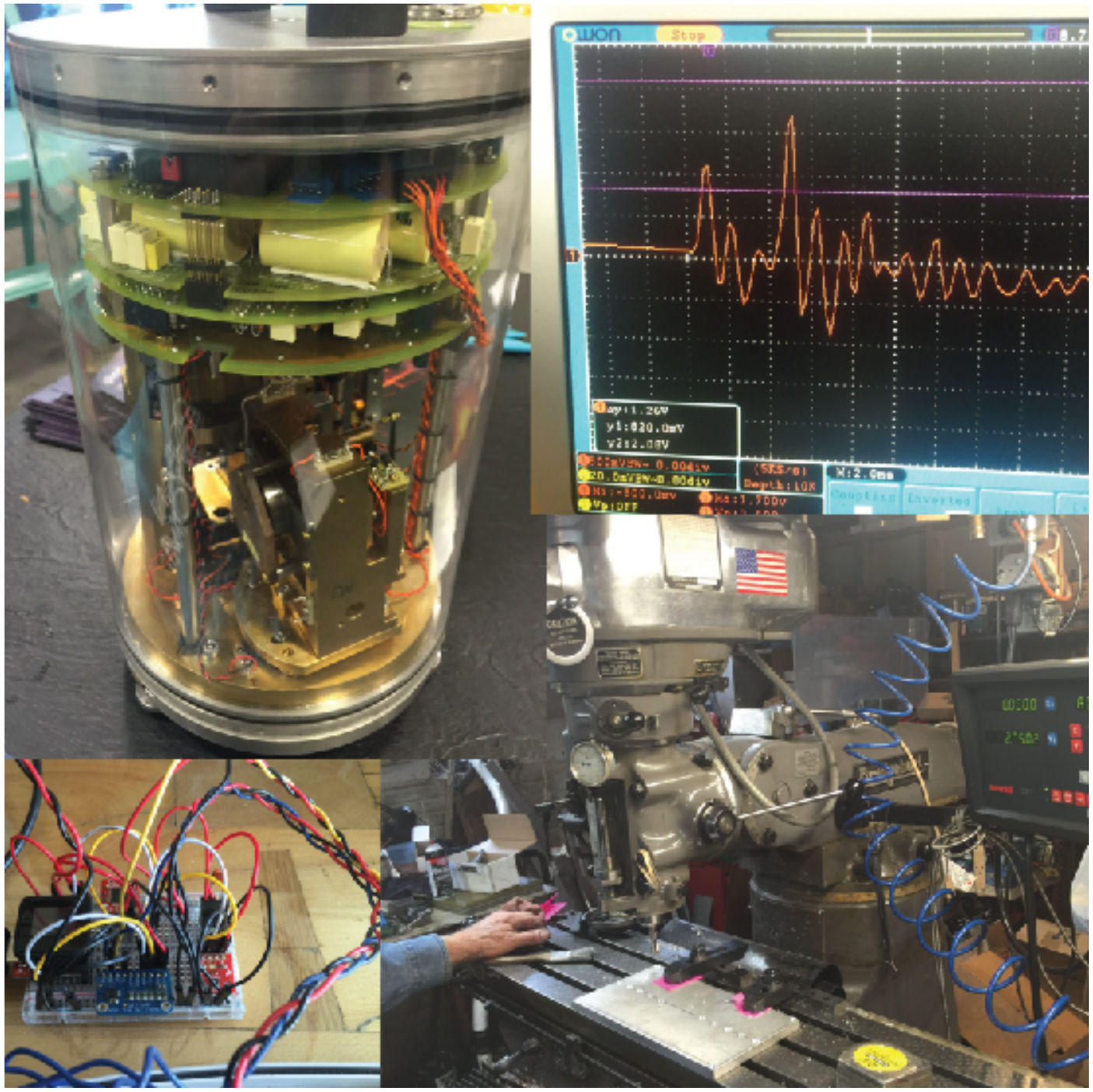
Electronics Components and Schematics

J.R. Leeman and C. Marone

Techniques of Geoscientific Experimentation

October 11, 2016



Today we will cover components, schematics, and basic circuit analysis - which is a lot of material

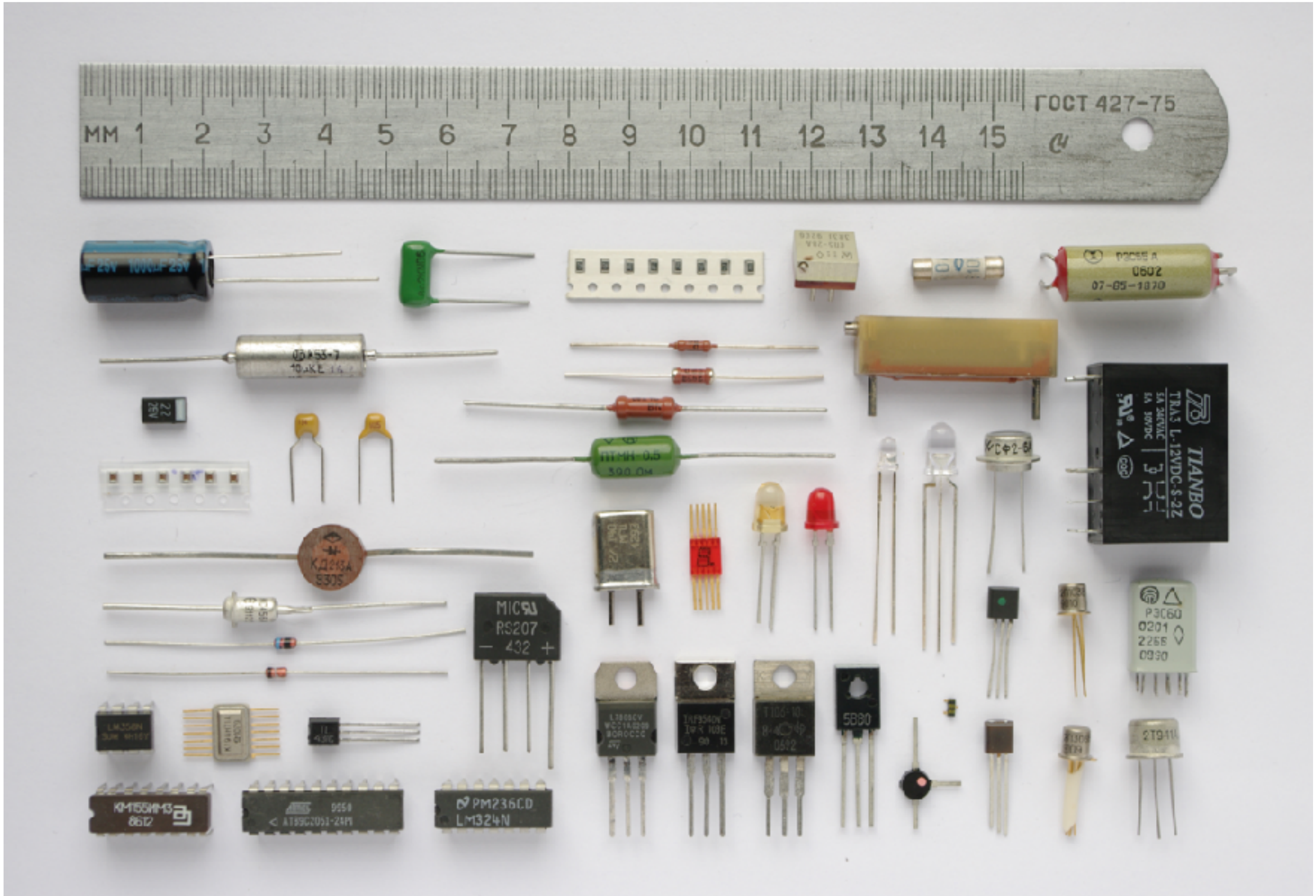


Image: Wikipedia

Electronics Fundamentals

Electric circuits are closed loops that electrons flow through.
Electrical energy is the stored electrical potential difference

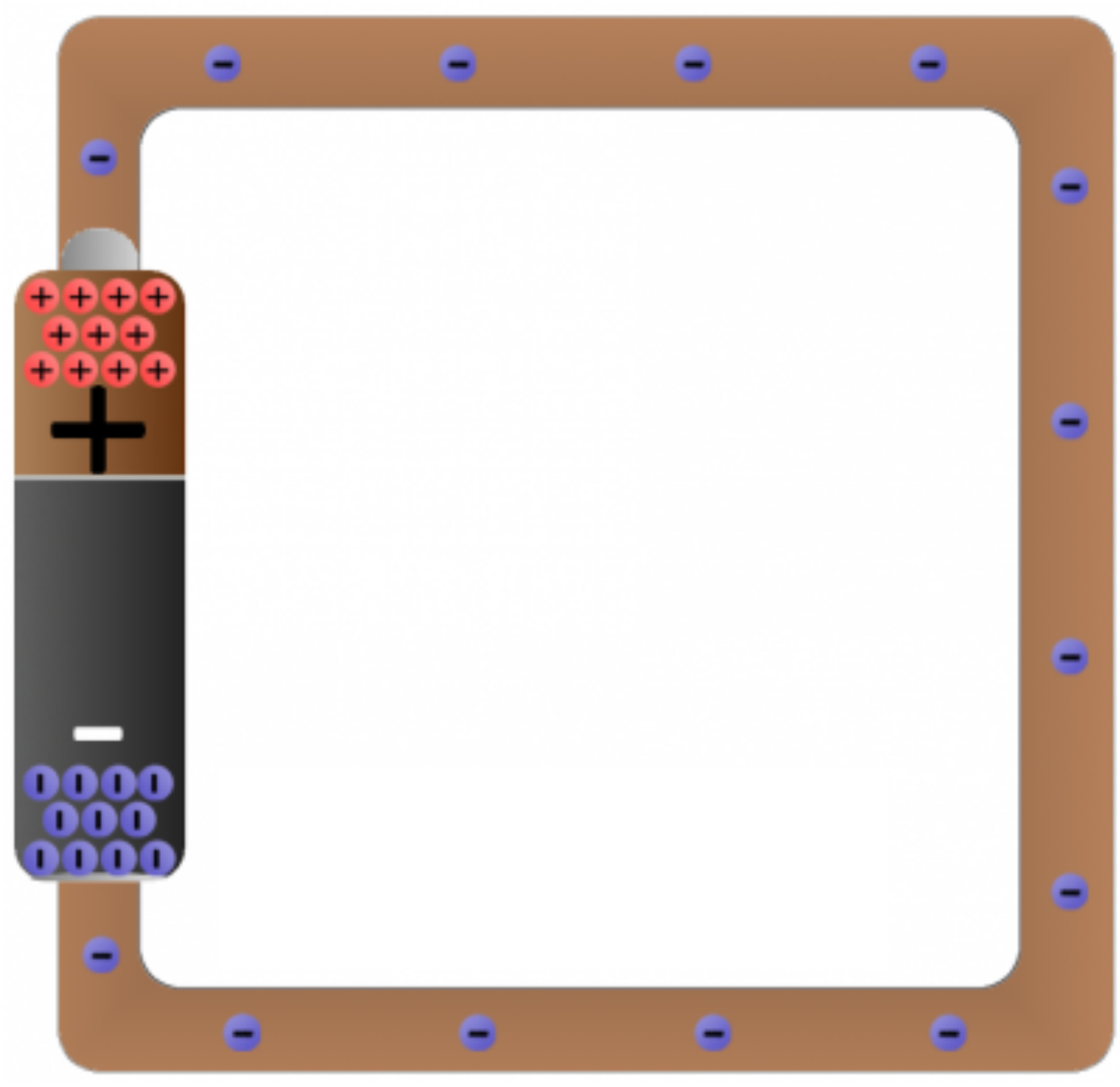


Image: Sparkfun

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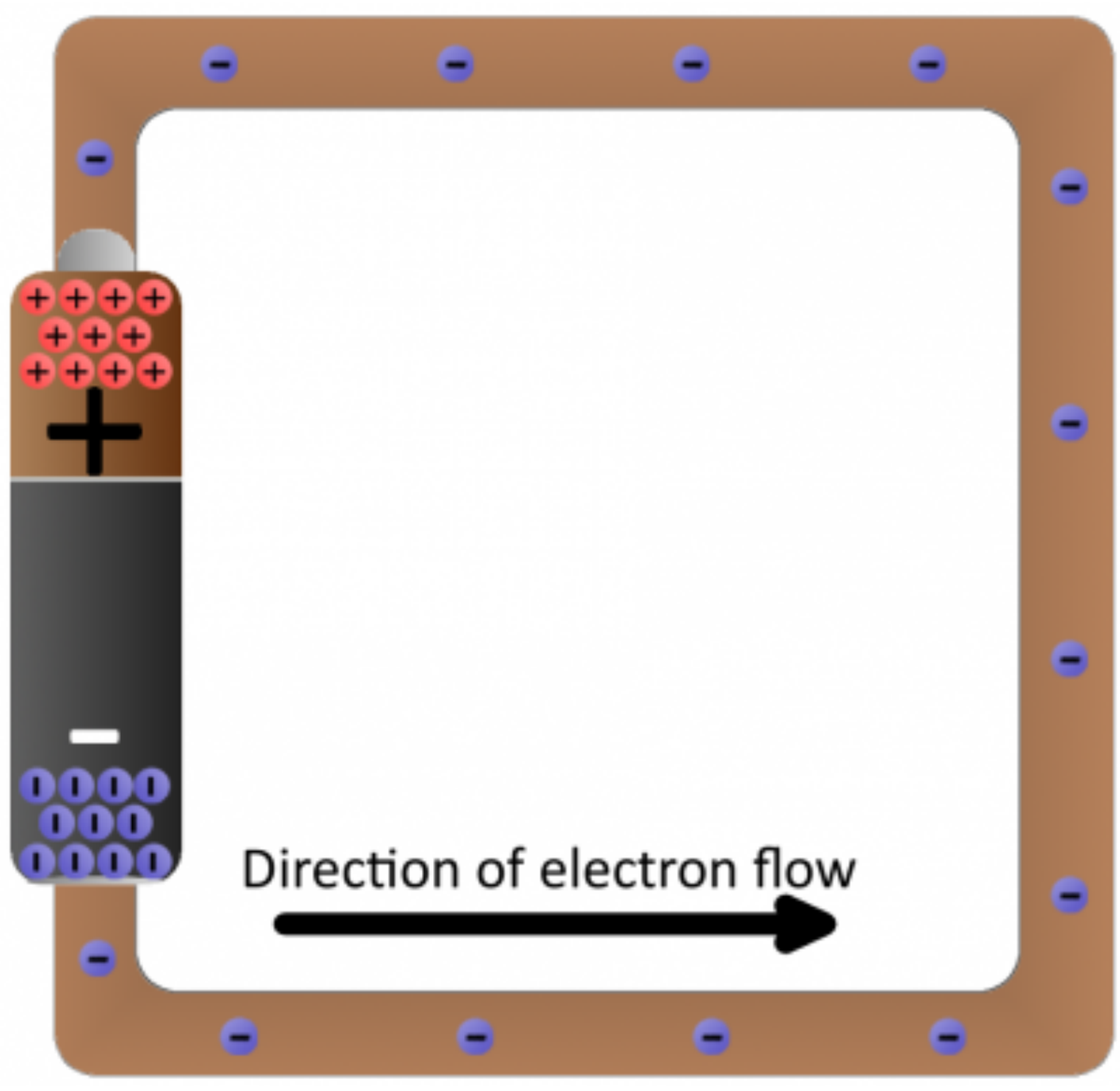


Image: Sparkfun

Often circuits are thought of in terms of conventional current flow, not electron flow

Image: XKCD

We'll start by looking at voltage, current, resistance and their relation

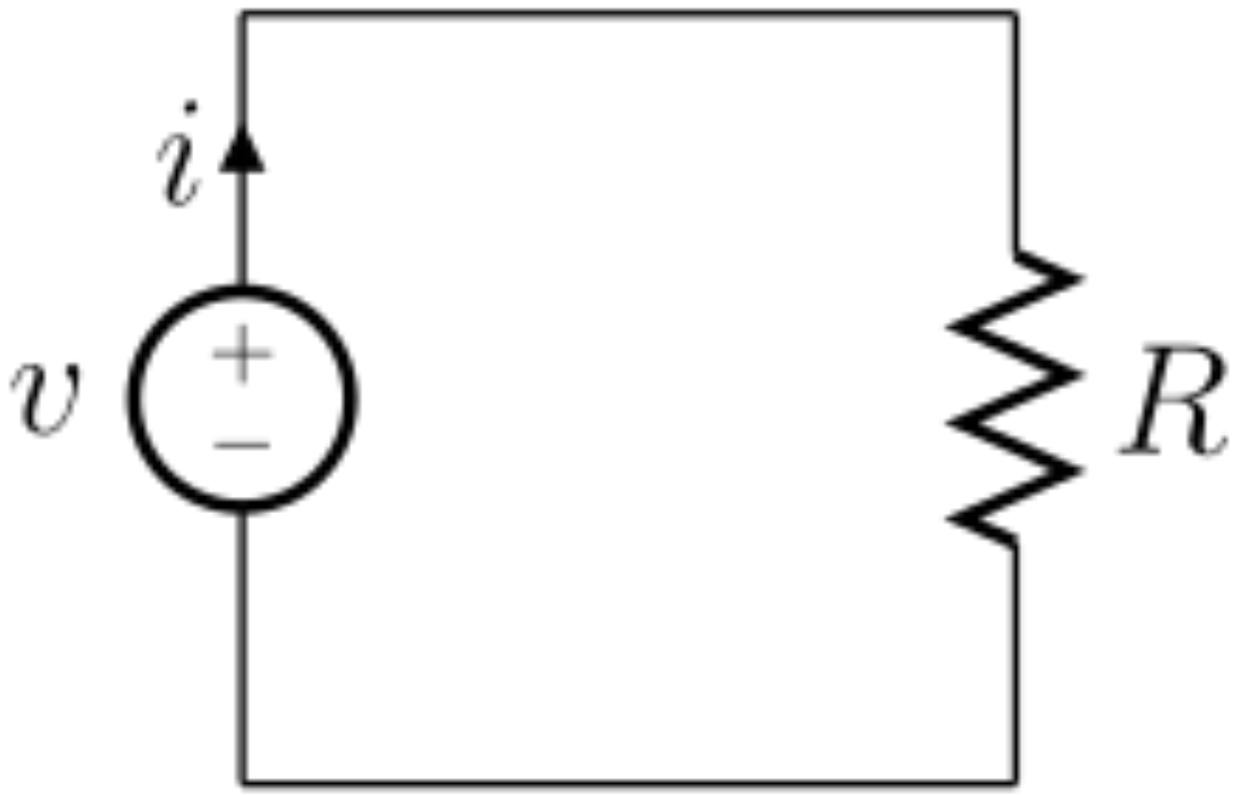
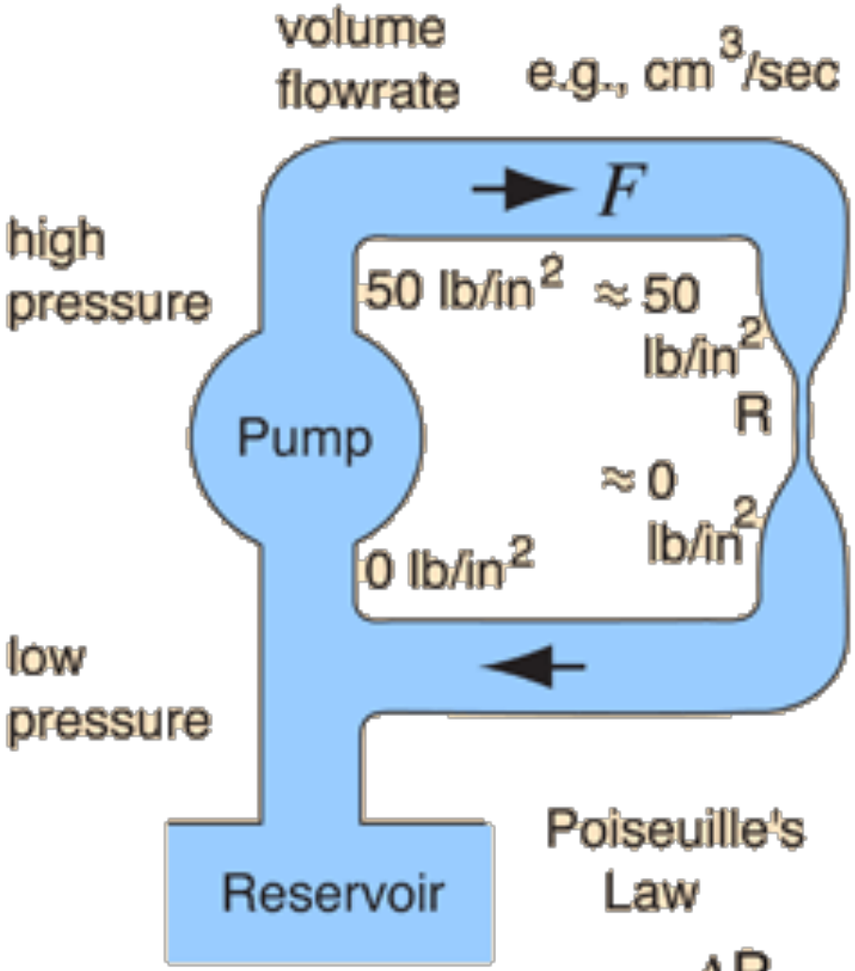


Image: Wikipedia

A water system is used as a common analogy



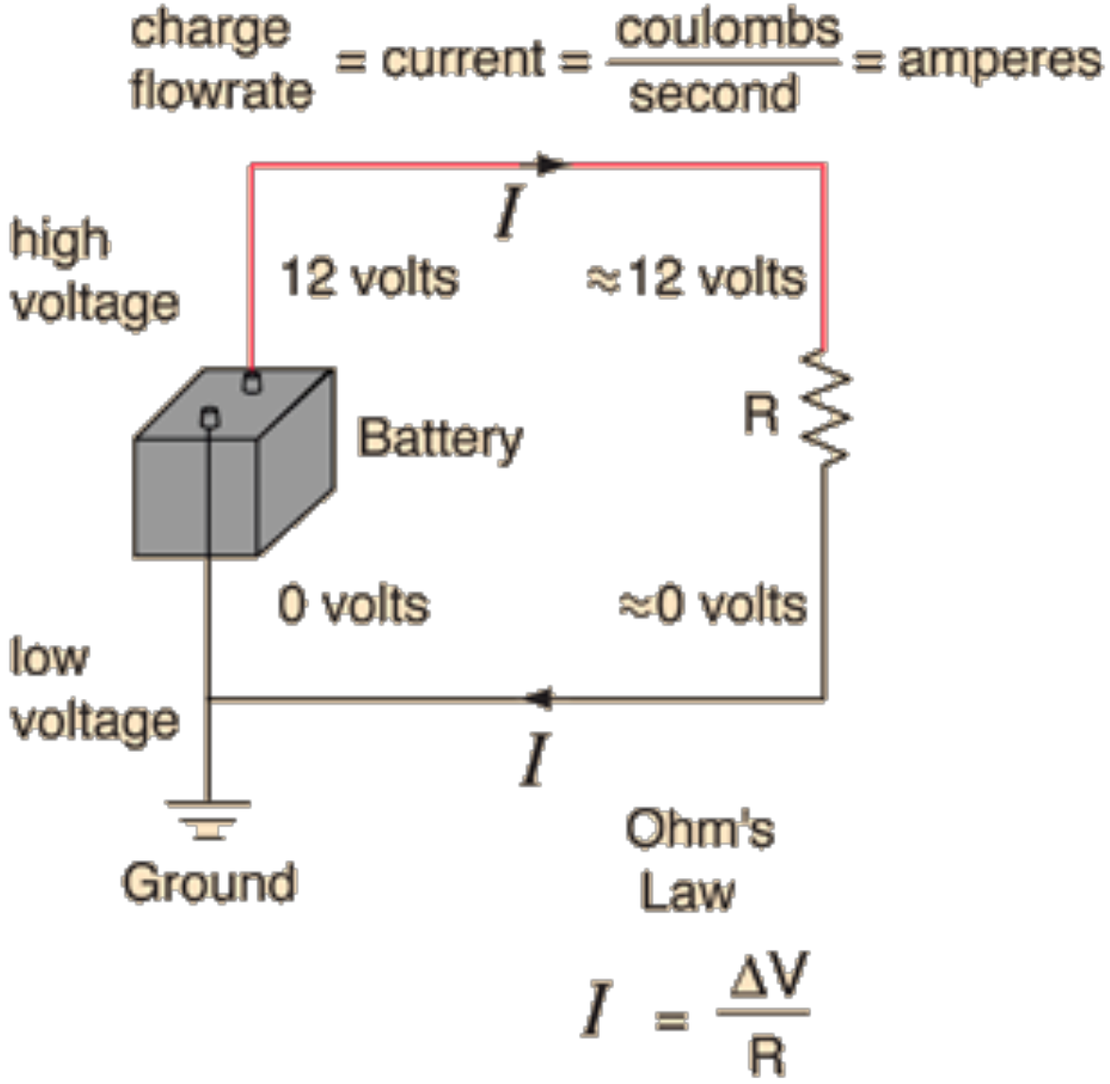


Image: Hyperphysics

Voltage is similar to water pressure in a hydraulic system

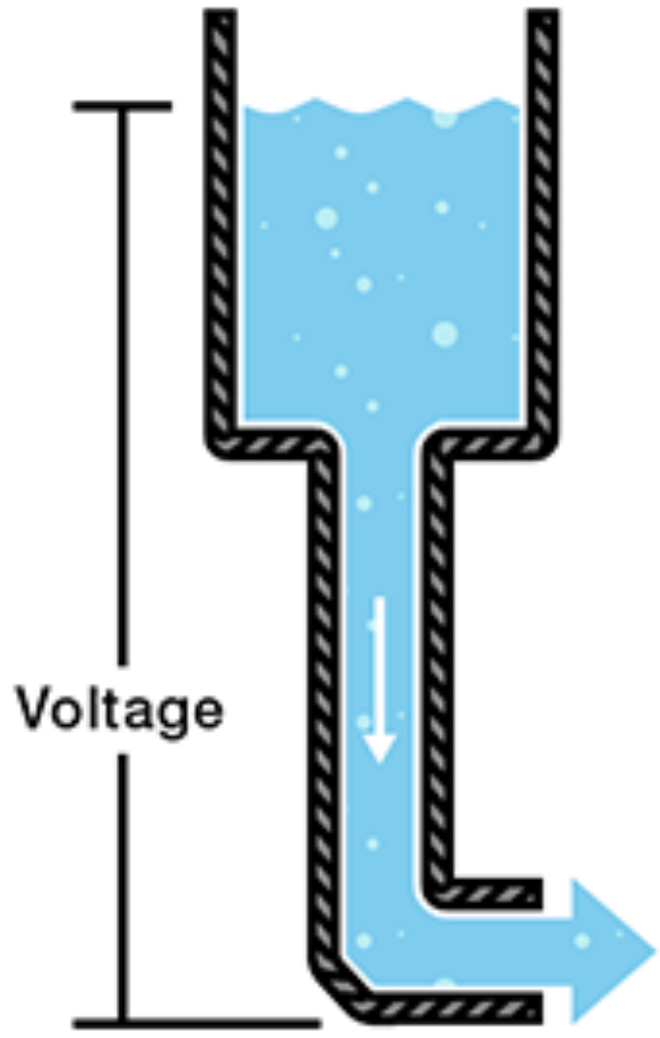


Image: Sparkfun

Current is analogous to water flow

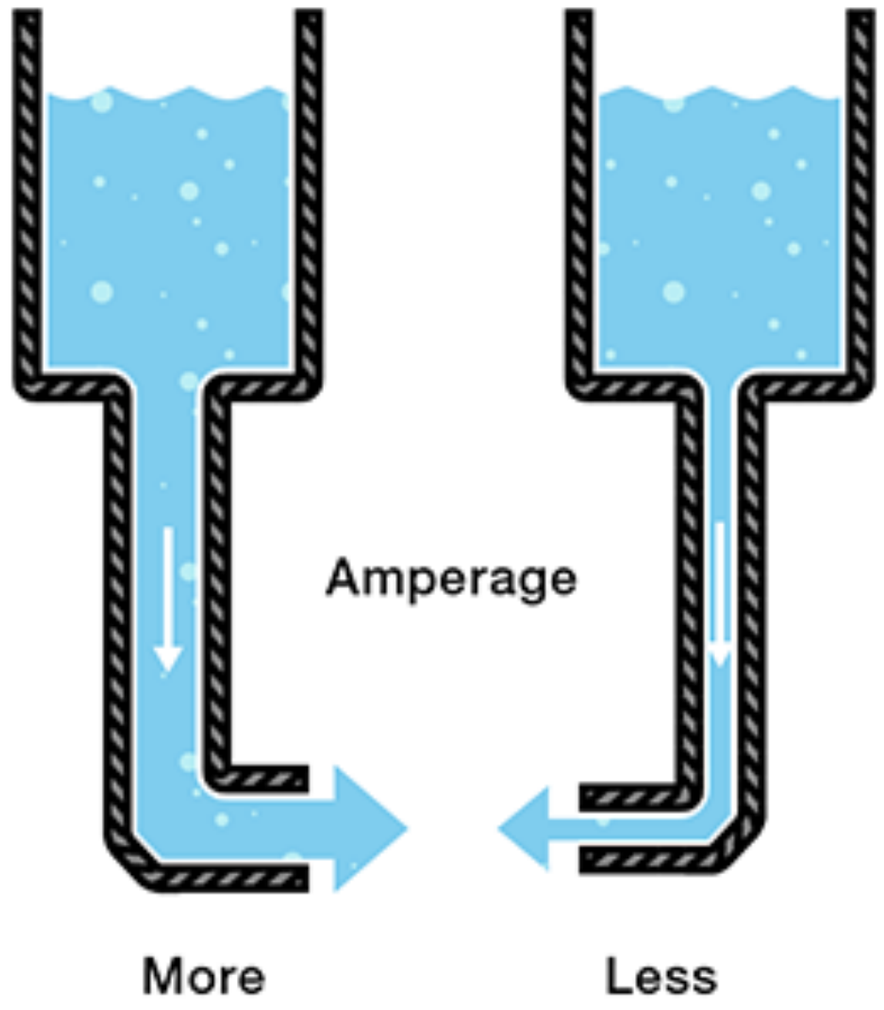


Image: Sparkfun

Resistance is similar to flow limits due to the water pipe size

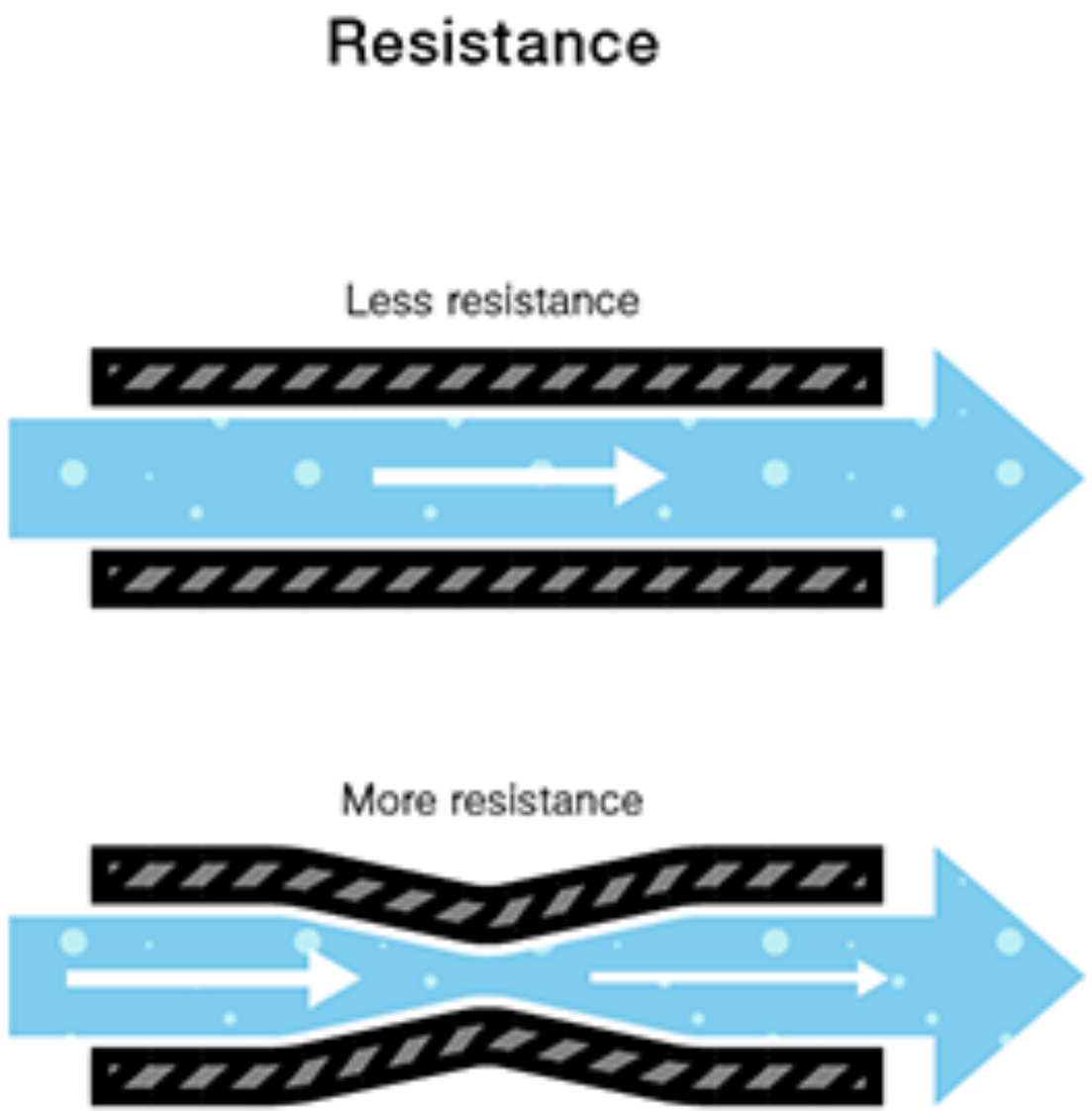


Image: Sparkfun

Voltage, Current, and Resistance are all related

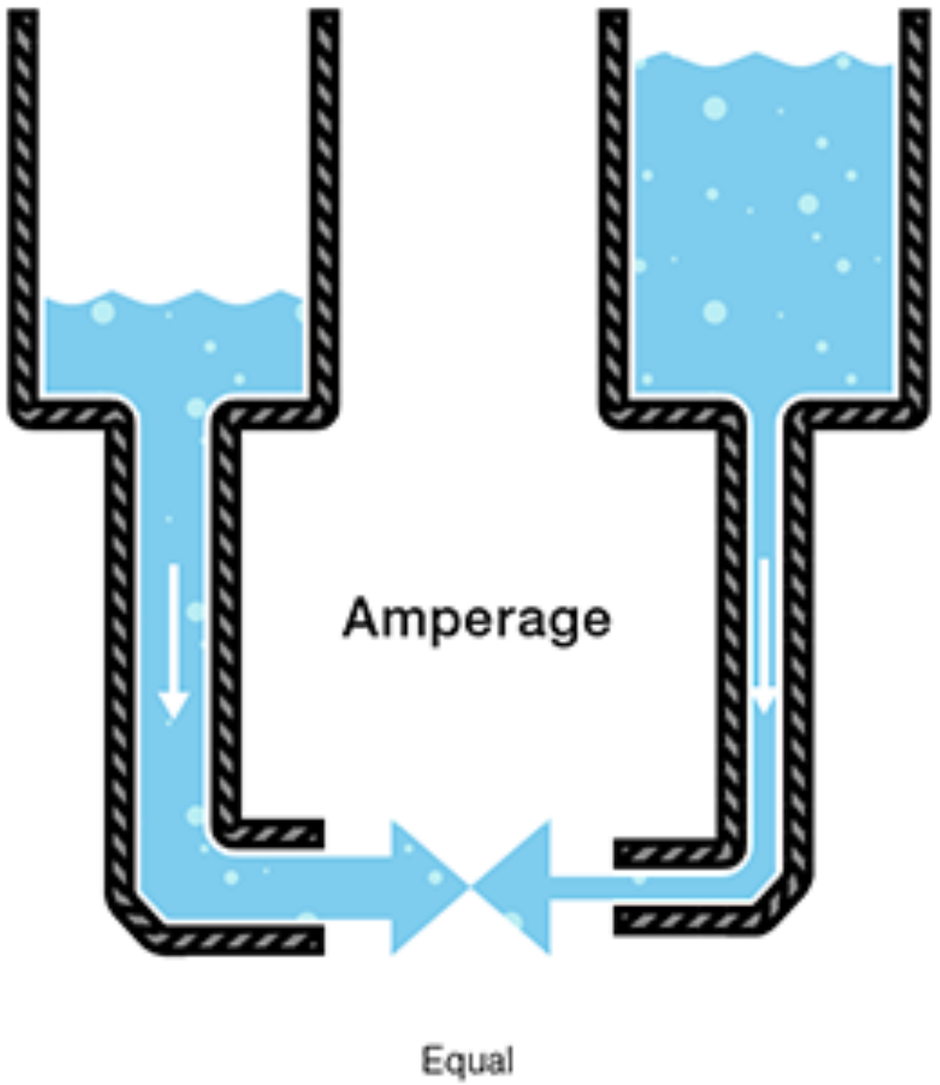


Image: Sparkfun

Kirchhoff’s Laws

Kirchoff's Current Law

At any node (junction) in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node
or equivalently the algebraic sum of currents in a network of conductors meeting at a point is zero.

