How To Make (Almost) Anything 2023

Recitation - Electronics

Miana Smith, Fangzheng Liu

Slides adapted from prior HTMAA years

Slides available here:
https://docs.google.com/presentation/d/1RAJqF2f2H65iTIqb9B1hG3qcKtz2Ty1J/edit?usp=sharing&ouid=111928349056878132437&rtpof=true&sd=true

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1. Learn (or recall) basic electrical engineering
2. Use it to design a custom circuit board in a new software program (EDA)
3. Mill it and solder on all the parts properly
4. Program your board to do something

Ohm's Law:

$$V = I * R$$

Voltage (measure in volts)

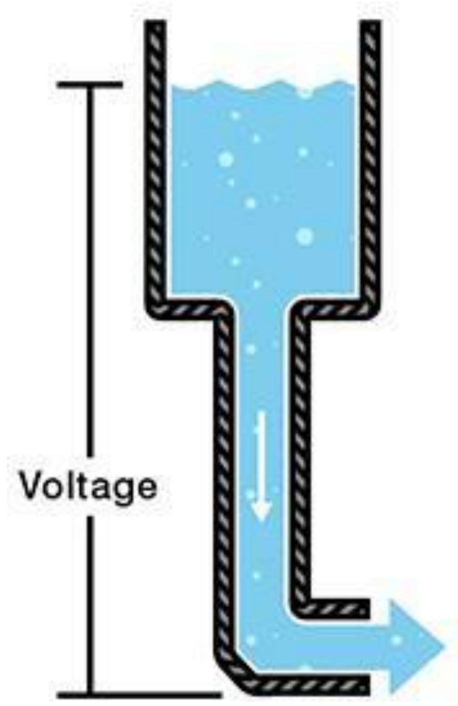
I: Current (measure in amps)

Resistance (measured in ohms)

https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law/all

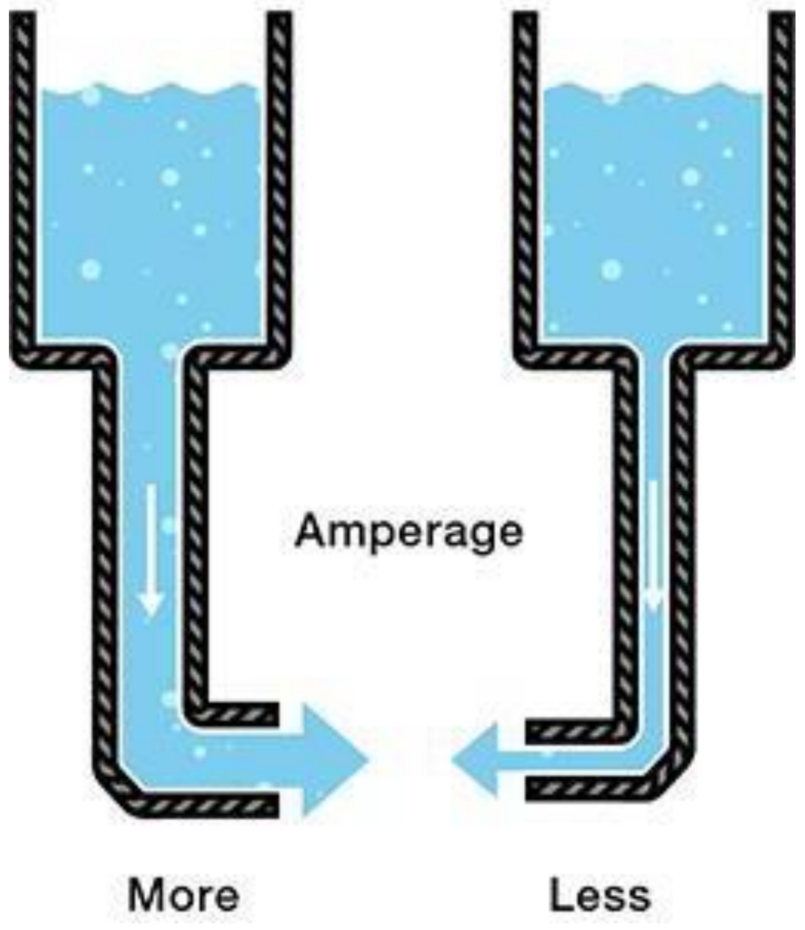
Voltage

Measures the **difference in electrical potential** between two points – often an input voltage (vcc) and ground (gnd)



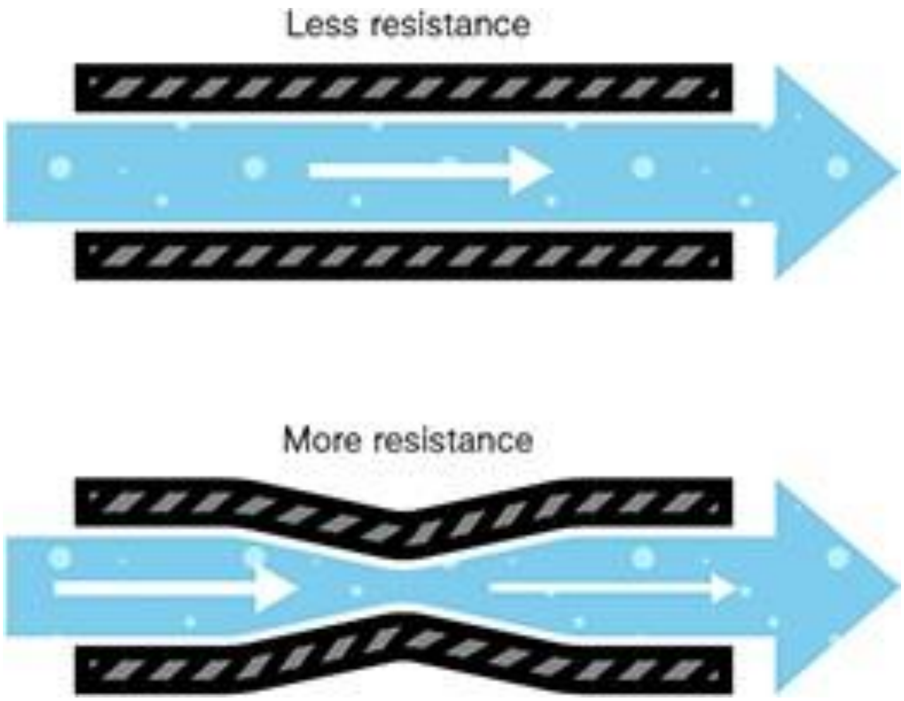
Current

Measures the **rate of flow of electrons** in a circuit



Resistance

Measures **how hard it is for electrons to move** through a circuit



Triplets

- Voltage: potential to do work (electron pressure)
- Current: work (electron flow)
- Resistance: … friction (electron resistance)

Ohm’s Law:

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Voltage (measure in volts)

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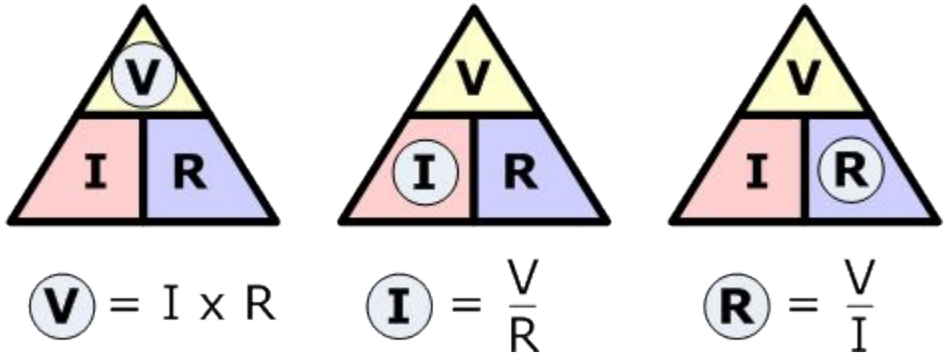
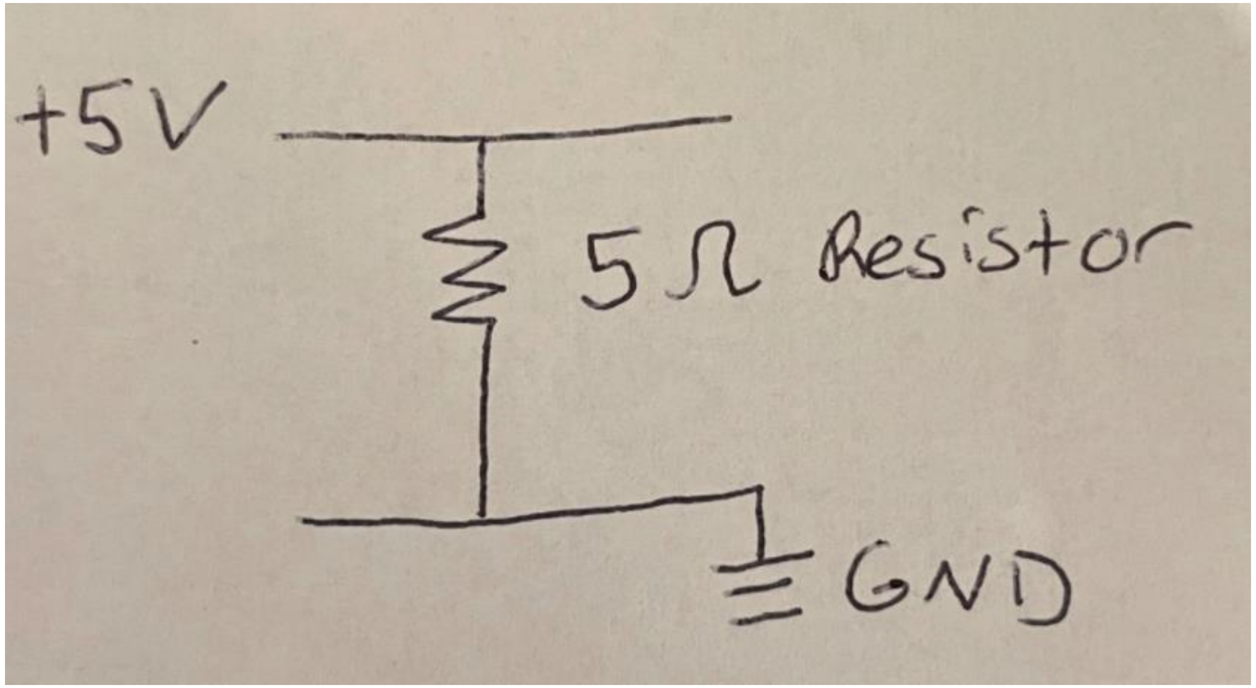


How much current goes through this resistor?



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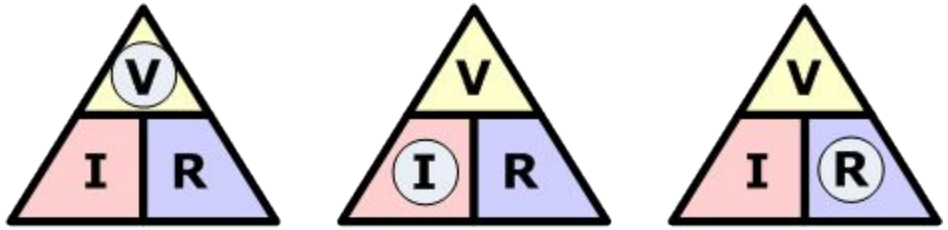

$V = I \times R$ $\quad I = \frac{V}{R}$ $\quad R = \frac{V}{I}$

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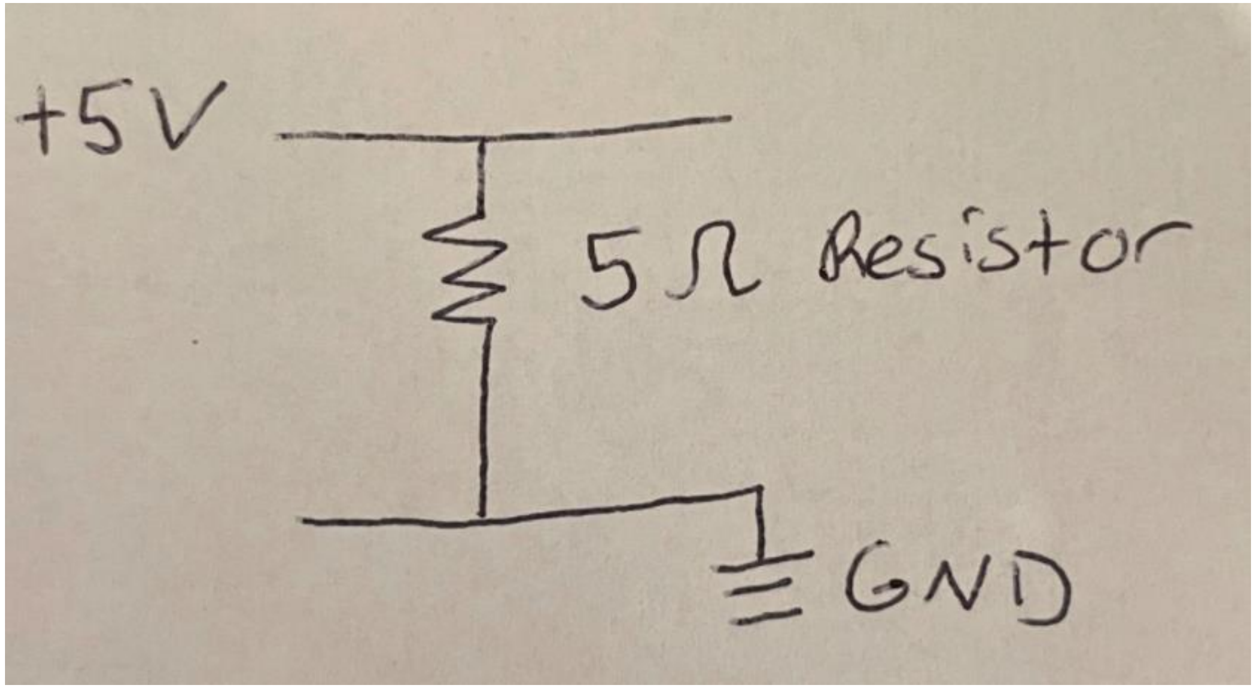

