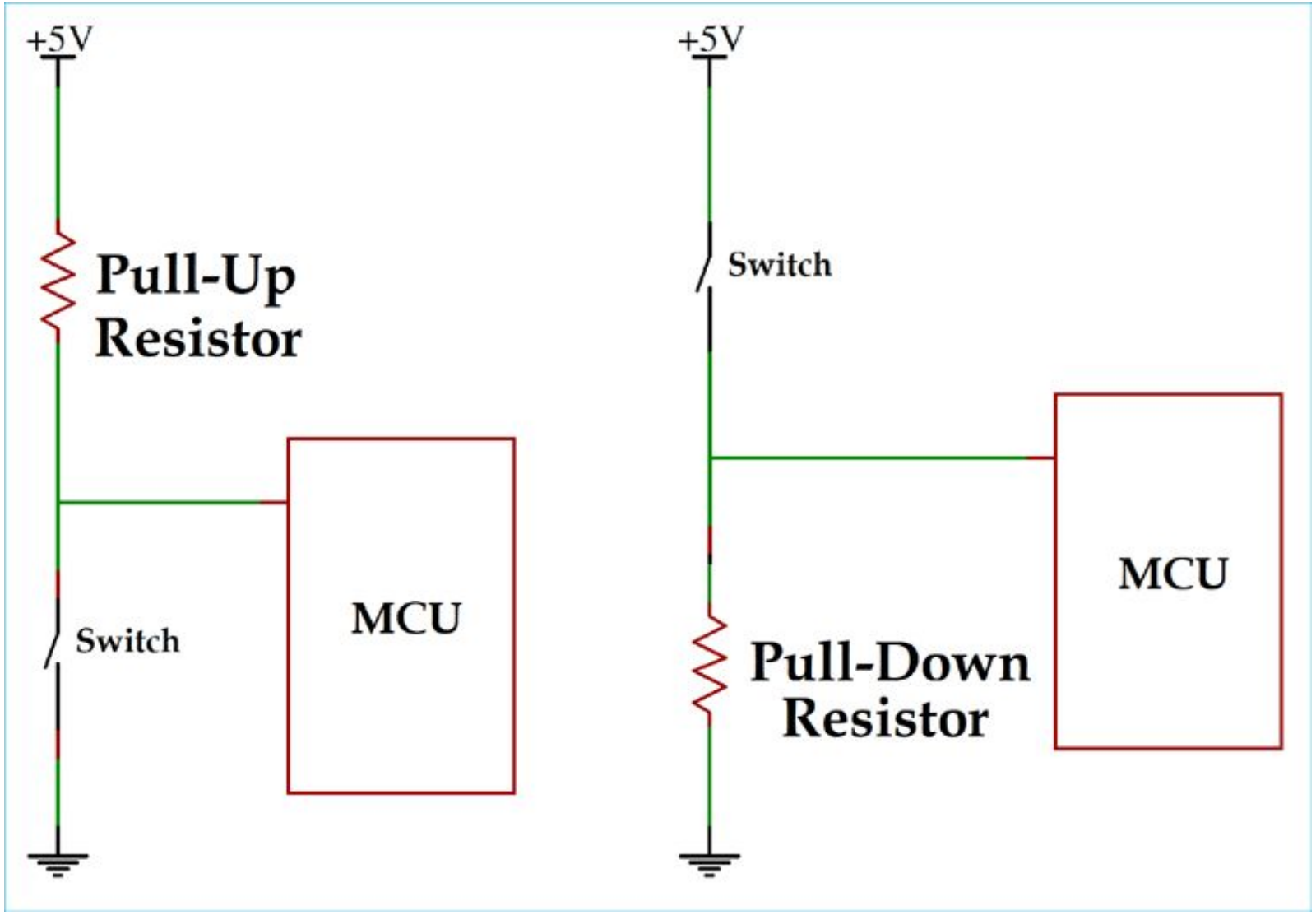
Speccing Resistors

- Different resistors are made for different applications.
- When designing a circuit, it is important to choose correct components (**speccing**) to fit your application.
- For resistors, **power rating** is what matters:
  - This uses the formulas we discussed before.
  - Wattage rating cause resistors to be massively different in size (100W on the left and 0.25W on the right)