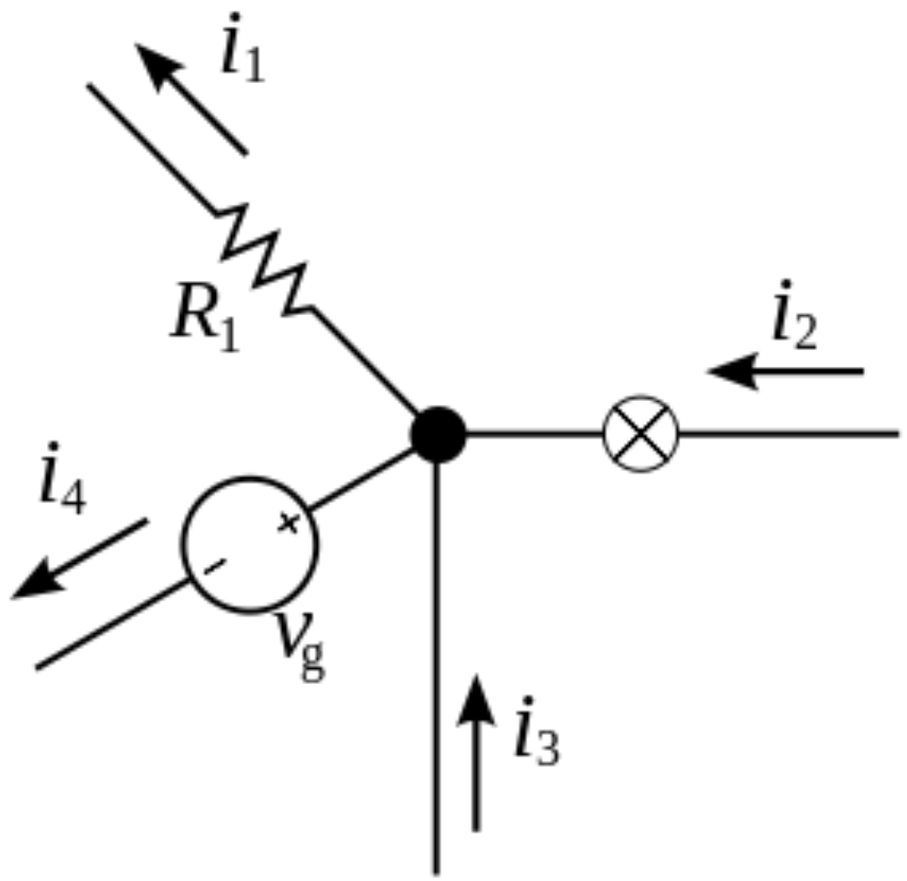


Image: Wikipedia

Kirchoff's Voltage Law

The directed sum of the electrical potential differences (voltage) around any closed network is zero.

More simply, the sum of the emfs in any closed loop is equivalent to the sum of the potential drops in that loop.

The algebraic sum of the products of the resistances of the conductors and the currents in them in a closed loop is equal to the total emf available in that loop.

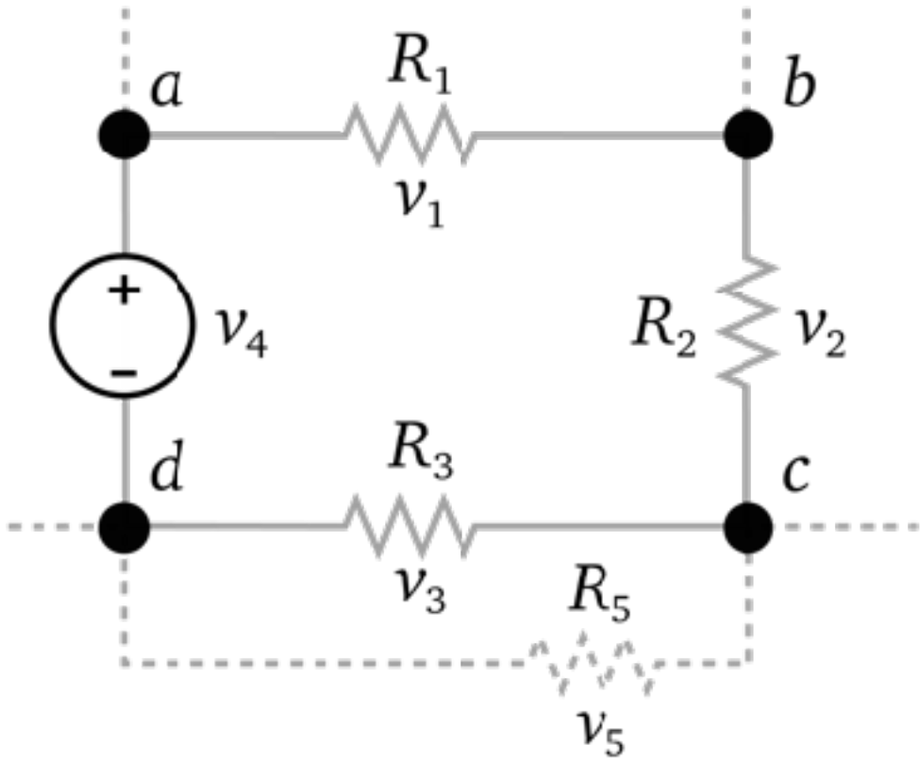


Image: Wikipedia

Ohm’s Law

Ohm’s Law relates voltage, current, and resistance

$$V = I * R$$

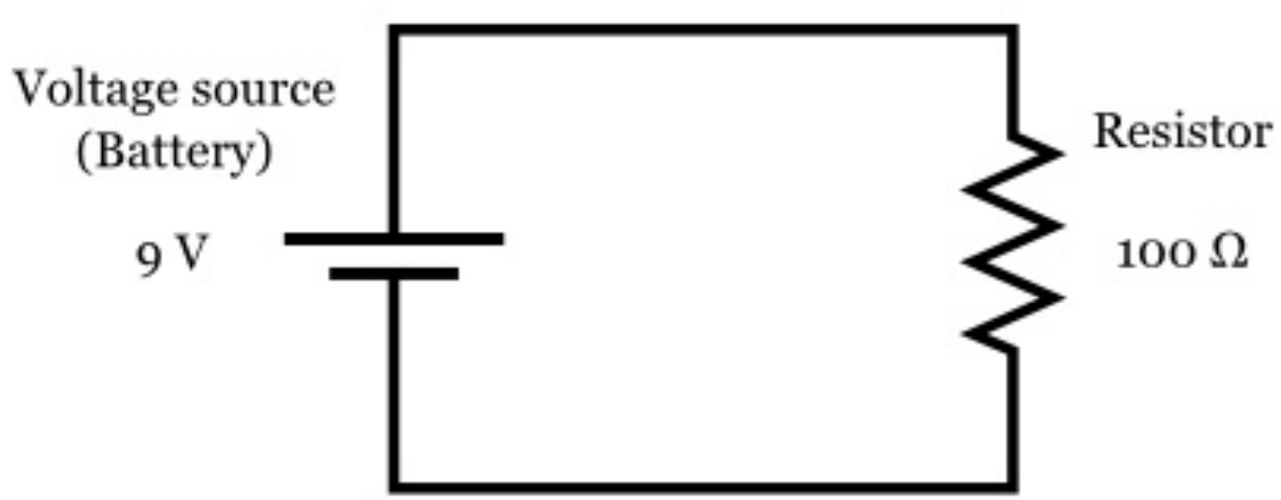


Image: Sparkfun

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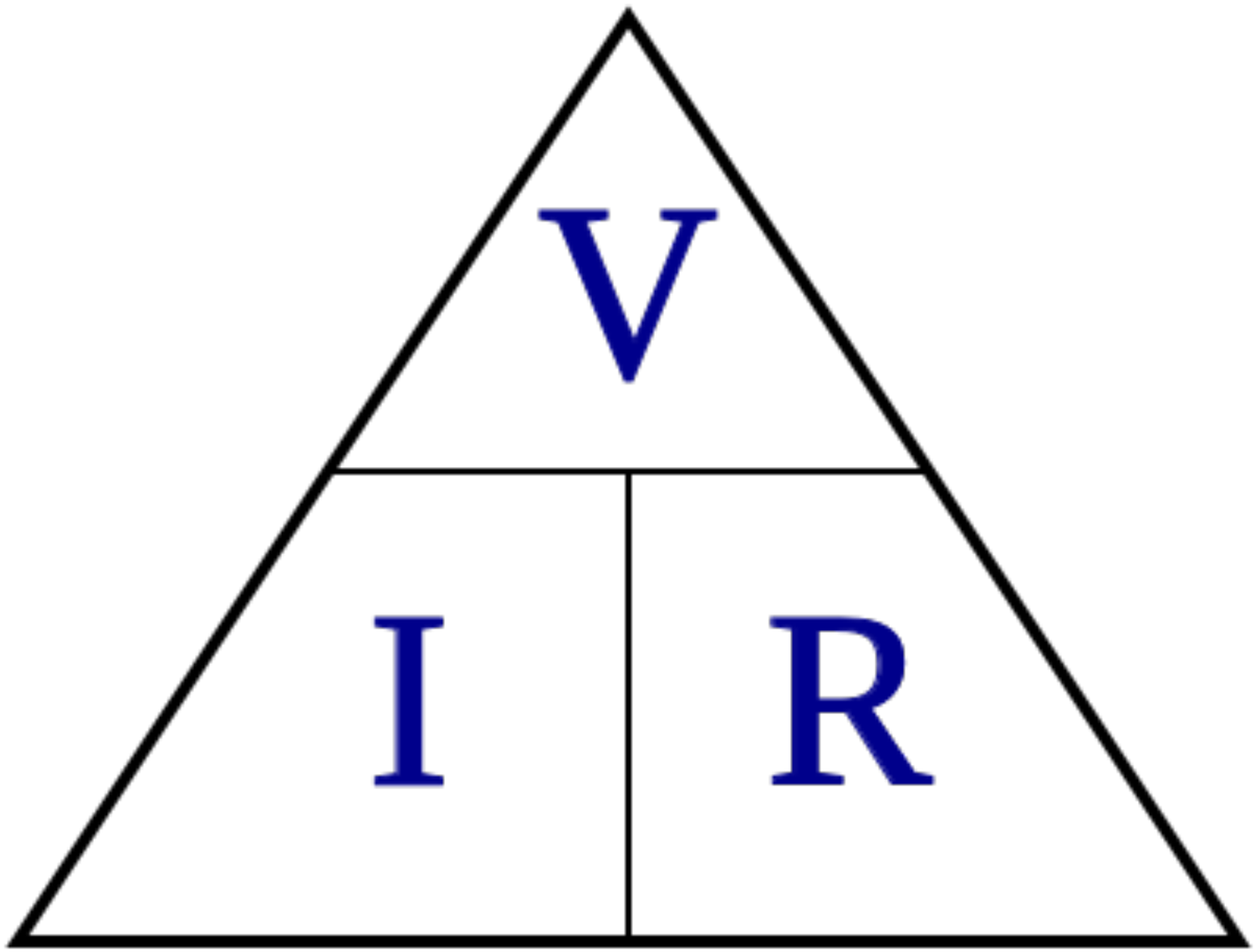

Image: Wikipedia

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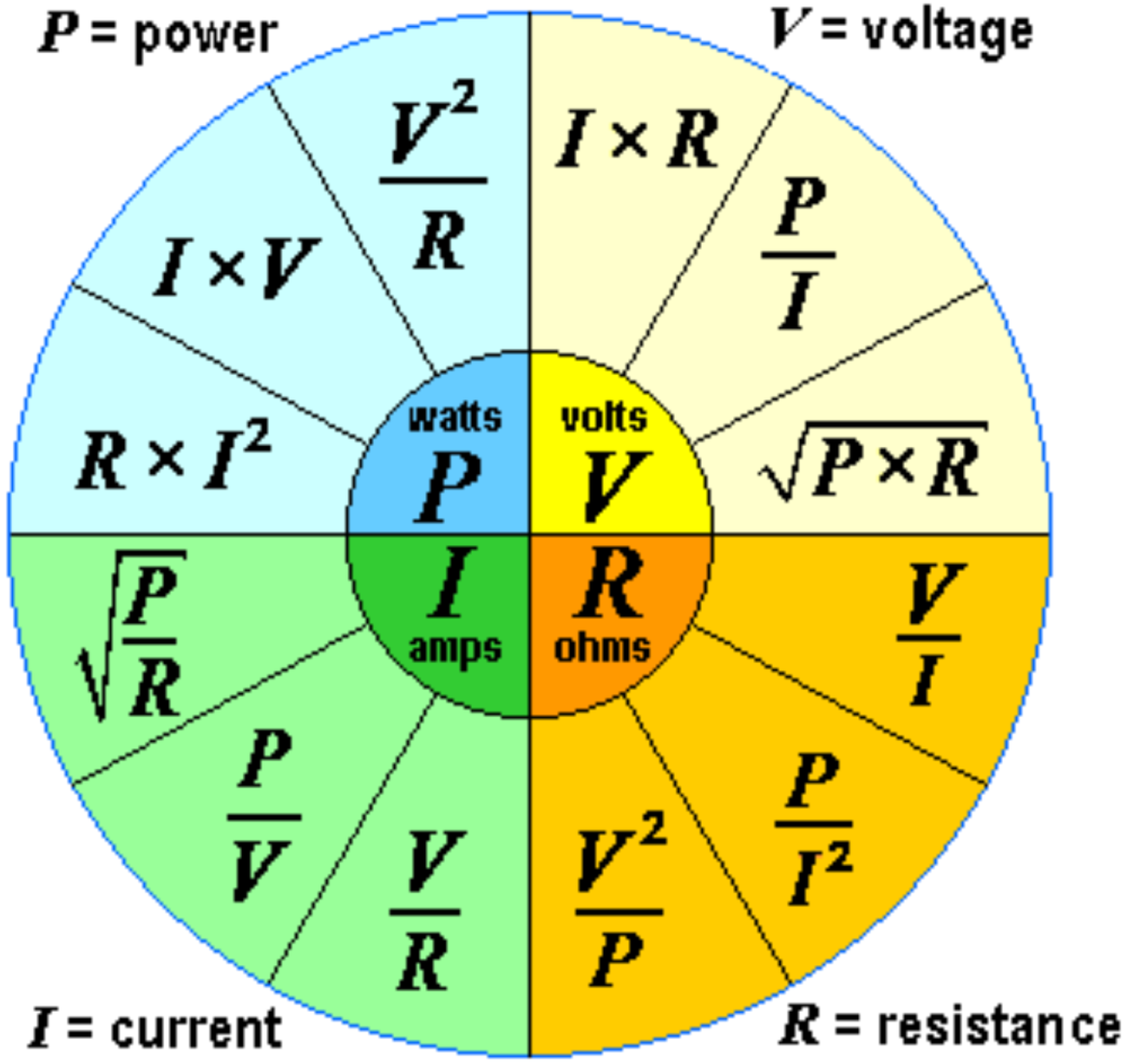
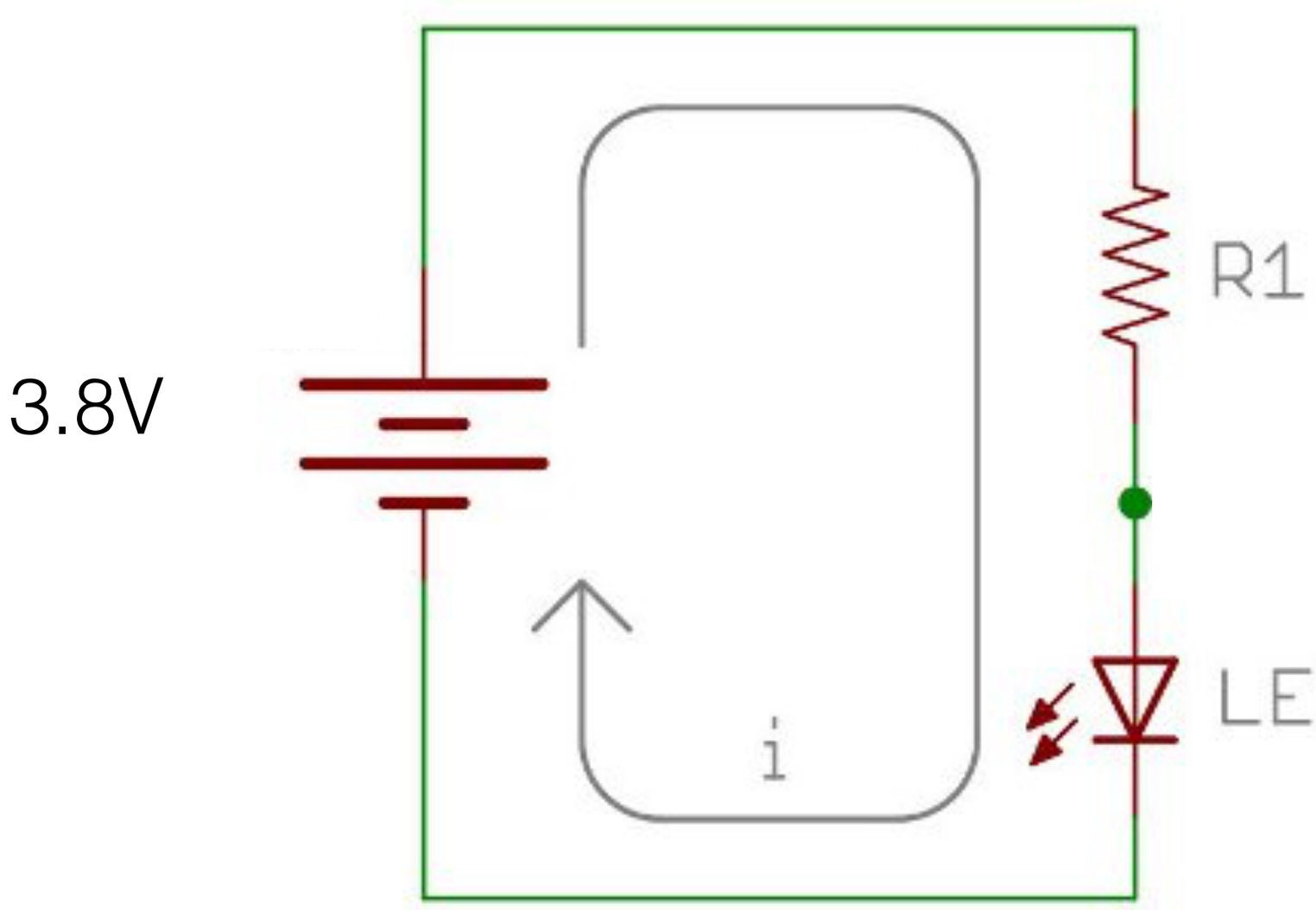


Image: sengpielaudio.com

Let’s calculate the dropper resistor for an LED



Vf = 3.1 V
If = 30 mA

Image: Sparkfun

Your turn!

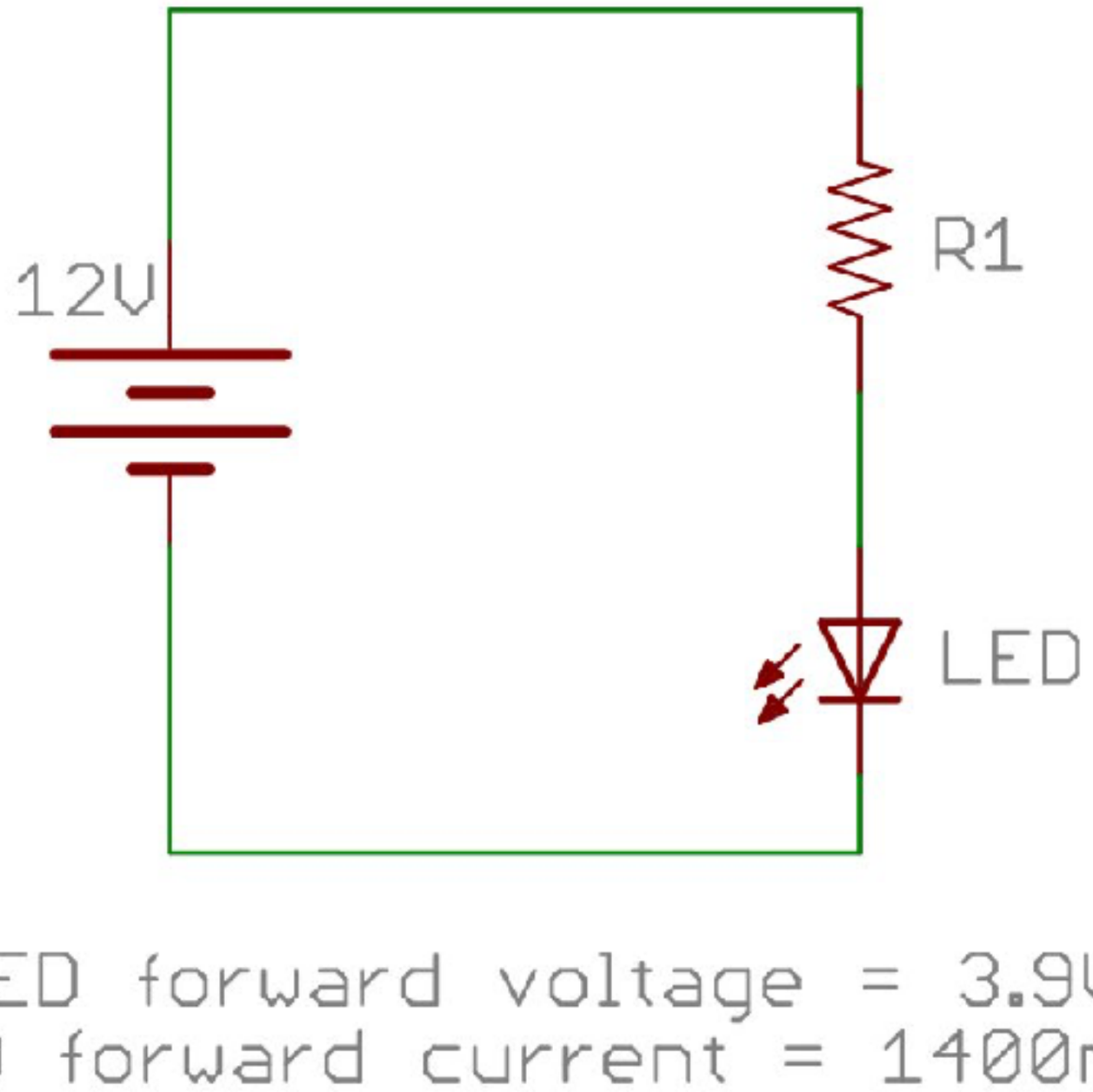


Image: Sparkfun

Now that’s calculate the power that resistor must handle

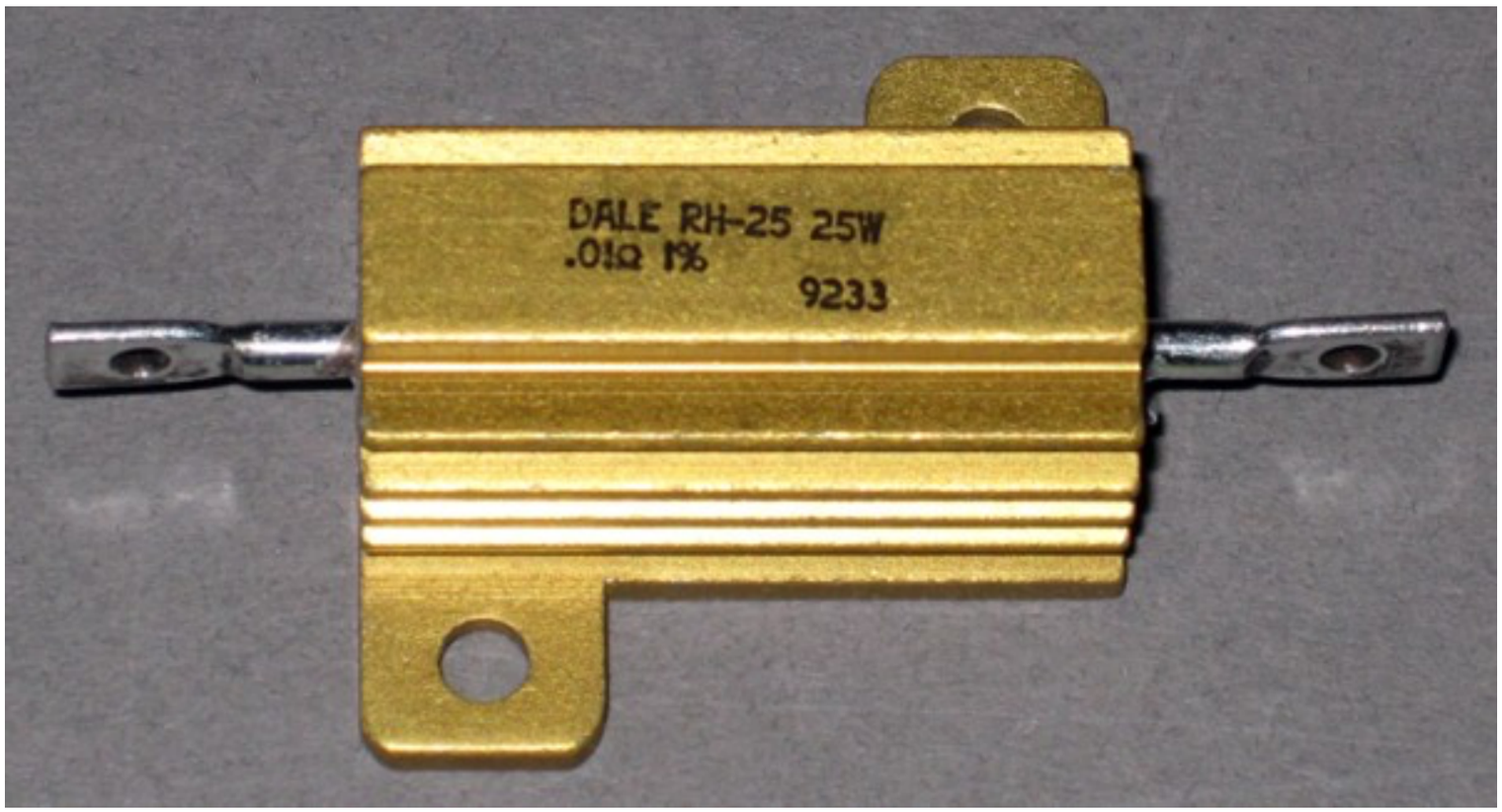


Image: theelectrostore.com

Let’s apply our knowledge to a more complex example

Calculate the currents in this circuit

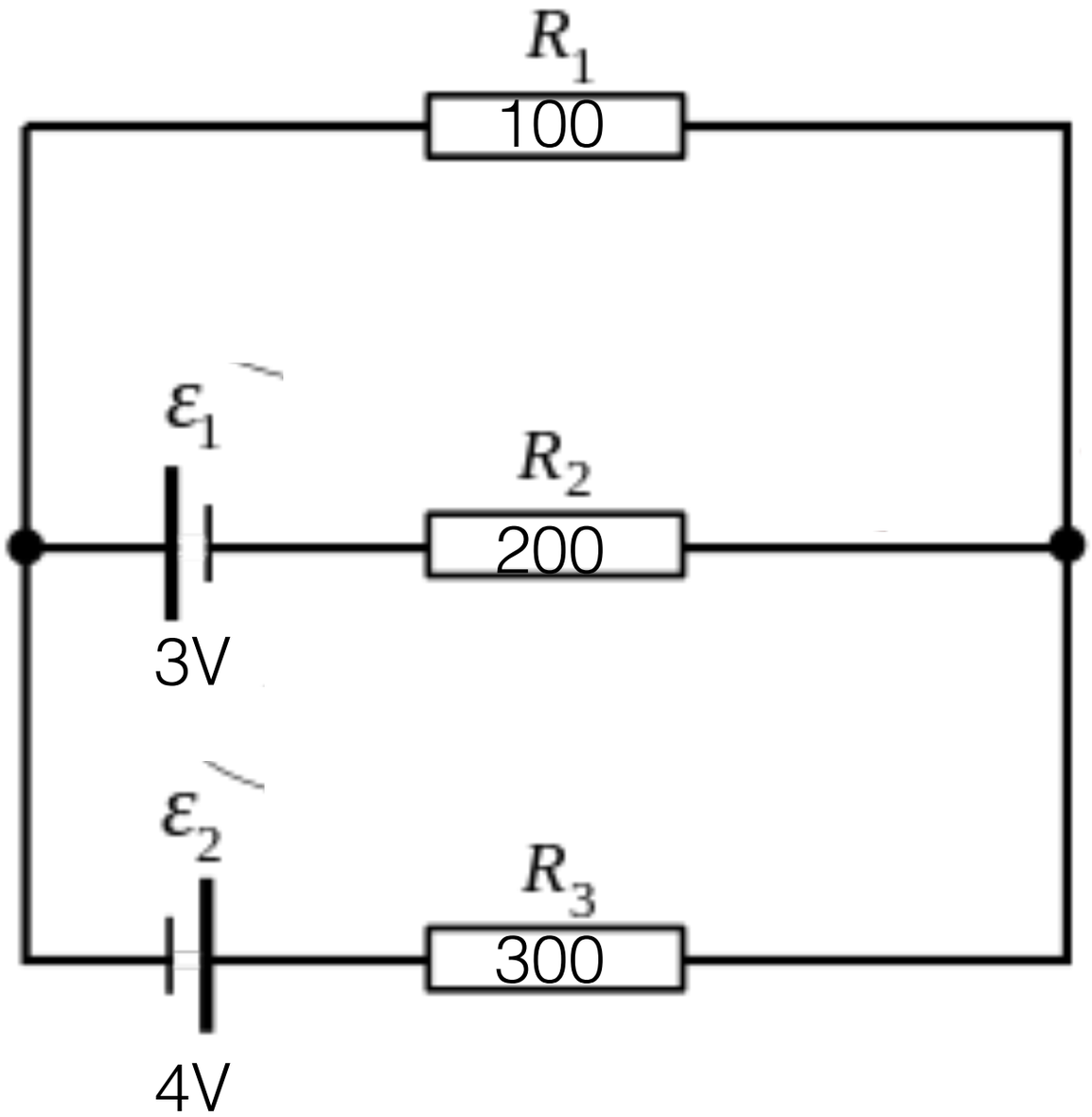
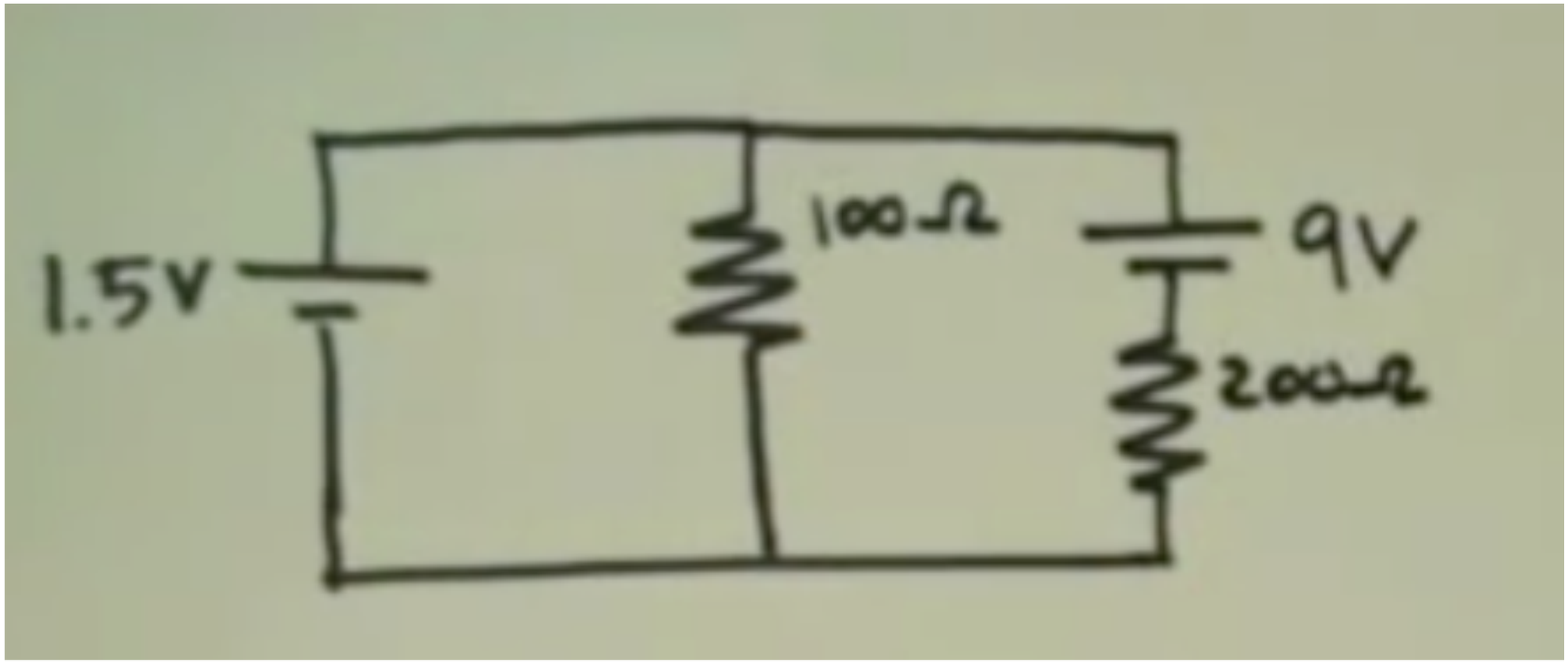