1A

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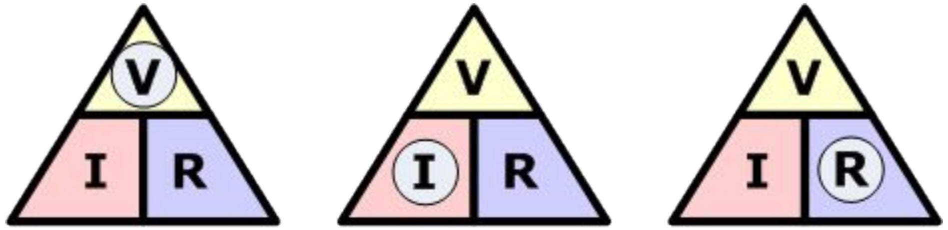

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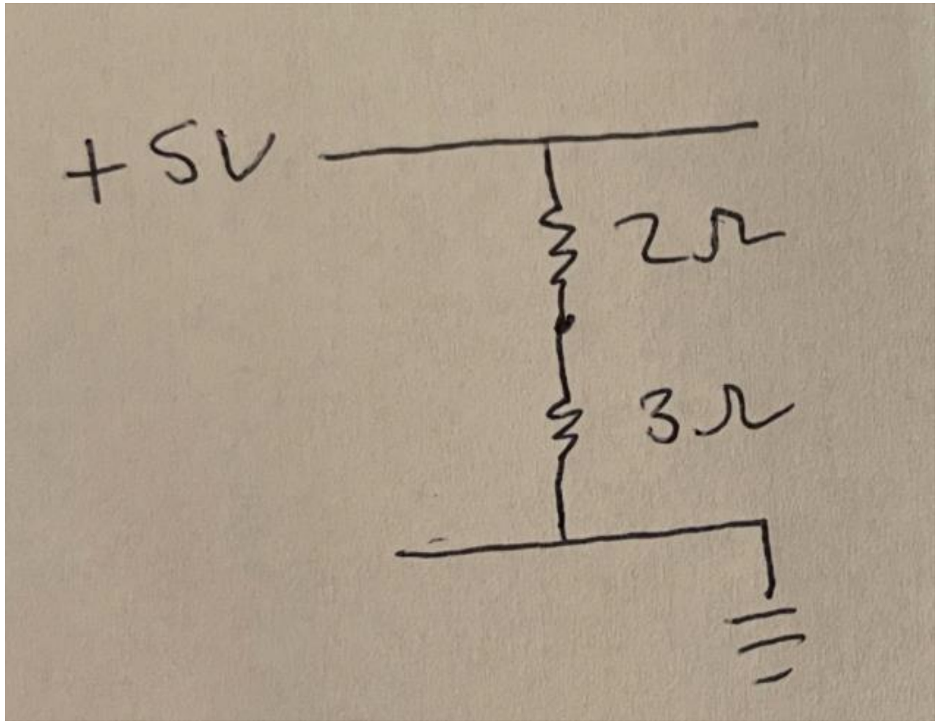
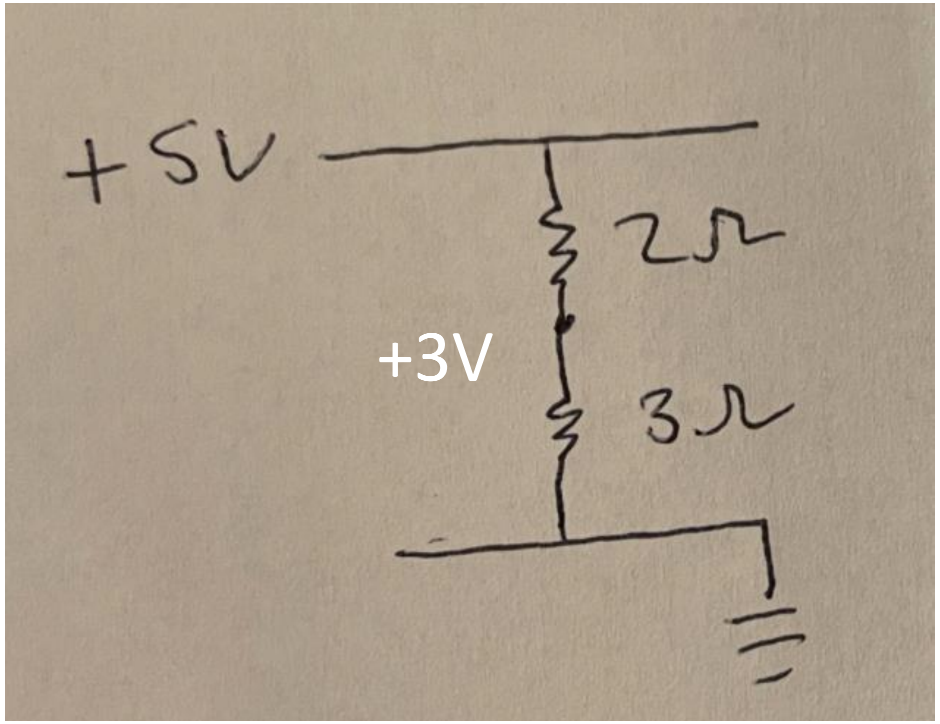
How about these resistors?



Ohm's Law:

- Resistance in series adds
- To learn more about series and parallel check out this link: https://en.wikipedia.org/wiki/Series_and_parallel_circuits

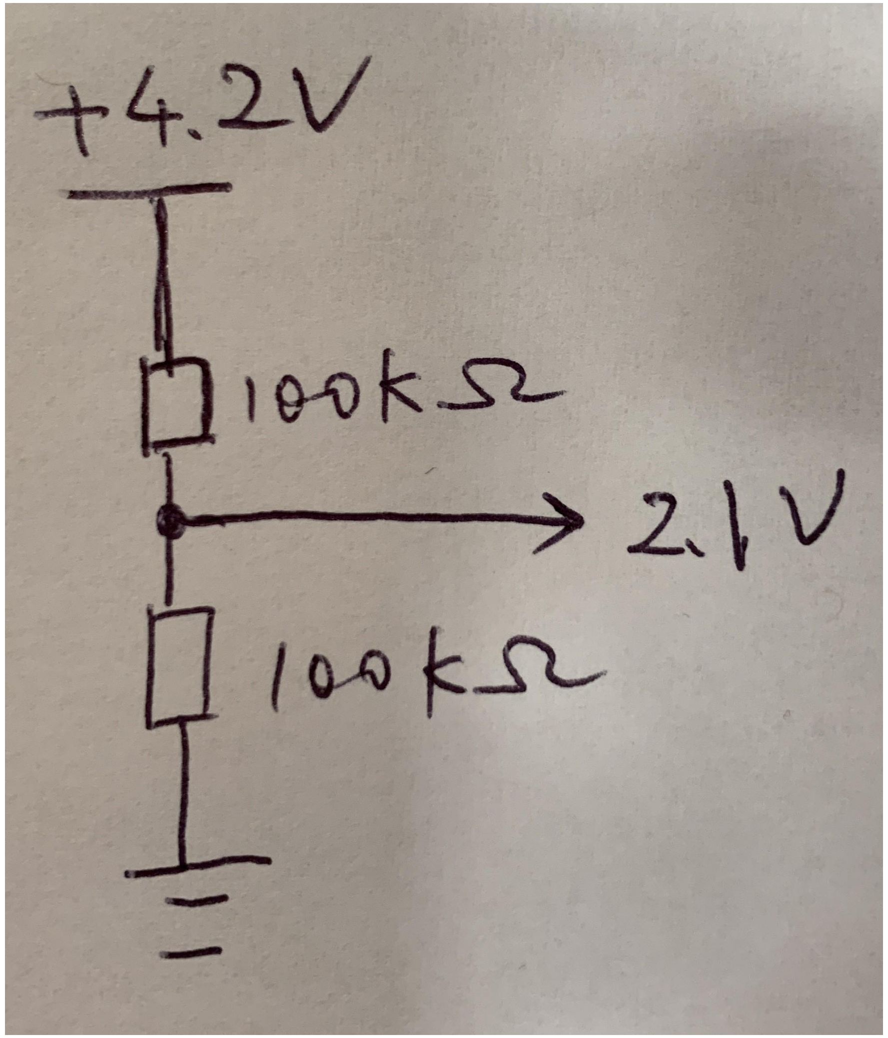
How about these resistors?



1A

Ohm’s Law:

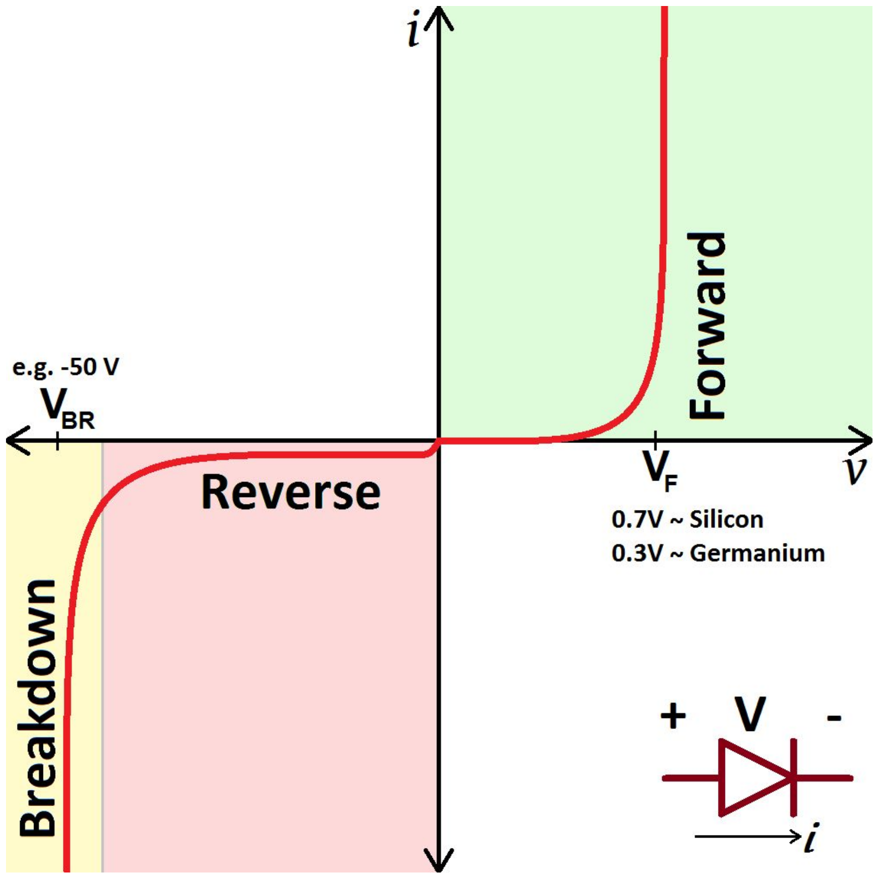
Voltage divider



Very useful for monitoring babttery voltage

Diodes:

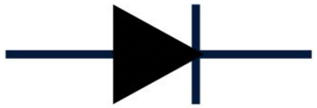
Current flow in one direction only

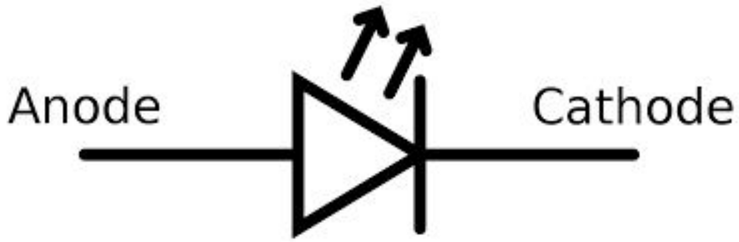


Img: https://cdn.sparkfun.com/assets/4/4/a/5/b/5175b518ce395f2d49000000.png

Sort of… :p

Diodes:

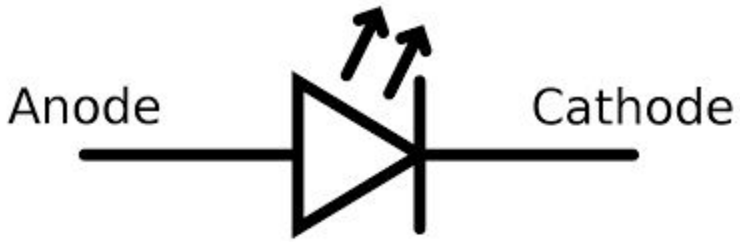


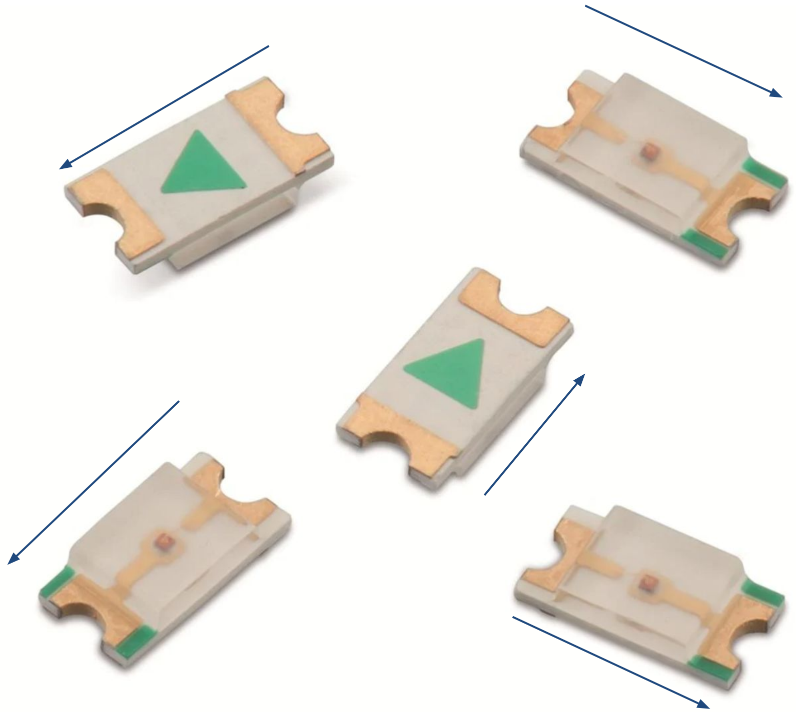


Who is this

Diodes:

Light emitting diode (LED)