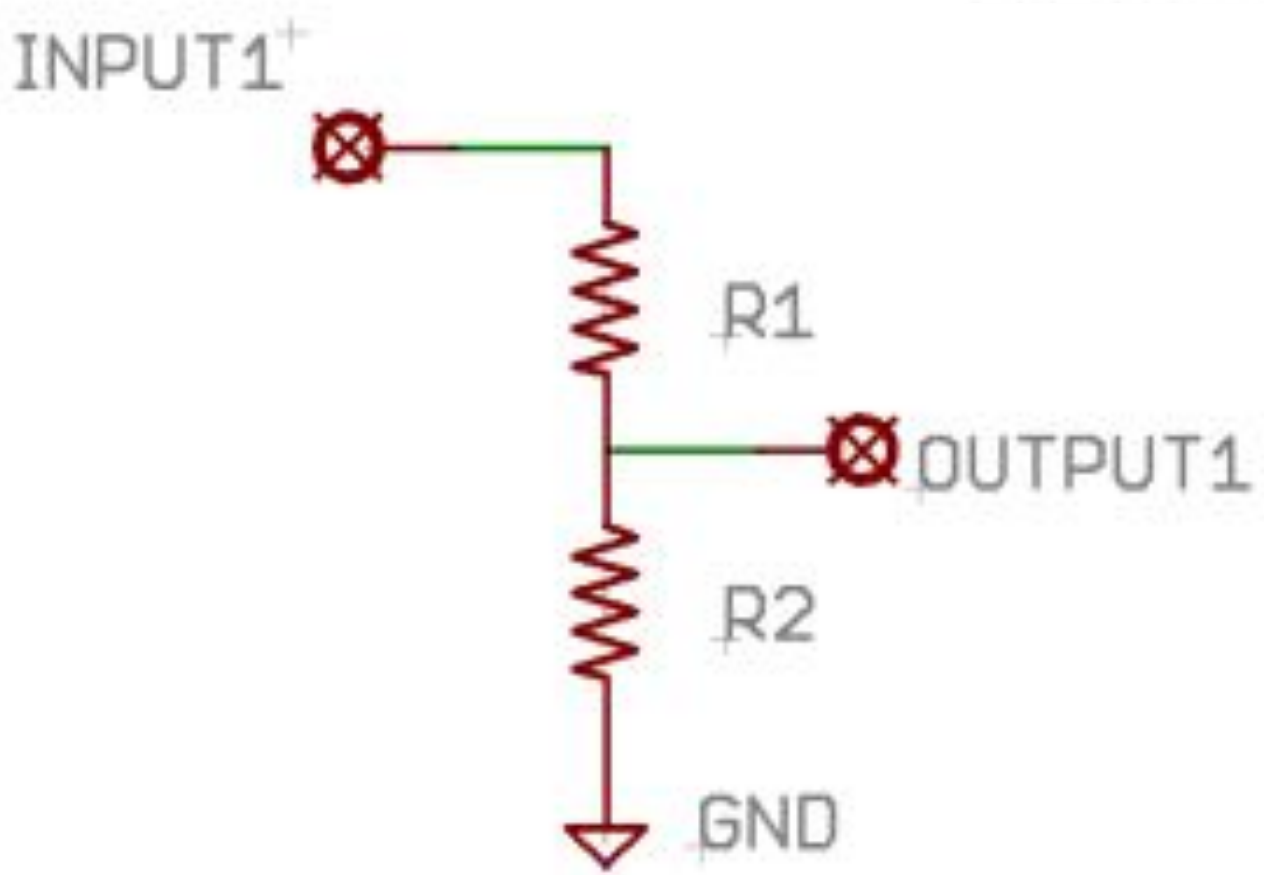
Pull-Up/Pull-Down Resistors

- There are two major applications of resistors.
  - **Pull-up resistors** are used to ensure that a signal line goes to **Power** if disconnected from the source of the signal. (e.g. buttons and switches)
  - **Pull-down resistors** are used to ensure that a signal line goes to **Ground** if disconnected from the source of the signal. (e.g. sensor signal)



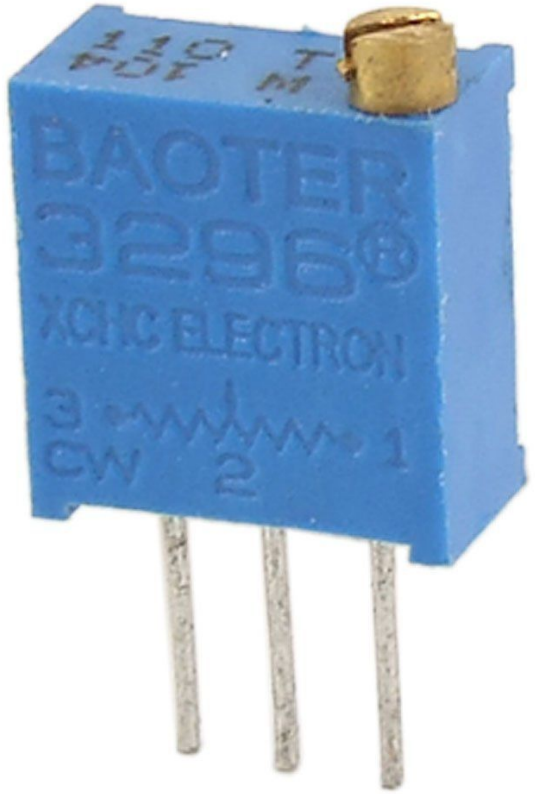
Voltage Dividers

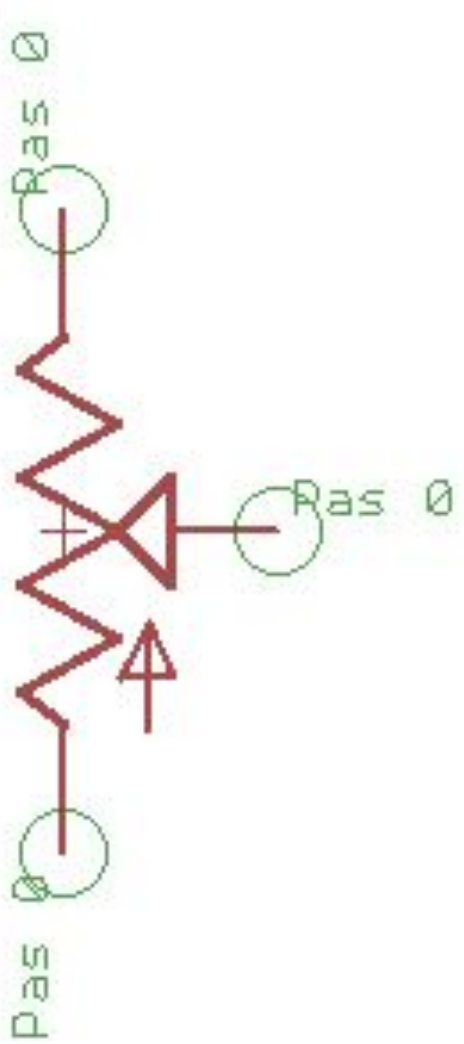
- **Voltage dividers** do exactly what they sound like, they divide the voltage of a input.
- HyTech often uses voltage dividers (e.g. to read an analog signal that has a range of 0-12V with a microcontroller that can only accept up to 5V).
- Their behavior can be calculated using Ohm's Law.
- It is defined as $OUTPUT1 = INPUT1 \cdot \frac{R2}{R1 + R2}$.
  - An example is converting a 12V signal from the charger into a 3V signal for the charger controller microcontroller.
  - R1 is 30kΩ and R2 is 10kΩ, which is ¼ ratio of output to input.