Image: Wikipedia

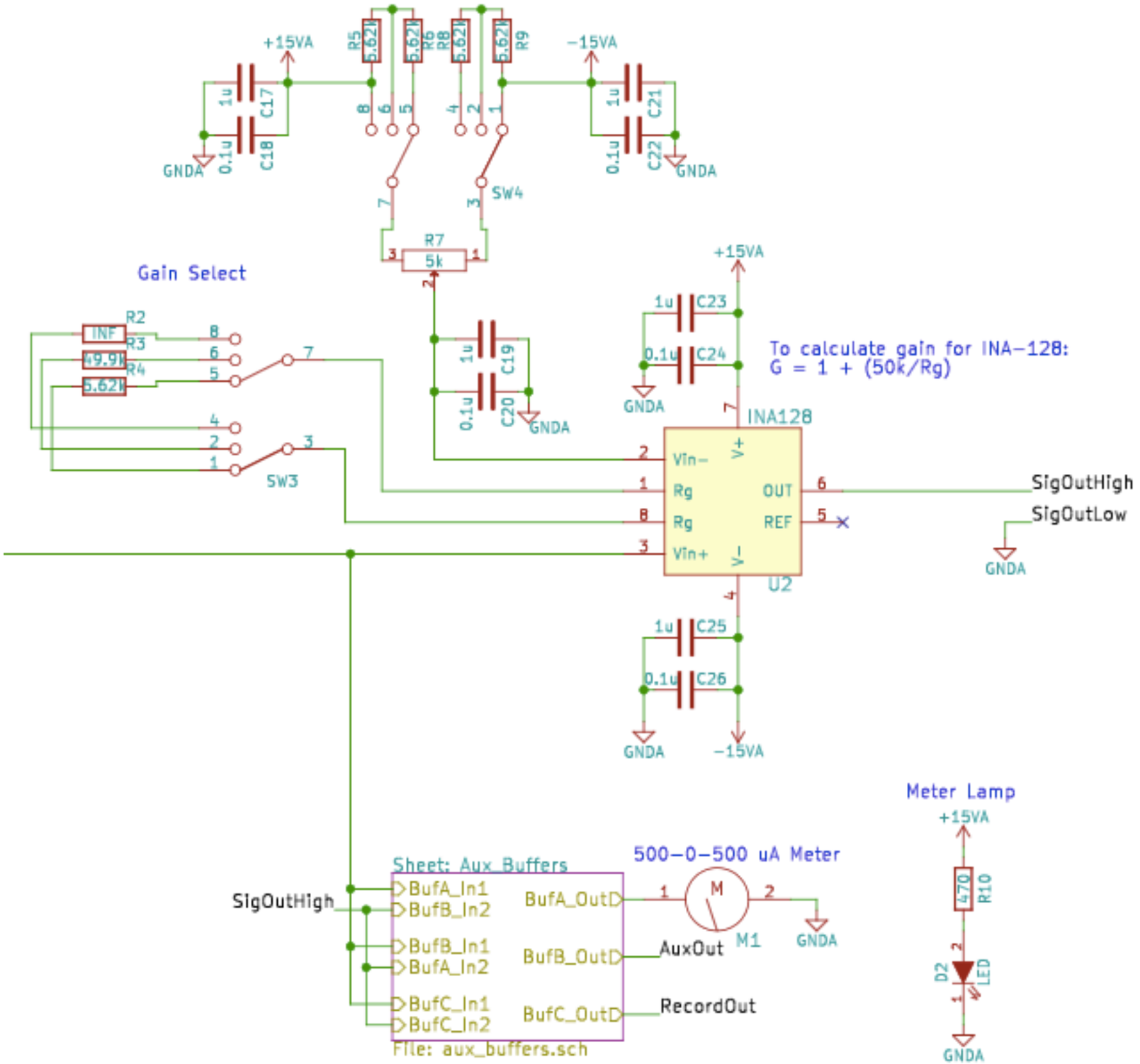
Your turn!

Calculate the currents, resistor voltage drops, and resistor power consumption in this circuit



Reading a Schematic

We draw circuits in schematic diagrams with symbols to represent the parts in the circuit



The symbols are standardized for the basic components

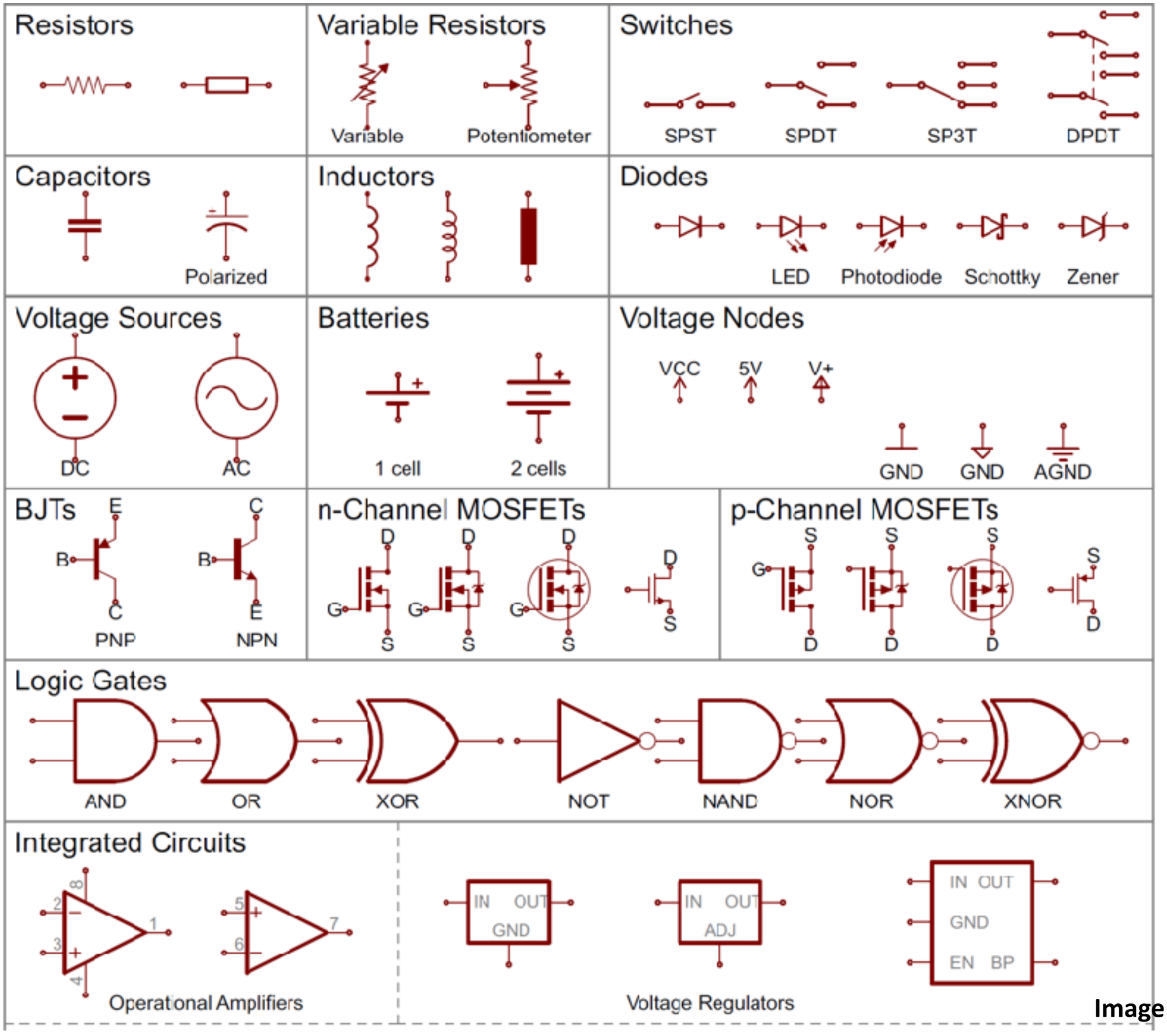


Image: Sparkfun

Junctions mark where wires are connected

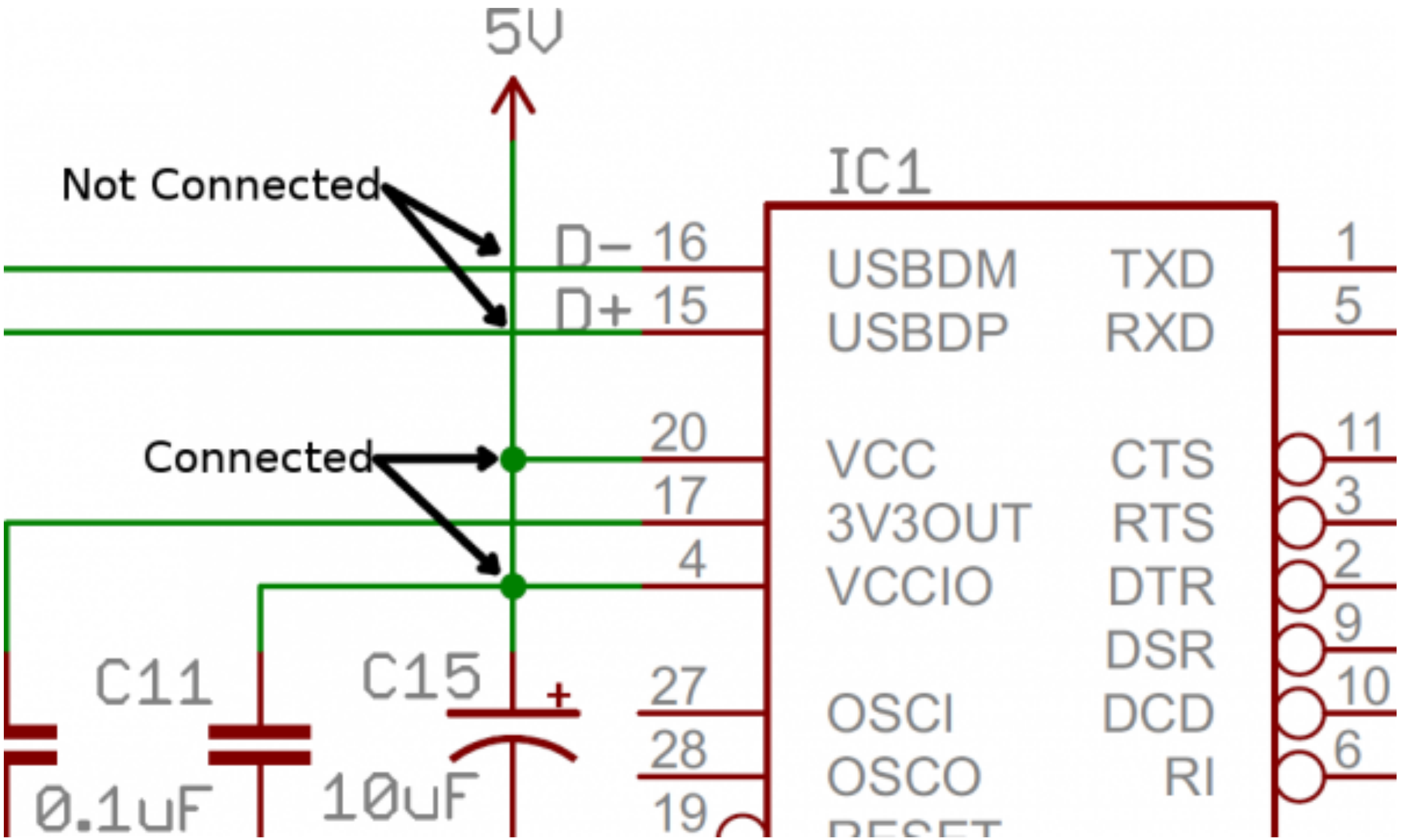


Image: Sparkfun

We also use net name labels to reduce schematic clutter

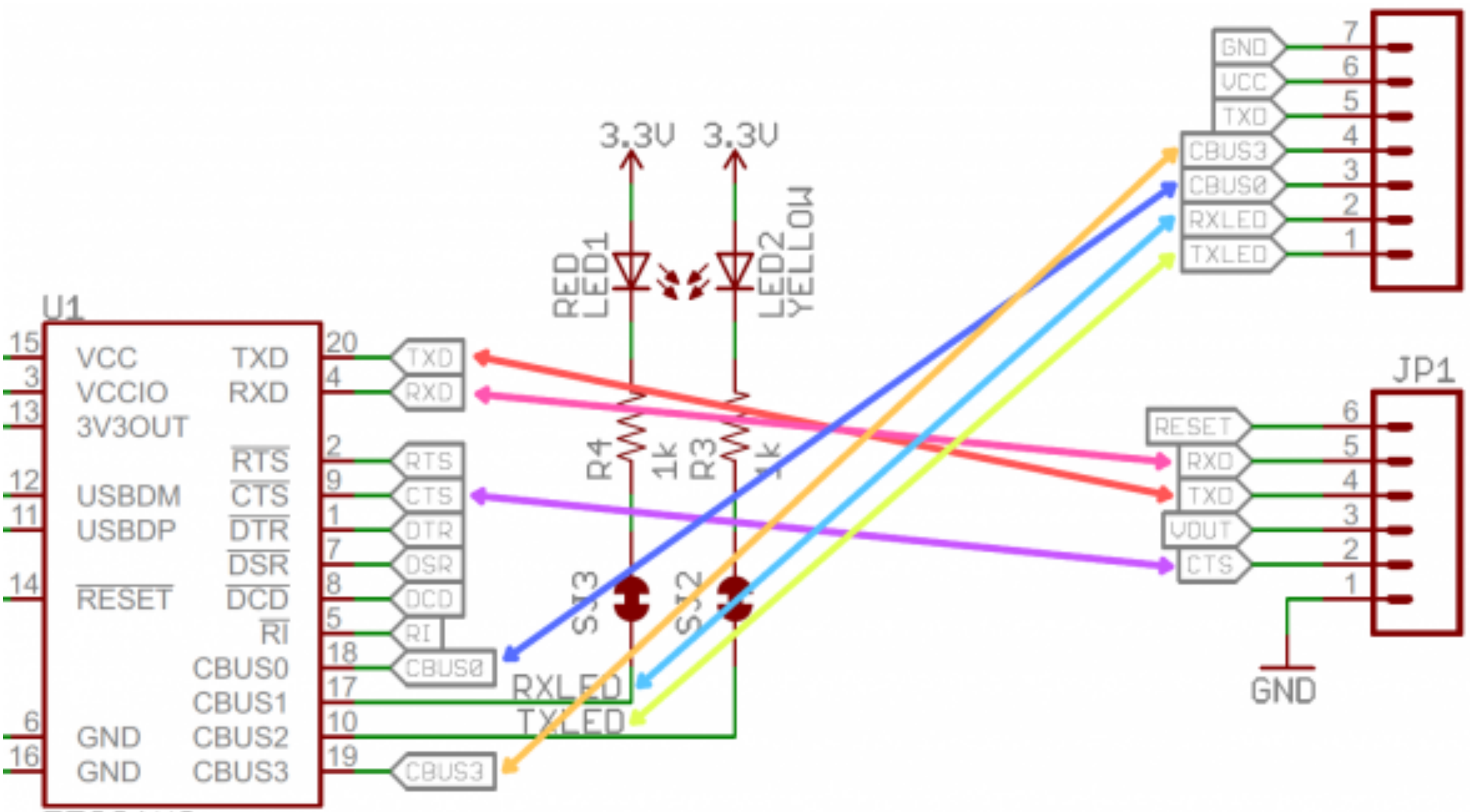
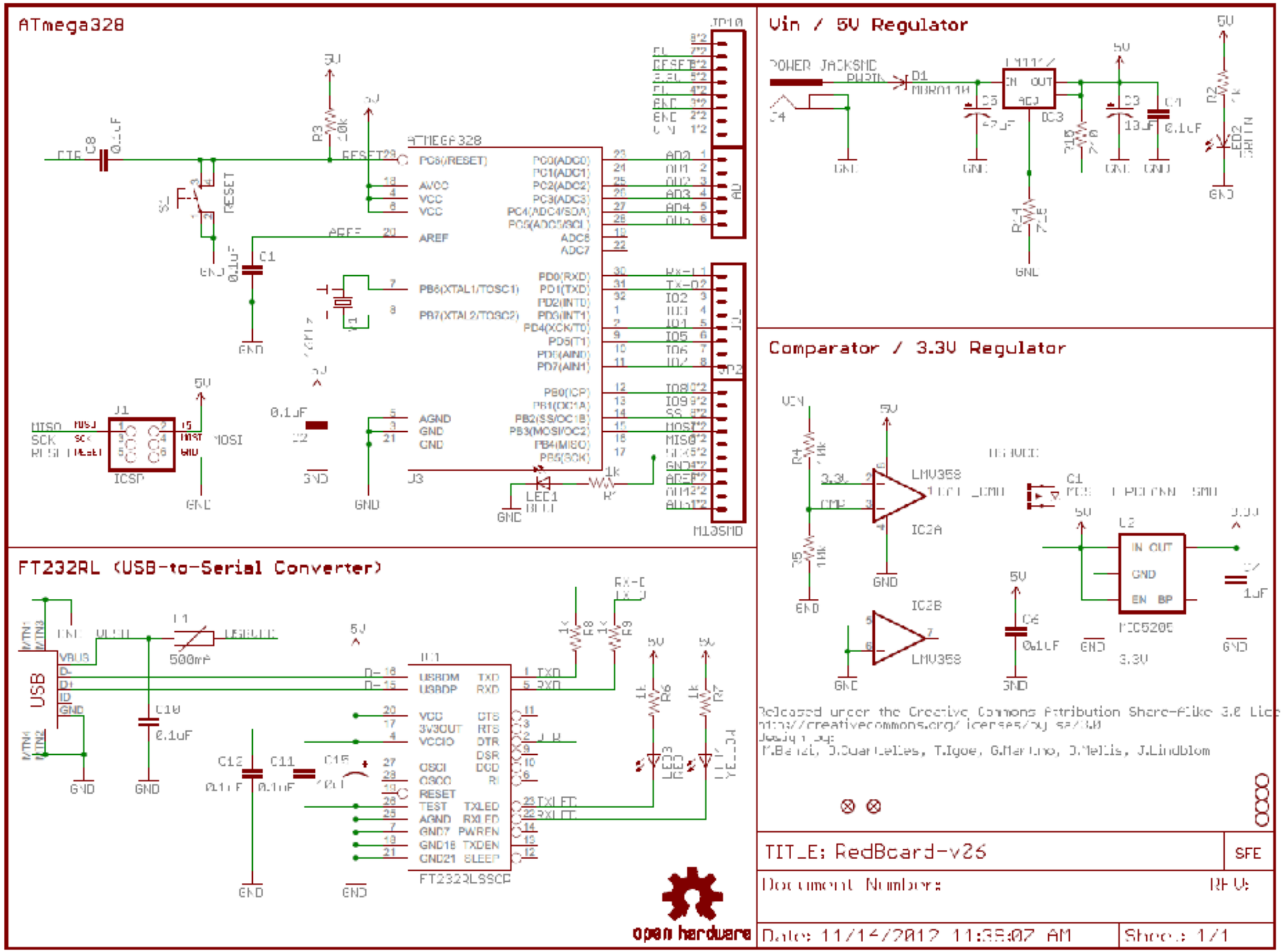


Image: Sparkfun

When encountering a schematic, split it up into functional blocks



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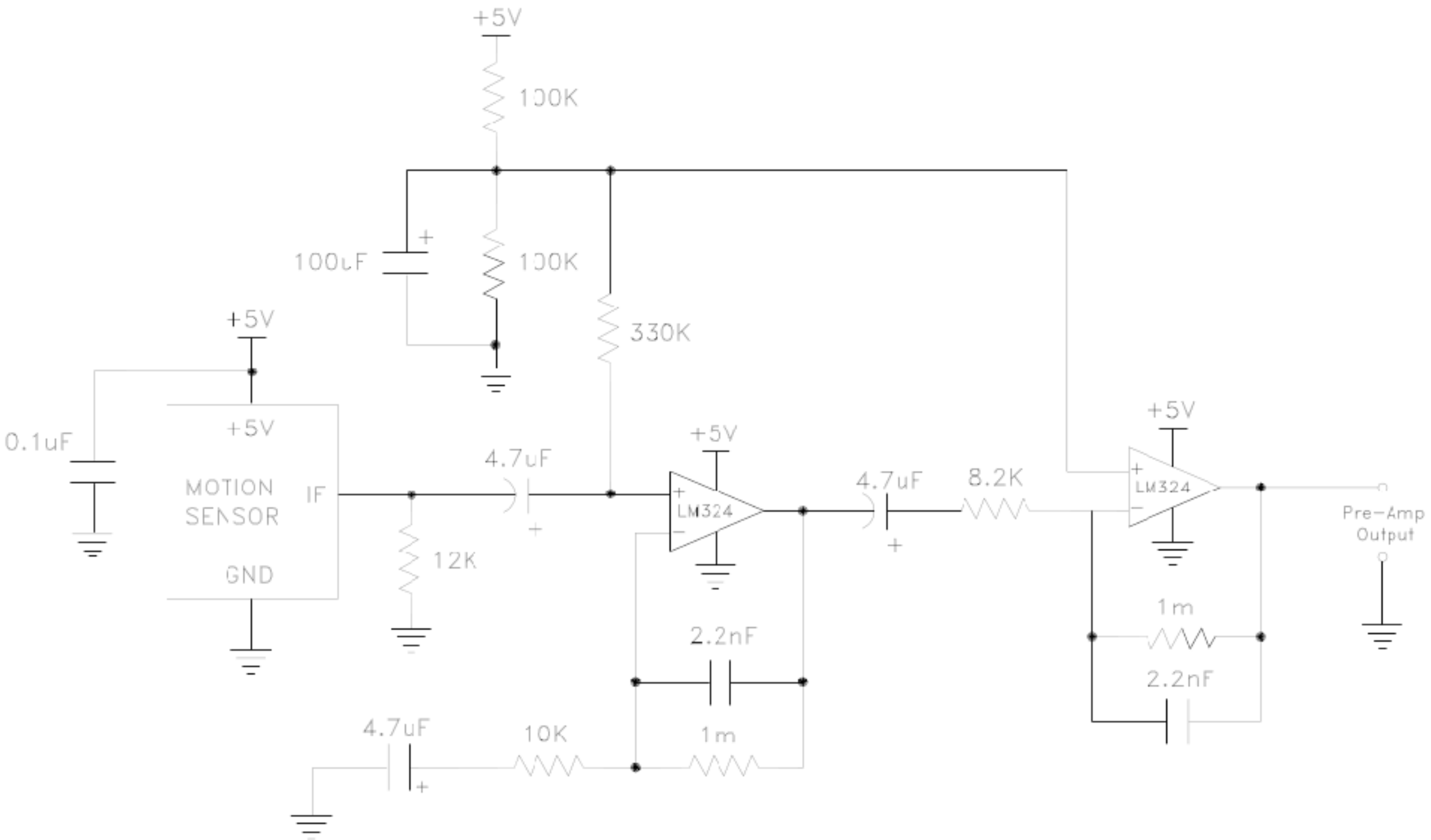
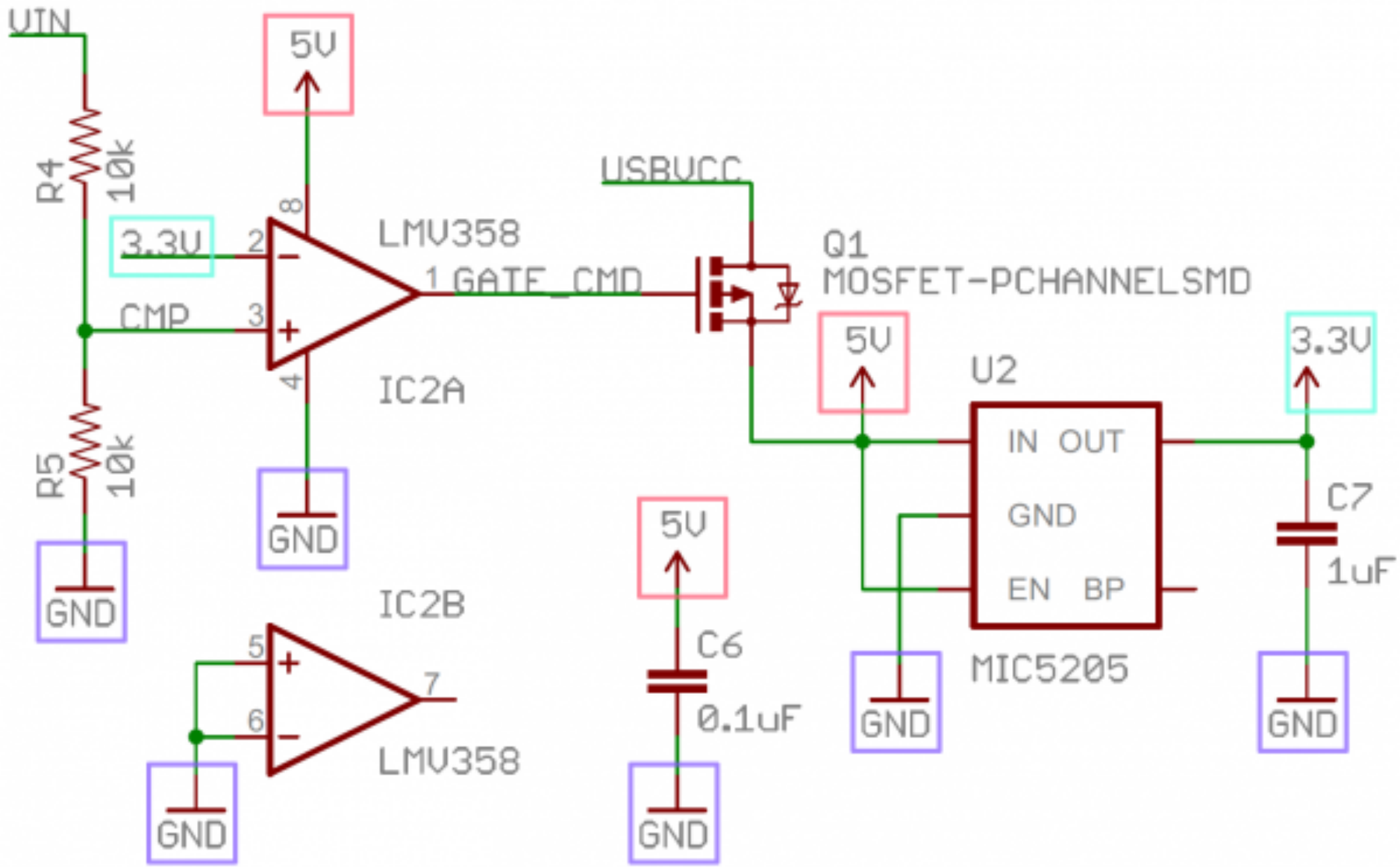


Look for voltage rails, these a great staring test points



Images: Sparkfun

Read the datasheets, there is a lot of helpful information in them

TEXAS INSTRUMENTS

LM124-N, LM224-N
LM2902-N, LM324-N
SNOSC16D – MARCH 2000 – REVISED JANUARY 2015

LMx24-N, LM2902-N Low-Power, Quad-Operational Amplifiers

1 Features

- Internally Frequency Compensated for Unity Gain
- Large DC Voltage Gain 100 dB
- Wide Bandwidth (Unity Gain) 1 MHz (Temperature Compensated)
- Wide Power Supply Range:
  - Single Supply 3 V to 32 V
  - or Dual Supplies ±1.5 V to ±16 V
- Very Low Supply Current Drain (700 μA) —Essentially Independent of Supply Voltage
- Low Input Biasing Current 45 nA (Temperature Compensated)
- Low Input Offset Voltage 2 mV and Offset Current: 5 nA
- Input Common-Mode Voltage Range Includes Ground
- Differential Input Voltage Range Equal to the Power Supply Voltage
- Large Output Voltage Swing 0 V to V^+ − 1.5 V
- **Advantages:**
  - Eliminates Need for Dual Supplies
  - Four Internally Compensated Op Amps in a Single Package

3 Description

The LM124-N series consists of four independent, high-gain, internally frequency compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124-N series can directly operate off of the standard 5-V power supply voltage which is used in digital systems and easily provides the required interface electronics without requiring the additional ±15 V power supplies.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM124-N	CDIP (14)	19.56 mm × 6.67 mm
LM224-N		
LM324-N	CDIP (14)	19.56 mm × 6.67 mm
	PDIP (14)	19.177 mm × 6.35 mm
	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	5.00 mm × 4.40 mm

Now let’s take a deeper dive into the basic components

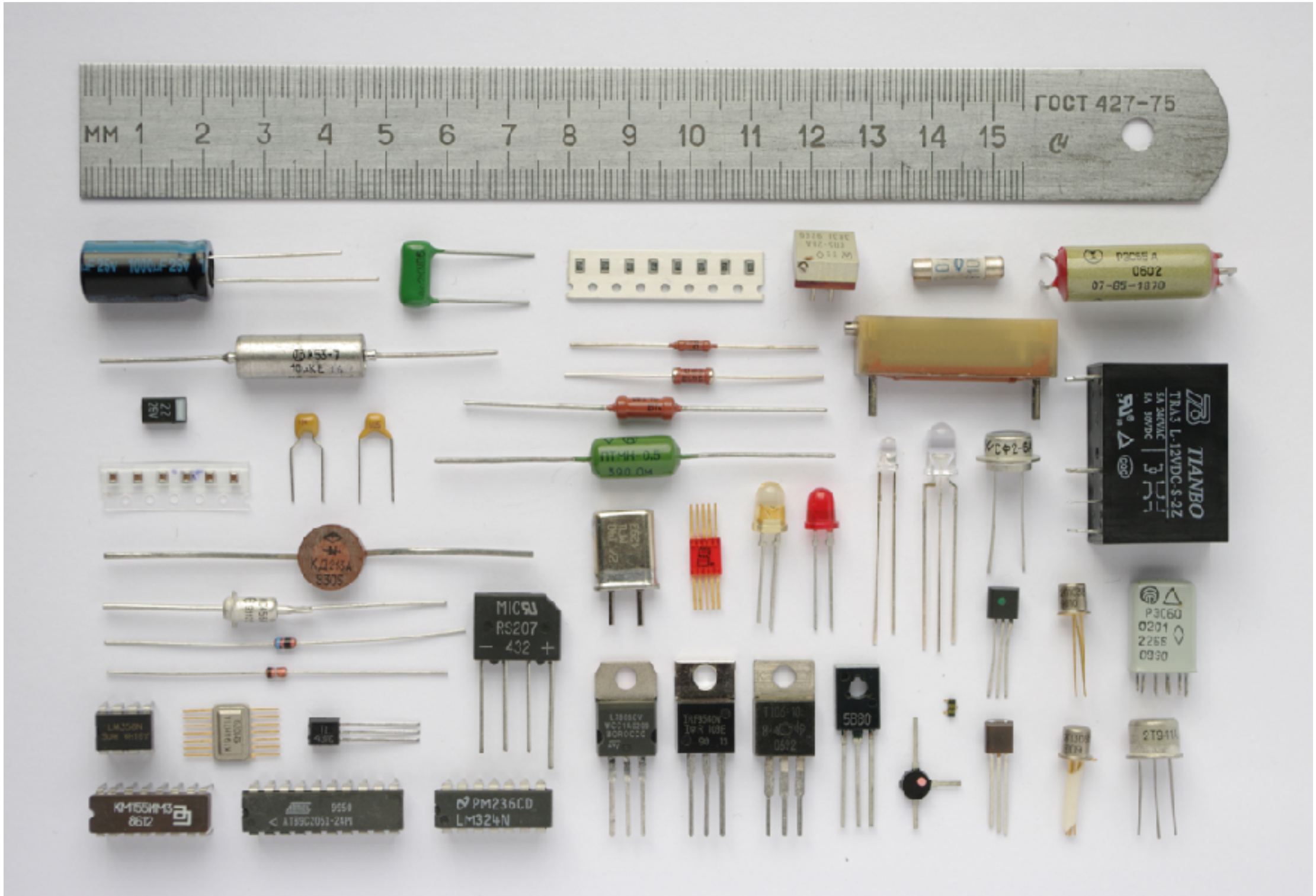
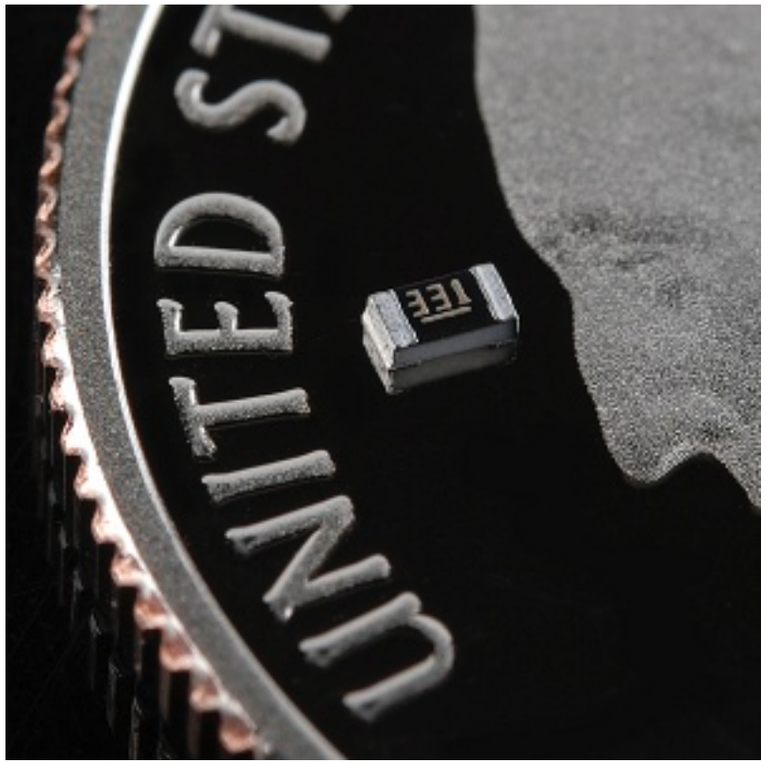