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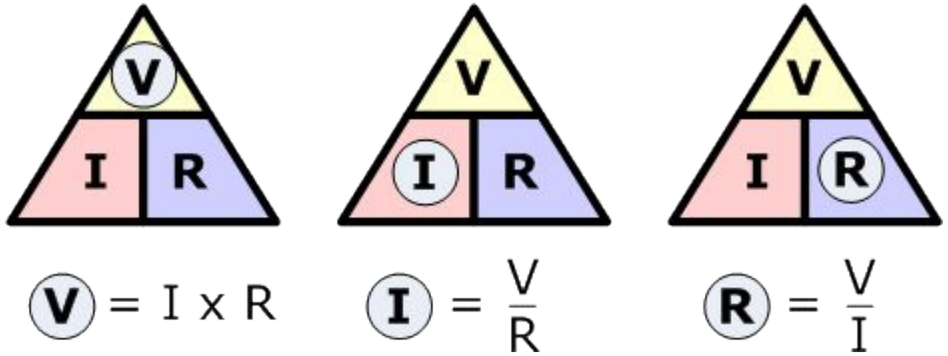

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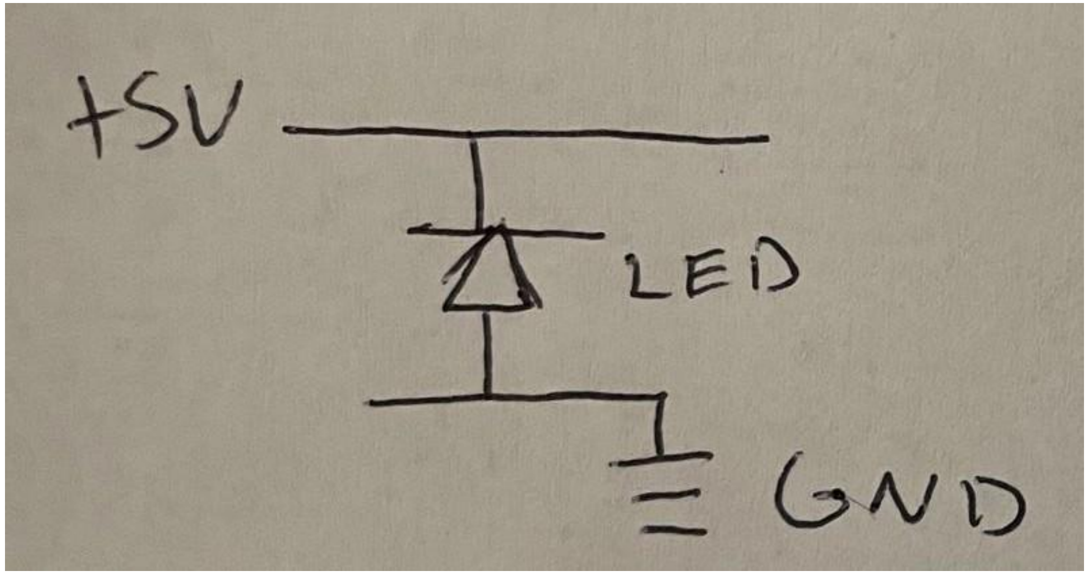

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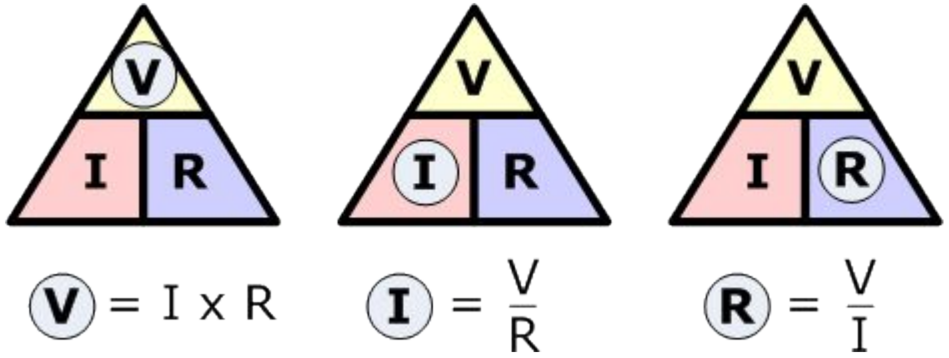

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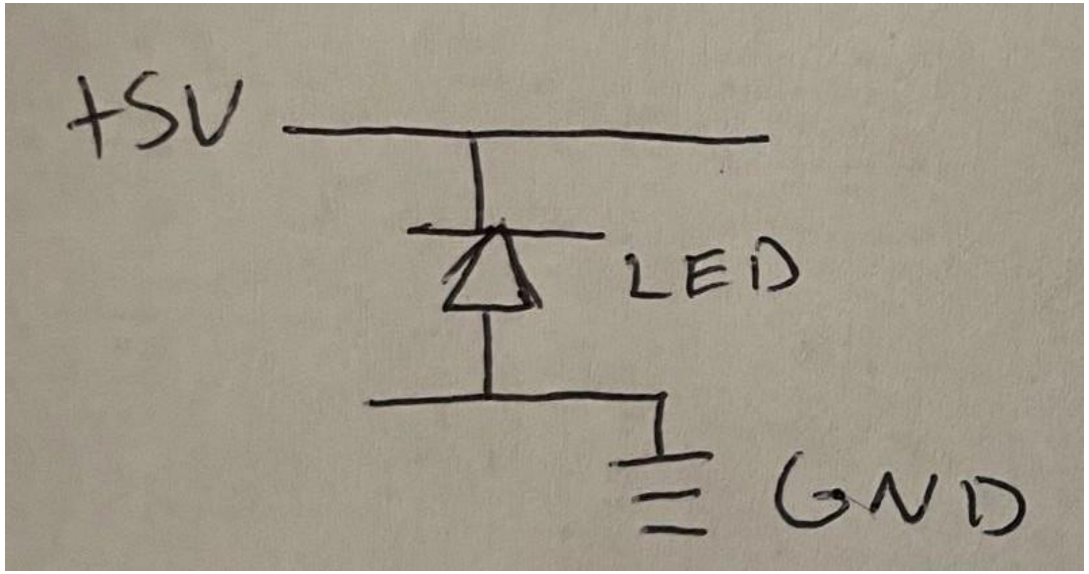

0A … installed wrong way

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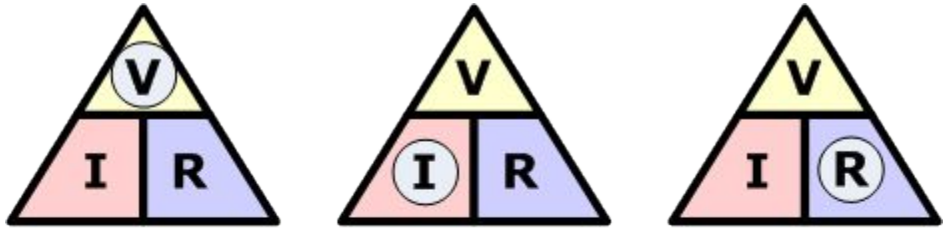

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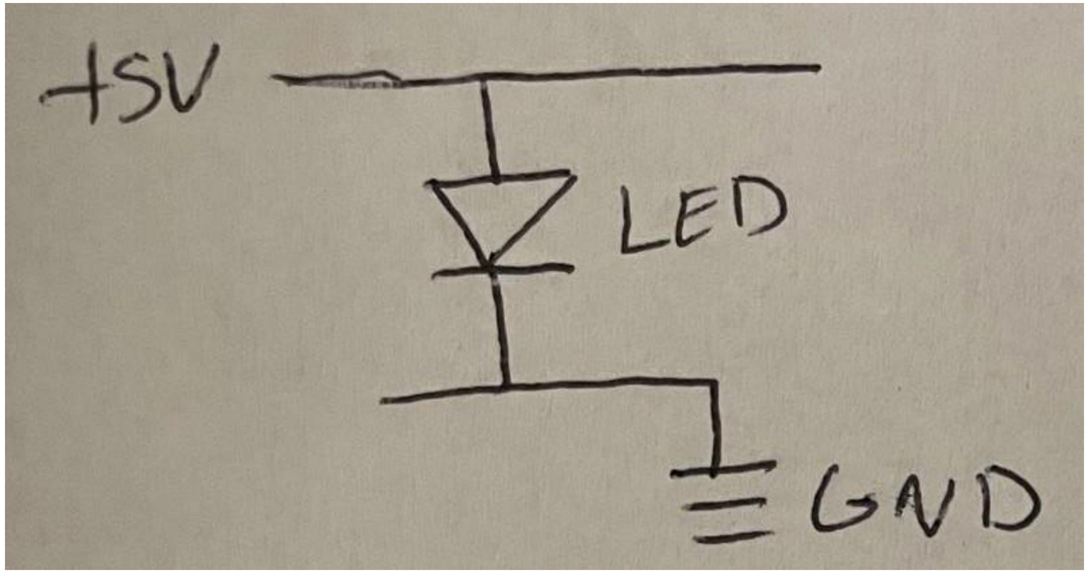
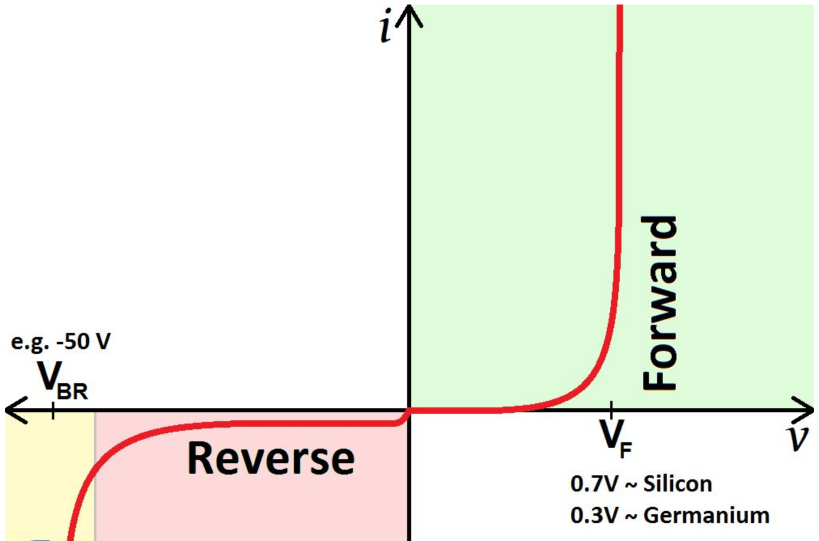
Ok so what about this (correct direction) LED?





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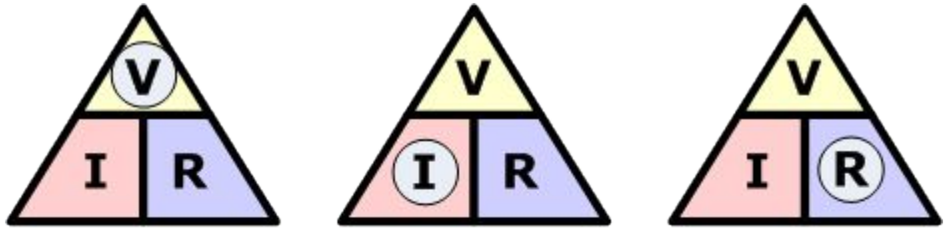

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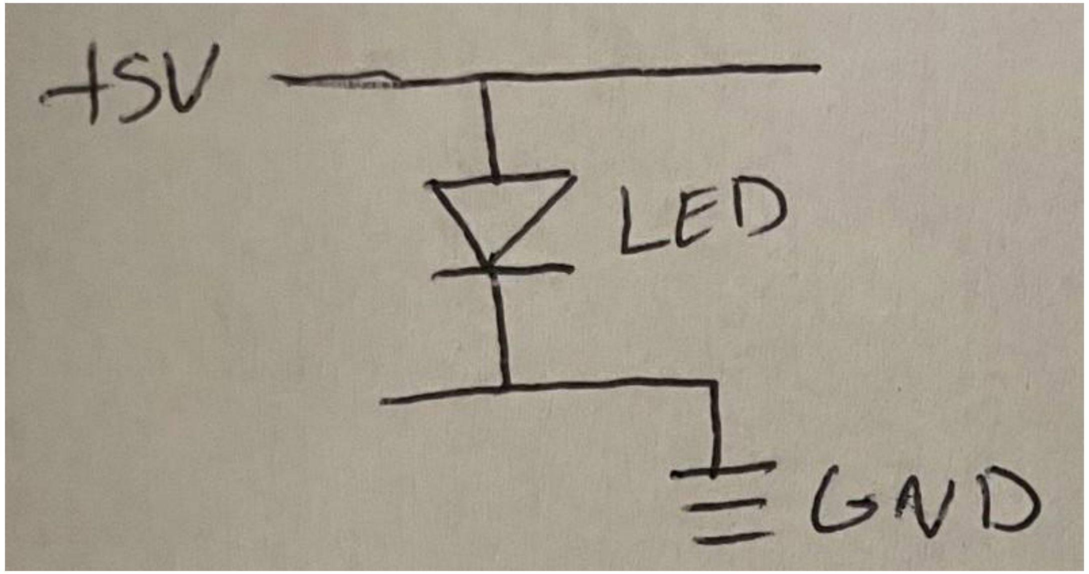

∞A

Diodes have 0 resistance!