Potentiometers

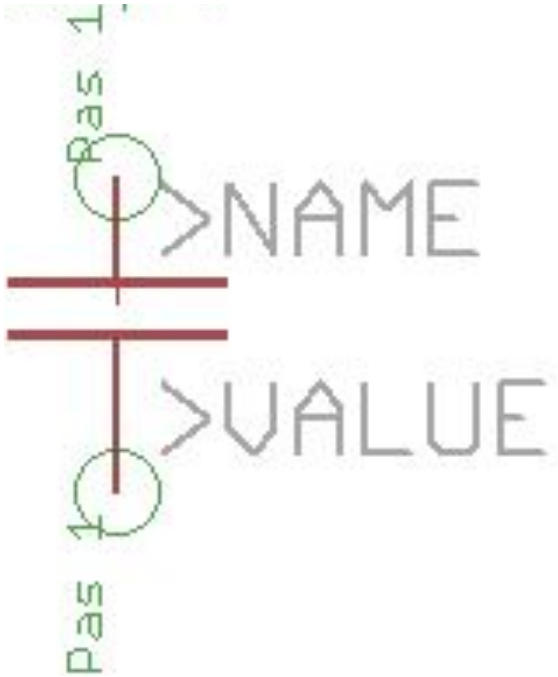
- A **potentiometer** is a passive three-terminal component that has **adjustable** electrical resistance.
- It is also called a trimpot or pot.
- It is often part of a tunable voltage divider to allow for later circuit adjustment:
  - The middle lead to an outer lead has the adjustable resistance.
  - The outer leads combined have the maximum fixed resistance





Capacitors

- A **capacitor** is a passive two-terminal device that **stores electrical charge**.
- The measure of the amount of stored charge is **capacitance**, which is measured in **Farads (F)**.
- It is a more complex part to use, however, as it **nonlinearly** relates voltage and current.