Image: Wikipedia

Resistors

Resistors restrict the flow of electrons through a circuit



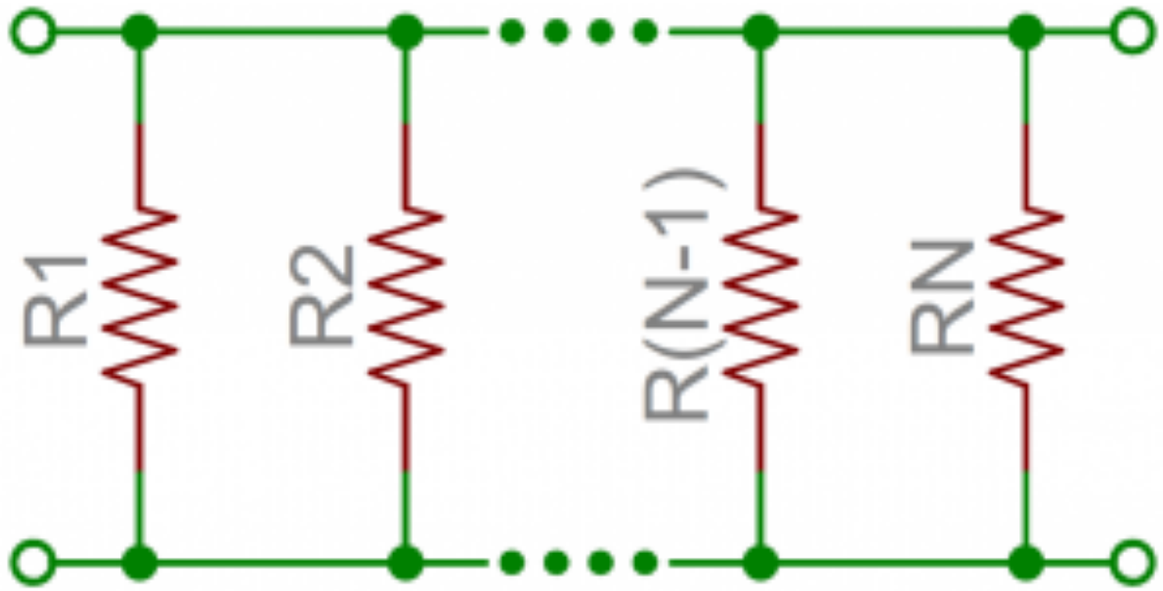
Images: Sparkfun

Resistors in series are added together

$$R_{tot} = R_1 + R_2 + ... + R_{N-1} + R_N$$

Image: Sparkfun

Resistors in parallel are the inverse sum of the inverse resistances



$$\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_{N-1}} + \frac{1}{R_N}$$

Image: Sparkfun

Let’s workout an example simple resistor network

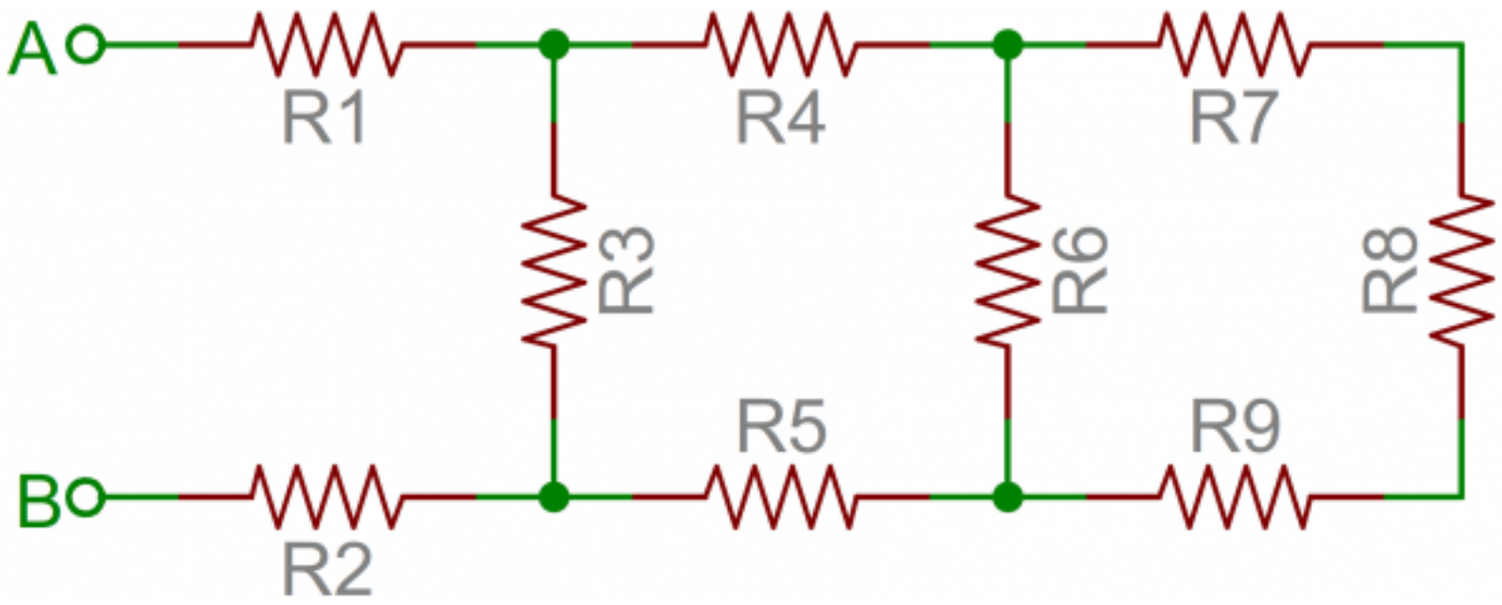


Image: Sparkfun

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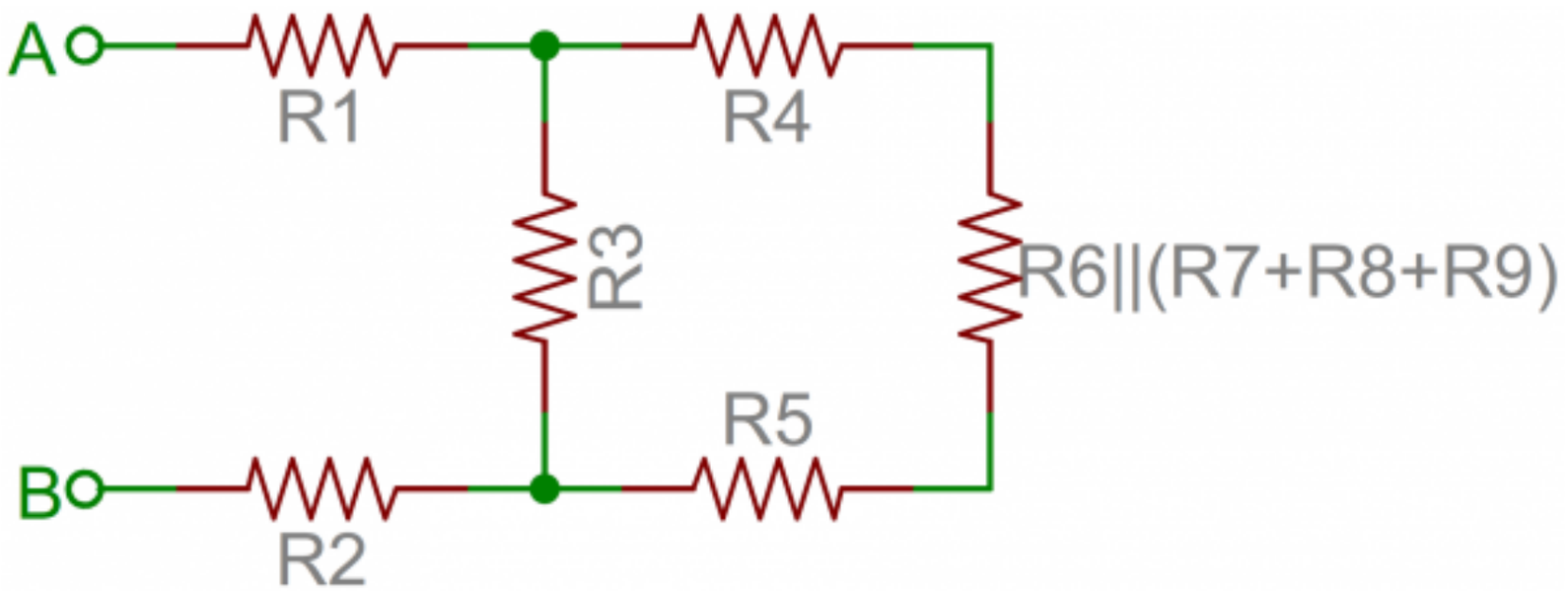

Image: Sparkfun

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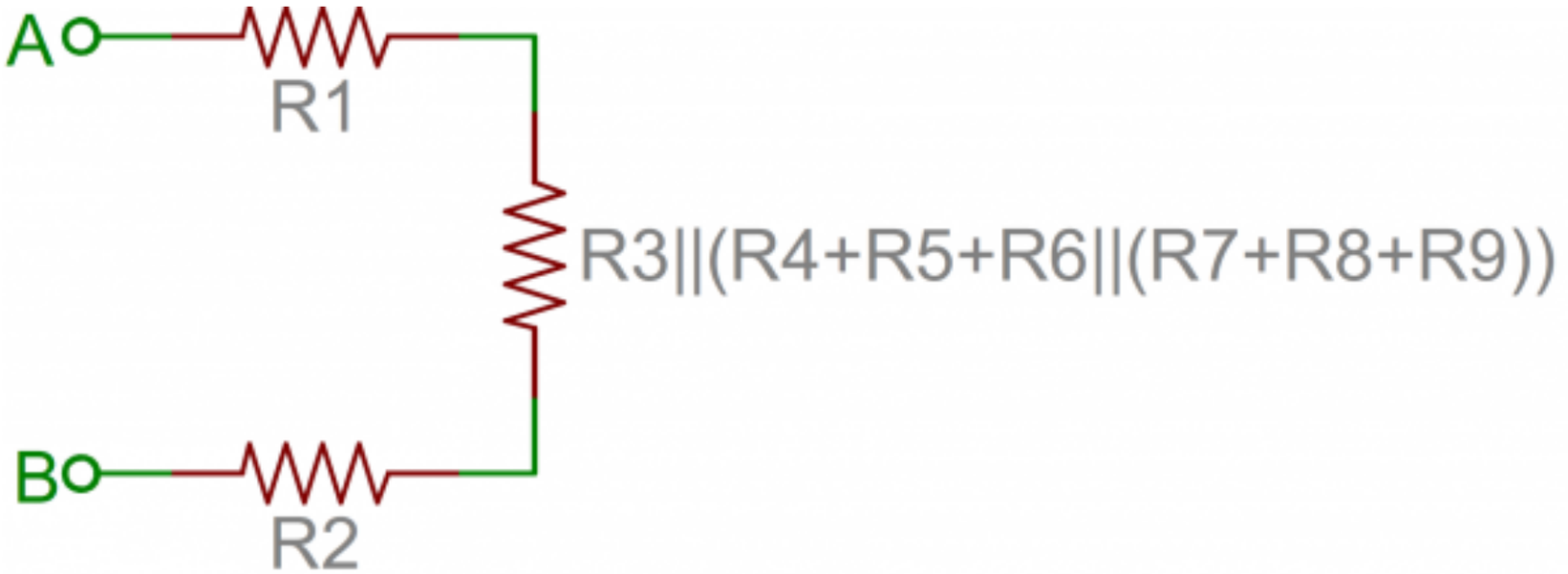


Image: Sparkfun

Capacitors

Capacitors can store energy in a circuit and resist voltage changes

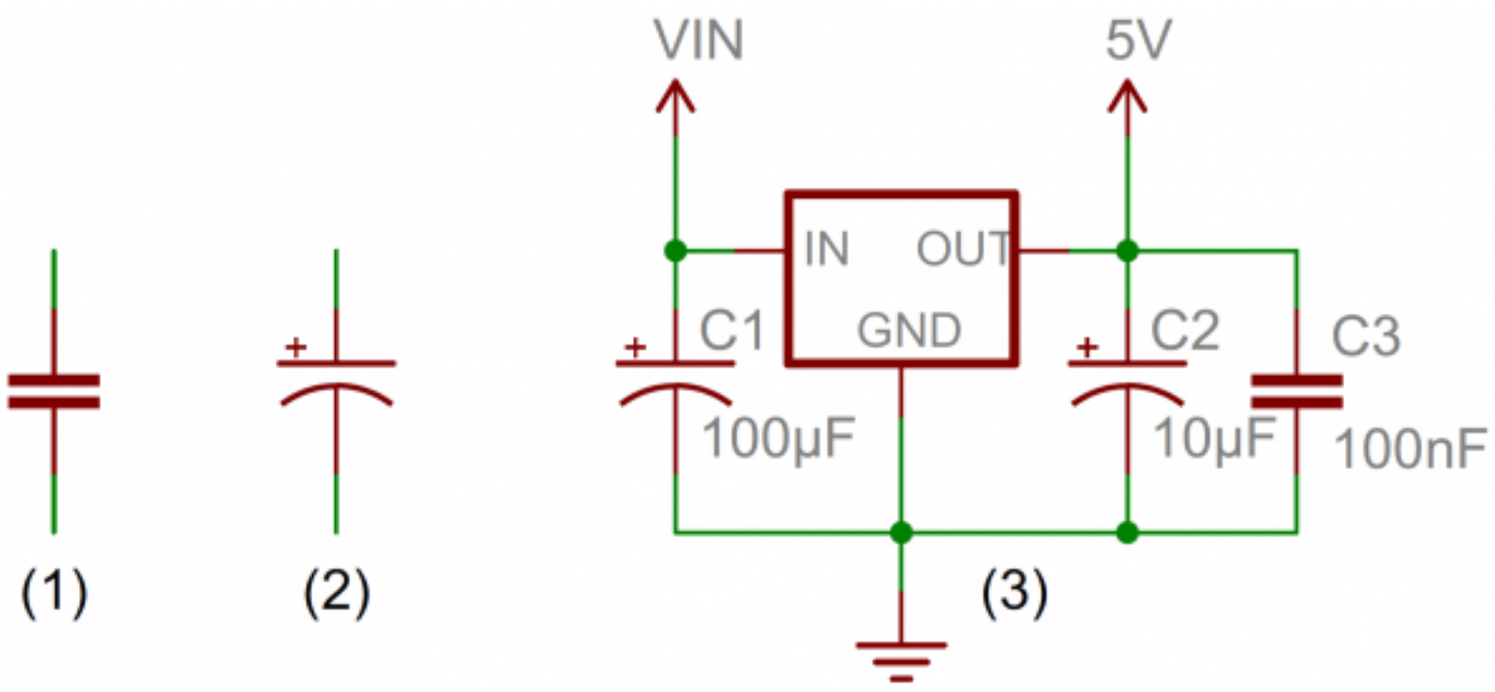
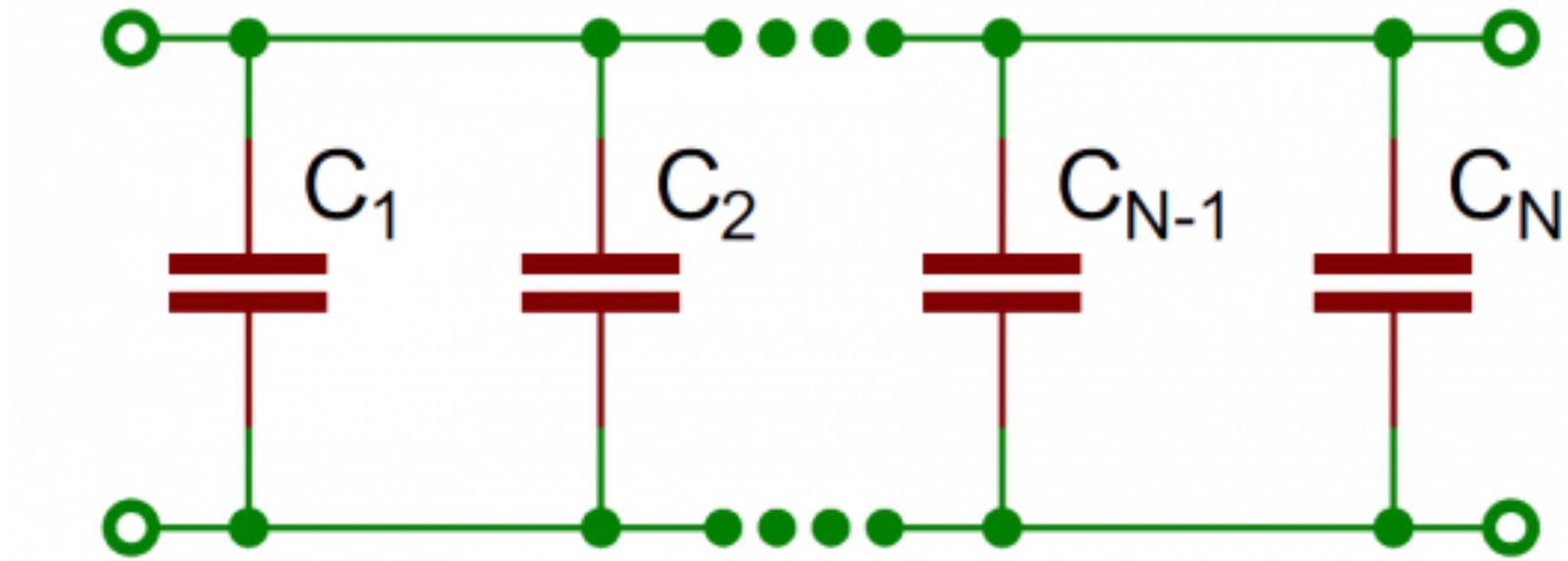


Image: Sparkfun

Caps in parallel are added together



$$C_{Tot} = C_1 + C_2 + \ldots + C_{N-1} + C_N$$

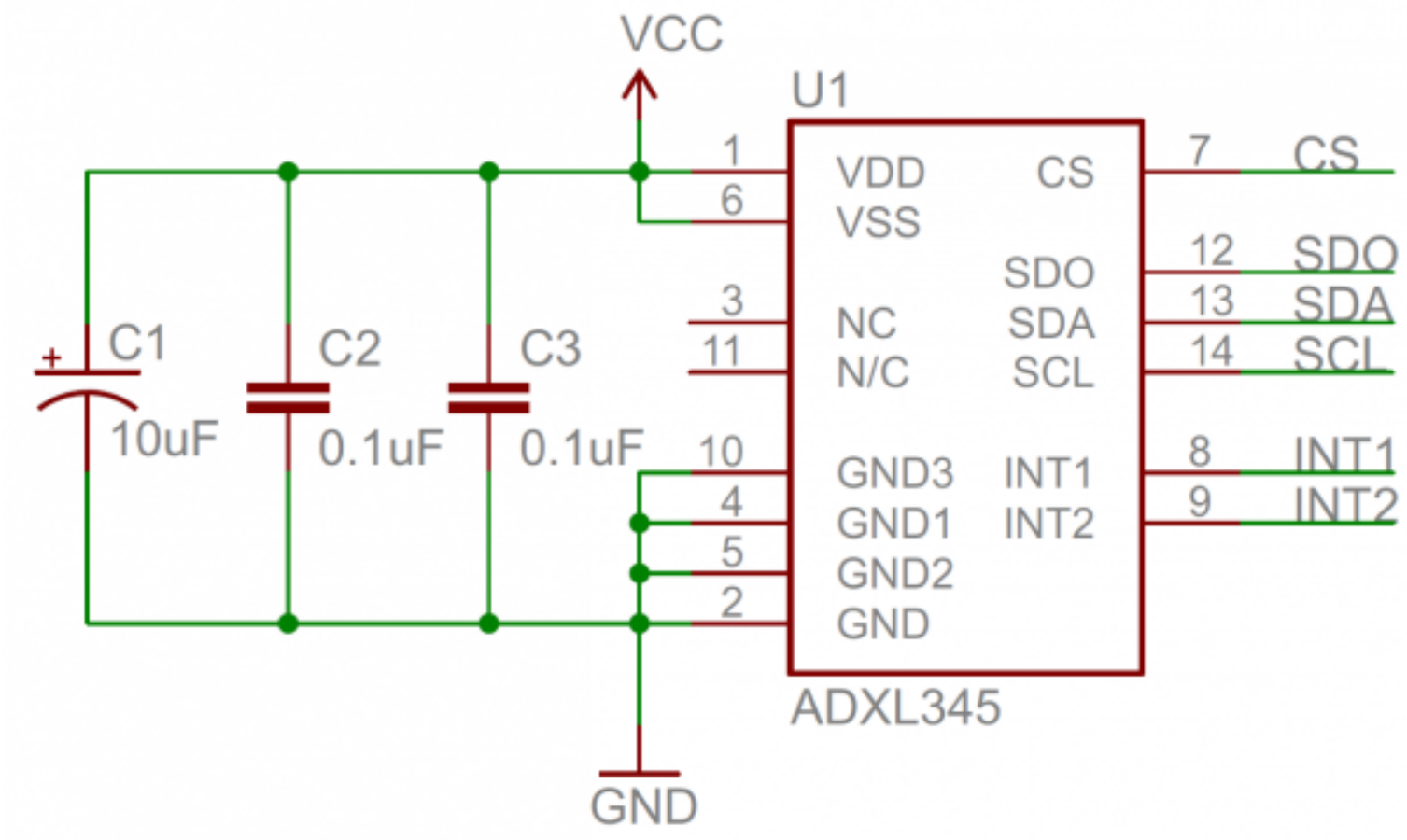
Image: Sparkfun

Caps in series go as the inverse sum

$$\frac{1}{C_{Tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_{N-1}} + \frac{1}{C_N}$$

Image: Sparkfun

Power supply decoupling/bypass is a common application



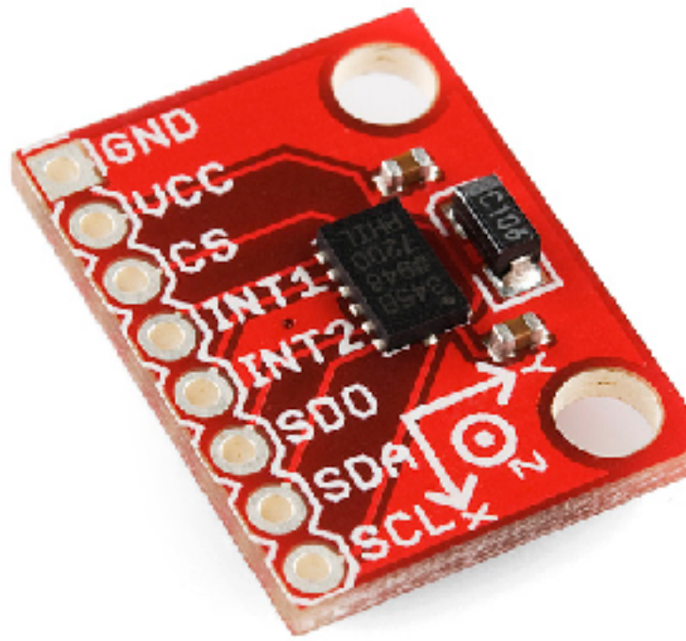


Image: Sparkfun

Filtering is another common application of caps

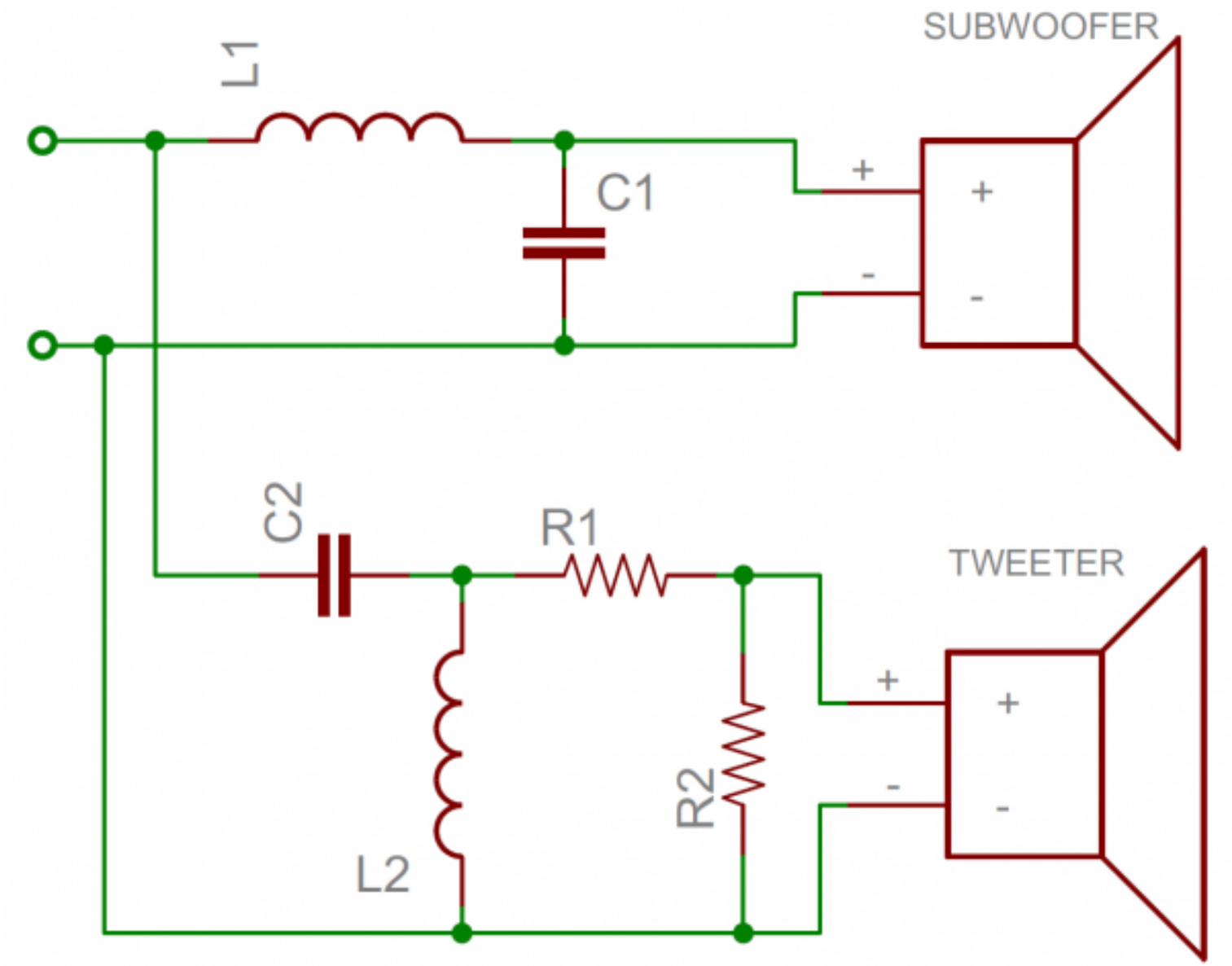
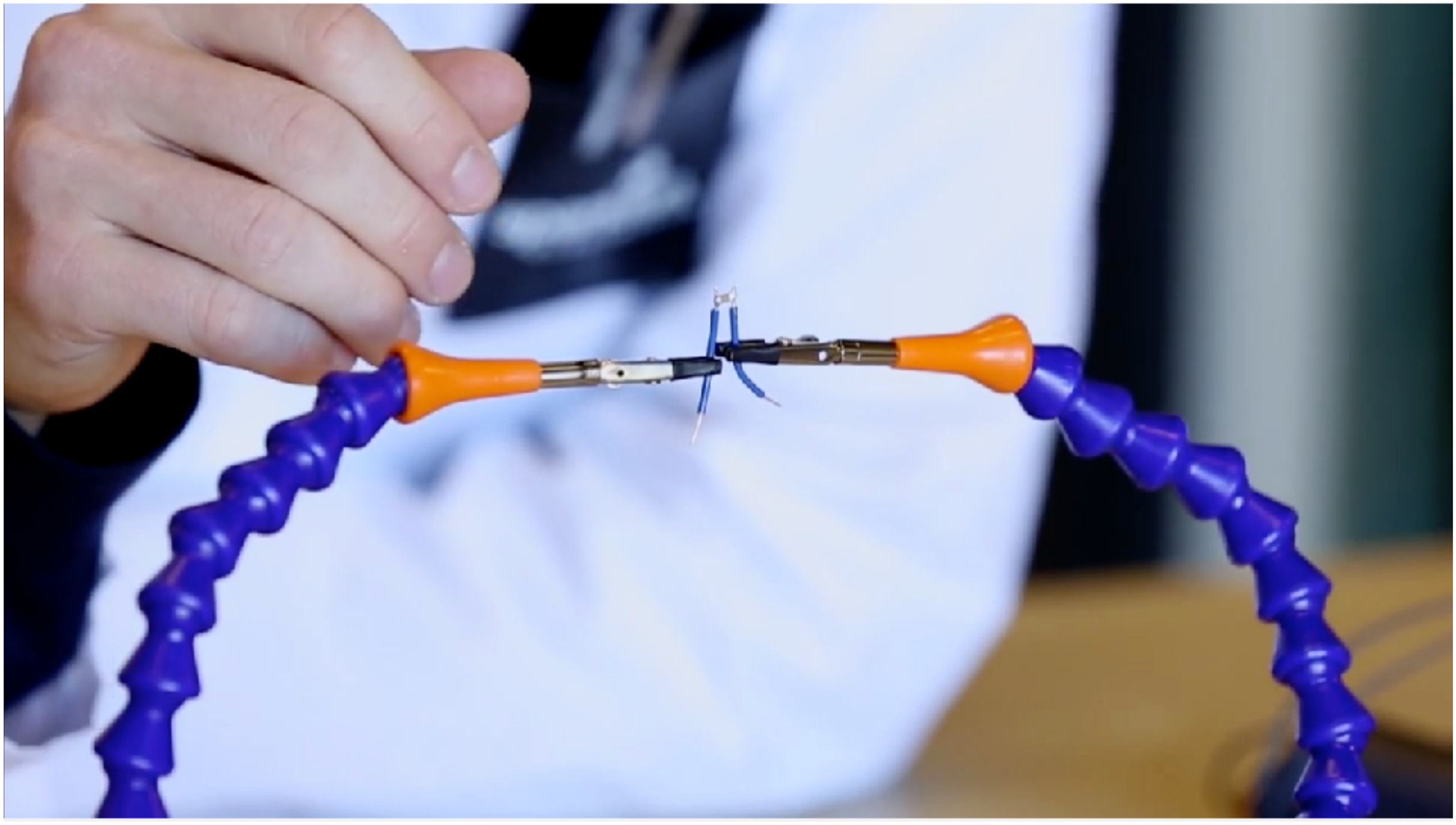