INFINITE CURRENT ->
THE PART WILL
MELT :(

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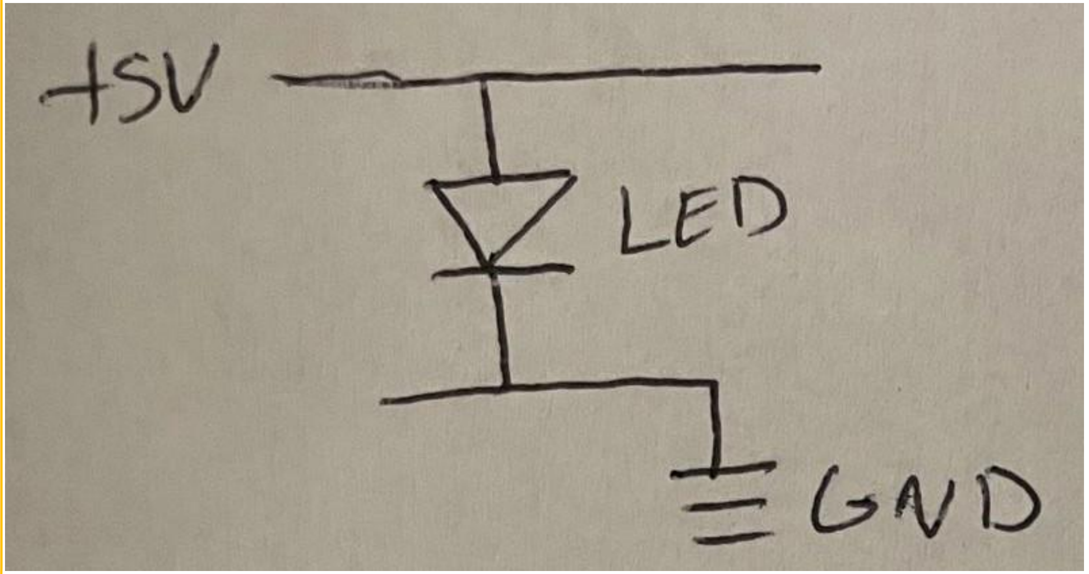

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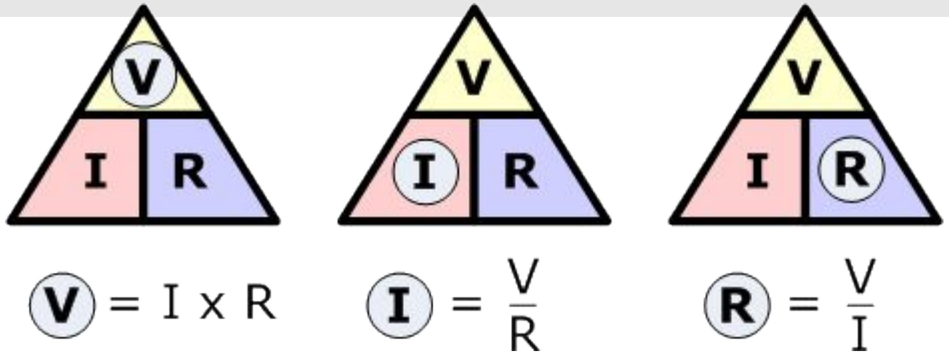
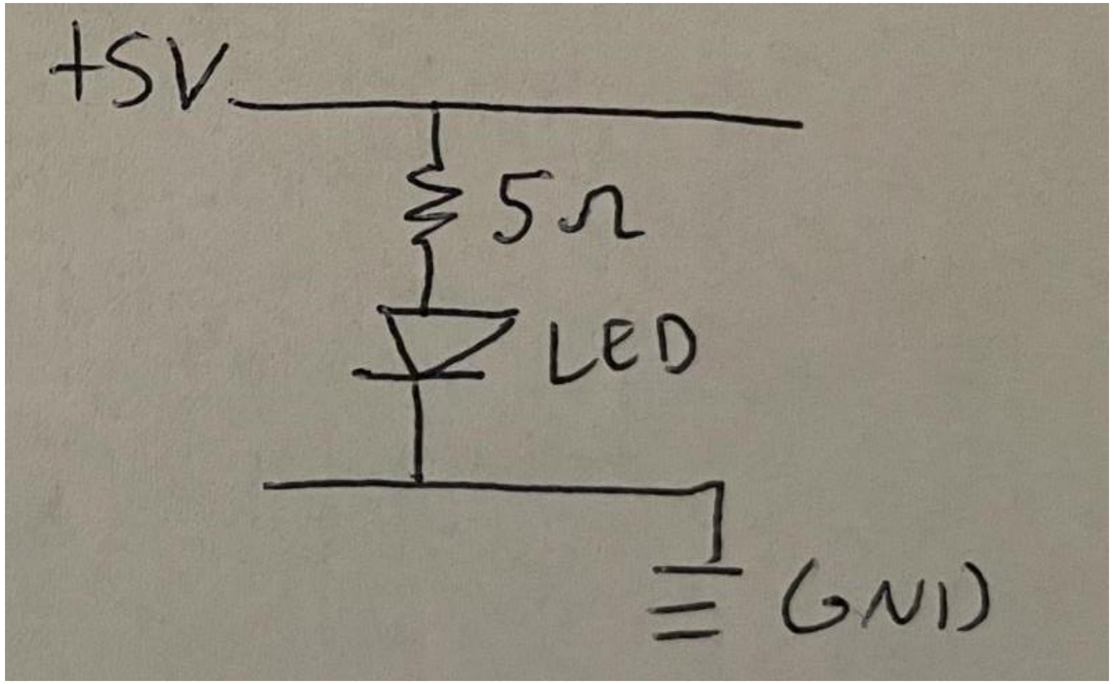


Ok so what about this (correct direction) LED with a **current limiting resistor!**



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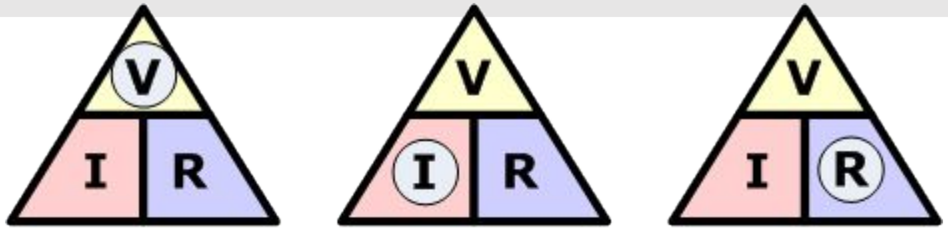

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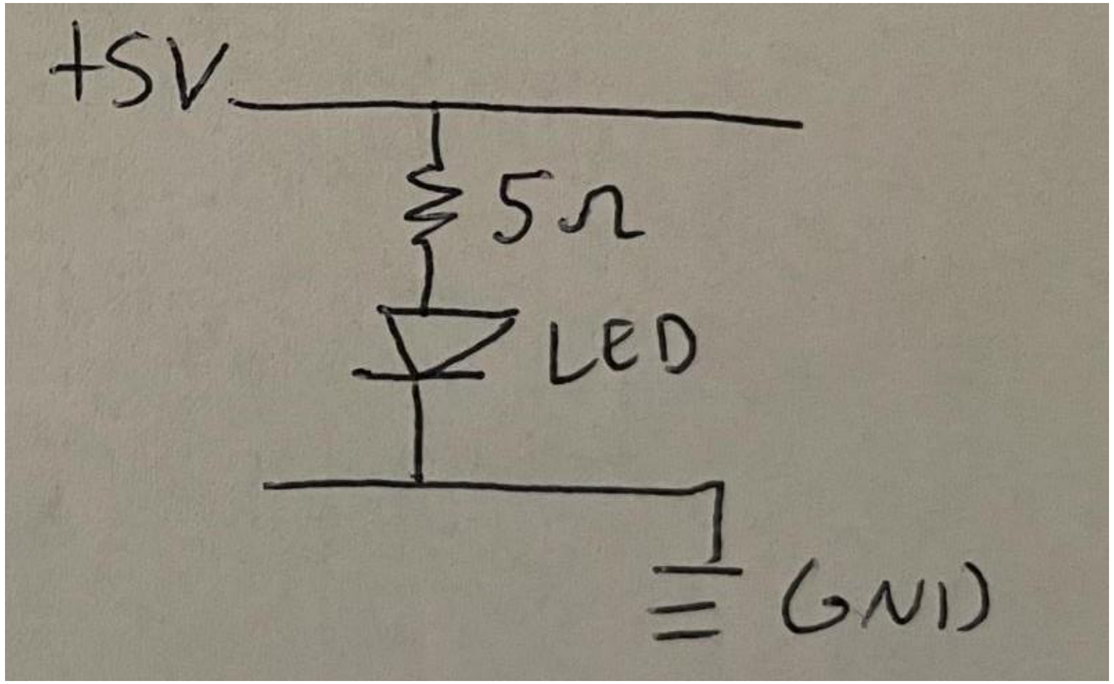
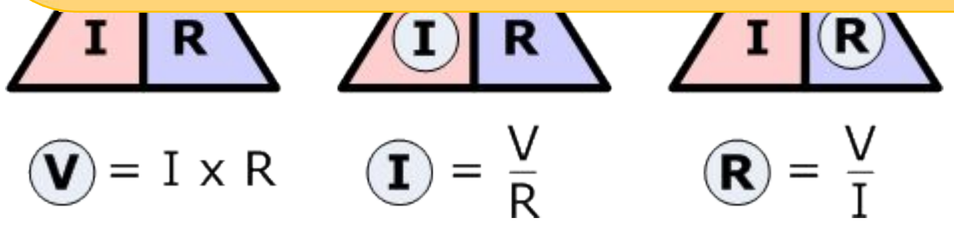


1A

In practice, you will probably use in the range of 250-1000Ω resistors

(I basically always do either 499Ω or 1kΩ since they're always in stock :p)



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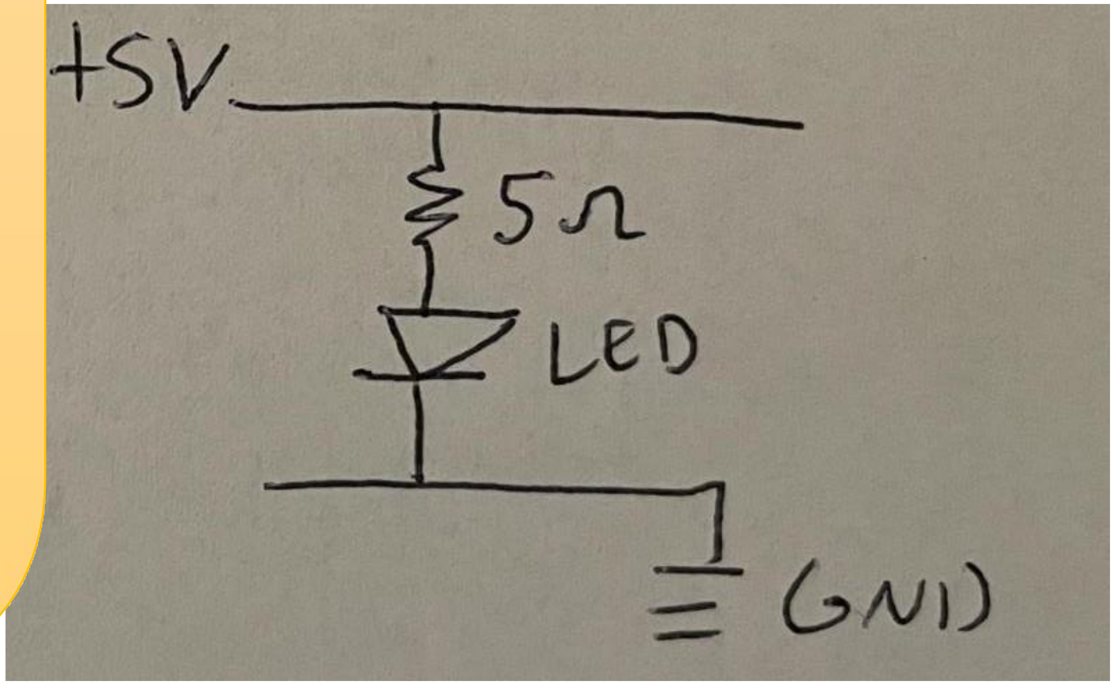
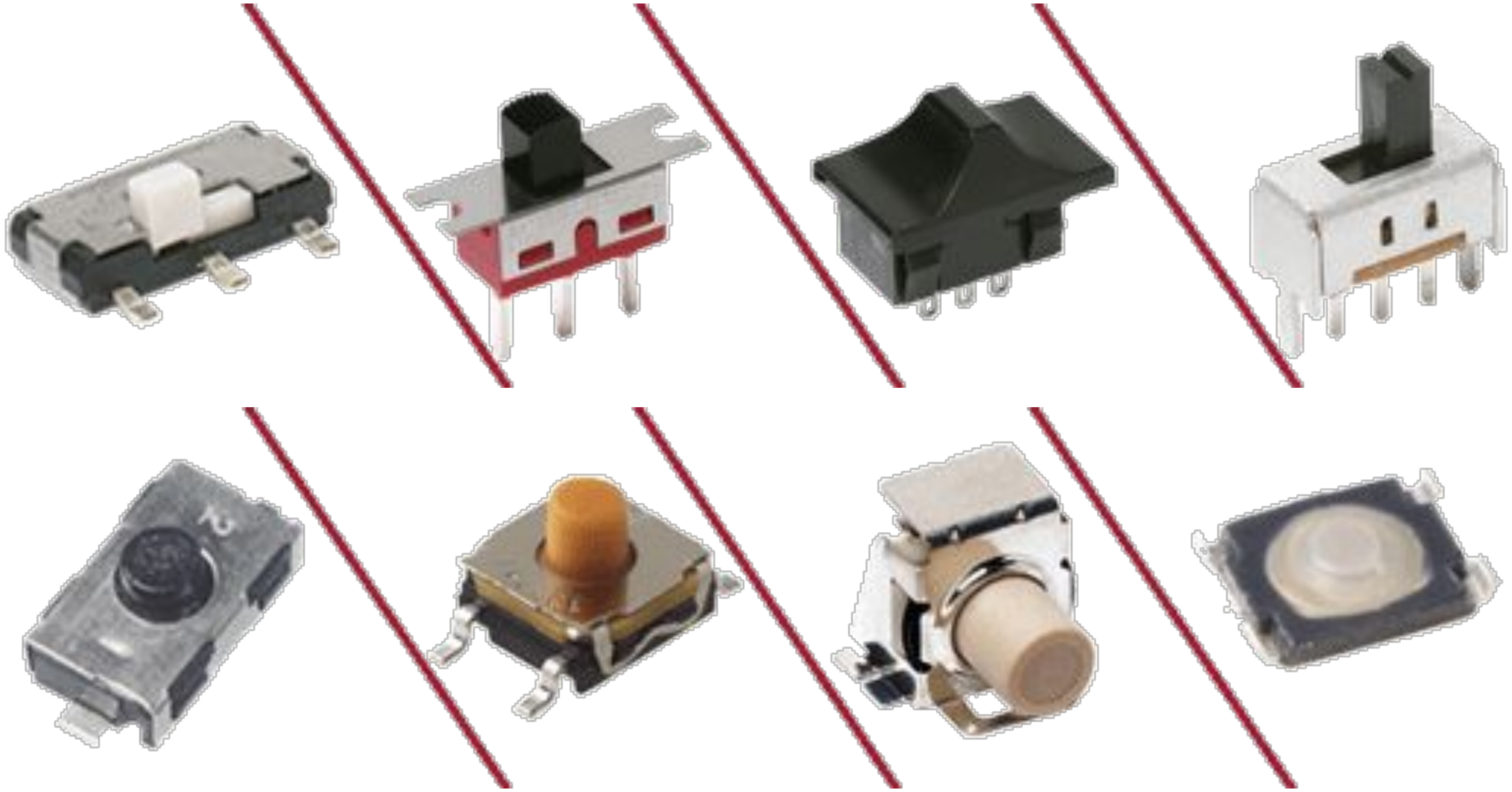
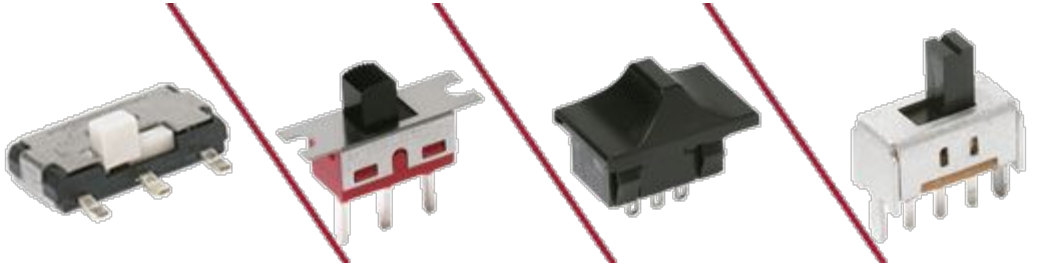