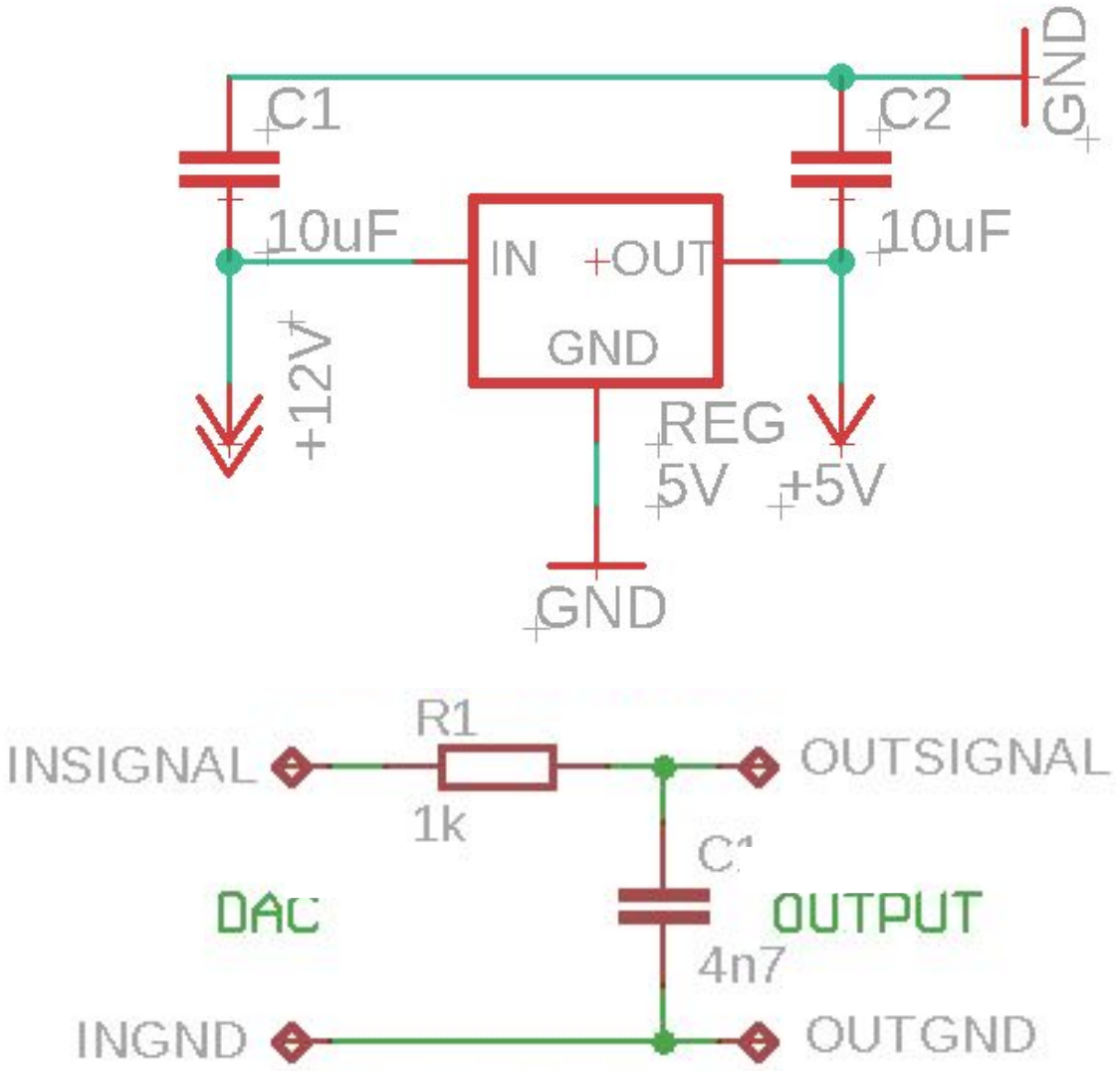


Speccing Capacitor

- Different capacitors are made for different applications.
- For capacitors, **voltage rating** and **capacitance** is what matters:
  - Capacitance causes the capacitors to be massively different in size (1F on the left and 1μF on the right).
  - Voltage rating cause capacitors to be made of different materials.

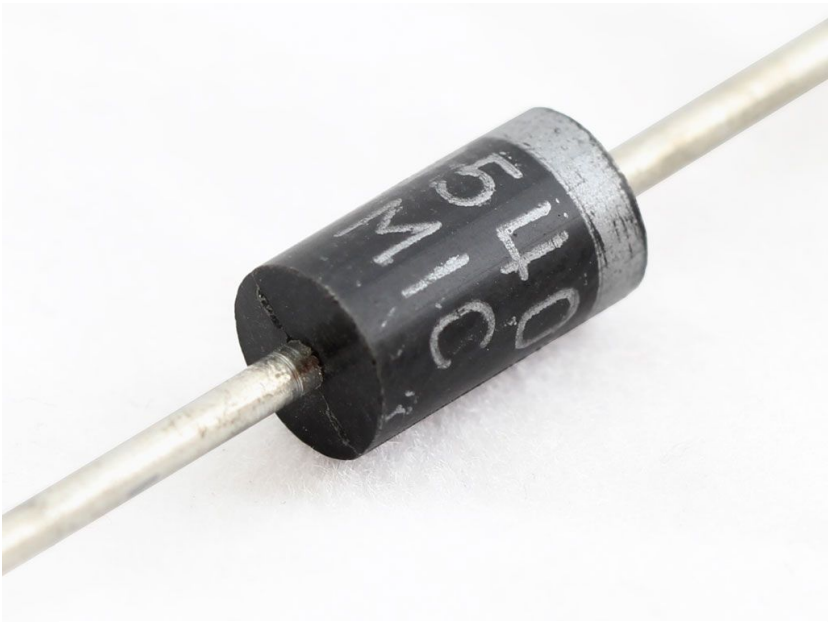
Capacitor Uses

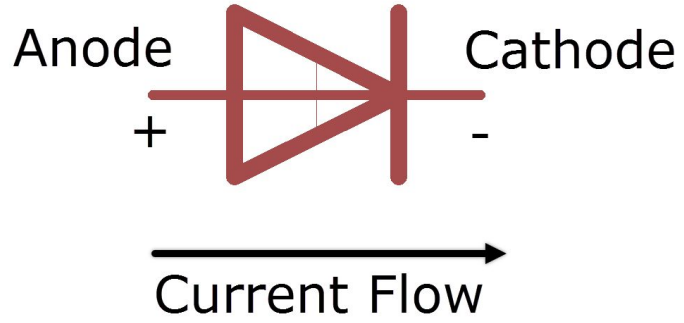
- There are three major uses:
  - **Decoupling capacitors** (top) are capacitors between power and ground that ensure there is no noise on the power rails.
  - **Delay timing** uses the charging/discharging of a capacitor, which is nonlinear, to act as a delay to activate a signal.
  - **Filtering** (bottom) uses a resistor and capacitor to remove certain signals to have less "noise" in the signal.