Image: Sparkfun

Beware of polarized capacitors and design with the appropriate ratings/type in mind



https://www.youtube.com/watch?v=sW0a9d_vWoc

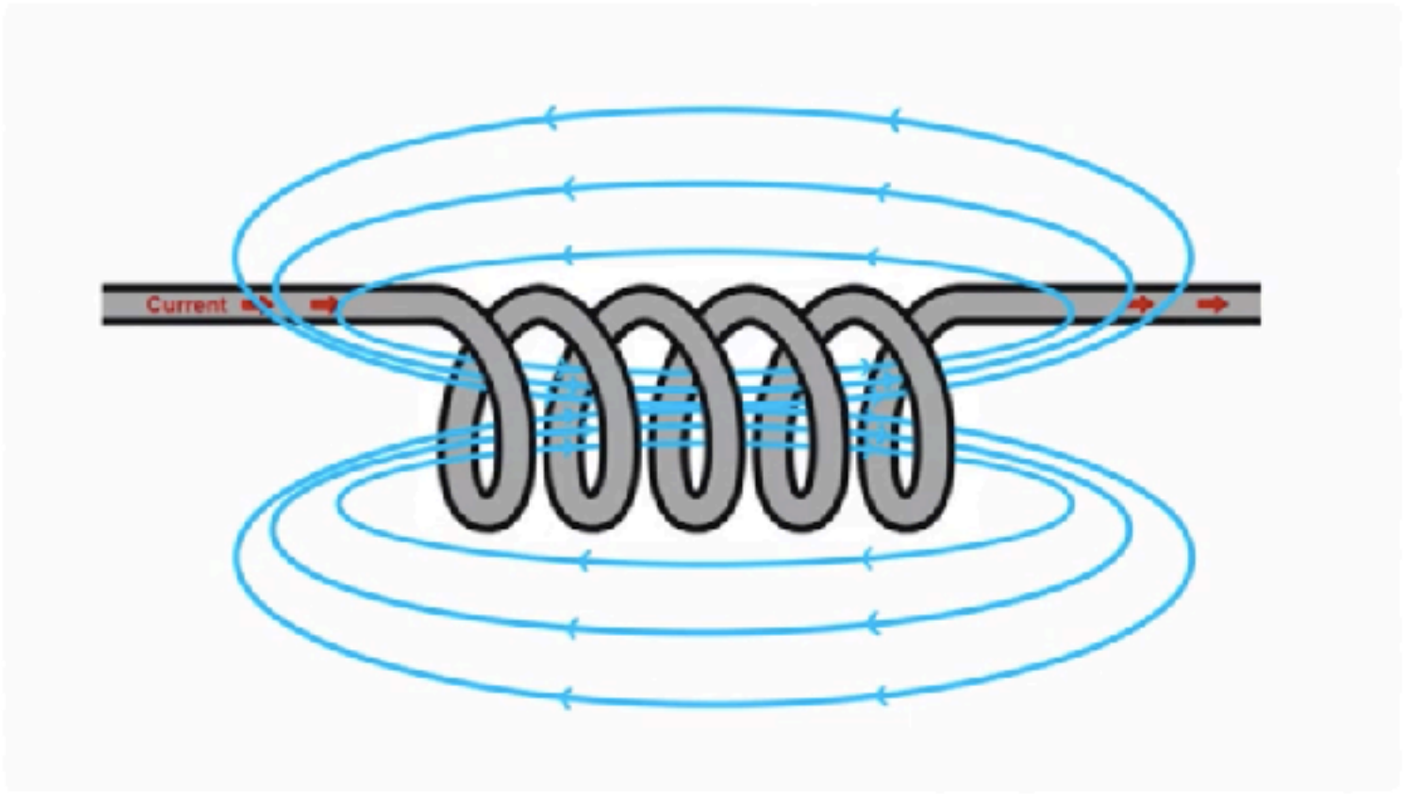
Image: Sparkfun

Inductors

Inductors are coils of wire, generally on a ferrous core that store energy in a magnetic field. They resist changes in current

Image: embeddedmicro.com

When power is applied a magnetic field is built up



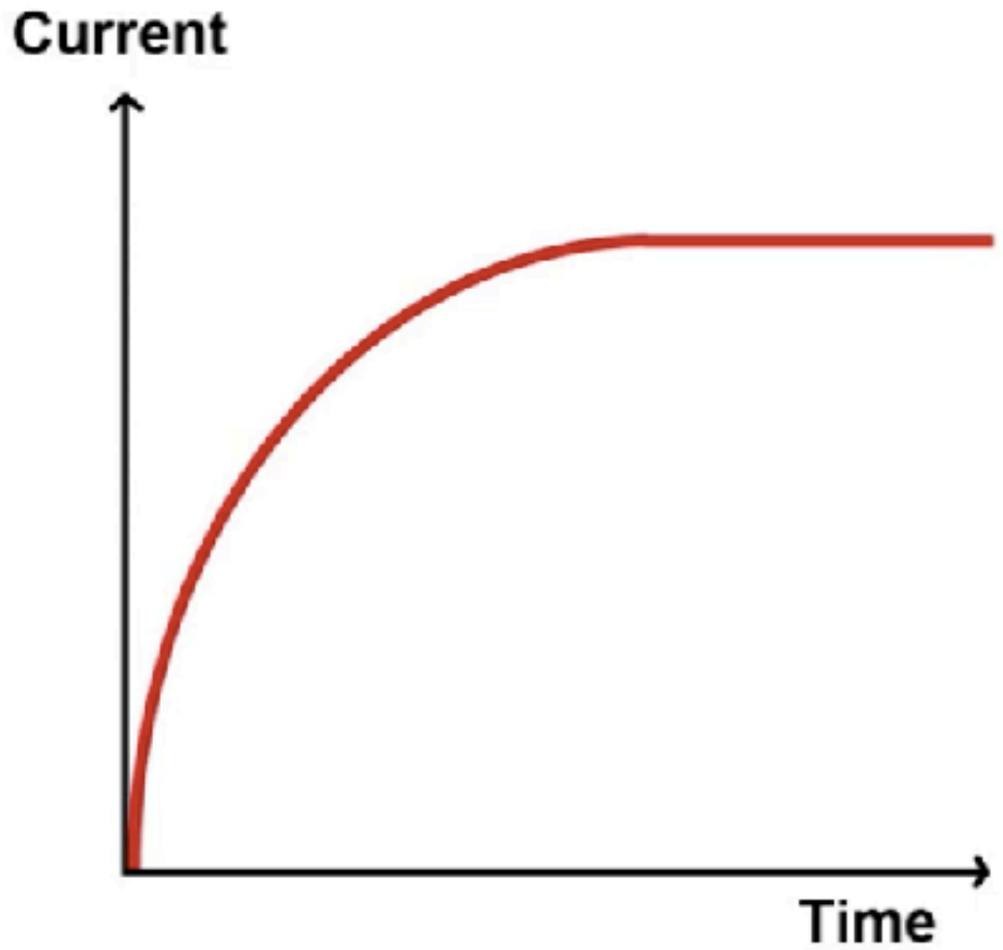
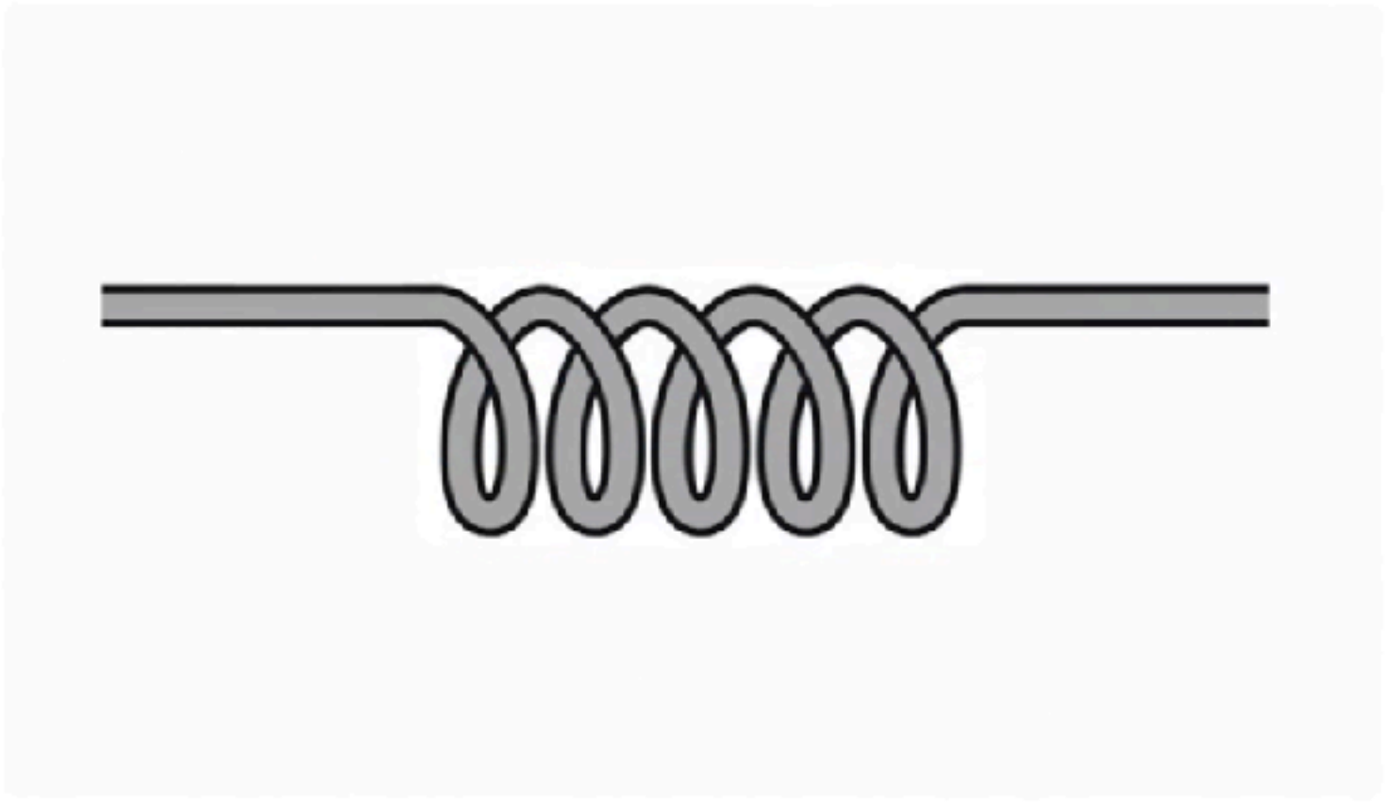


Image: afrotechmods

When power is removed that magnetic field dumps its energy



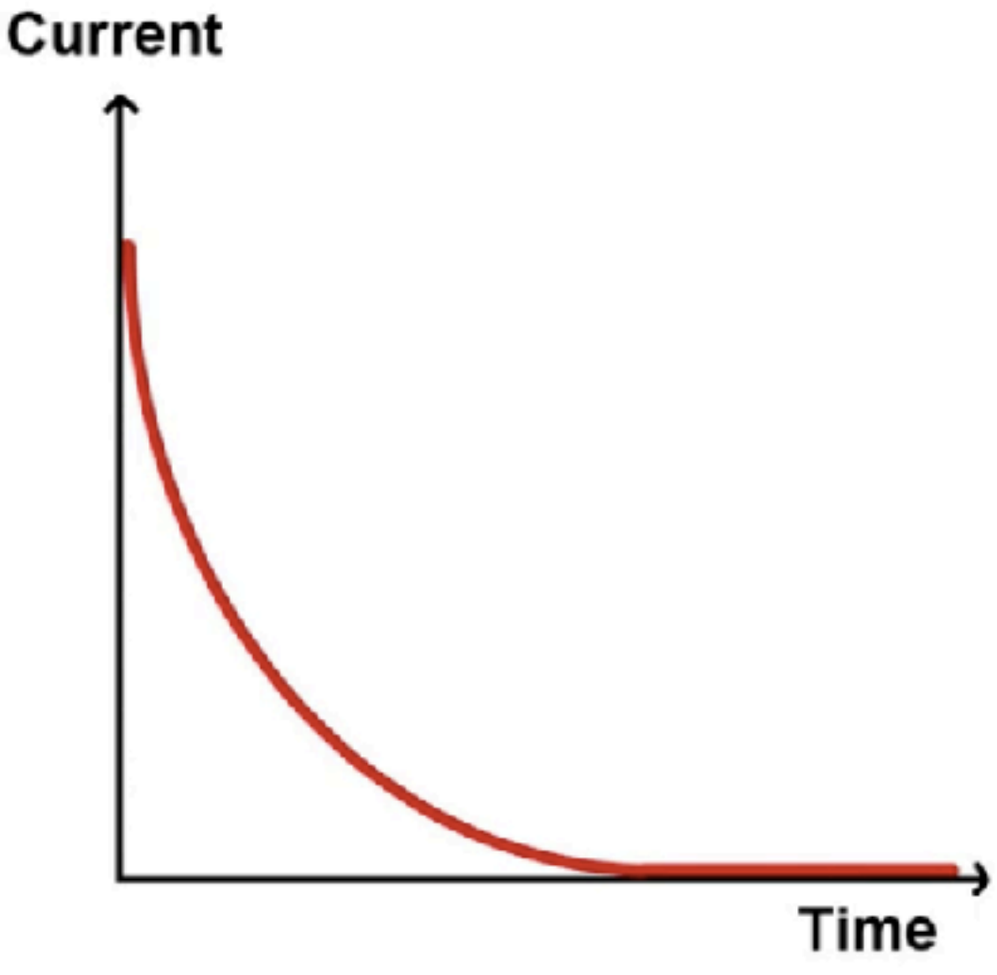


Image: afrotechmods

Inductors are the basis for transformers as well

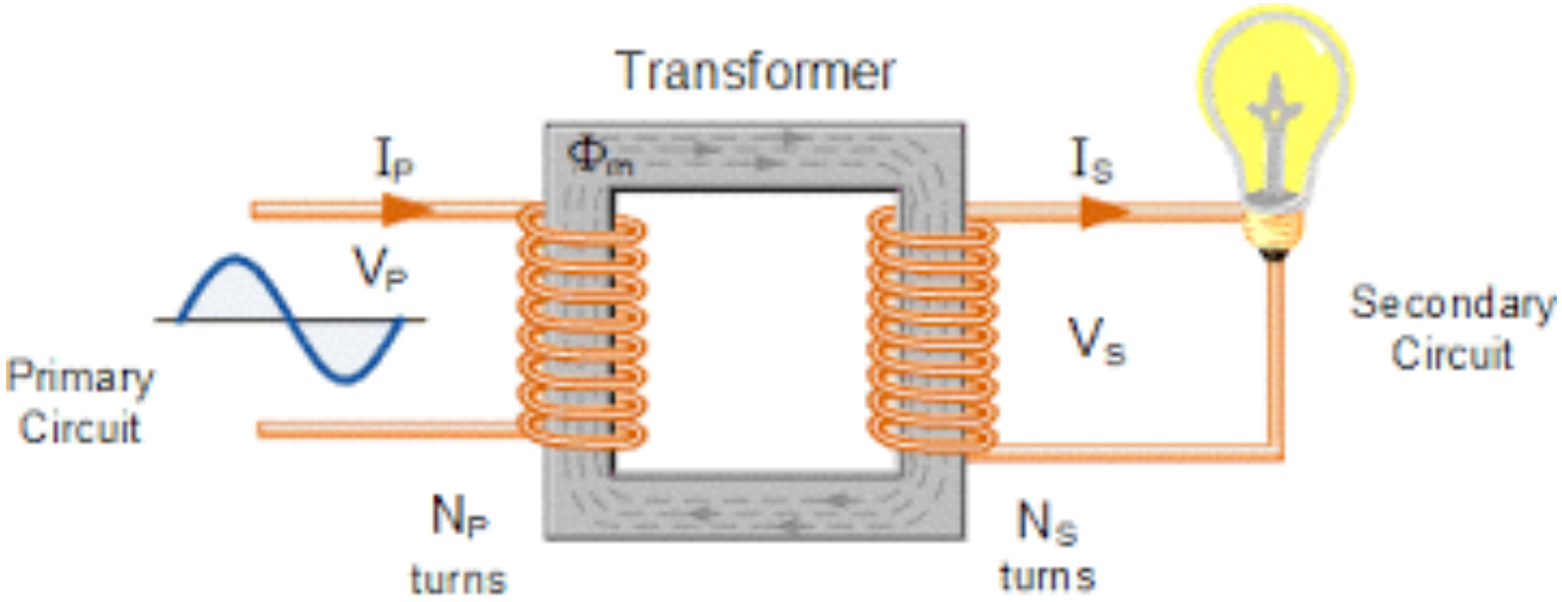


Image: electronics-tutorials.ws, Wikipedia

Diodes

Diodes are like the one-way valve of electronics (ideally)

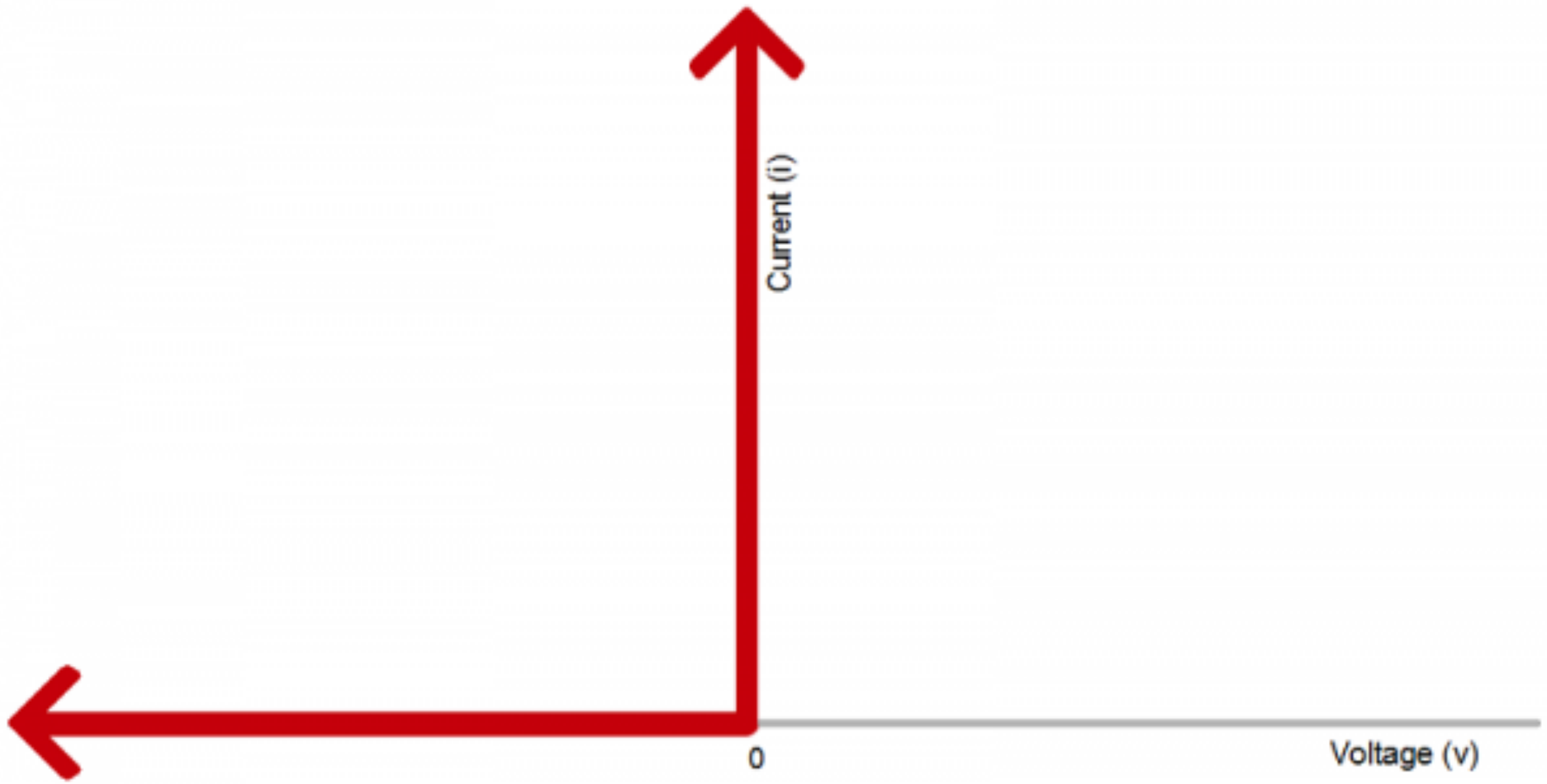


Image: Sparkfun

Current can from from the anode to the cathode, but not from the cathode to the anode

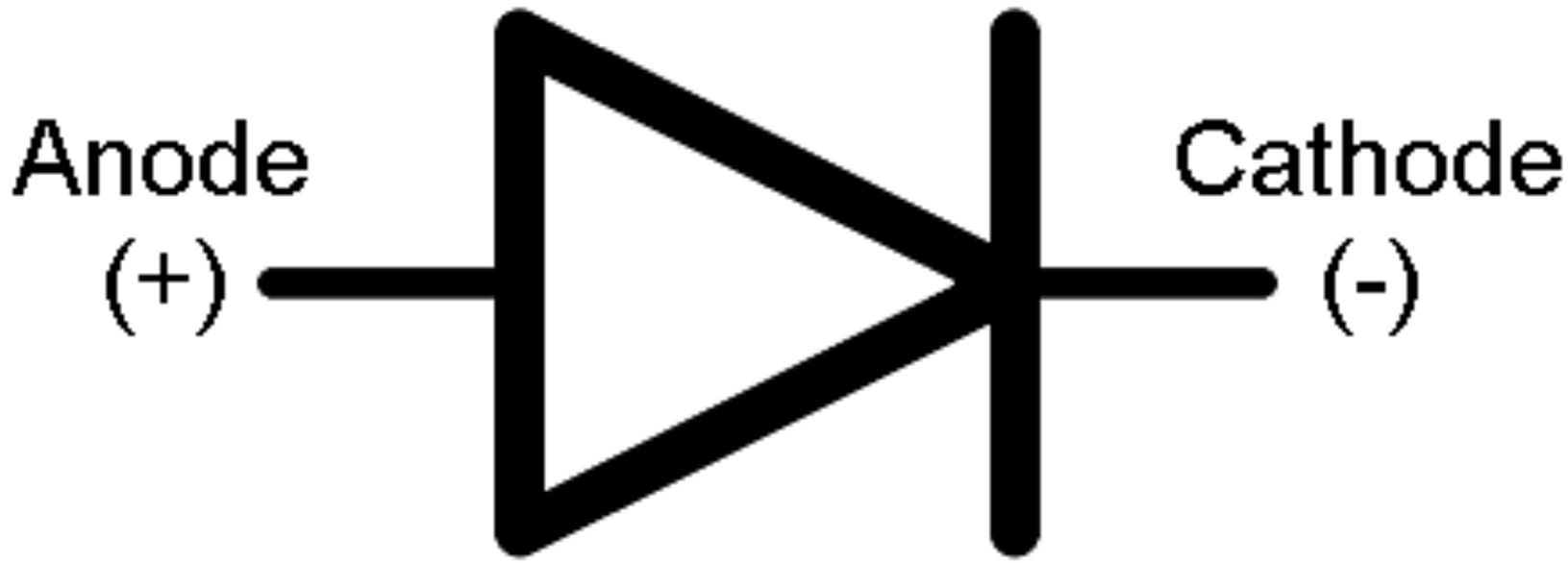


Image: Sparkfun

Here are two simple equivalent circuits

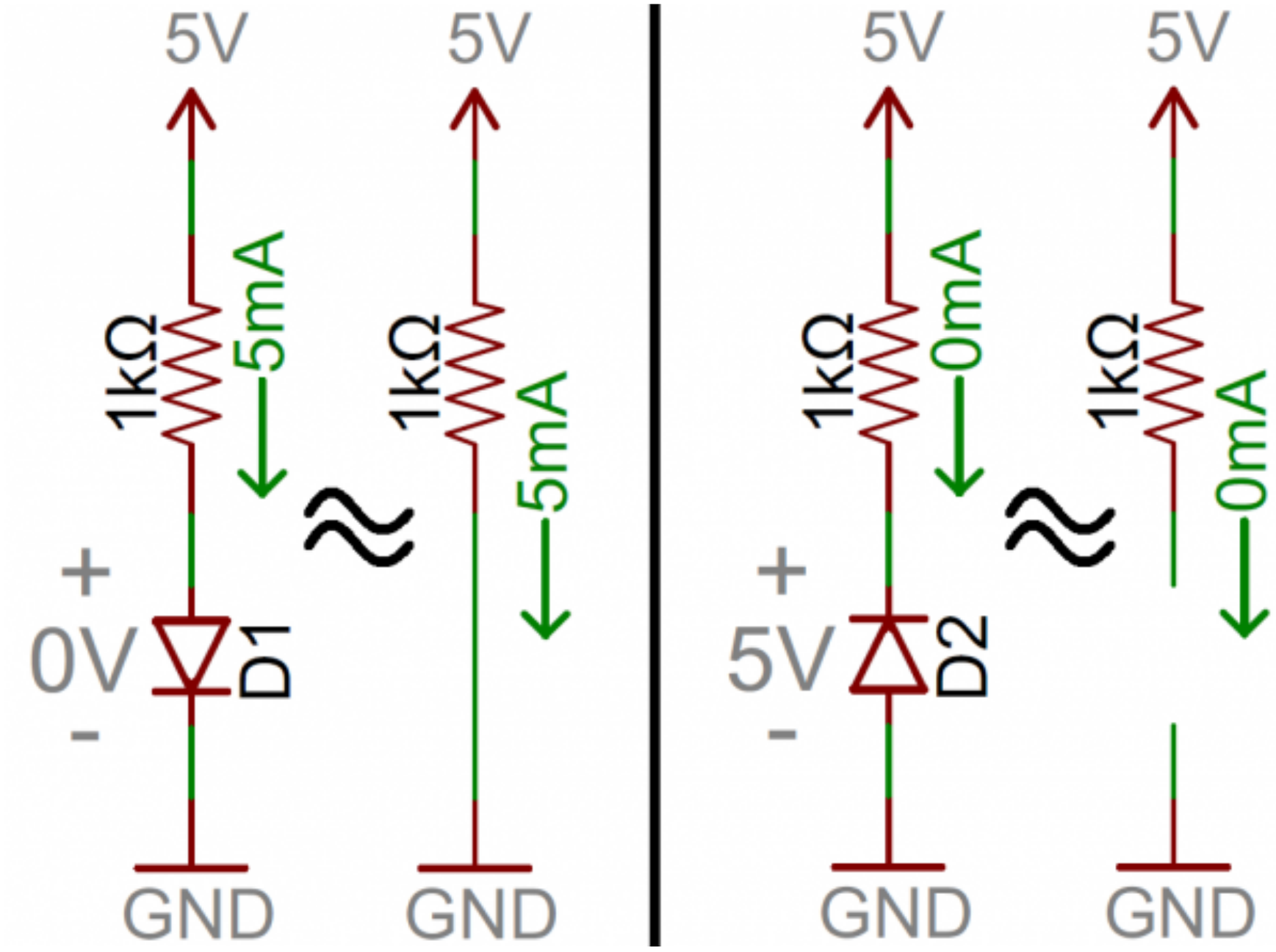


Image: Sparkfun

Real diodes are more complex than the ideal

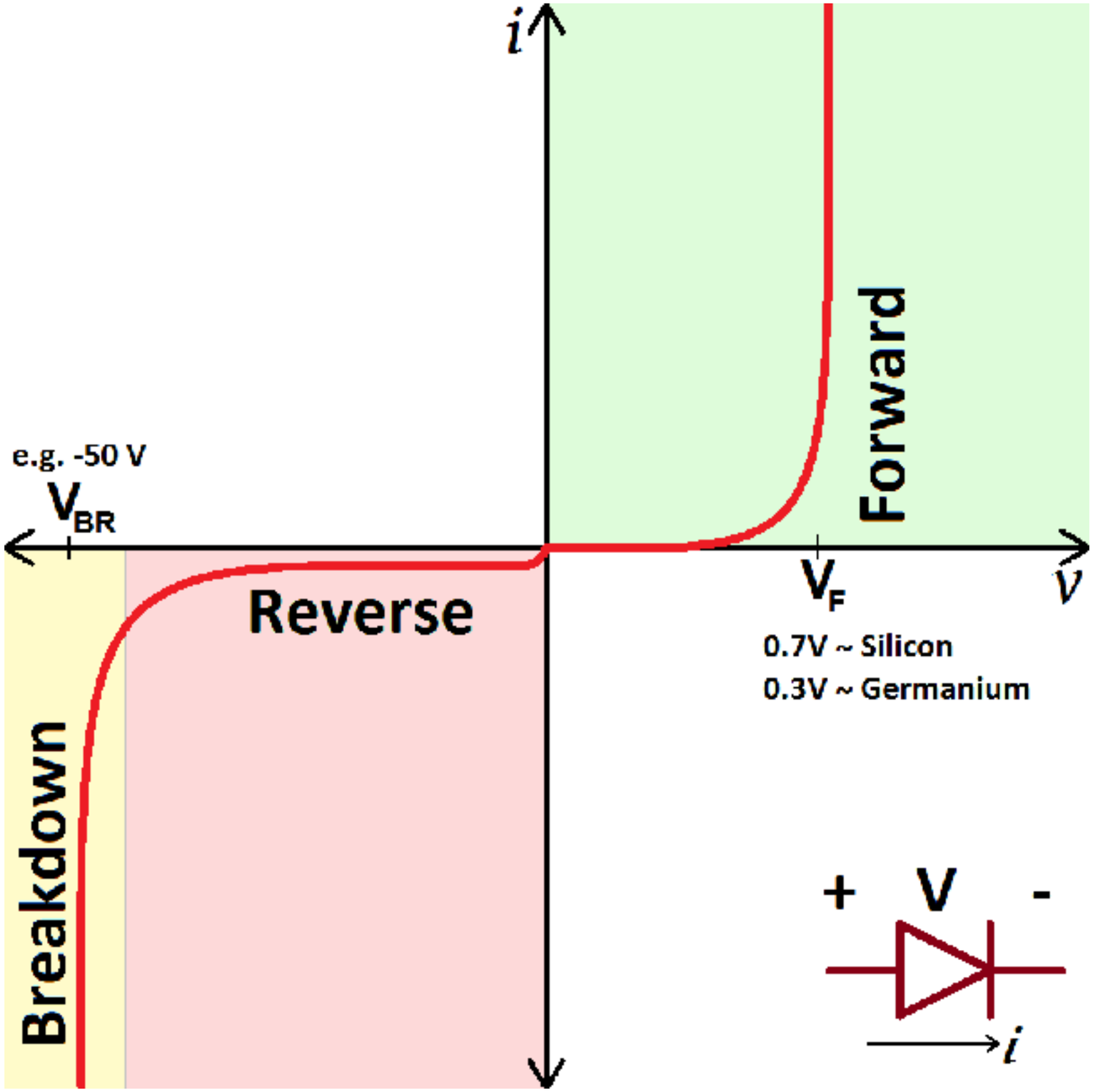


Image: Sparkfun

Small signal diodes are low current, inexpensive diodes (i.e. 1N4148)

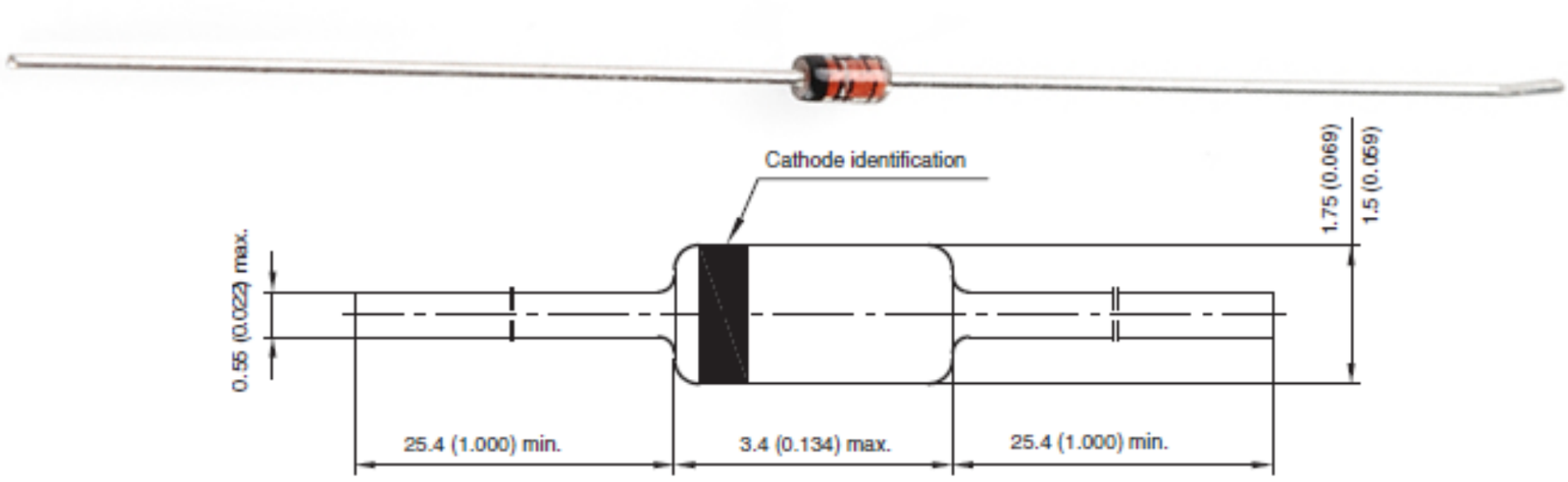


Image: Sparkfun

Power diodes have higher current ratings (i.e. 1N4001)