1A

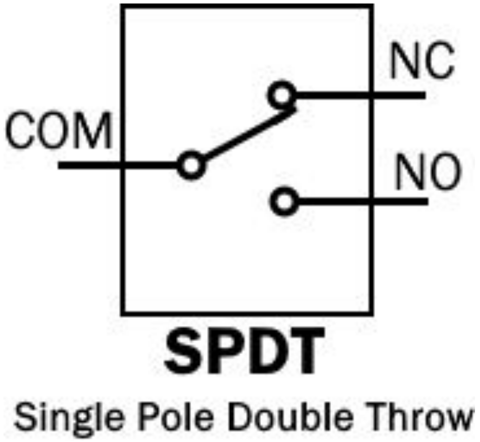
Switch

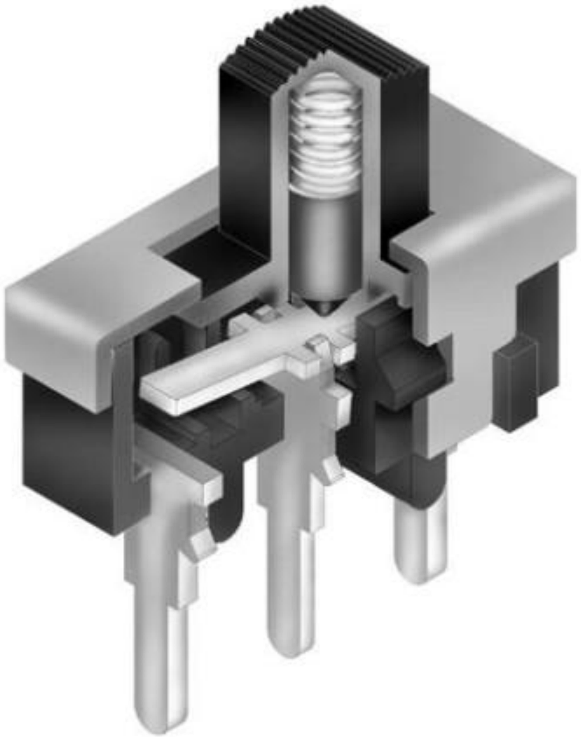


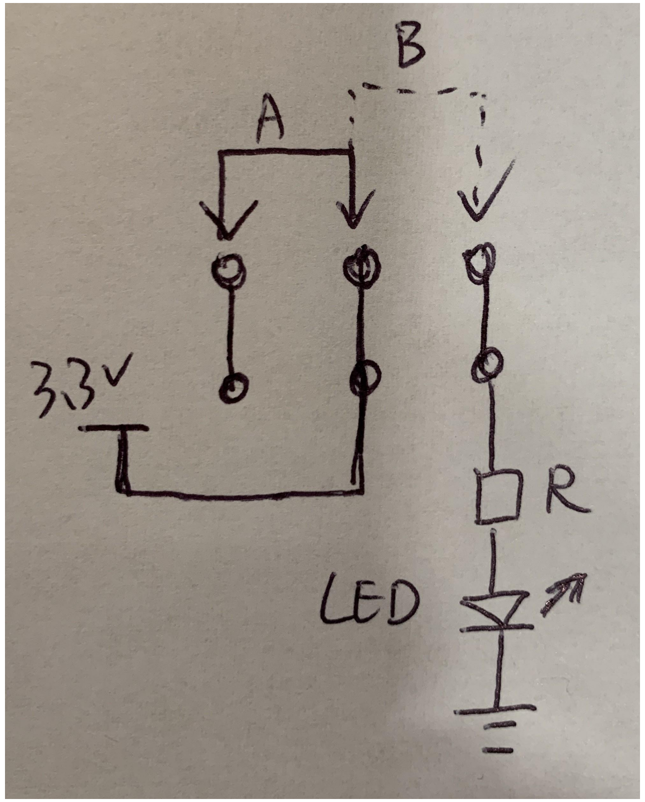
Switch - slide switch



SPDT:Single Pole, Double Throw



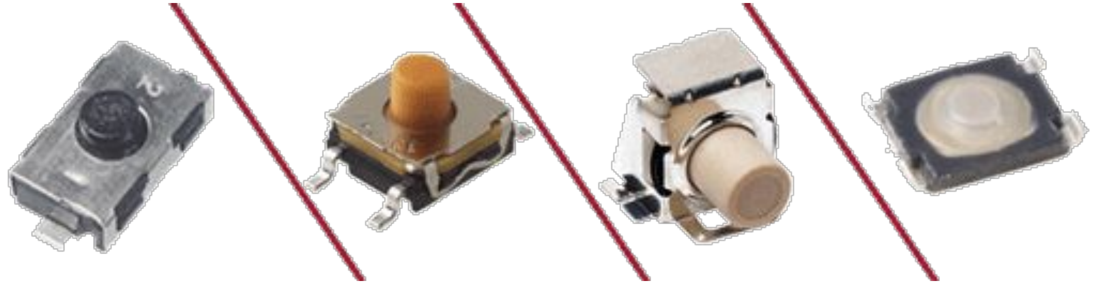


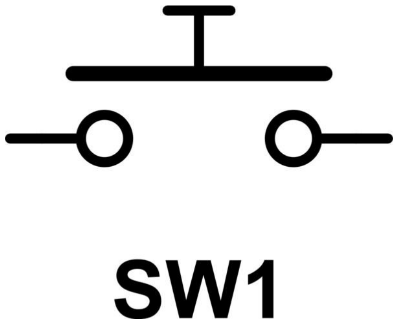


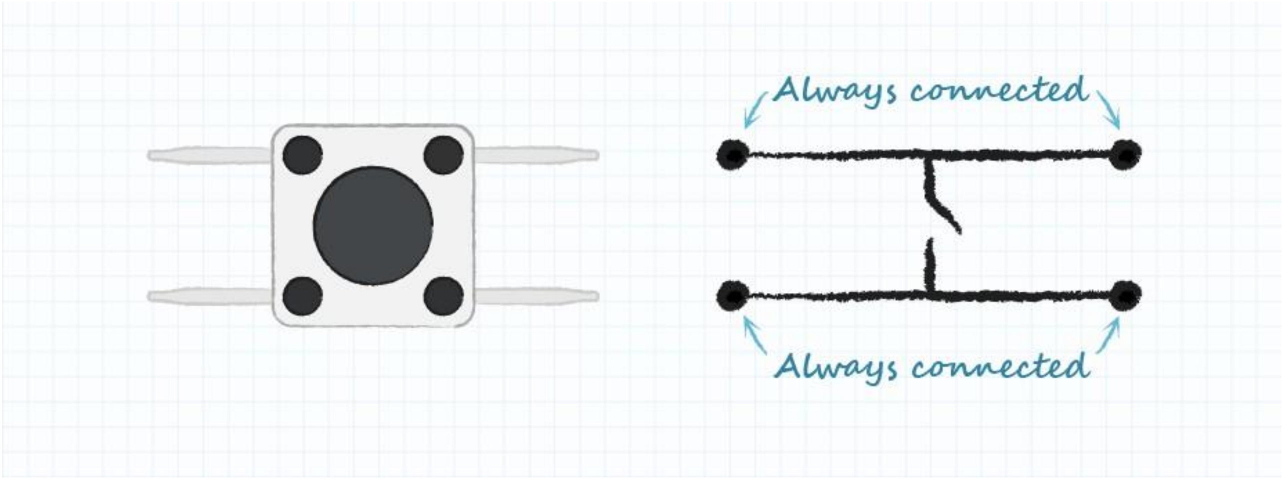
A: OFF

B: ON

Switch- tactile switch







Our second equation - Capacitance

$$C = I * dv/dt$$

Capacitance (measured in farads) (also a charge measurement, charge = CV)

I: Current (measure in amps)

dV/dt: Change in Voltage over time (measure in volts/second)

https://learn.sparkfun.com/tutorials/capacitors/

Capacitance

$$C = I * dv/dt$$

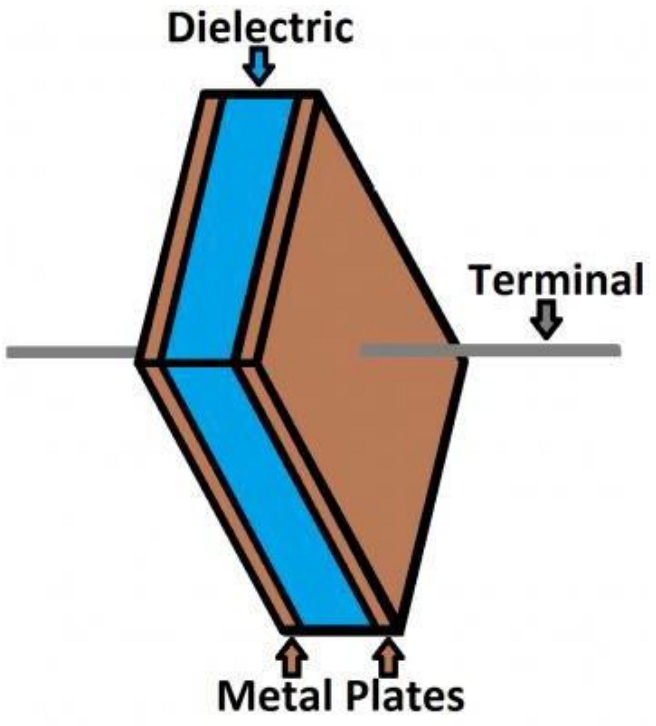
Capacitance (measured in farads)

I: Current (measure in amps)

dV/dt: Change in Voltage over time

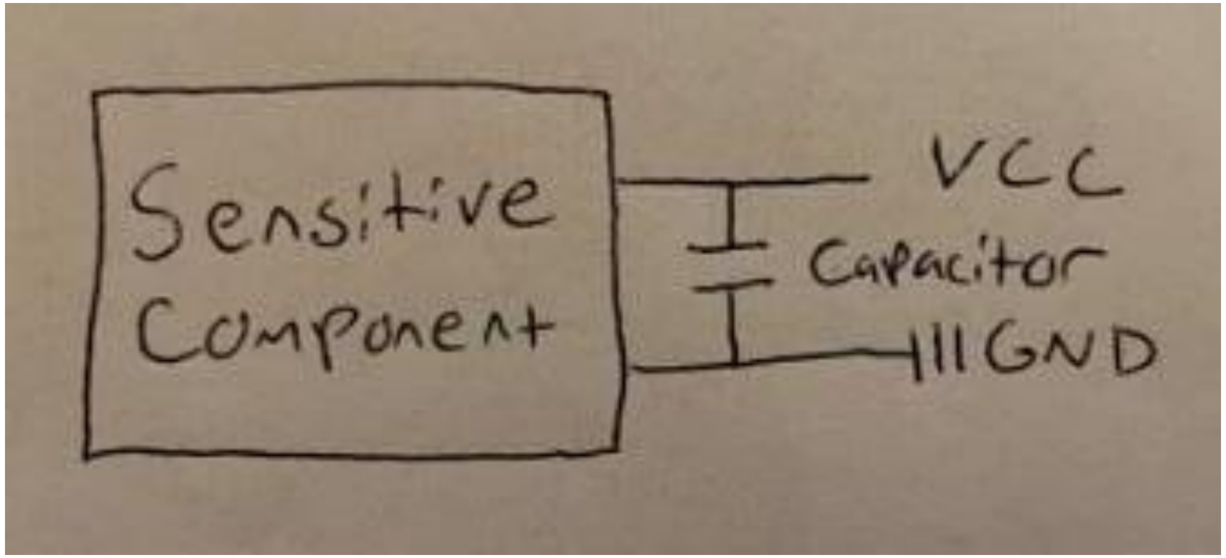
(measure in volts/second)