Diodes

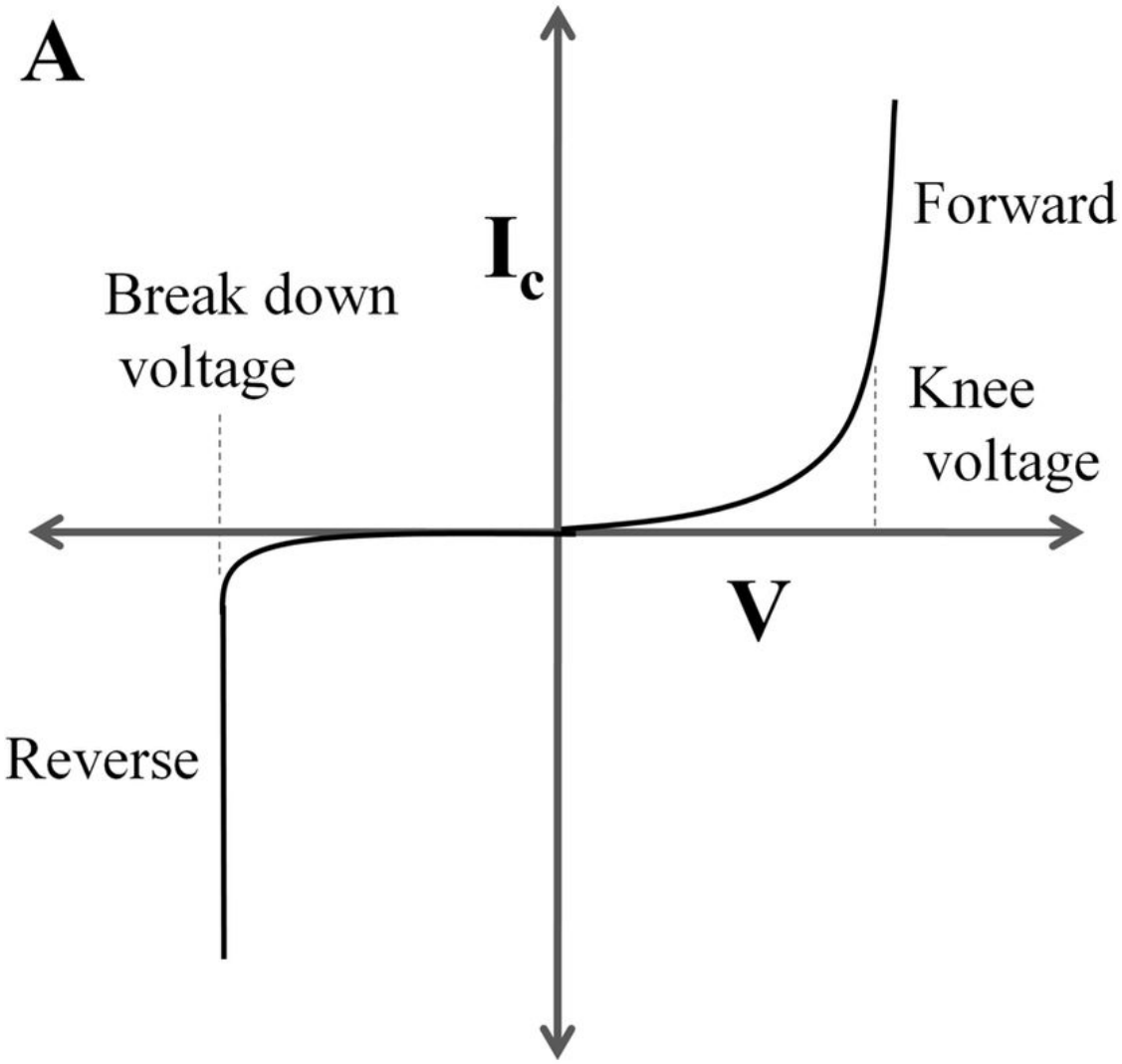
- A **diode** is a two-terminal device that conducts current primarily in **one direction**:
  - It has a very **low resistance** in one direction after a certain voltage.
  - It has a very **high resistance** in another direction.
- There are several different kinds of diodes:
  - **LEDs** emit light.
  - **PN Junction diodes** are the main diodes HyTech uses.