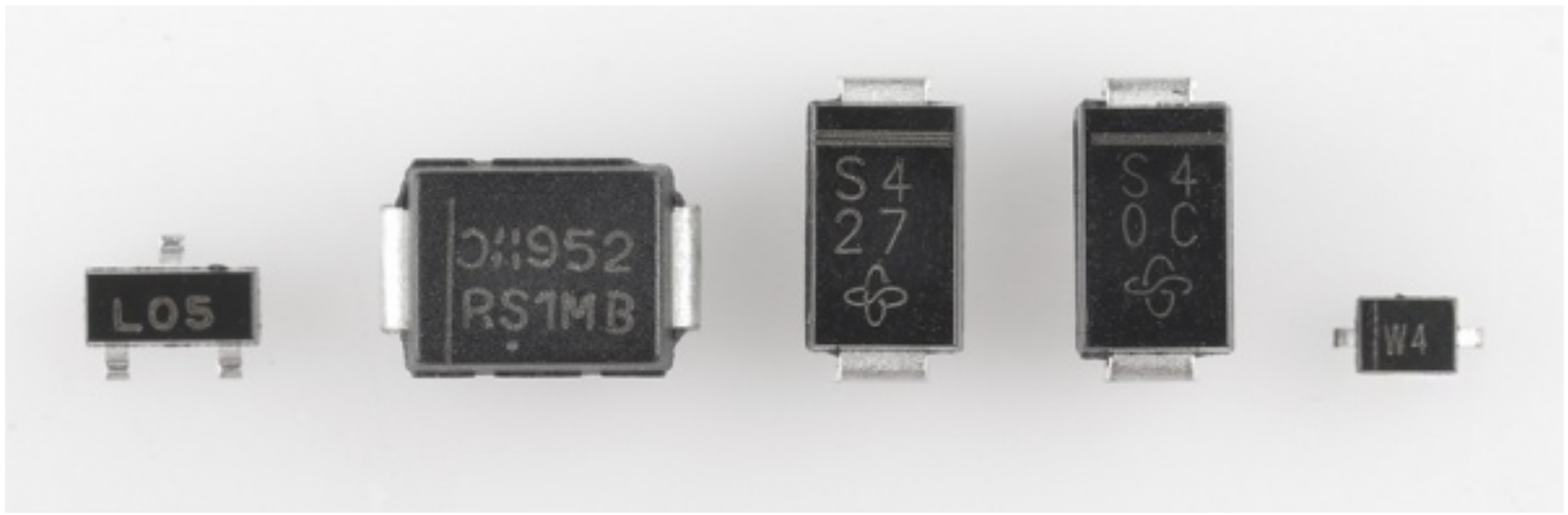


Image: Sparkfun

Schottky diodes have very low forward voltages, good when you cannot tolerate large voltage drops

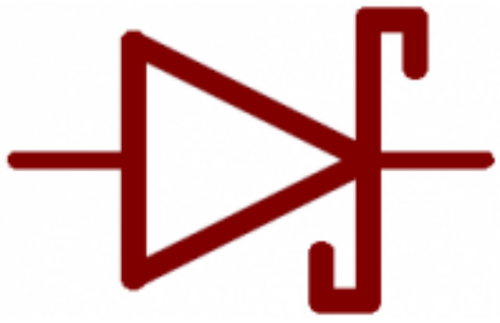


Image: Sparkfun

Zener diodes are meant to be used in reverse bias to take advantage of their precise breakdown (zener) voltage

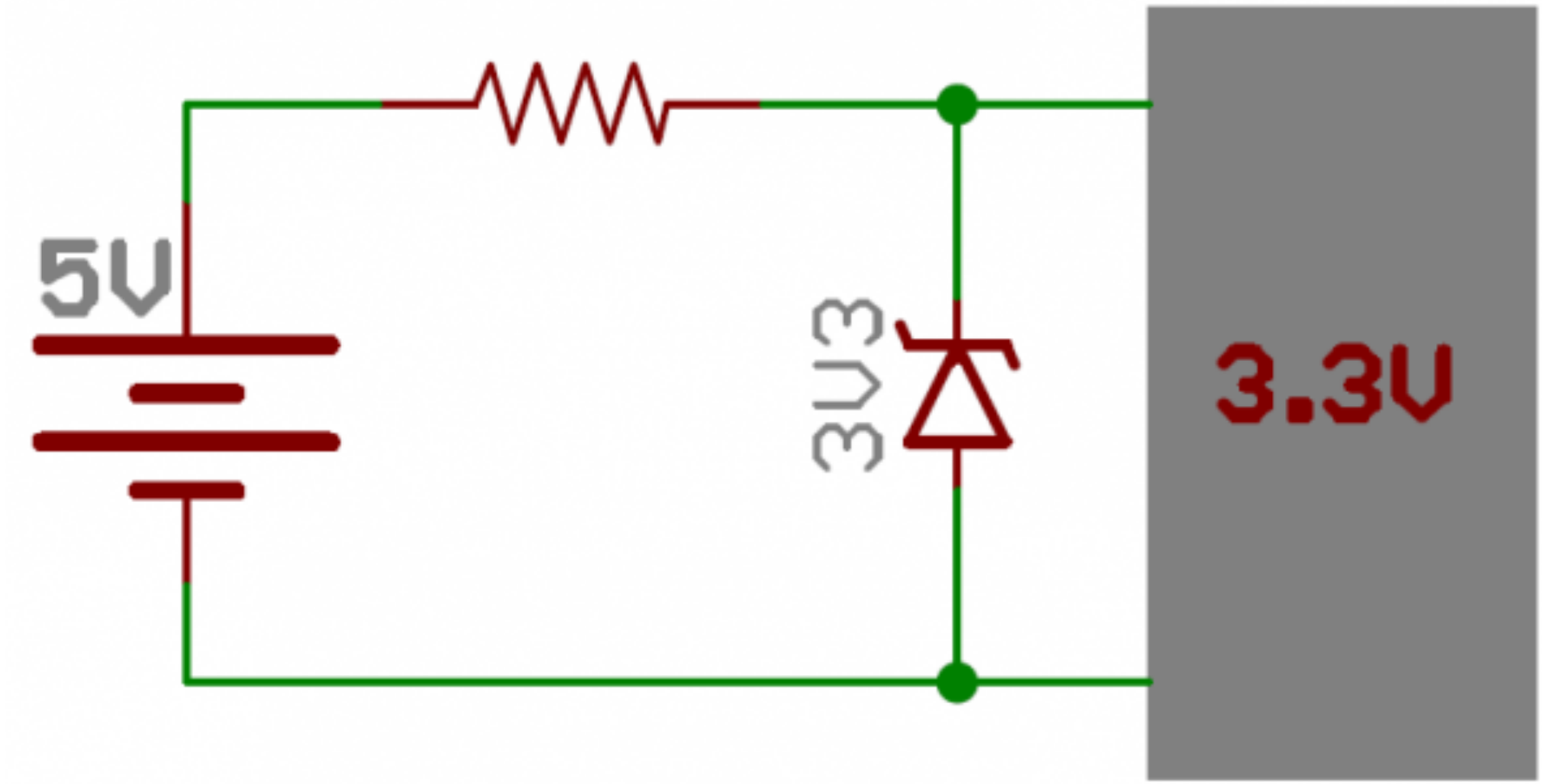
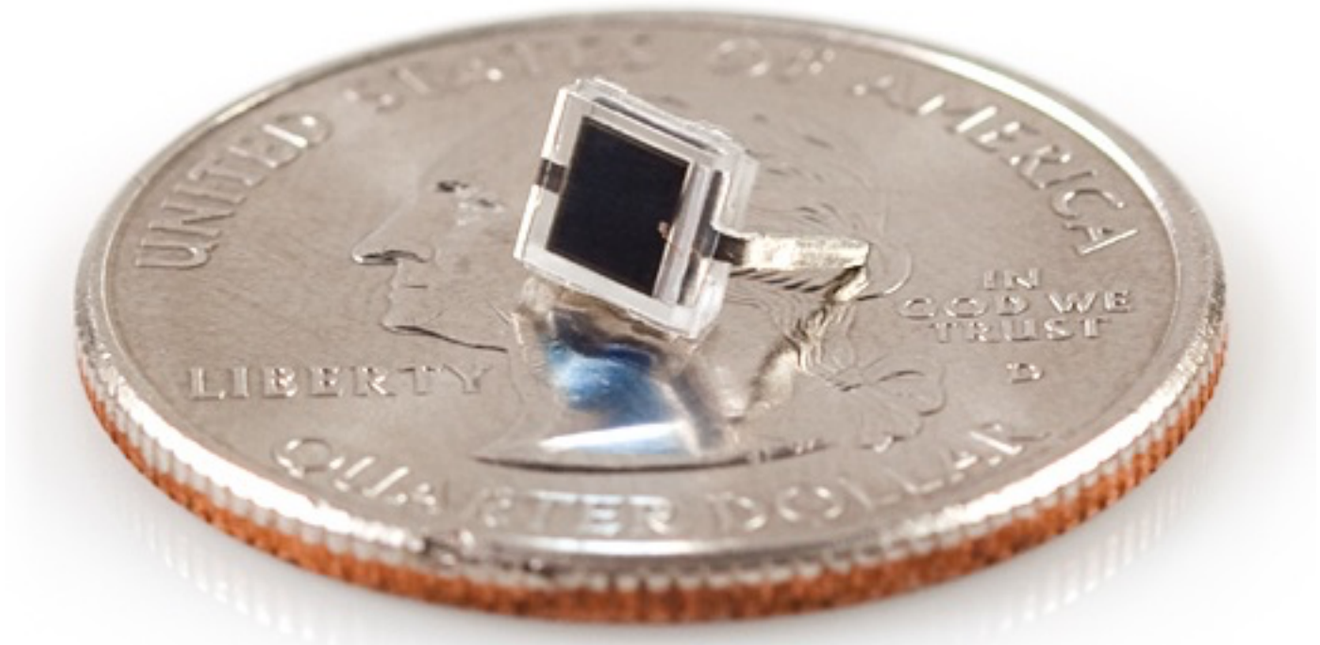


Image: Sparkfun

There are also optical diodes (light emitting and current generating)



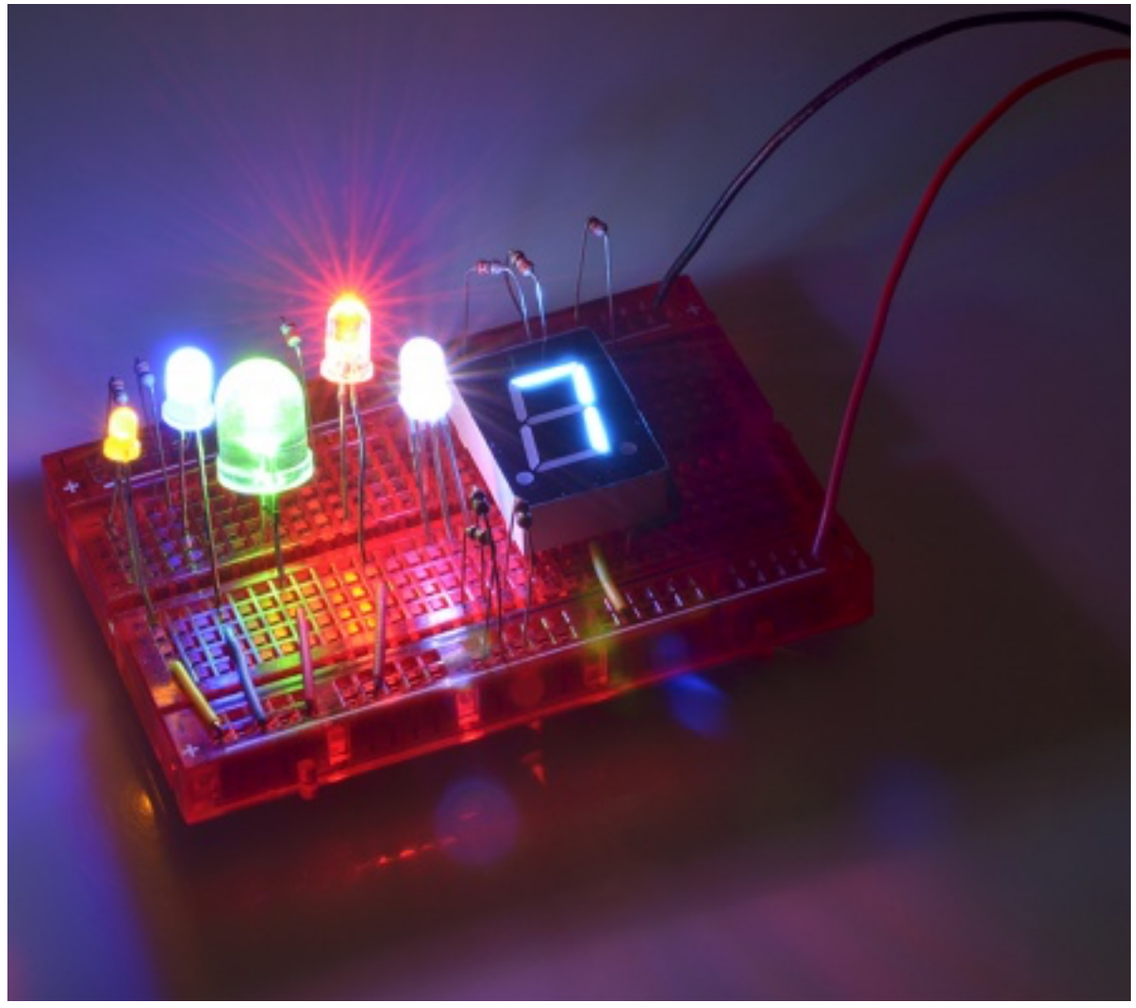
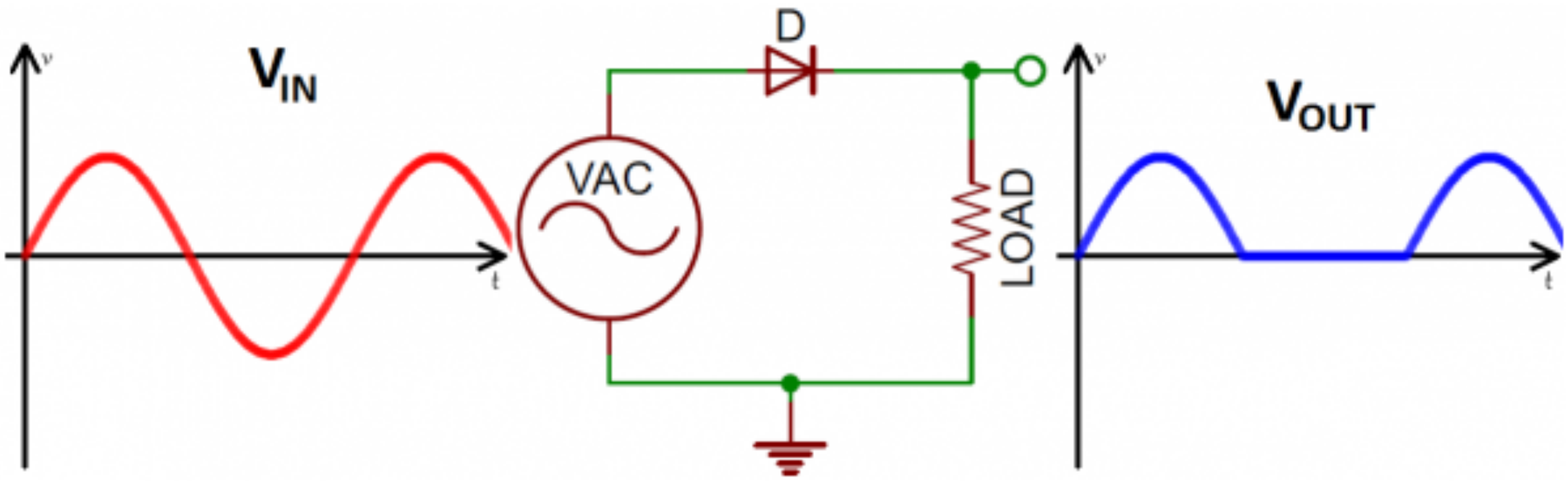


Image: Sparkfun

Diodes can be used as a rectifier to convert AC to DC



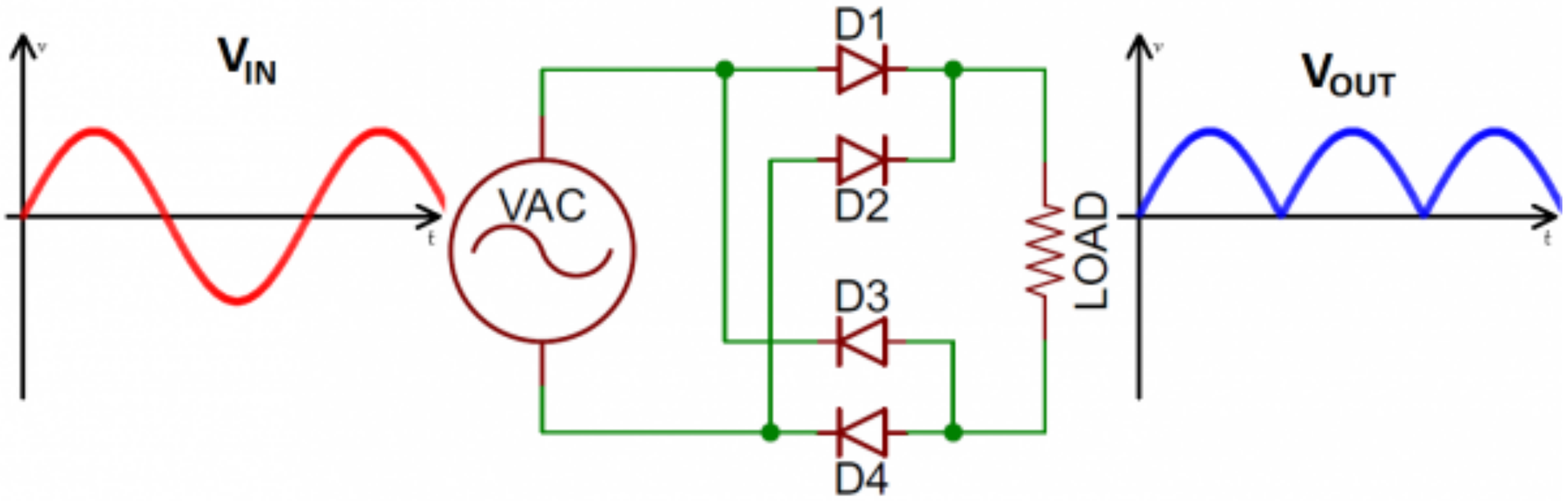


Image: Sparkfun

Diodes are often used as reverse polarity protection

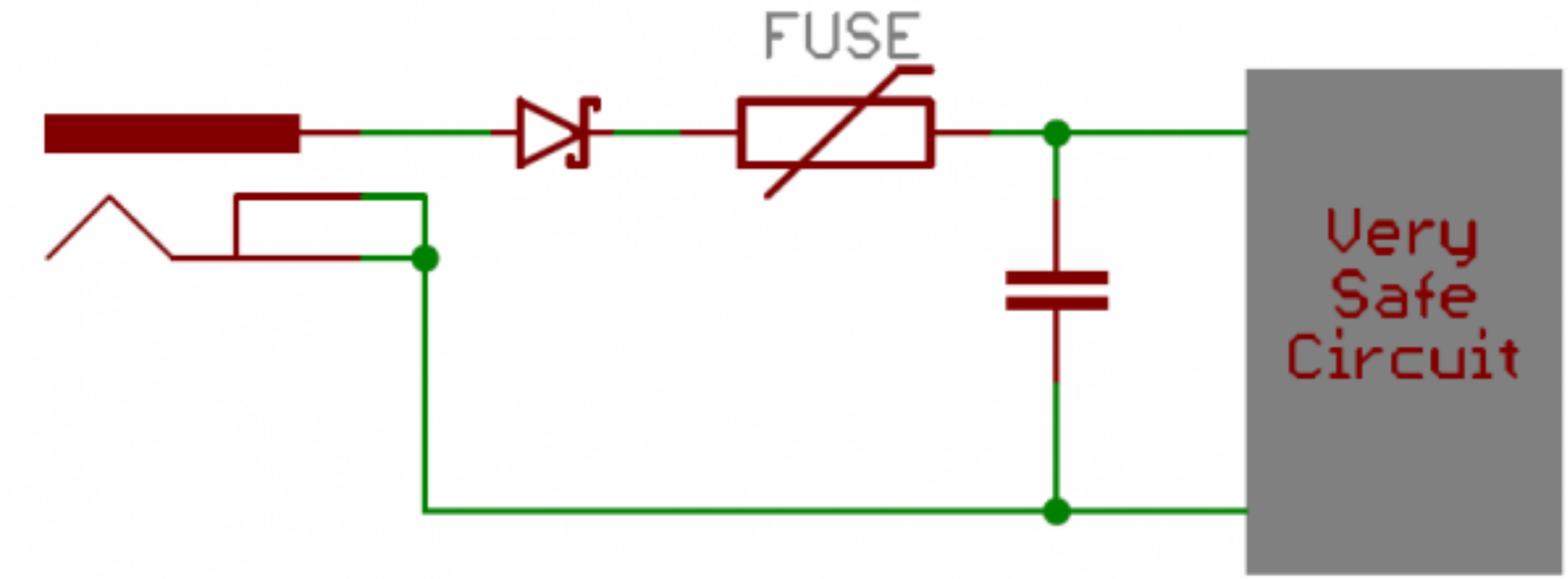
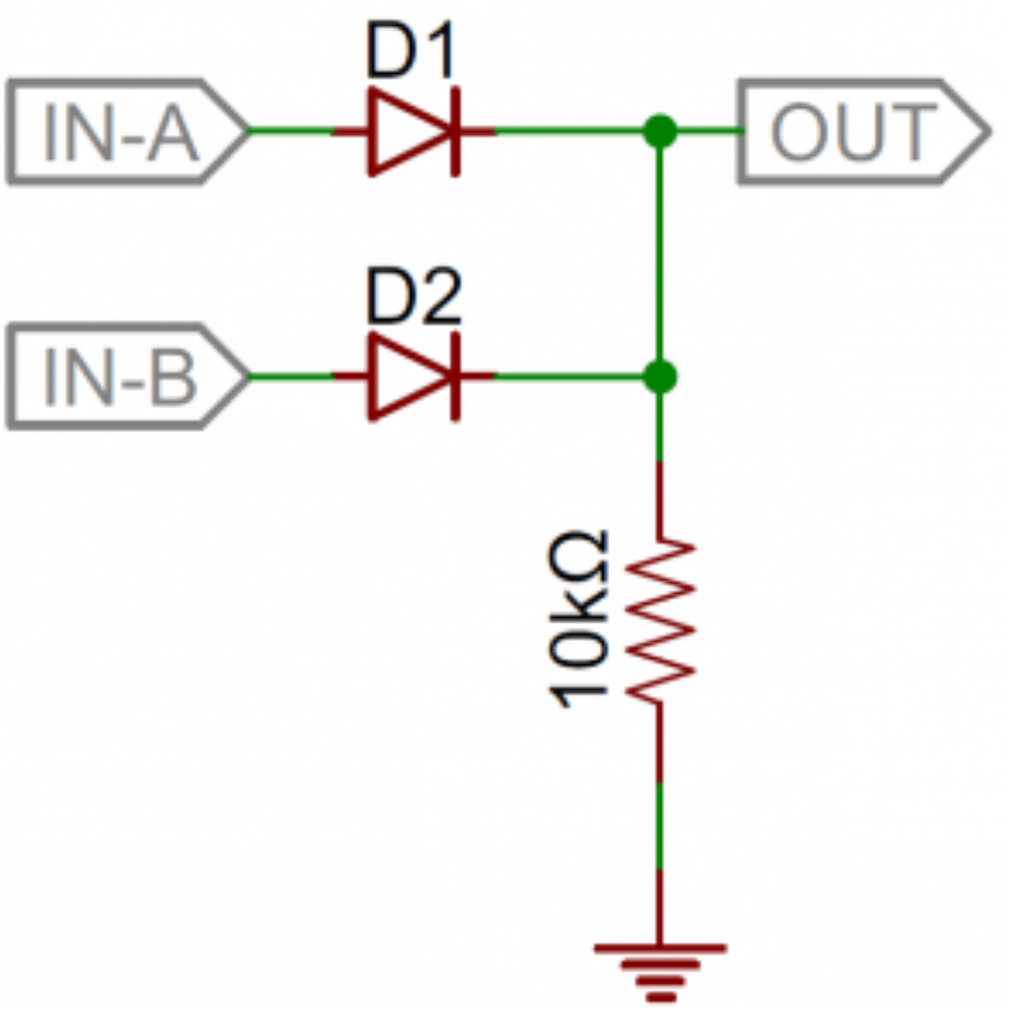


Image: Sparkfun

You can even build logic gates! What are these gates?



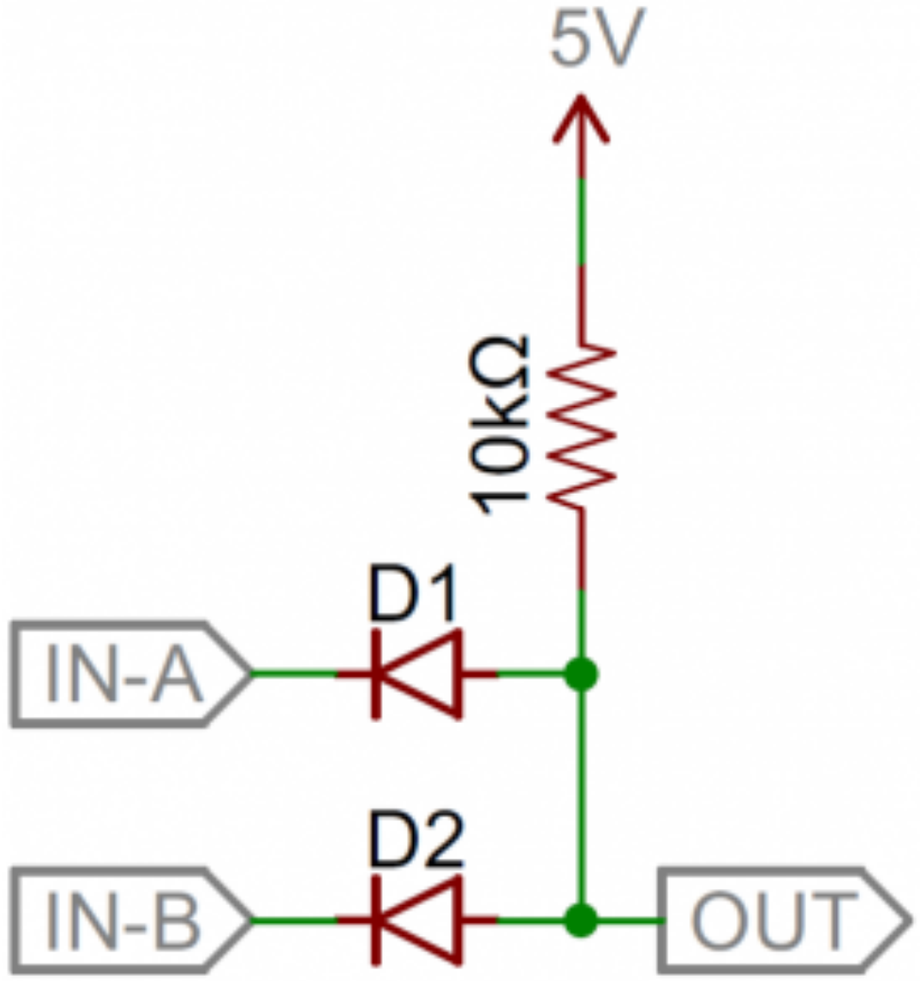
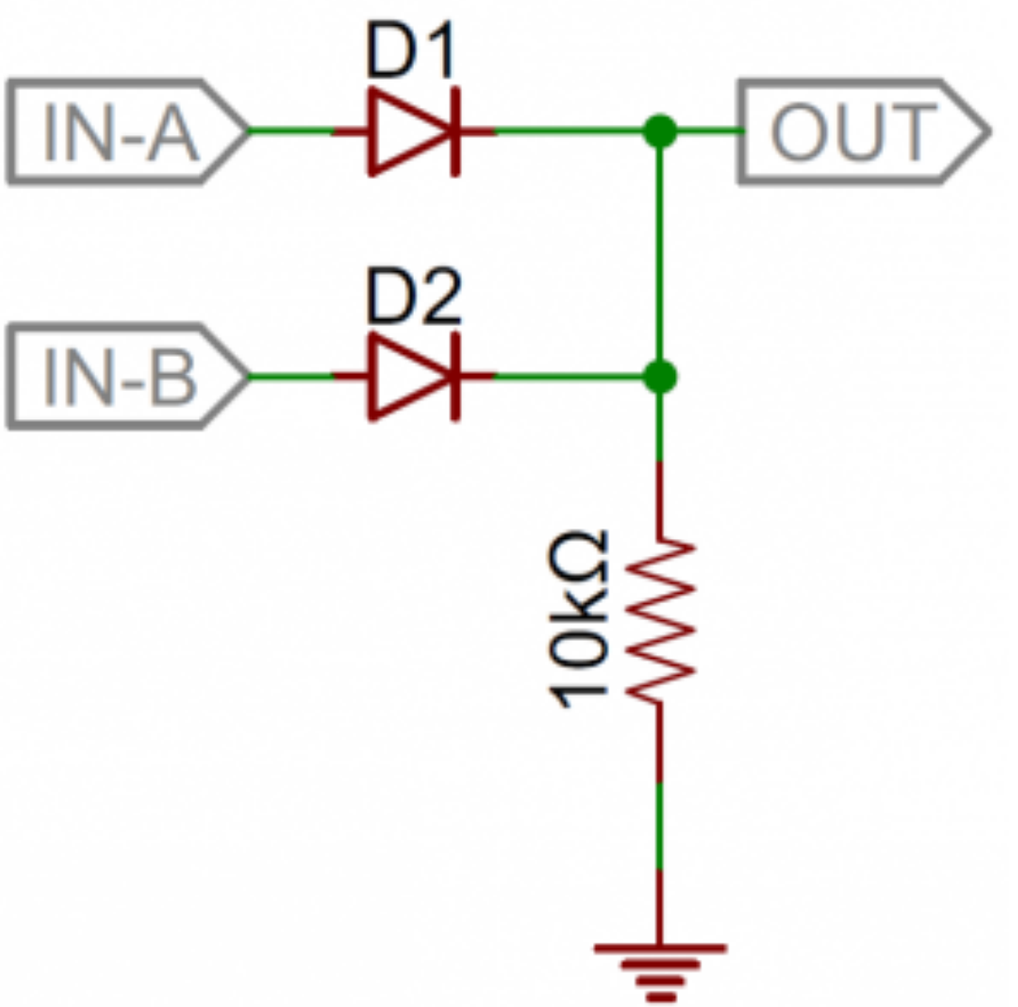


Image: Sparkfun

You can even build logic gates! What are these gates?