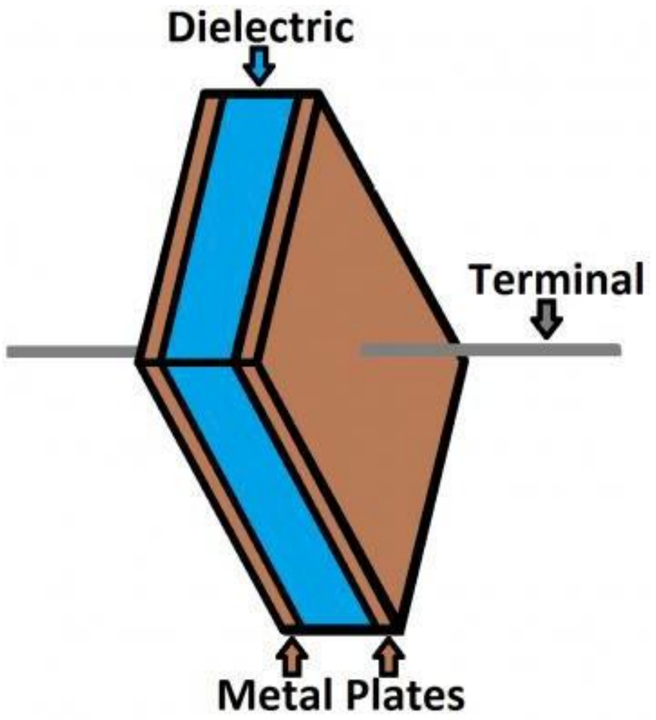
Energy is stored in an *electric* field



Capacitance

The science here can get a little complicated but/and I like to think of a capacitor as a **filter** for changes in voltage





https://learn.sparkfun.com/tutorials/capacitors/application-examples

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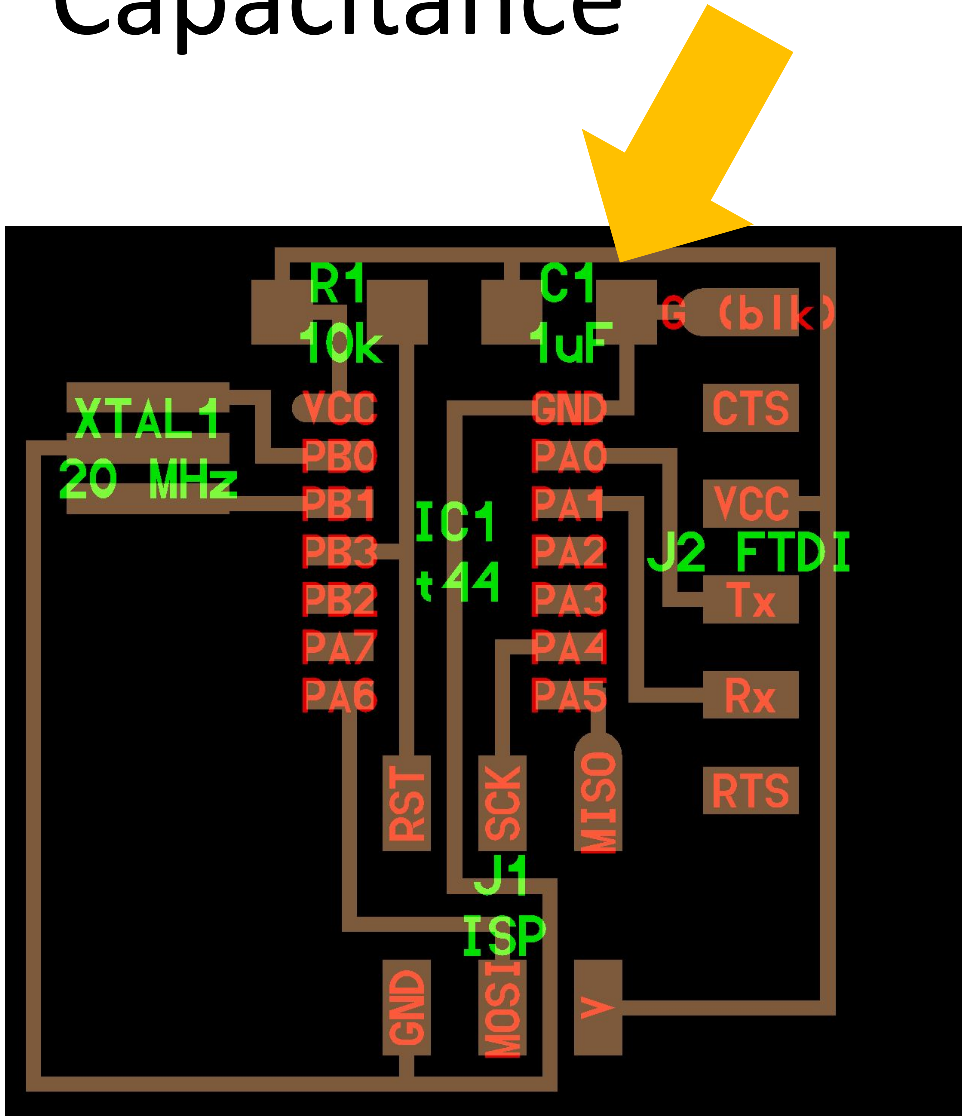

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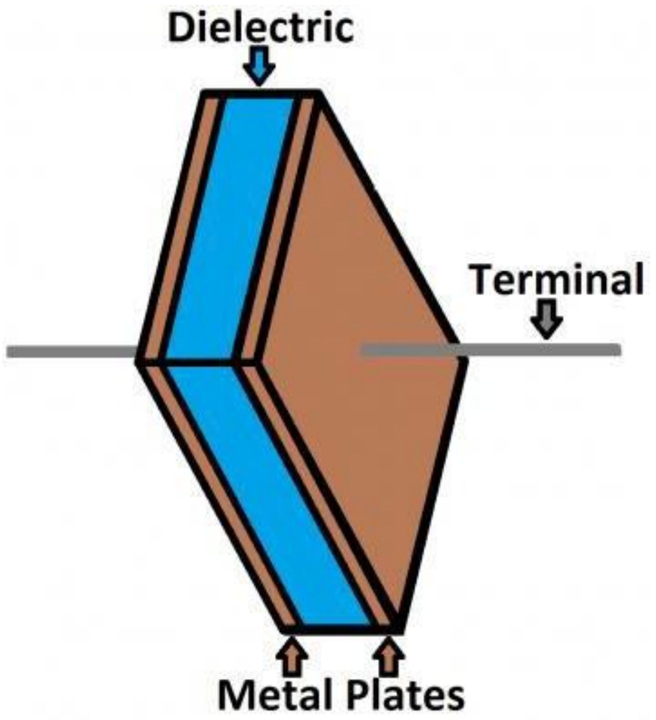

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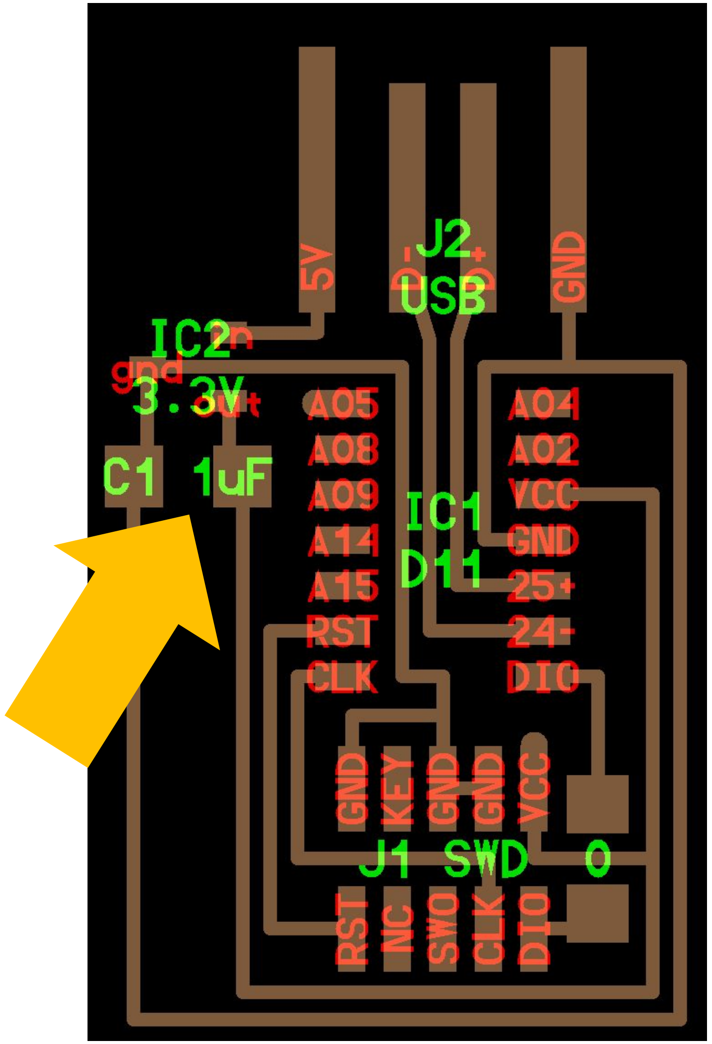

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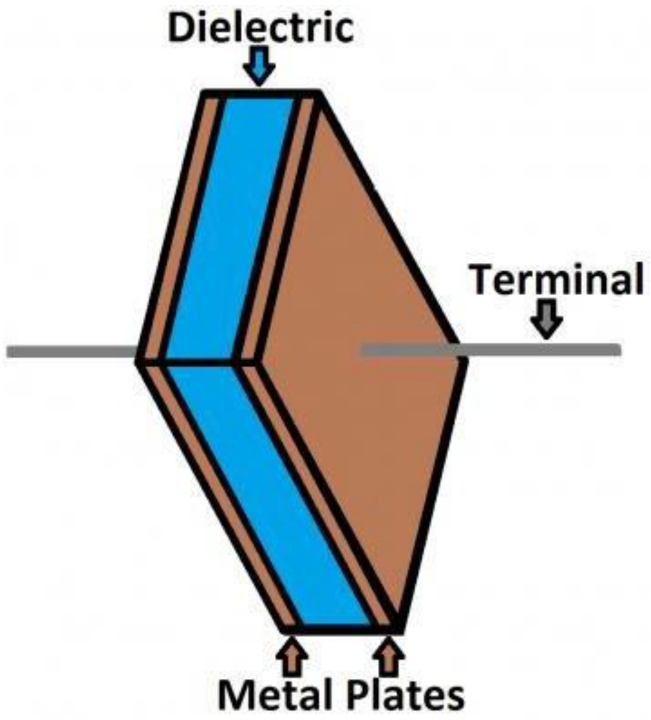

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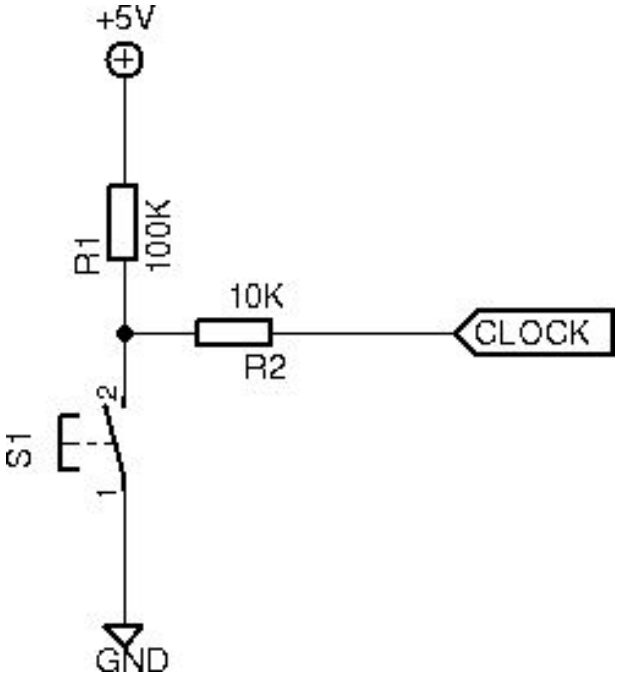
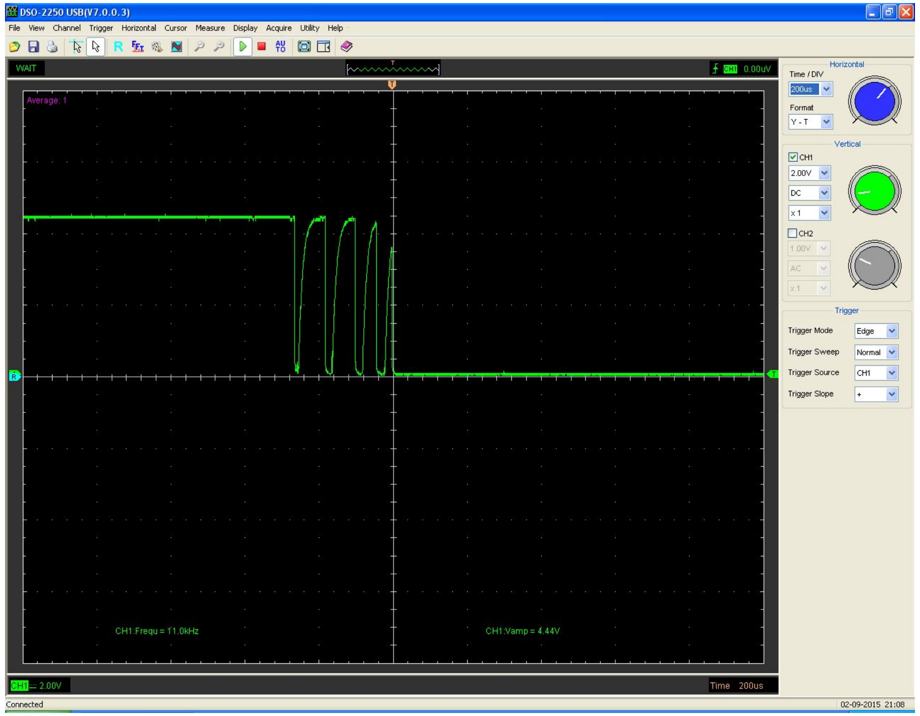
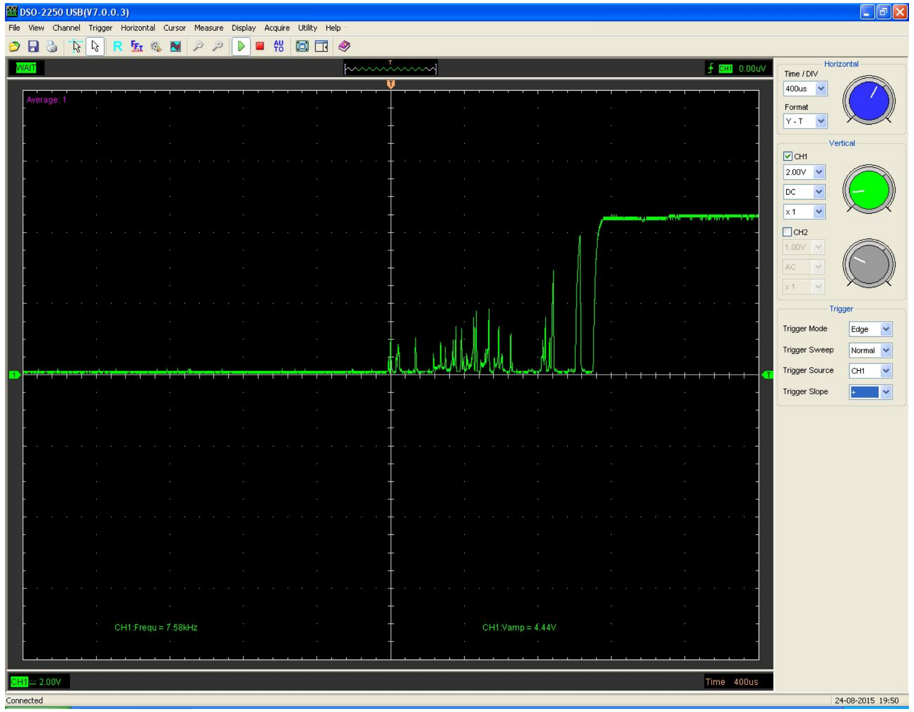
Capacitance - switch debouncing







https://www.allaboutcircuits.com/technical-articles/switch-bounce-how-to- deal-with-it/