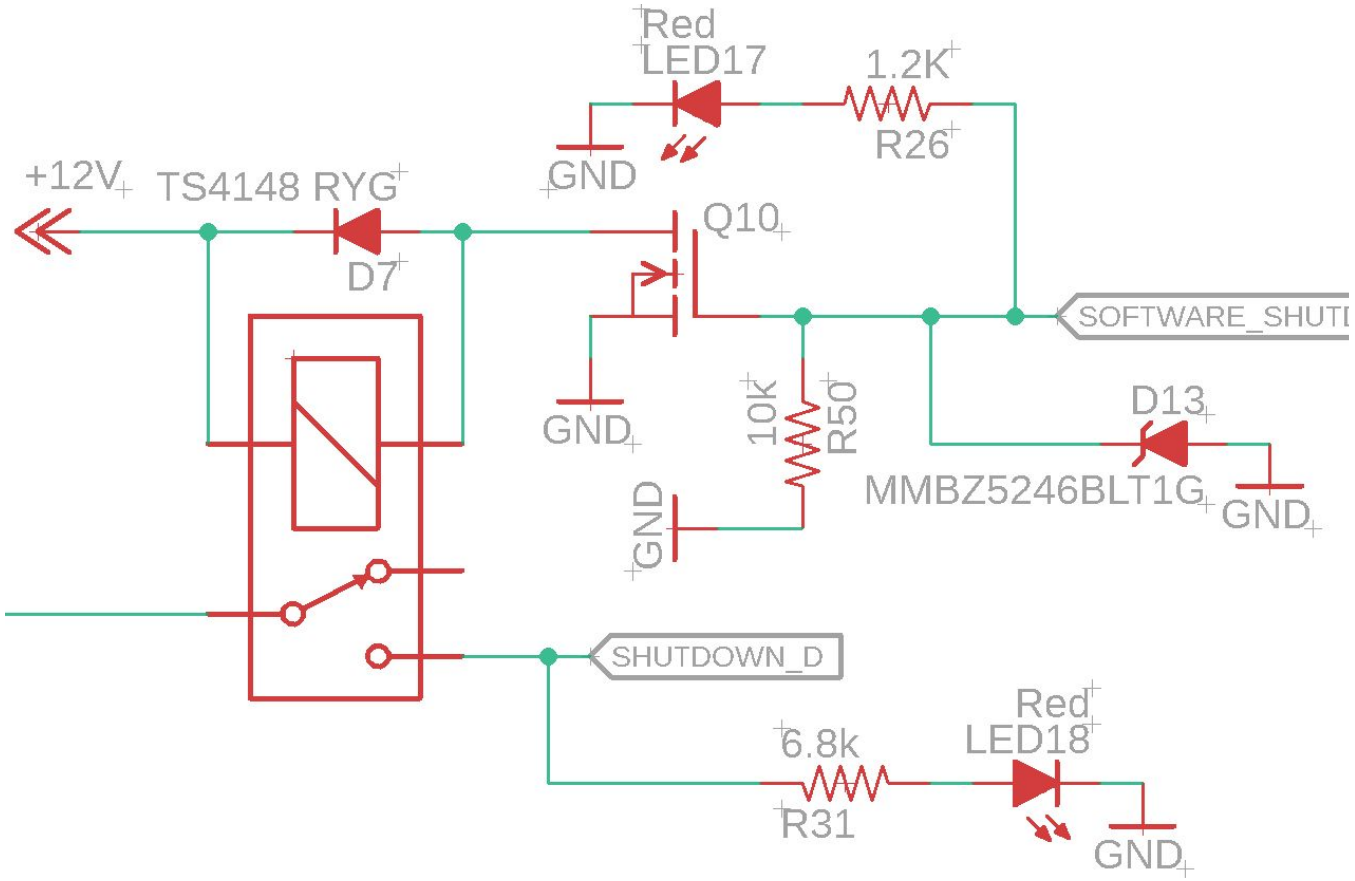
Diode Characteristics

- Diodes have a **bias** or direction.
- Diodes have a **knee voltage**.
  - Before its knee voltage, the diode has a very high resistance.
  - After the knee voltage, the diode has a very low resistance.
- Diodes have a **breakdown voltage** or reverse bias voltage.
  - This is the maximum voltage that can be applied in reverse.
  - Beyond this point usually causes **damage** to the diode.



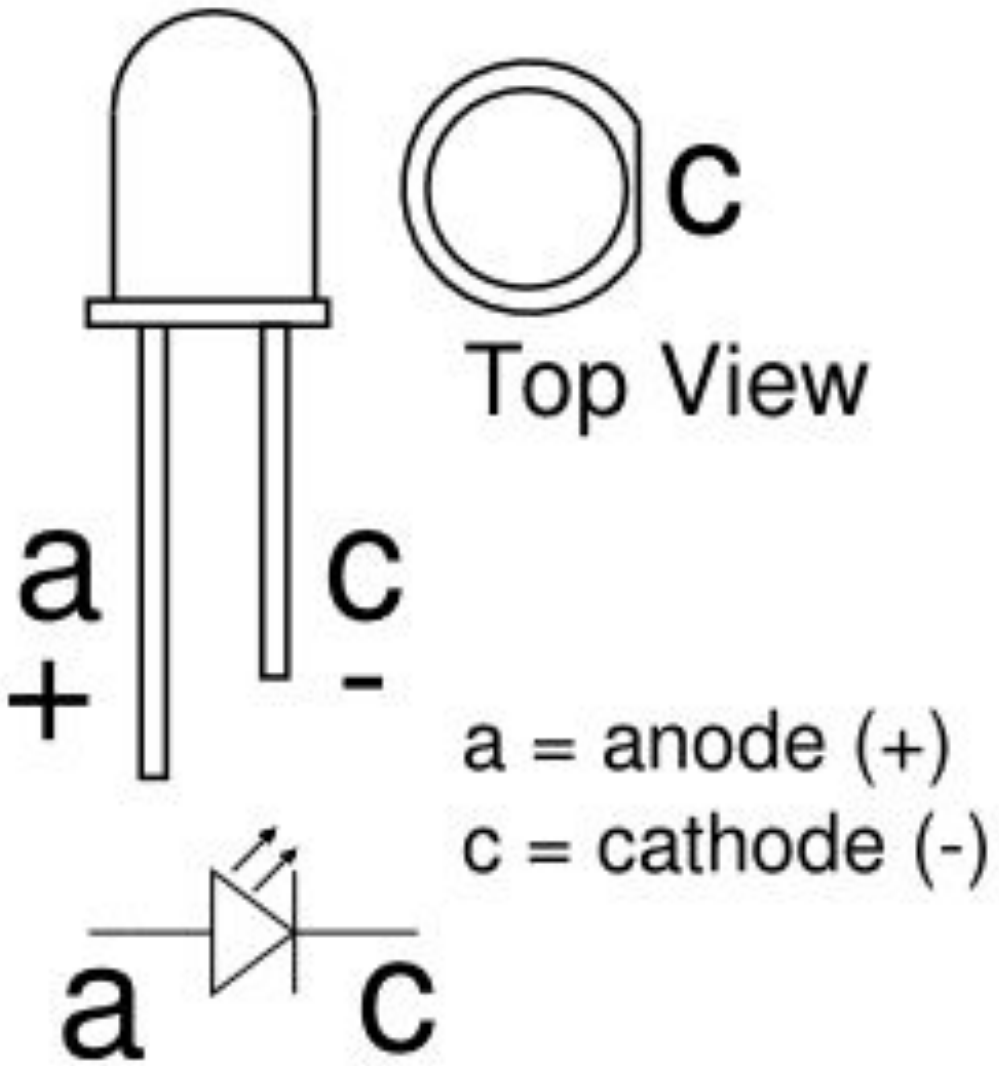
Diode Applications

- A **flyback diode** (**D7** in the schematic) is a PN Junction diode used to eliminate voltage spikes.
  - The reason for those spikes is complicated, but is due to the change in state of the big square relay.
- LEDs (**LED17** and **LED18** in the schematic) are used as status indications.
  - These are especially useful in debugging.