OR

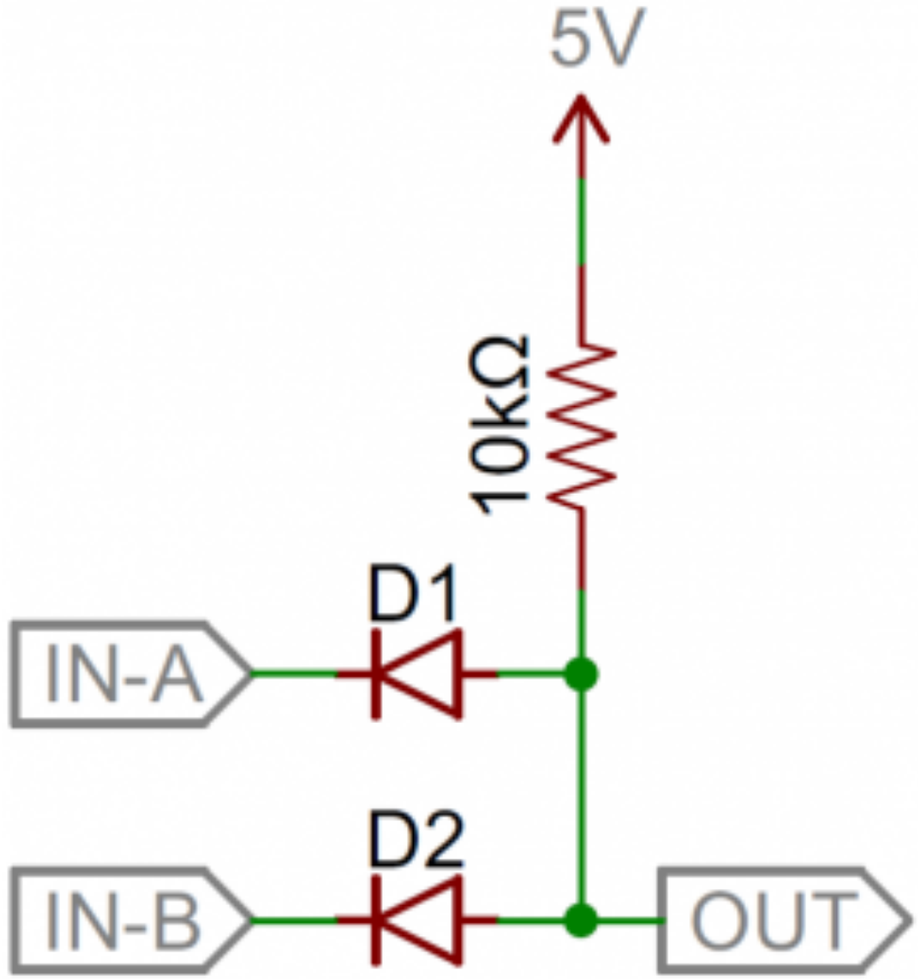
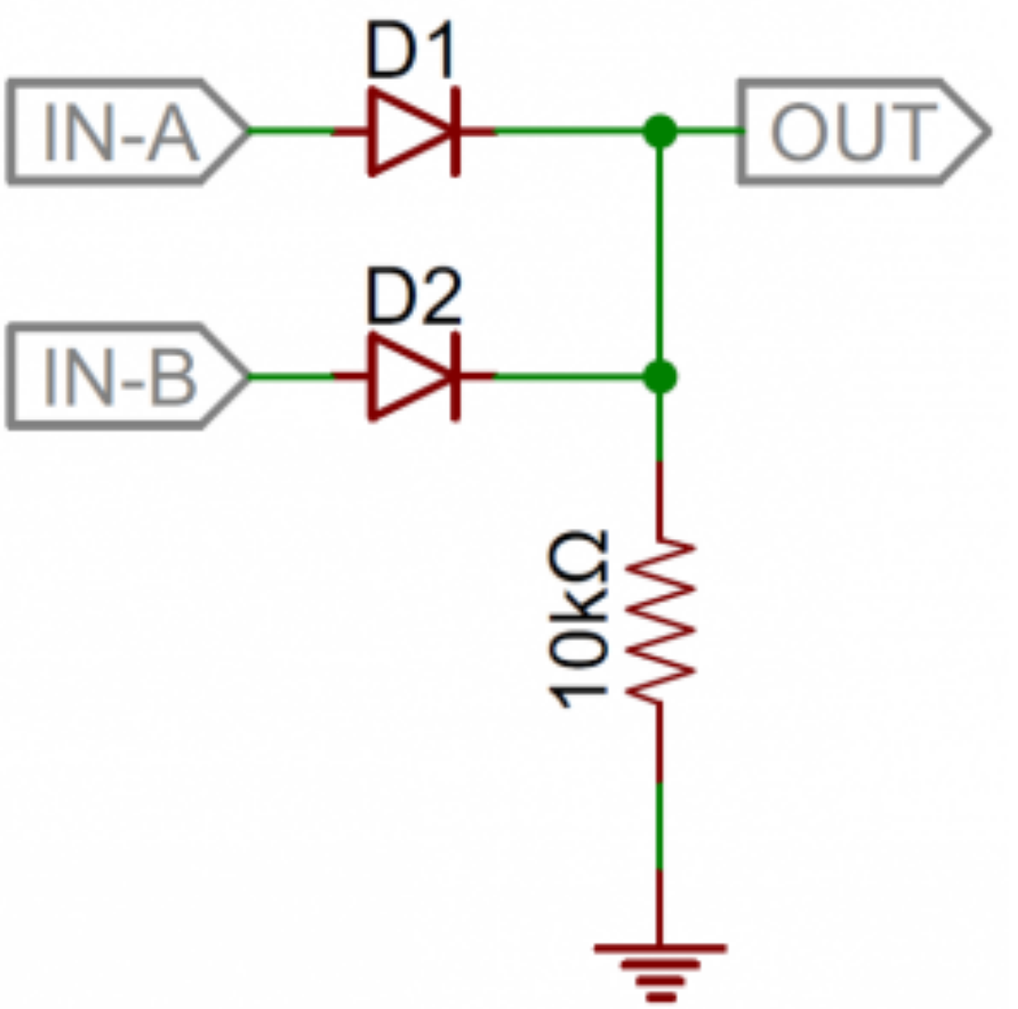
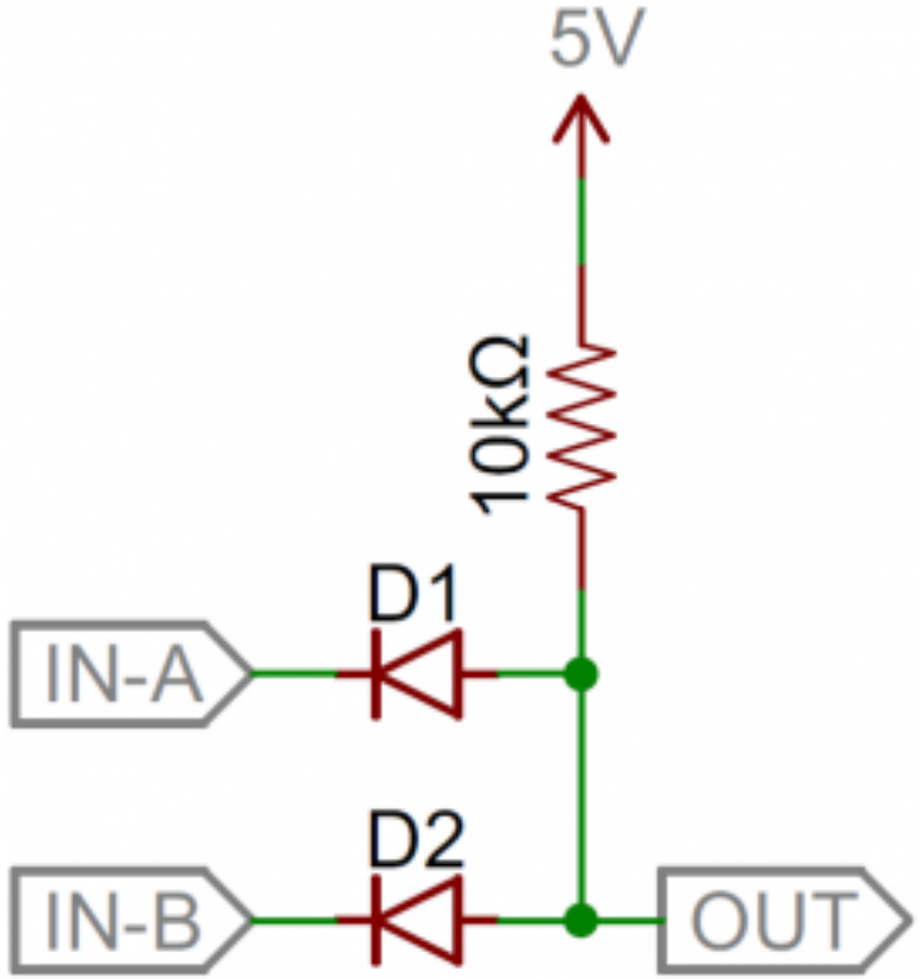


Image: Sparkfun

You can even build logic gates! What are these gates?



OR



AND

Image: Sparkfun

Flyback diodes protect your circuits from inductive voltage spikes

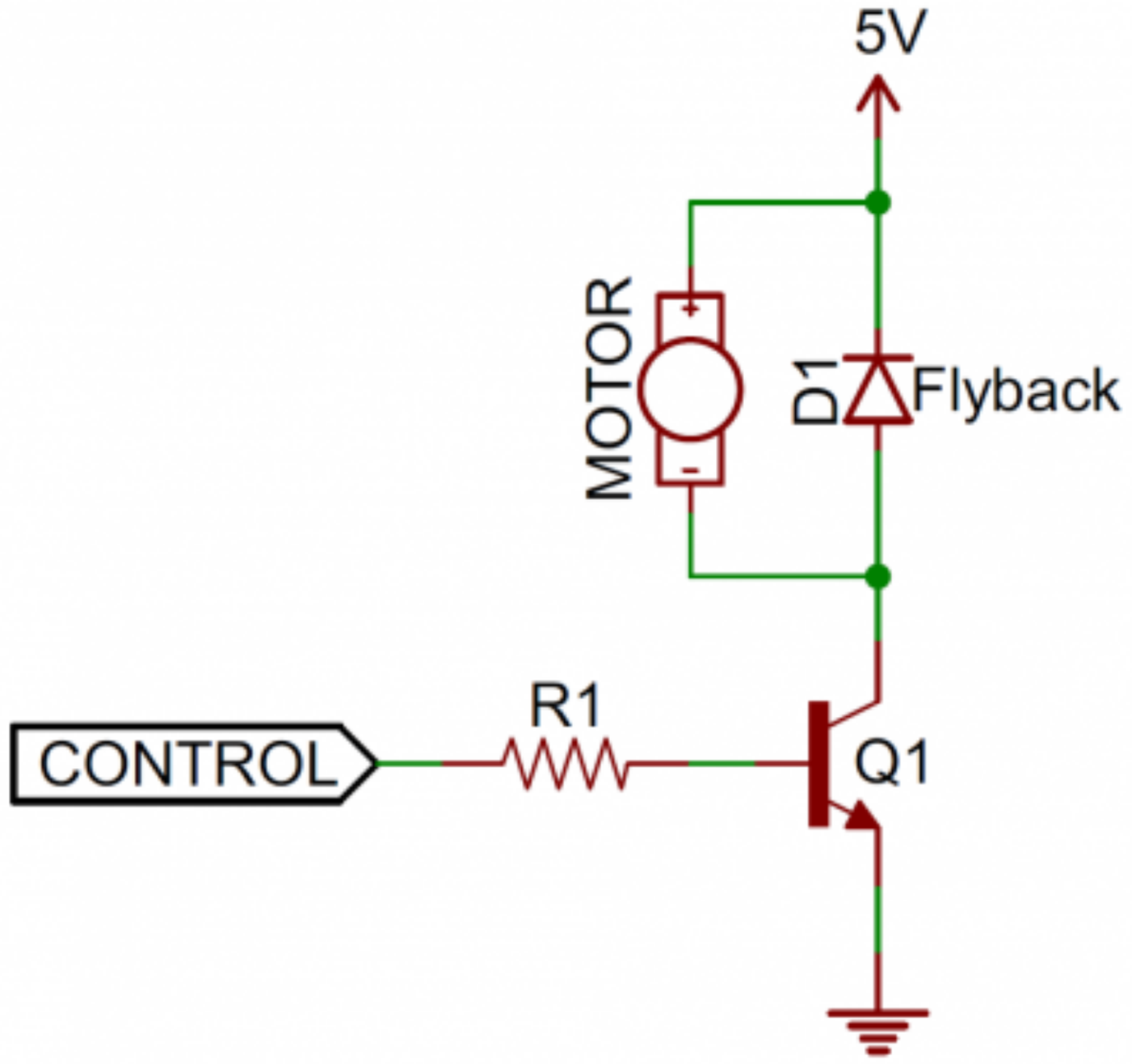
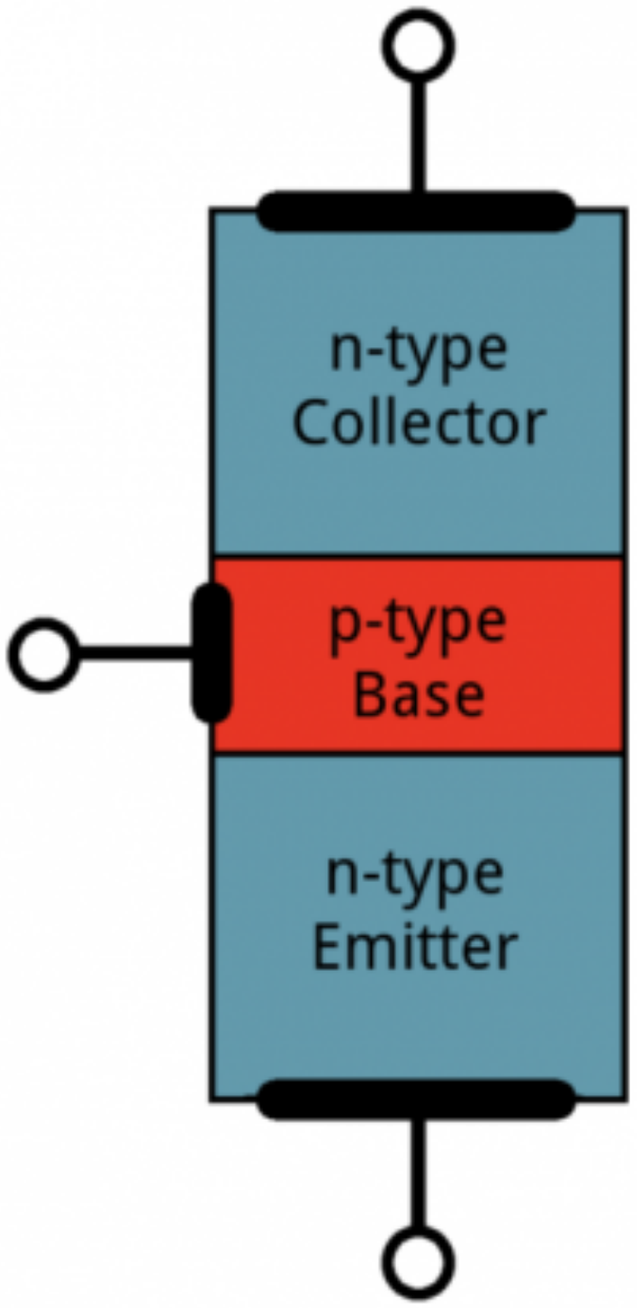


Image: Sparkfun

Transistors

For simplicity, we'll discuss the NPN BJT



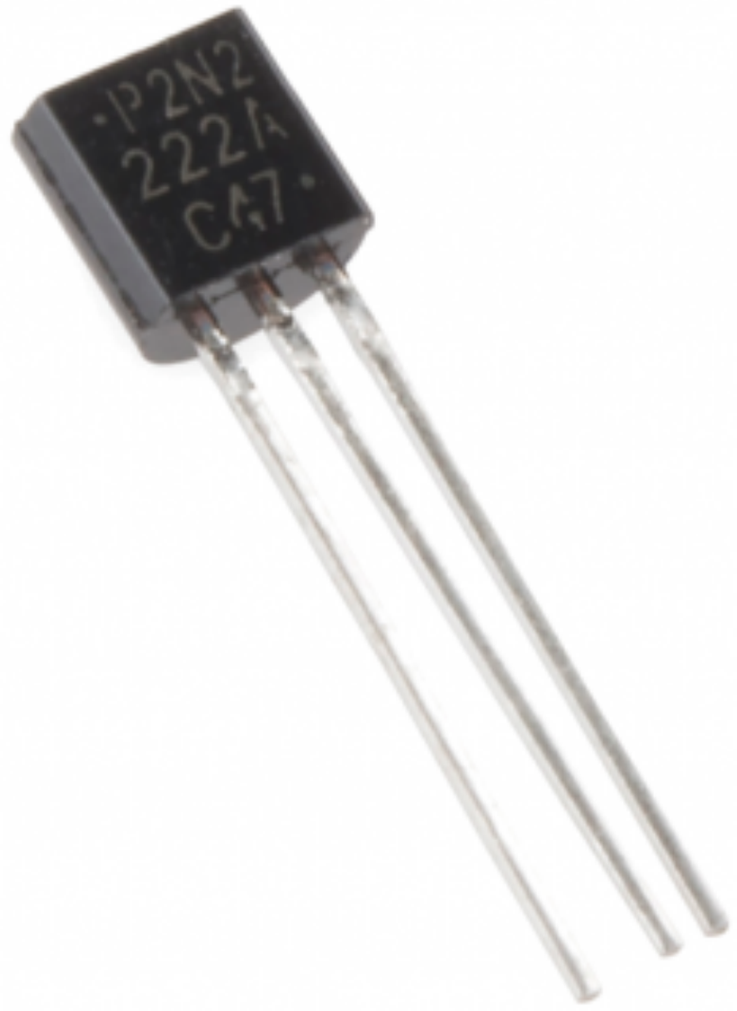


Image: Sparkfun

But there are two types of BJT - NPN and PNP

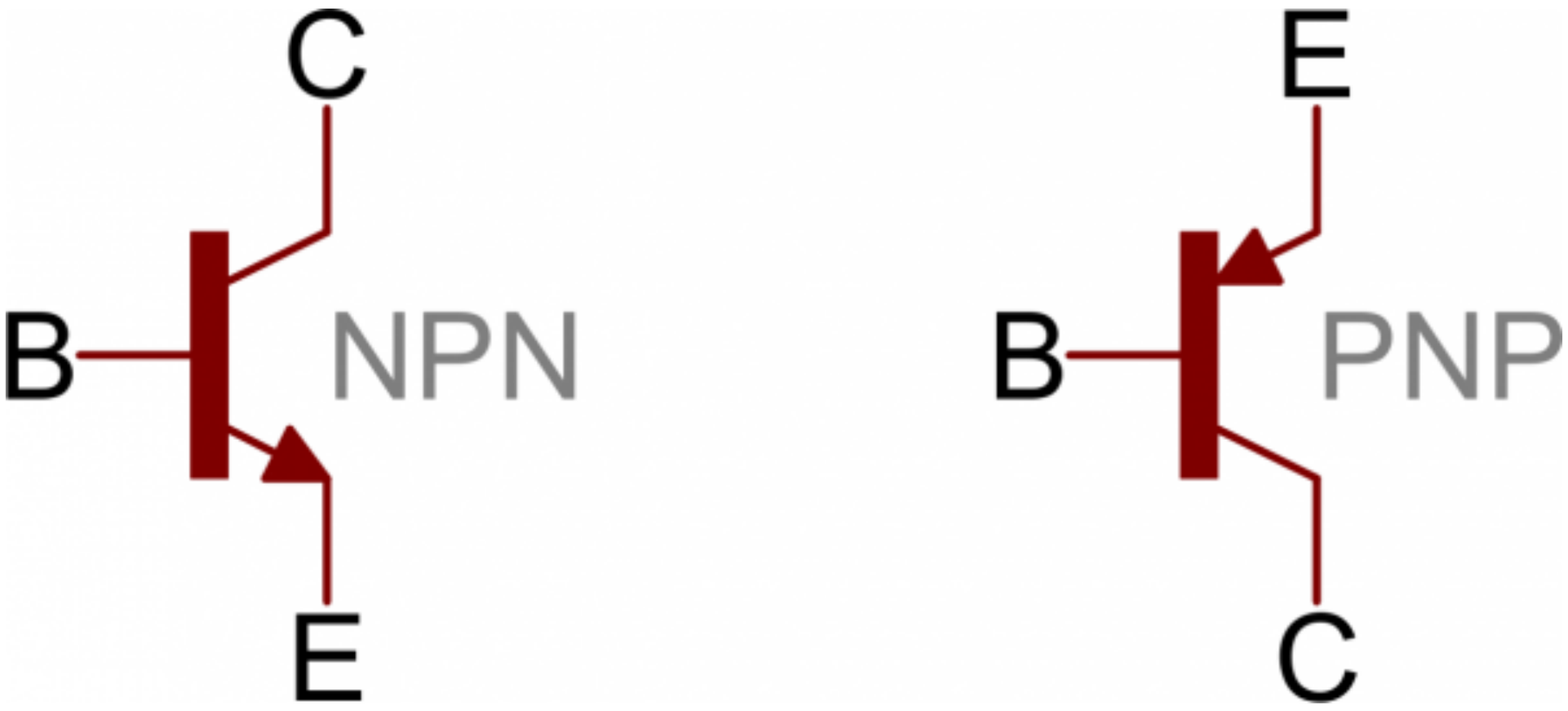


Image: Sparkfun

Transistors can be conceptualized as back-to-back diodes, but don’t take the analogy very far

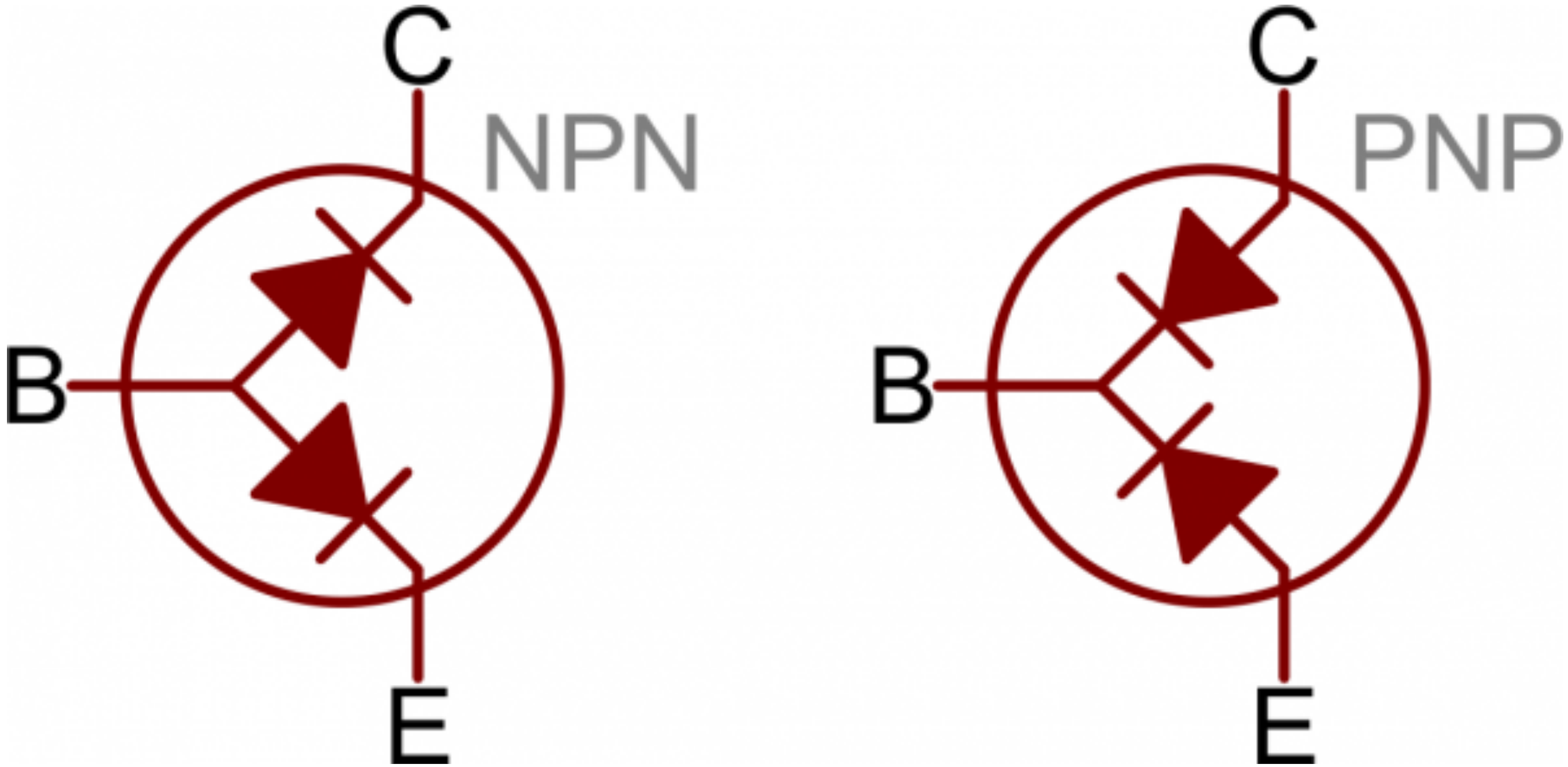


Image: Sparkfun

Electrons can easily from from N to P material, but not P to N

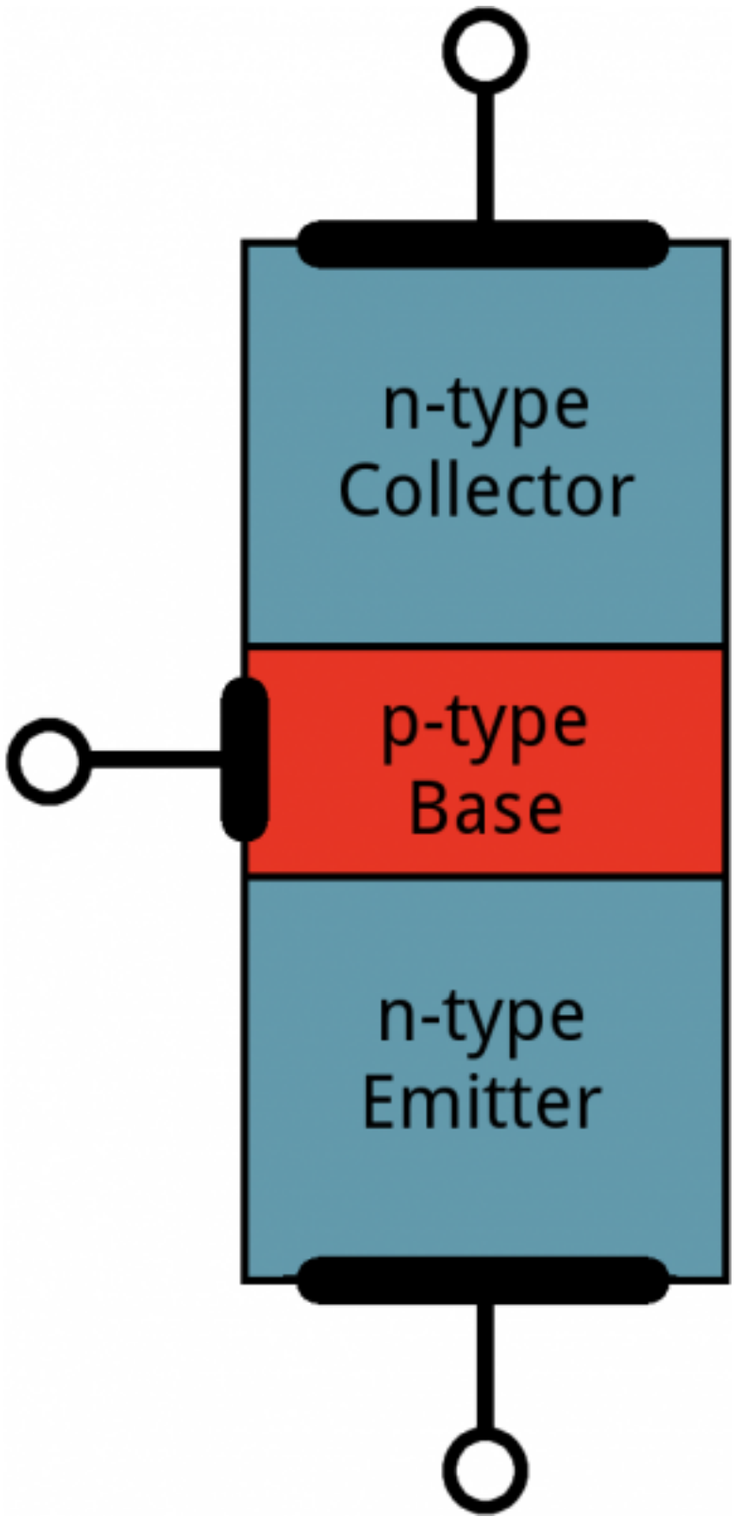


Image: Sparkfun

But electrons CAN flow from base to collector if Base-Emitter is forward biased

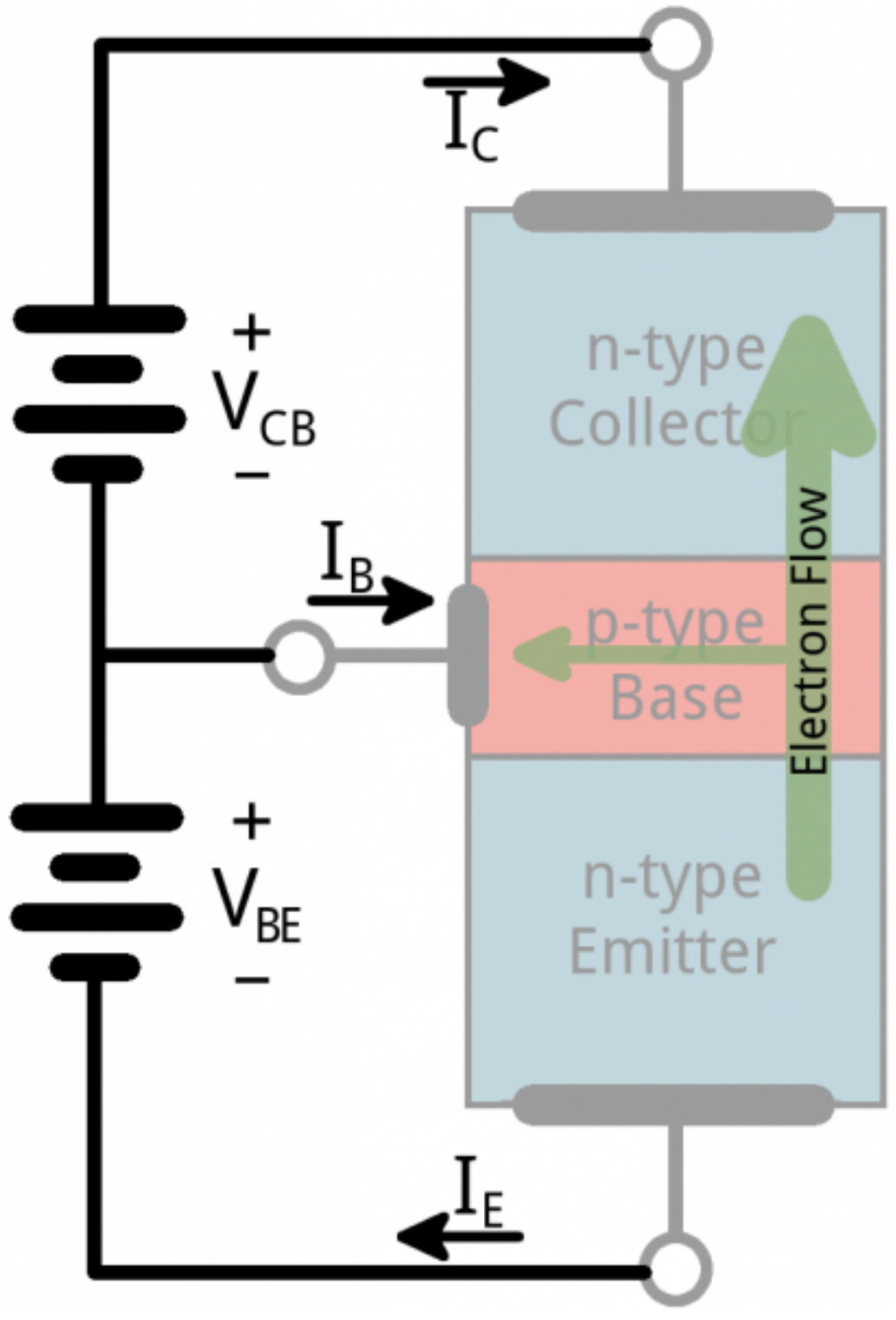
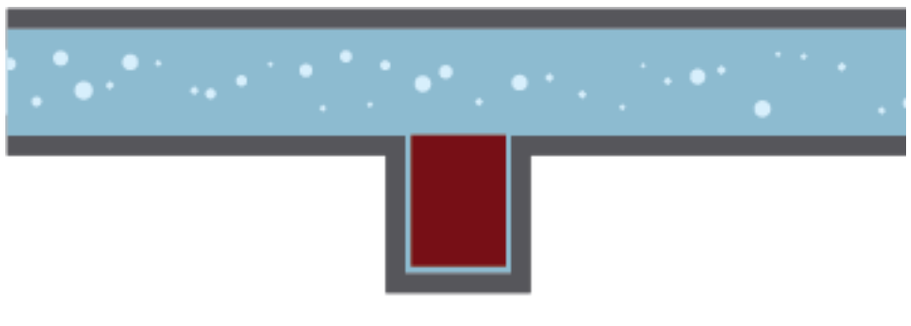
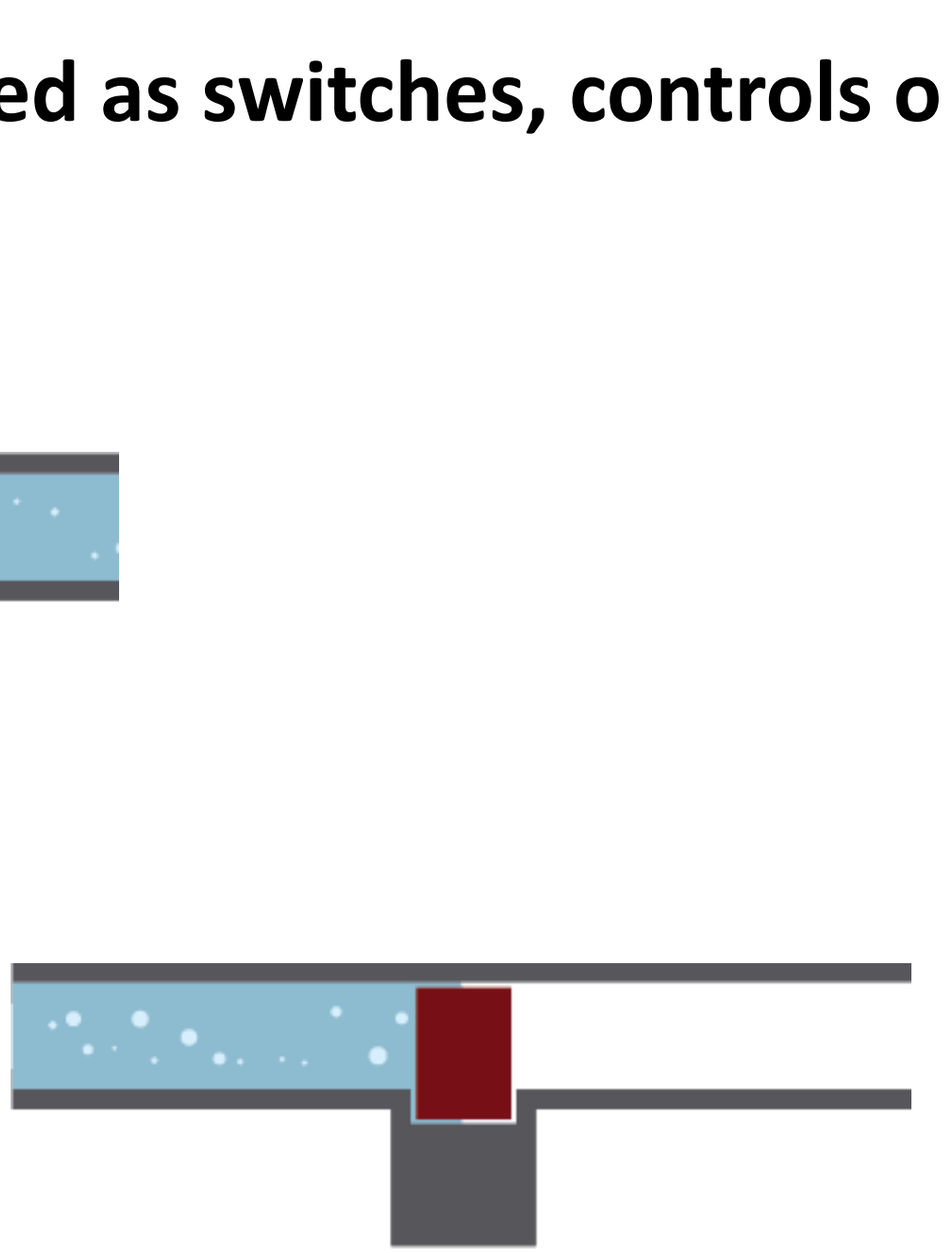


Image: Sparkfun

Transistors can be used as switches, controls or amplifiers



Transistor On



Transistor Off

Flow Control

Image: Sparkfun

Transistors are non-linear devices and operate in one of four quadrants of behavior