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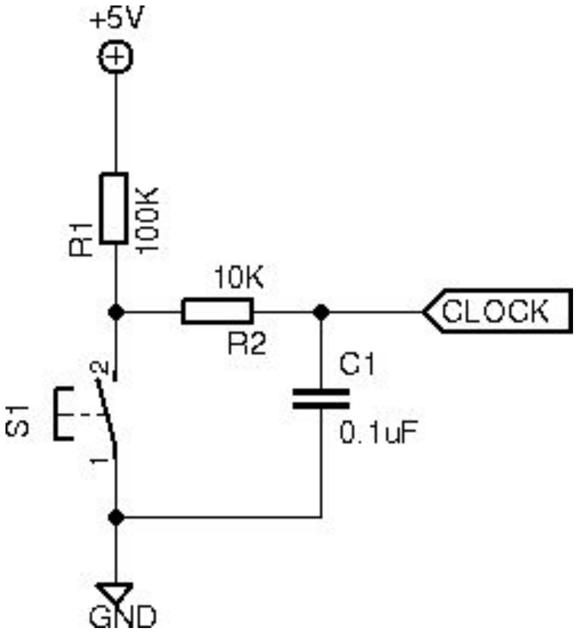
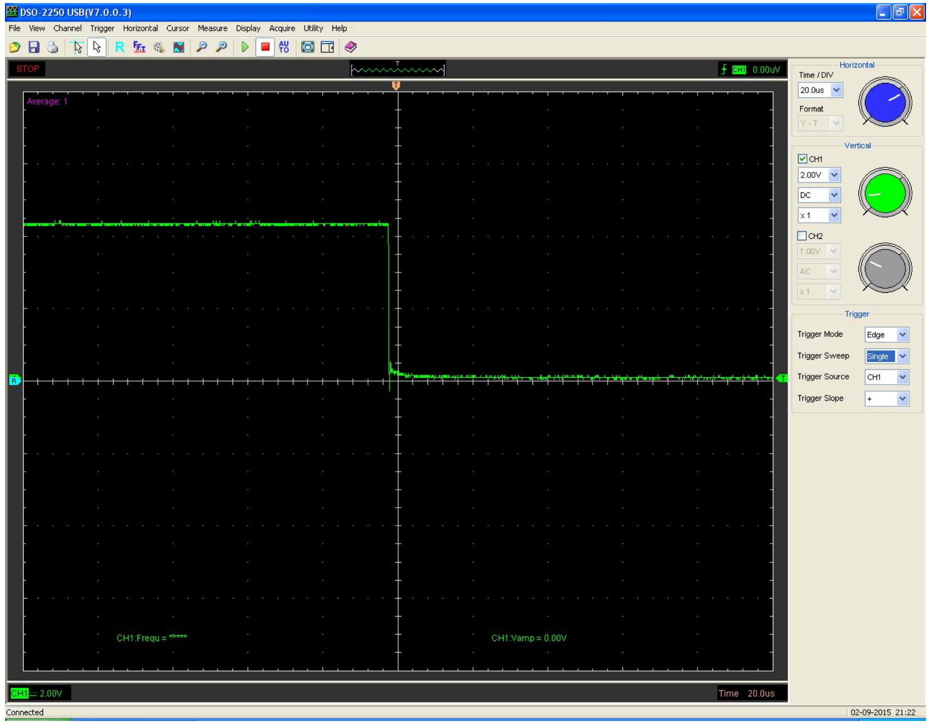
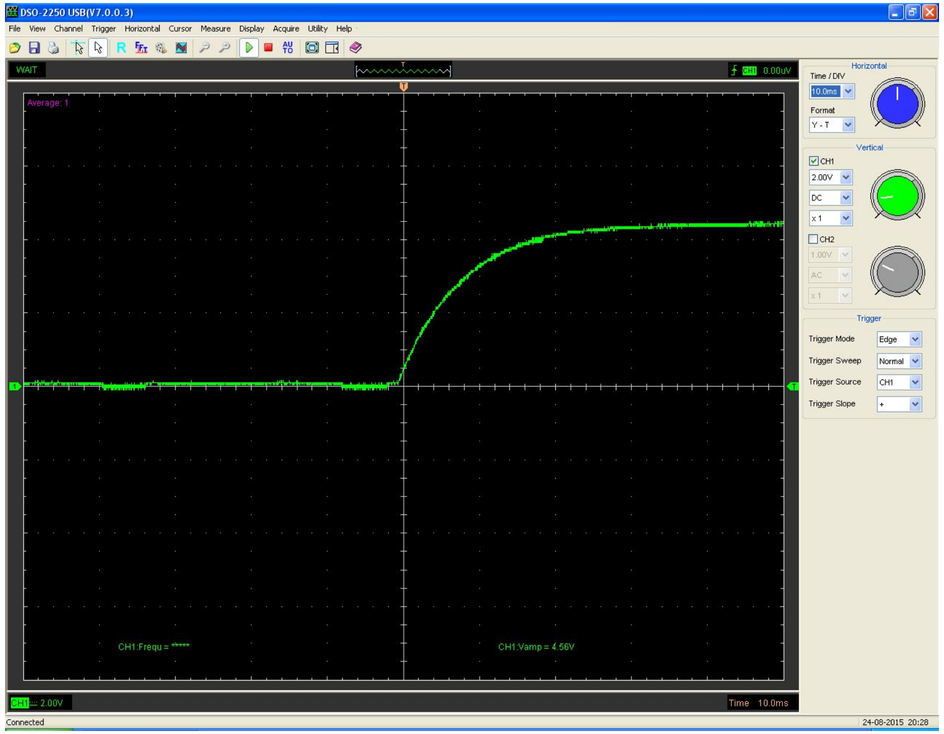






https://www.allaboutcircuits.com/technical-articles/switch-bounce-how-to- deal-with-it/

Inductance

$$v(t) = L\frac{di}{dt}$$

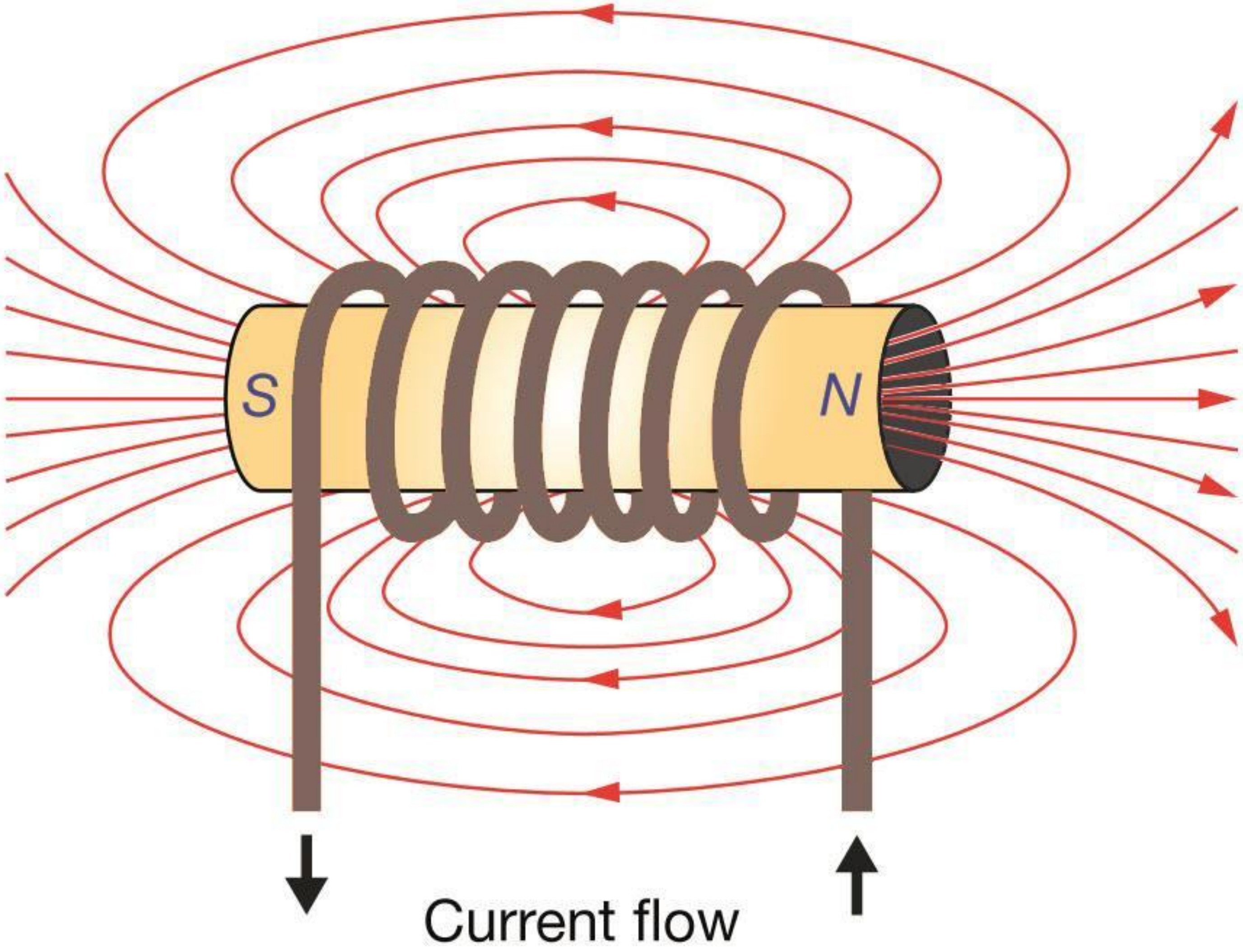
Inductance (measured in "henry"s)

v(t): voltage induced by inductor at this instant

di/dt: Change in Current over time (measure in volts/second)

Inductance

Energy is stored in a magnetic field (!)

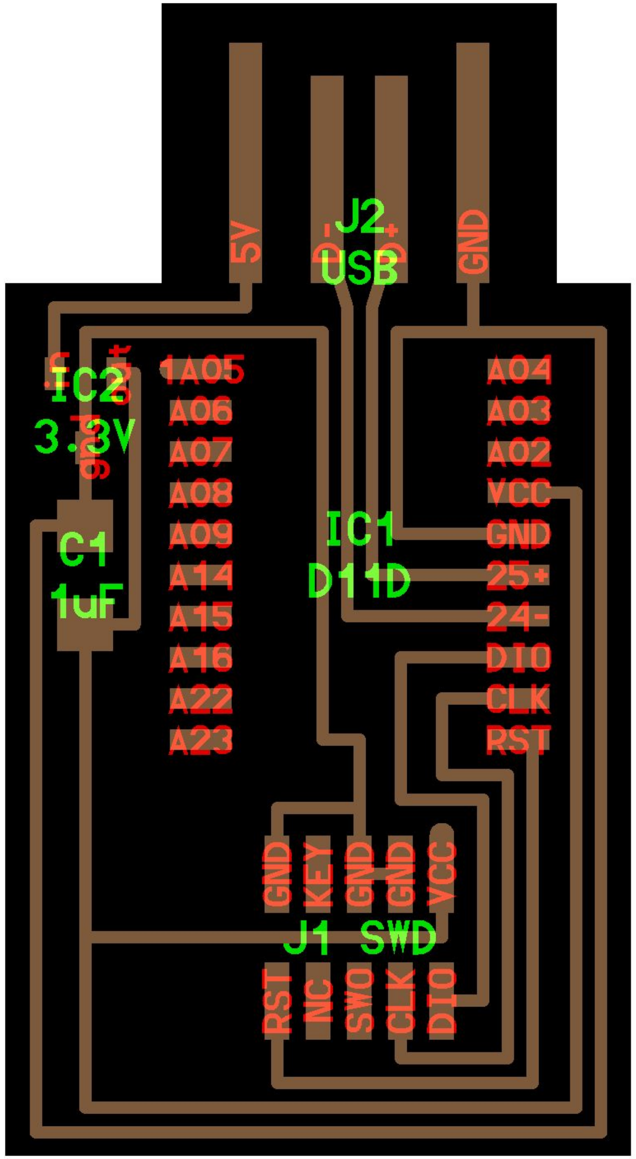


Triplets

- Resistance / Resistors: resists voltage, “does work”
- Capacitance / Capacitors: resists change in voltage
- Inductance / Inductors: resists change in current