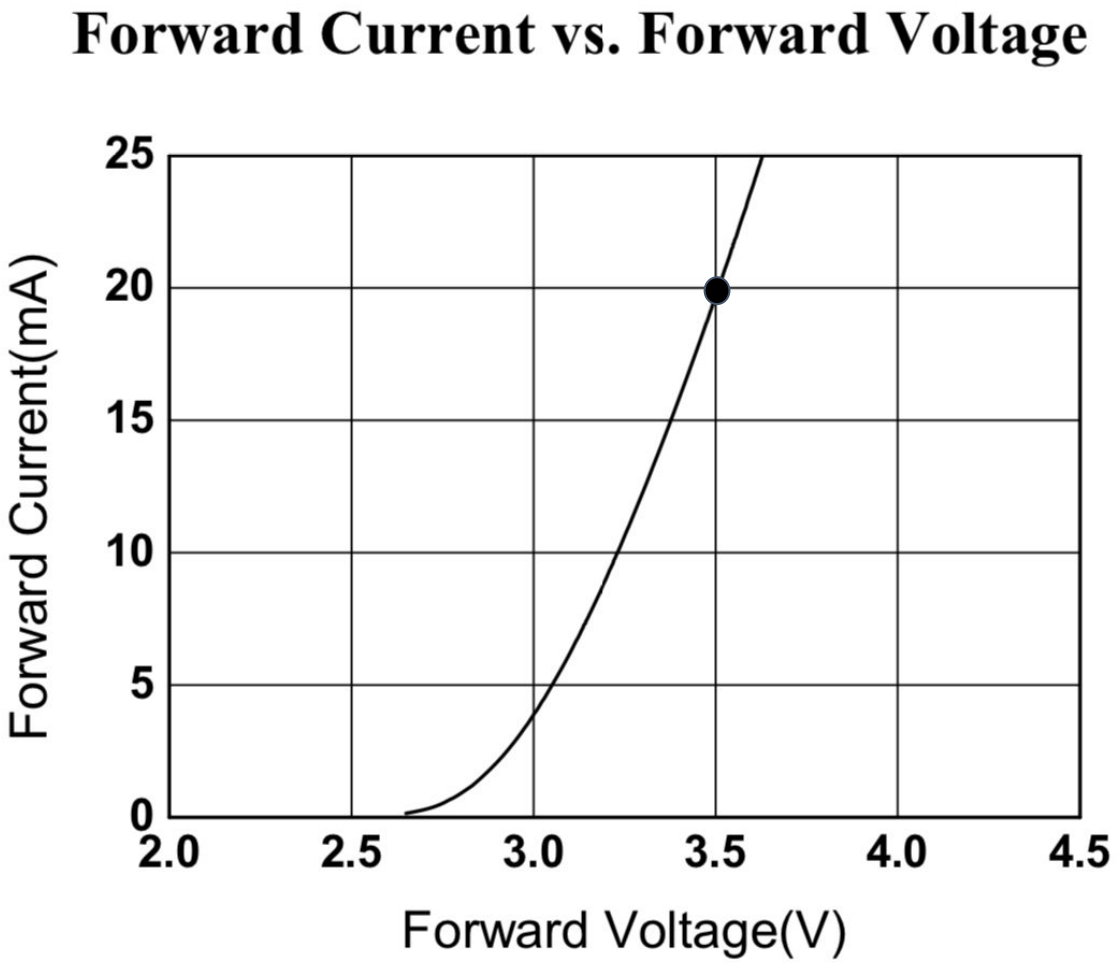
Light Emitting Diodes (LEDs)

- A **LED** is a two-terminal **diode** that **emits light** when current passes through it.
- It acts like a normal diode otherwise.
- It is important, however, to maintain a constant current for a steady brightness.
  - That value is usually listed in a datasheet.
  - Every color of LEDs have a different relationship between voltage and resistor.