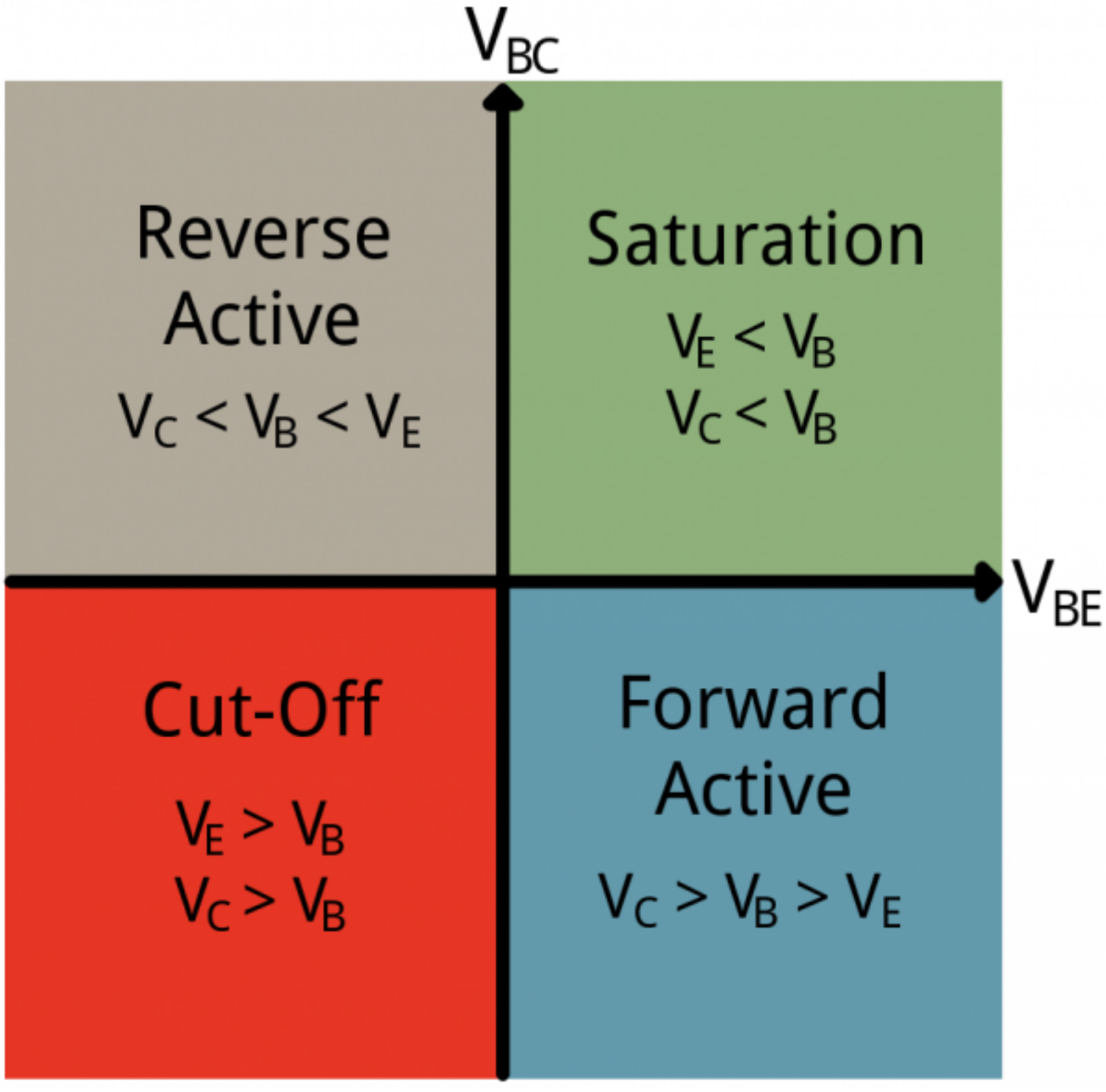
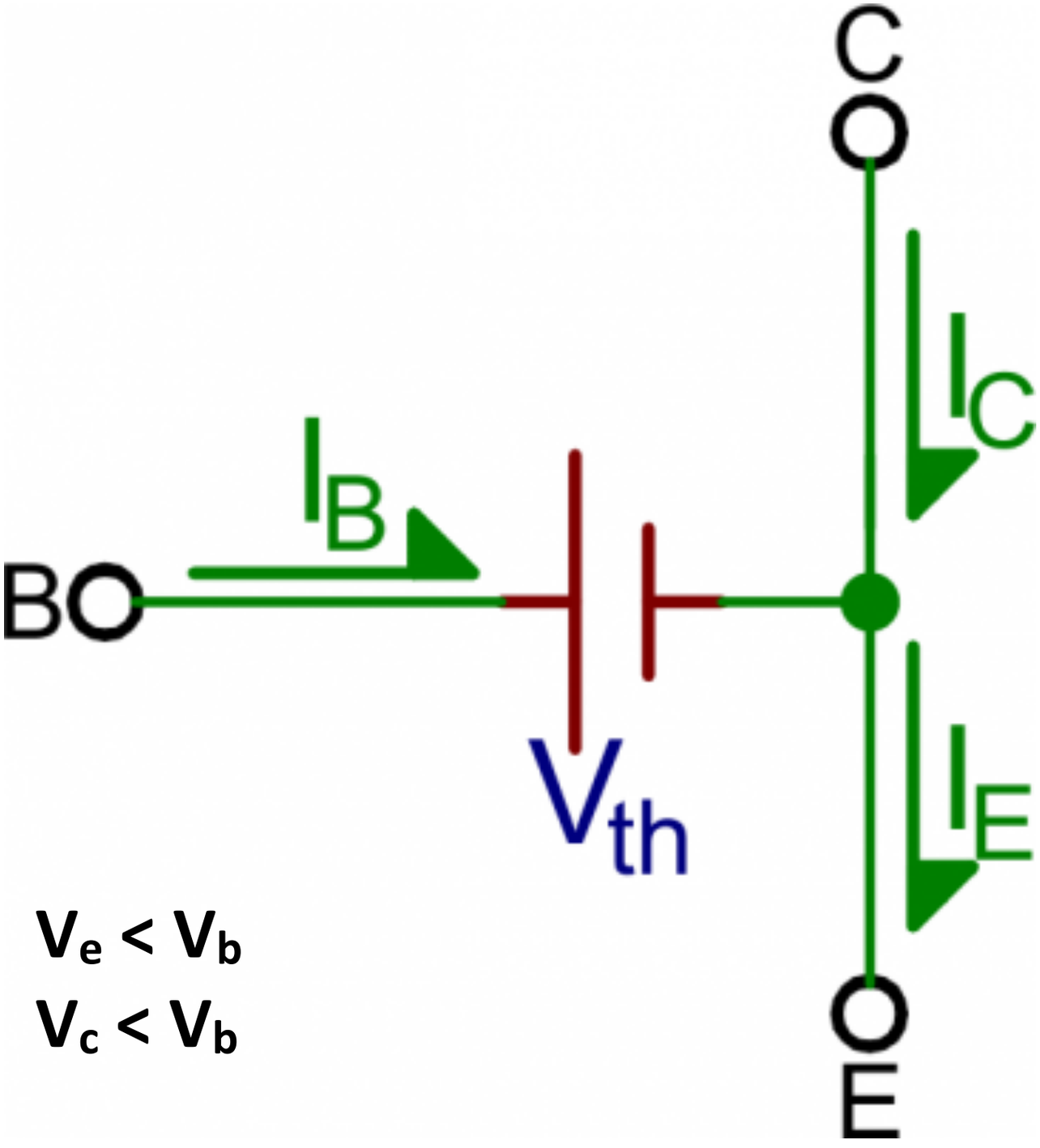


Image: Sparkfun

Saturation is the “ON” state of a transistor

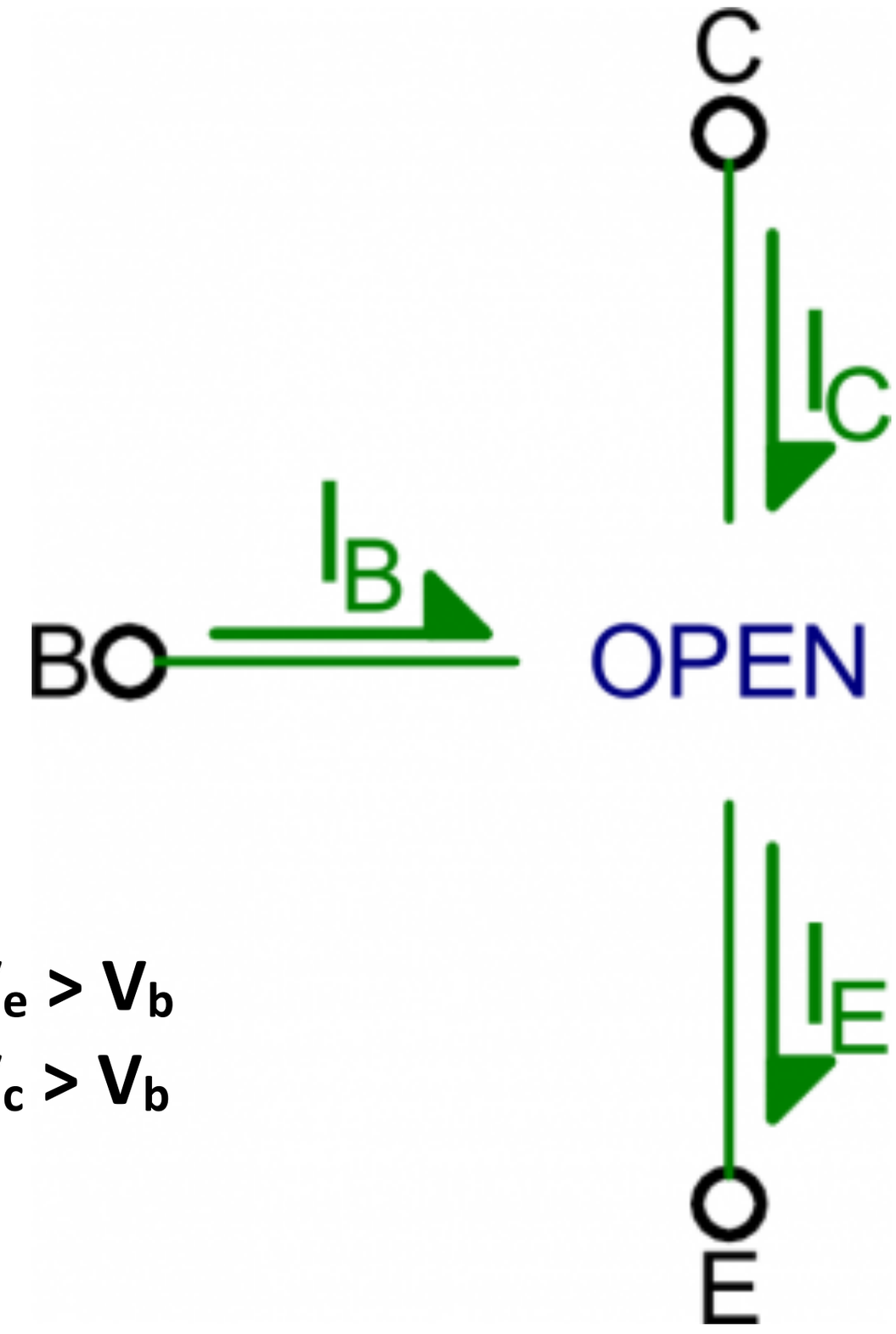


$V_e < V_b$

$V_c < V_b$

Image: Sparkfun

Cutoff is the “OFF” state of the transistor

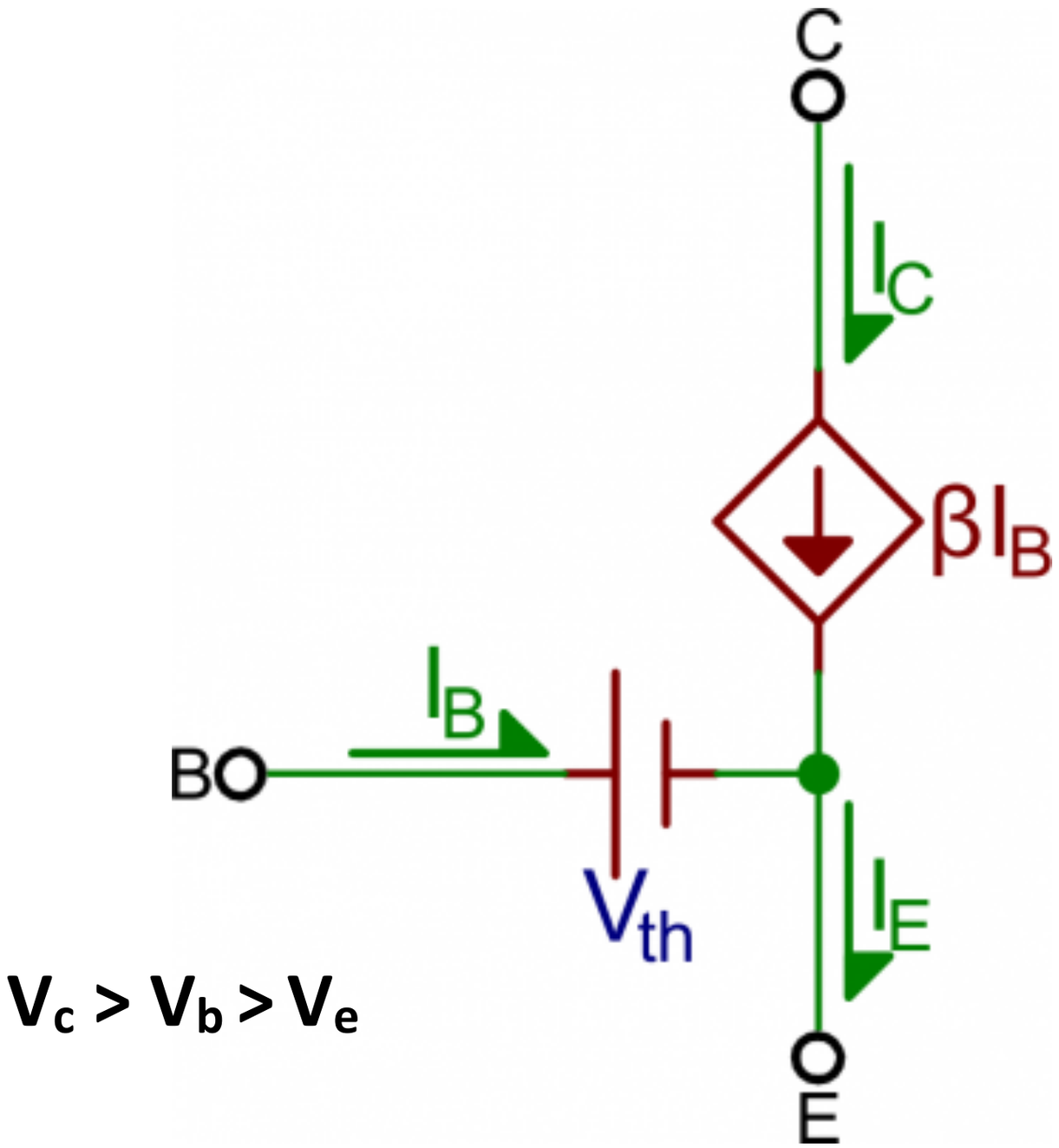


$V_e > V_b$

$V_c > V_b$

Image: Sparkfun

Active mode amplifies current into the base pin to the C-E current

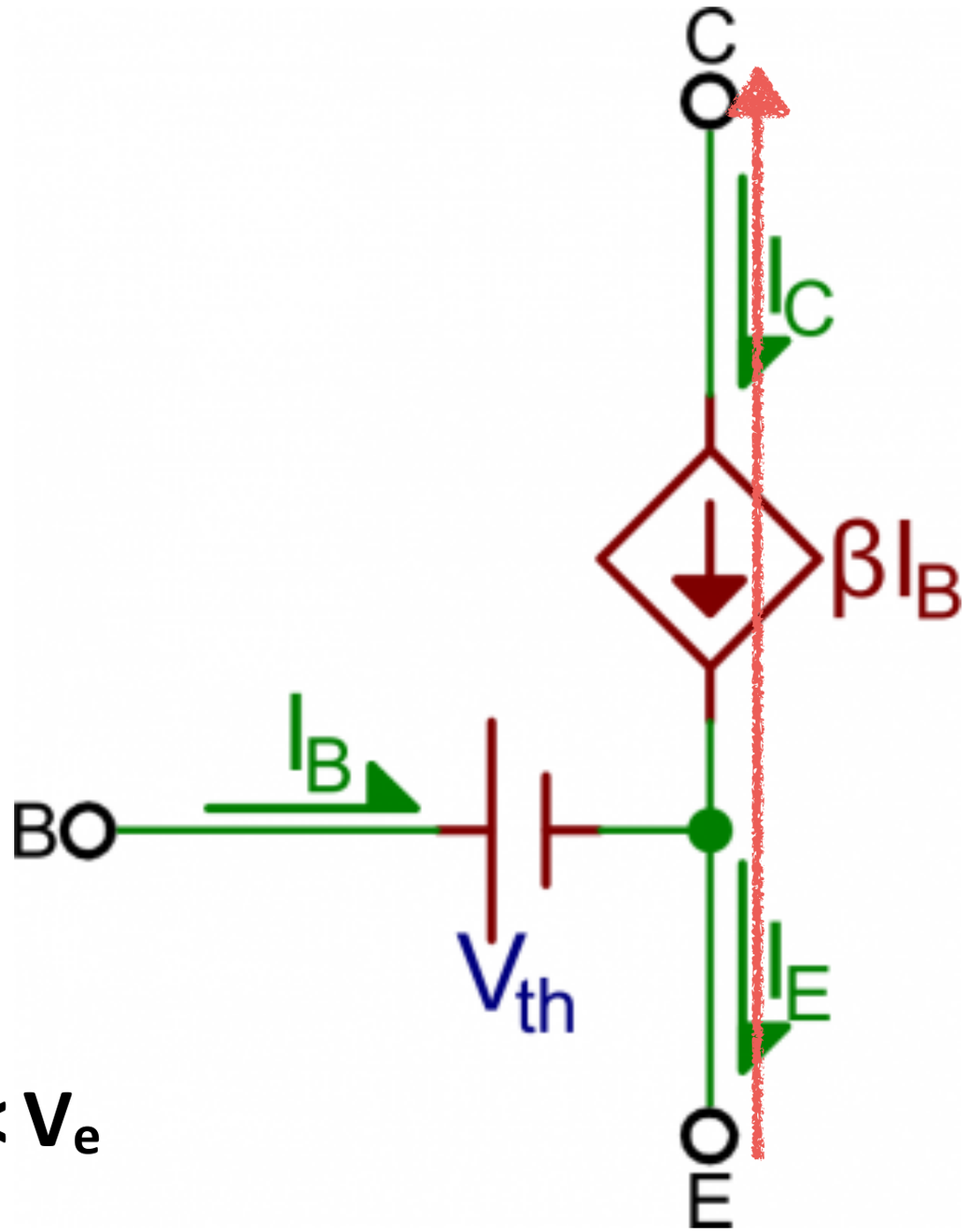


$$I_C = \beta I_B$$

$V_c > V_b > V_e$

Image: Sparkfun

Reverse active amplifies current from emitter to collector, but isn't a very common design case



$V_c < V_b < V_e$

Image: Sparkfun

Let’s use a transistor as a switch

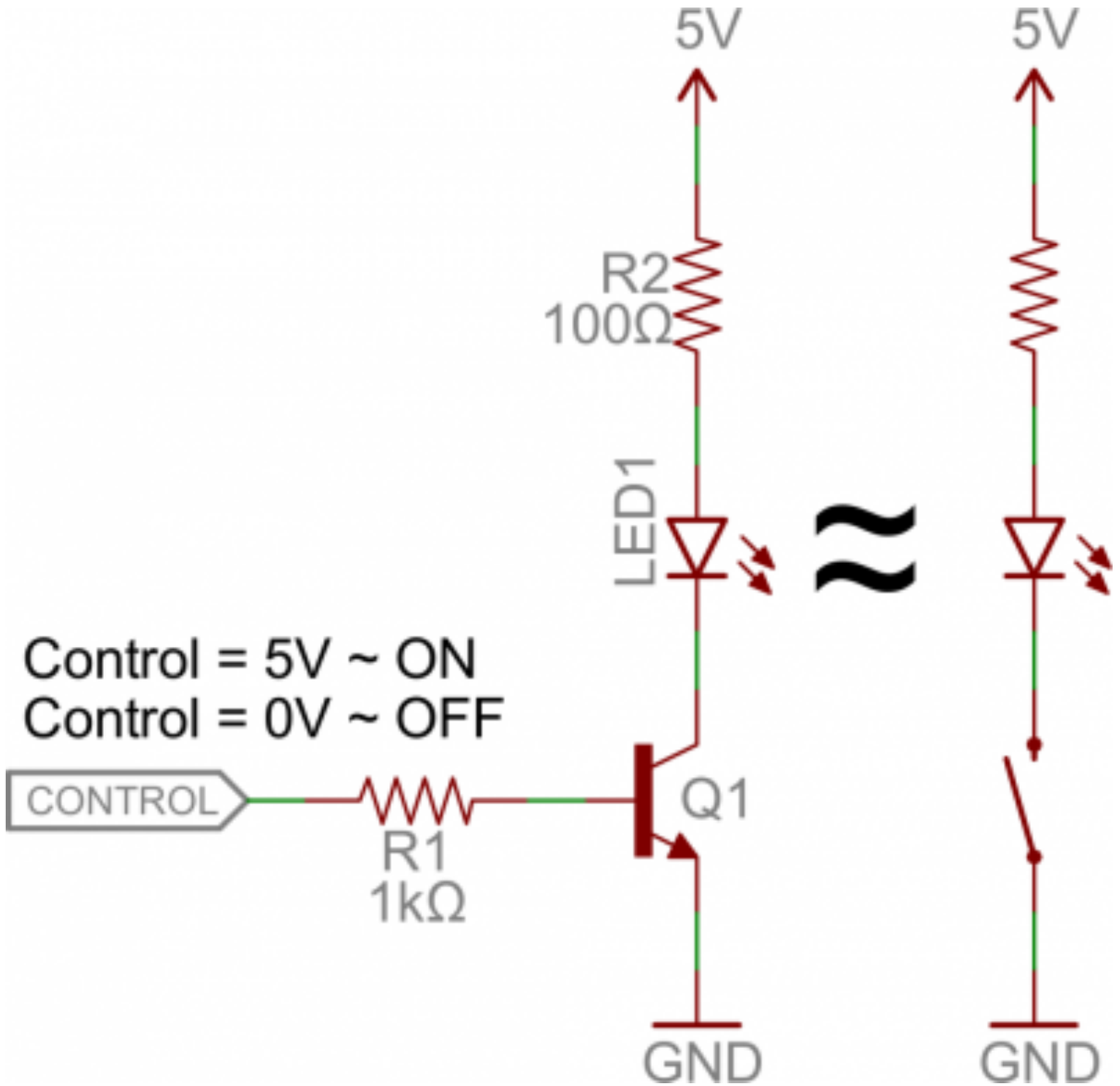


Image: Sparkfun

We can also high-side switch with a PNP

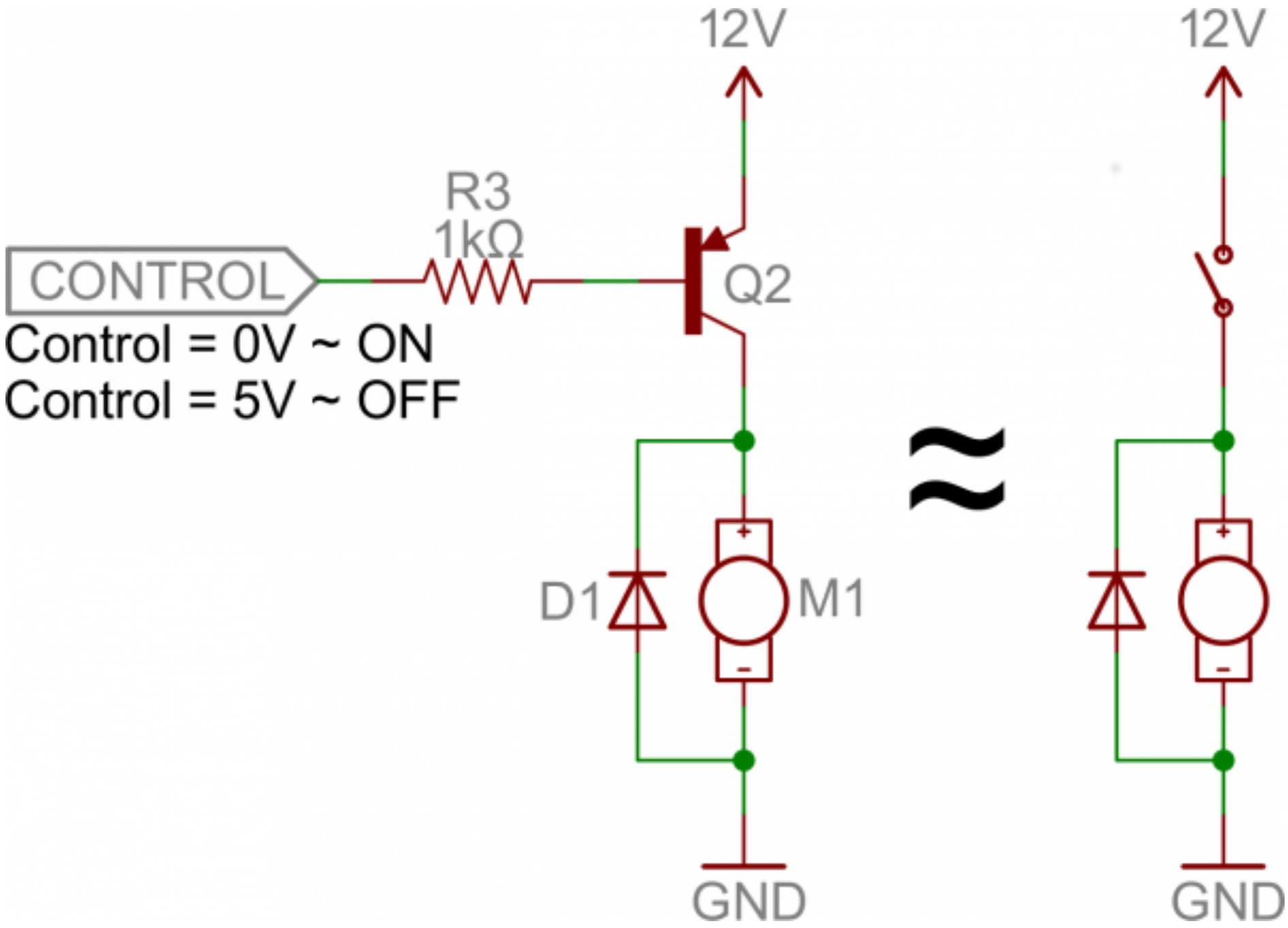


Image: Sparkfun

H-Bridges can drives motors in the CW or CCW direction

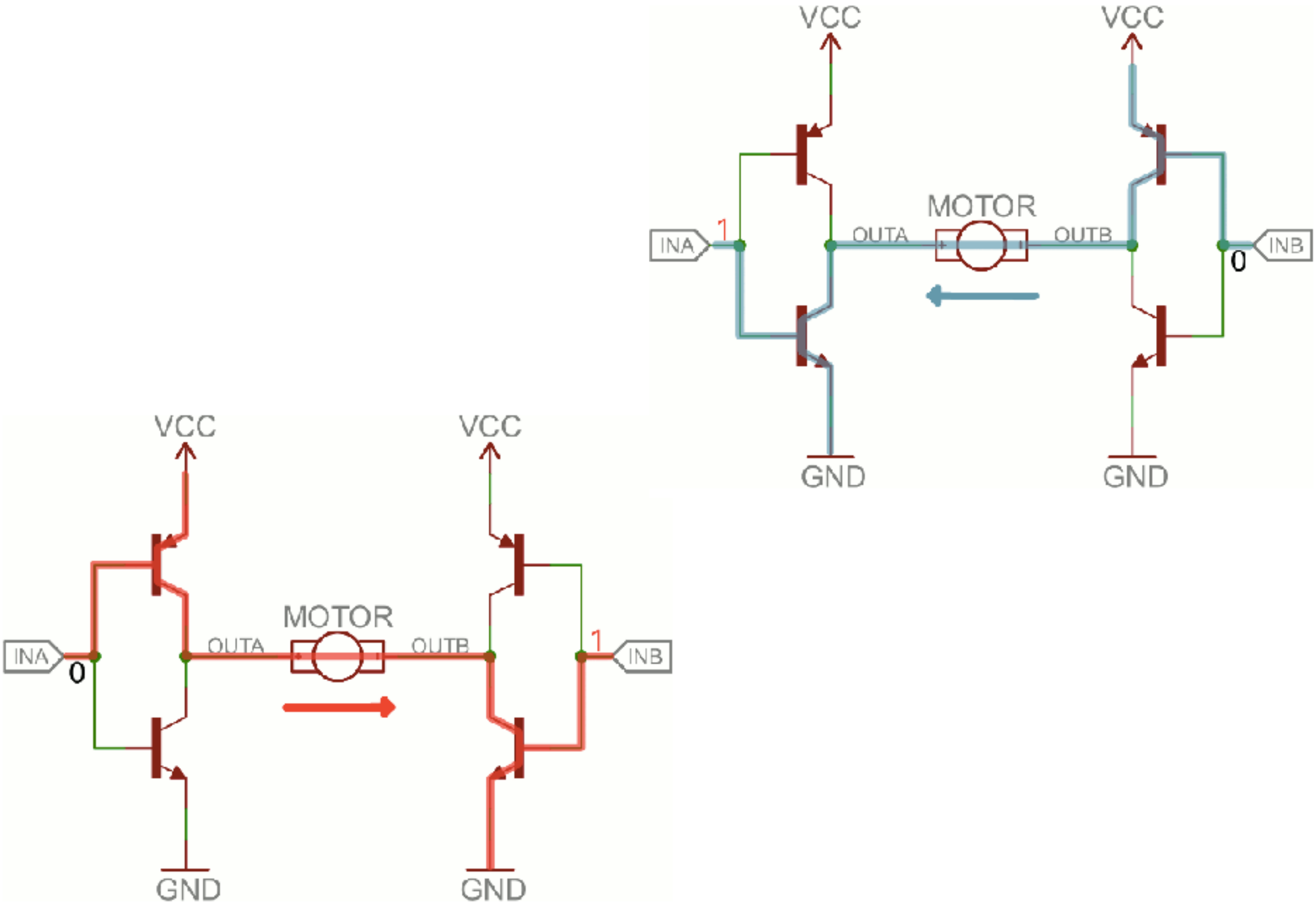


Image: Sparkfun

Amplifier circuits can be single or multi-stage and are only slightly more complicated

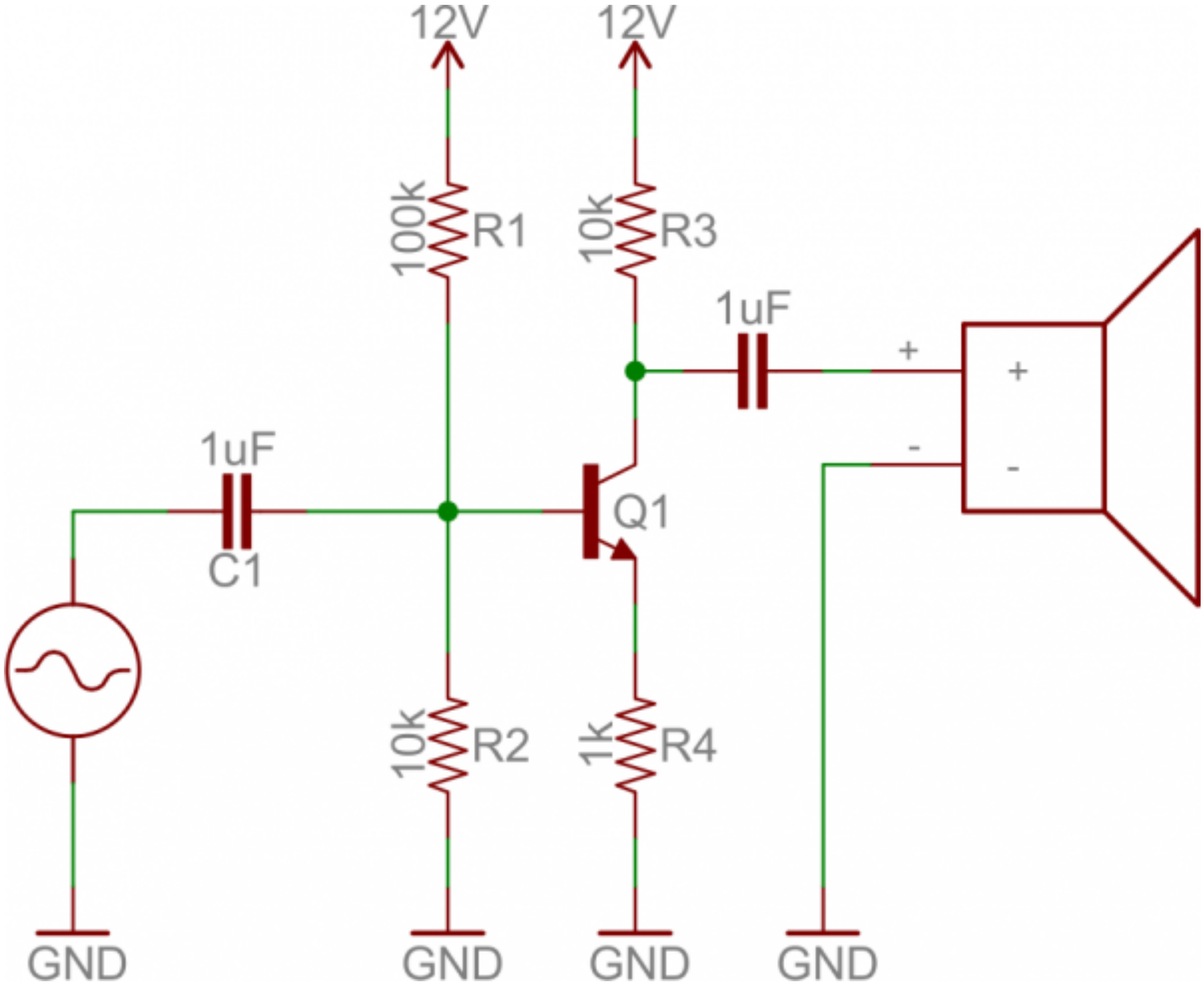


Image: Sparkfun

Assignment: Pair up and build the Arduino Voltmeter with one kit

Due : 10/13