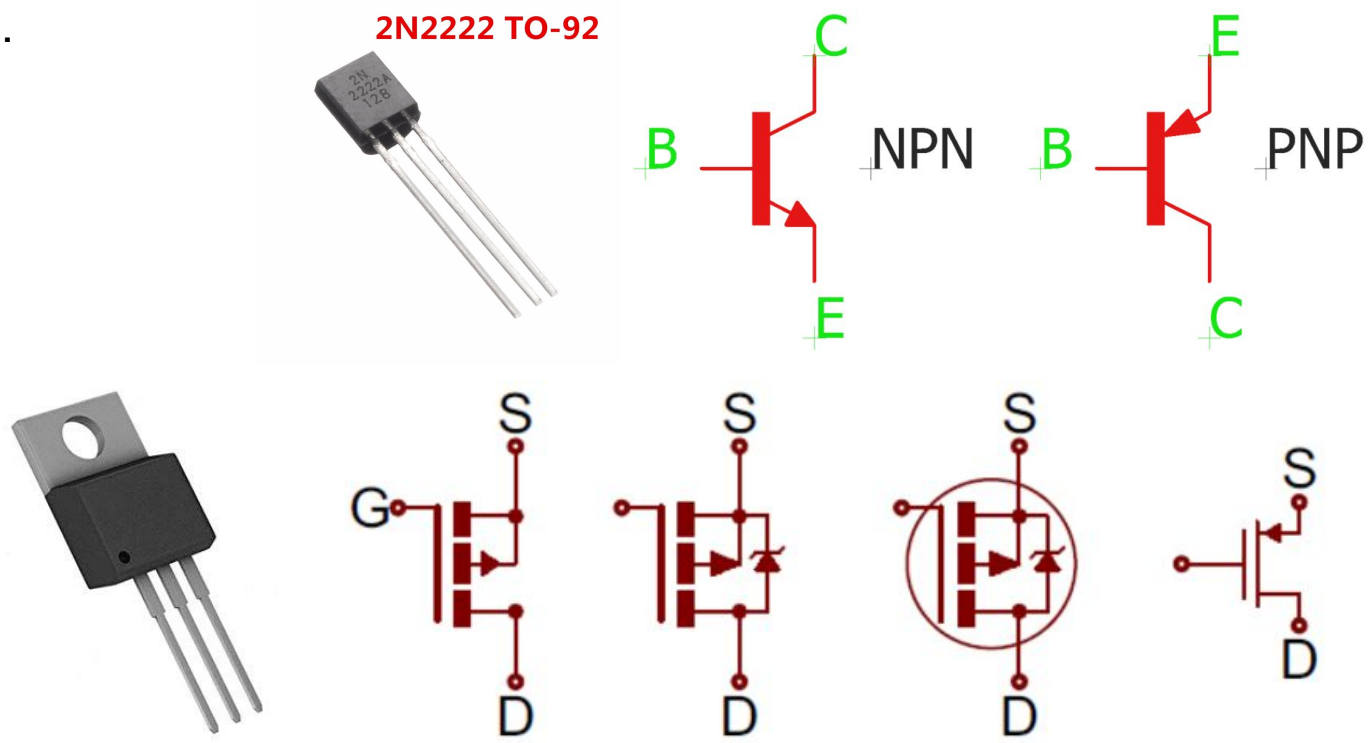
LED Applications

- The goal is to send a **constant current** to the LED.
- That means, if we have a known input voltage into the circuit, we need to figure out what resistor we need in series with the LED.
- It requires use of a **Current vs. Voltage Curves** like the one the right.
- If there is a 5V input, and 20mA needs to go through the LED:
  - We need to have 3.5V through the LED and 1.5V through the resistor (5V - 3.5V = 1.5V) and now apply Ohm's Law.
  - It should be a 75Ω resistor from 1.5V / 20mA = 75Ω.



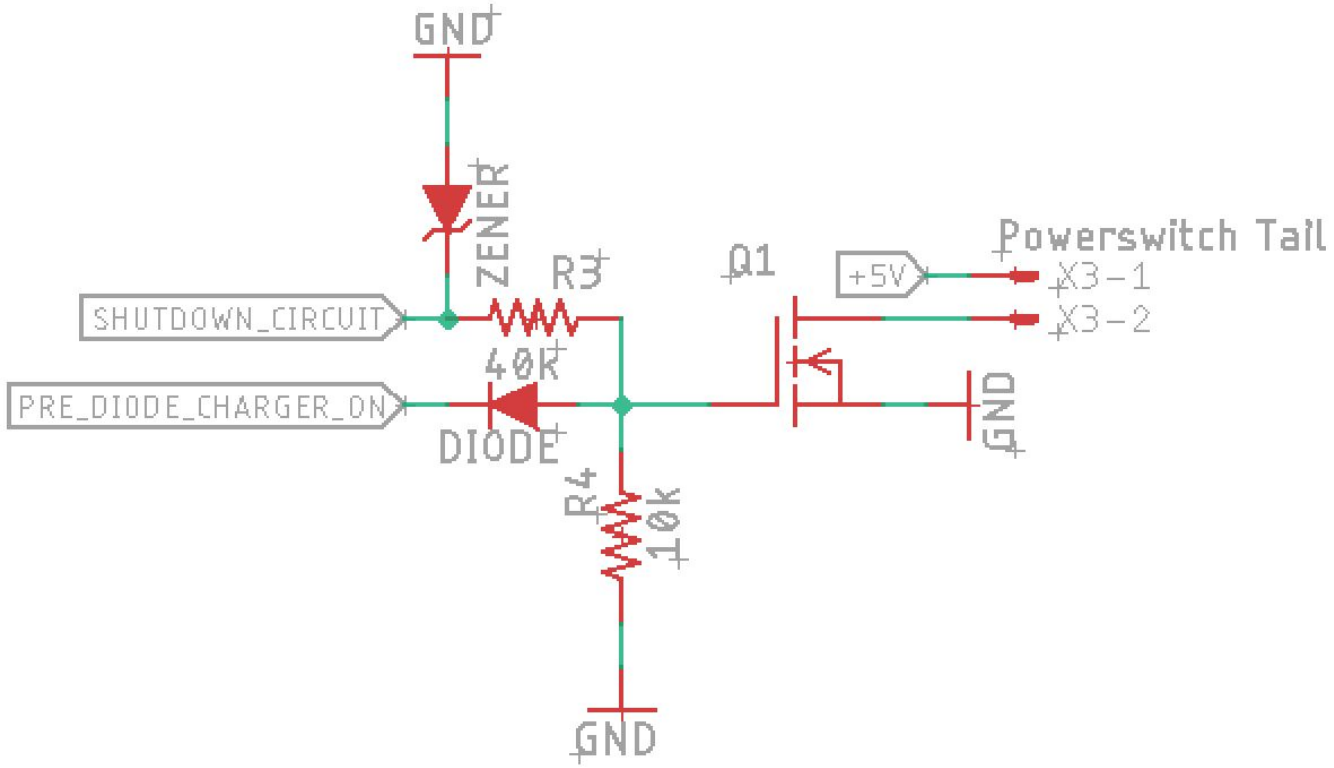
Transistors

- A **transistor** is a semiconductor device used to amplify or switch electronic signals, usually with three terminals.
- Similar to diodes, there are several types:
  - **BJTs** (top on the right) are one major type.
  - **MOSFETs** (bottom on the right) are the other major type that HyTech prefers to use.
- For each type, there are two versions:
  - **Normally open**
  - **Normally closed**



Transistor Applications

- A MOSFET (**Q1** in the schematic) here is used for switching on and off the charger.
  - The charger connection (**X3** in the schematic) is considered the **load**, which is what the transistor is controlling.
  - This transistor is **low side switching**, meaning that the transistor is after the load and between it and ground.
  - This is opposed to **high side switching**, which has the transistor between power and the load.



Training Schedule

Date	Time	Location	Theme
Sunday 9/8	4:00pm - 6:00pm	SCC (Shop) AP Classroom	EAGLE
Tuesday 9/10	6:30pm-8:15pm	SCC (Shop) AP Classroom	Arduino
Thursday 9/12	6:30pm-8:15pm	Invention Studio	Soldering and Car Circuitry/EAGLE
Sunday 9/15	4:00pm - 6:00pm	SCC (Shop) AP Classroom	Safety