Triplets

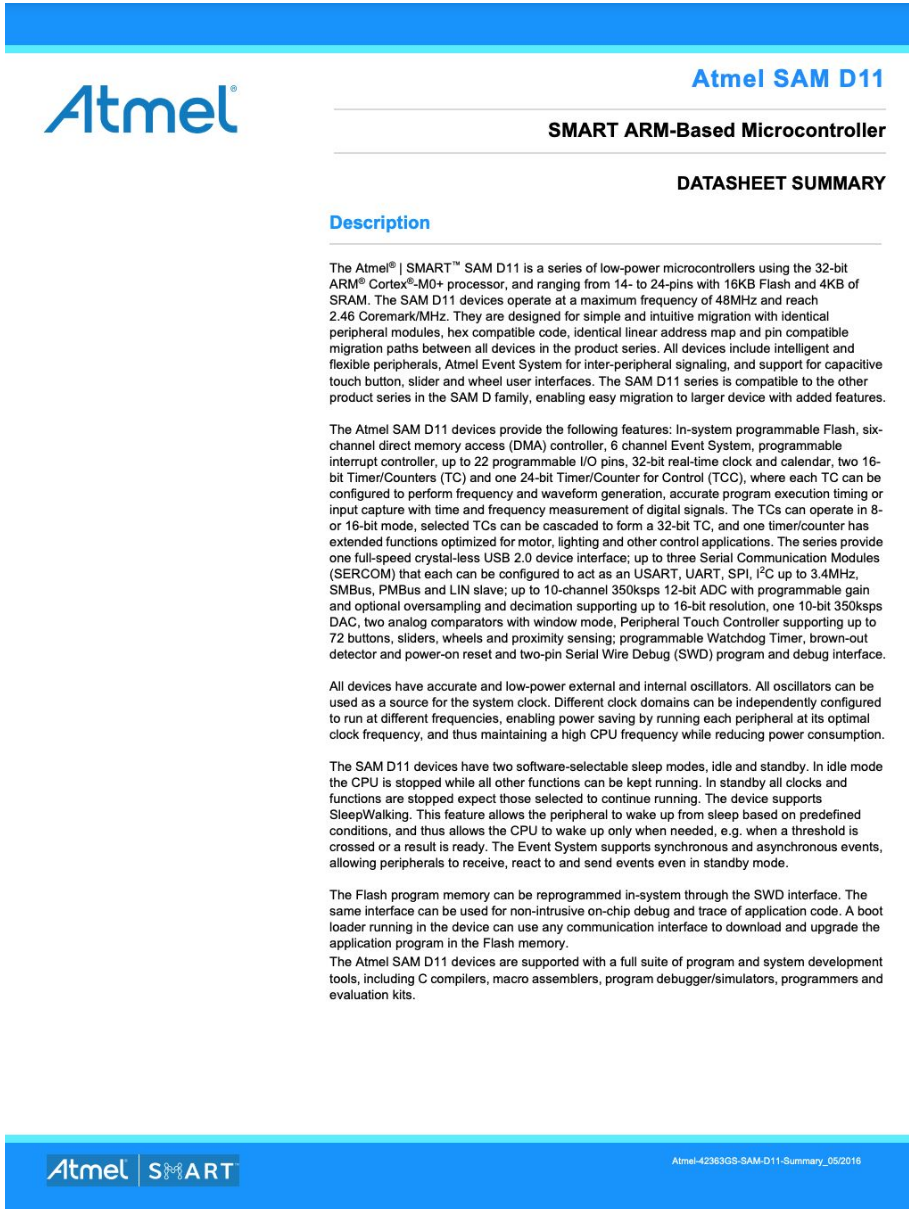
- *everything* has *some* resistance, inductance, and capacitance; resistors are inductors, capacitors are resistors, inductors are capacitors, etc…
- we can largely ignore this inconvenience until we hit high powers, high frequencies, and high precision



Neil's SAMD11 Hello World board:
http://academy.cba.mit.edu/classes/embedded_programming/D11D/hello.D11D.echo.png

But how will I know if my component needs a capacitor? And how big of a capacitor will I need? **(and what are all of those labels?)**

https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-42363-SAM-D11_Summary.pdf



Atmel

Atmel SAM D11

SMART ARM-Based Microcontroller

DATASHEET SUMMARY

Description

The Atmel® | SMART™ SAM D11 is a series of low-power microcontrollers using the 32-bit ARM® Cortex®-M0+ processor, and ranging from 14- to 24-pins with 16KB Flash and 4KB of SRAM. The SAM D11 devices operate at a maximum frequency of 48MHz and reach 2.46 Coremark/MHz. They are designed for simple and intuitive migration with identical peripheral modules, hex compatible code, identical linear address map and pin compatible migration paths between all devices in the product series. All devices include intelligent and flexible peripherals, Atmel Event System for inter-peripheral signaling, and support for capacitive touch button, slider and wheel user interfaces. The SAM D11 series is compatible to the other product series in the SAM D family, enabling easy migration to larger device with added features.

The Atmel SAM D11 devices provide the following features: In-system programmable Flash, six-channel direct memory access (DMA) controller, 6 channel Event System, programmable interrupt controller, up to 22 programmable I/O pins, 32-bit real-time clock and calendar, two 16-bit Timer/Counters (TC) and one 24-bit Timer/Counter for Control (TCC), where each TC can be configured to perform frequency and waveform generation, accurate program execution timing or input capture with time and frequency measurement of digital signals. The TCs can operate in 8- or 16-bit mode, selected TCs can be cascaded to form a 32-bit TC, and one timer/counter has extended functions optimized for motor, lighting and other control applications. The series provide one full-speed crystal-less USB 2.0 device interface; up to three Serial Communication Modules (SERCOM) that each can be configured to act as an USART, UART, SPI, I^2C up to 3.4MHz, SMBus, PMBus and LIN slave; up to 10-channel 350ksps 12-bit ADC with programmable gain and optional oversampling and decimation supporting up to 16-bit resolution, one 10-bit 350ksps DAC, two analog comparators with window mode, Peripheral Touch Controller supporting up to 72 buttons, sliders, wheels and proximity sensing; programmable Watchdog Timer, brown-out detector and power-on reset and two-pin Serial Wire Debug (SWD) program and debug interface.

All devices have accurate and low-power external and internal oscillators. All oscillators can be used as a source for the system clock. Different clock domains can be independently configured to run at different frequencies, enabling power saving by running each peripheral at its optimal clock frequency, and thus maintaining a high CPU frequency while reducing power consumption.

The SAM D11 devices have two software-selectable sleep modes, idle and standby. In idle mode the CPU is stopped while all other functions can be kept running. In standby all clocks and functions are stopped expect those selected to continue running. The device supports SleepWalking. This feature allows the peripheral to wake up from sleep based on predefined conditions, and thus allows the CPU to wake up only when needed, e.g. when a threshold is crossed or a result is ready. The Event System supports synchronous and asynchronous events, allowing peripherals to receive, react to and send events even in standby mode.

The Flash program memory can be reprogrammed in-system through the SWD interface. The same interface can be used for non-intrusive on-chip debug and trace of application code. A boot loader running in the device can use any communication interface to download and upgrade the application program in the Flash memory.

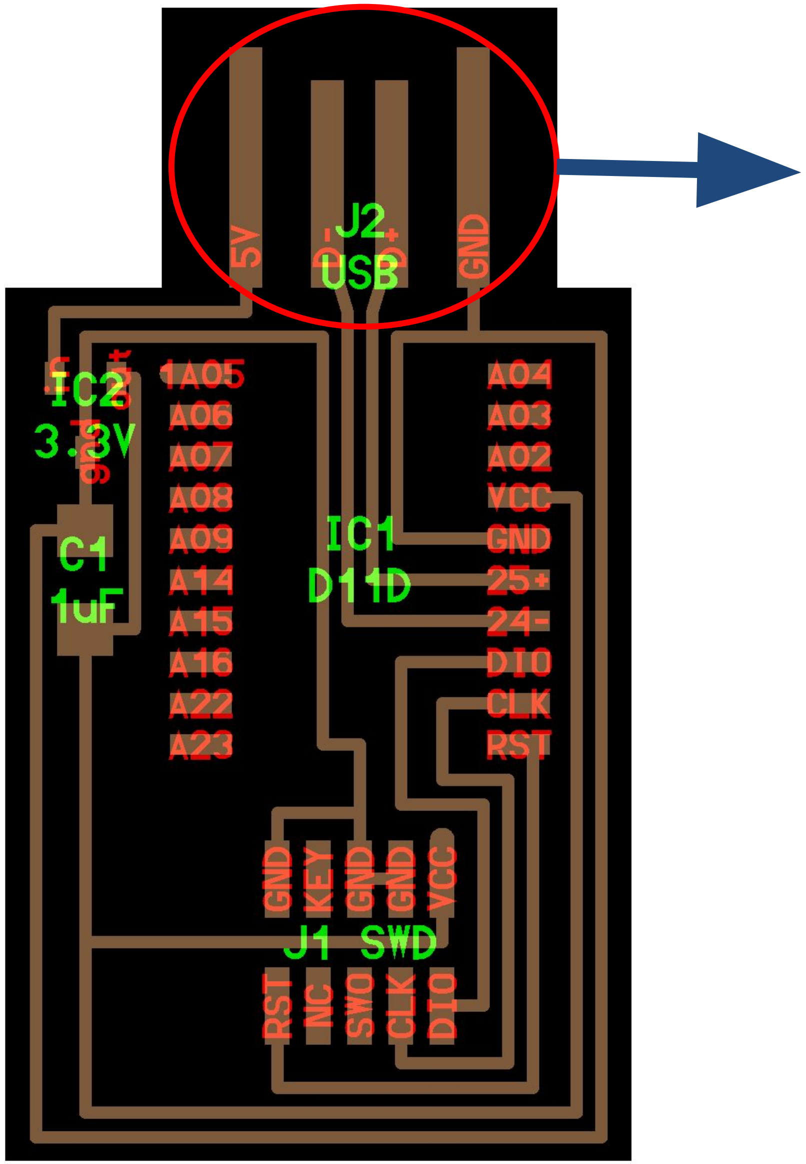
The Atmel SAM D11 devices are supported with a full suite of program and system development tools, including C compilers, macro assemblers, program debugger/simulators, programmers and evaluation kits.

Atmel | SMART

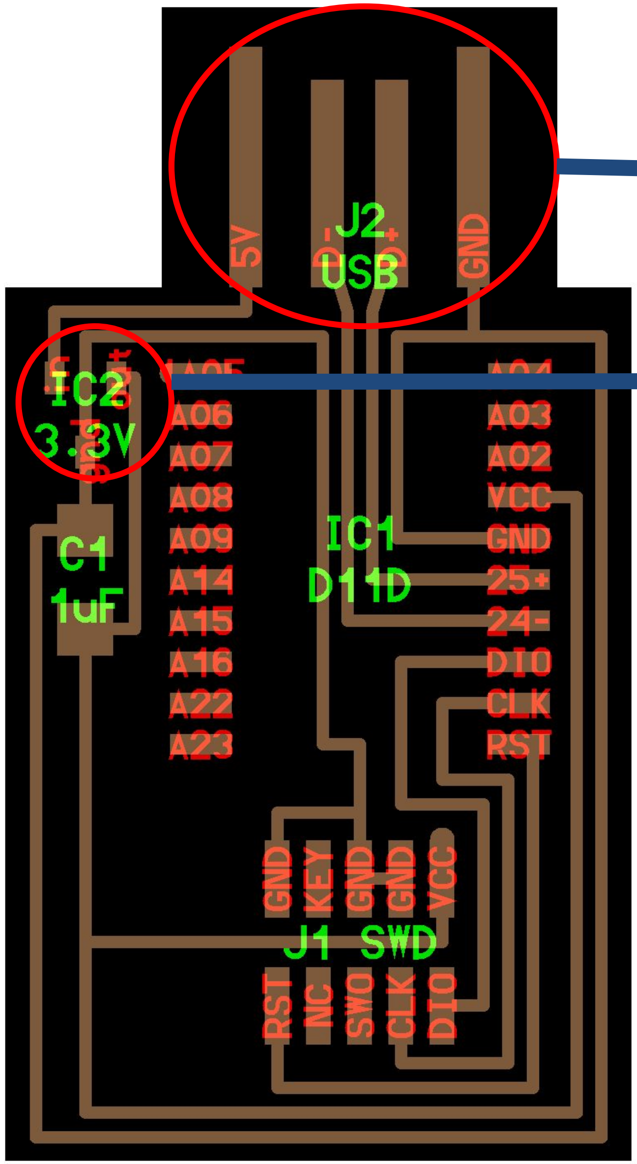
Atmel-42363GS-SAM-D11-Summary_05/2016

Sometimes: read the datasheet

Often: follow design patterns



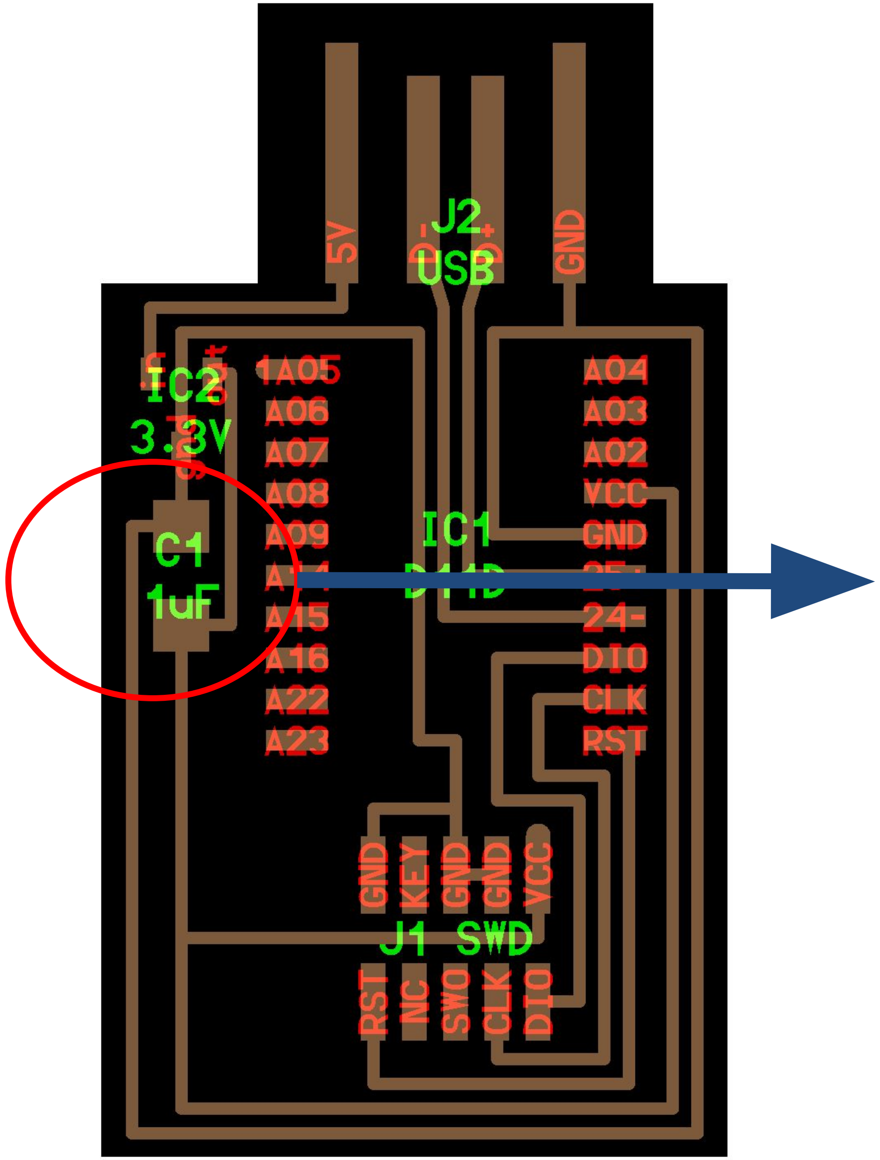
USB HEADER
(prefix J in Neil’s boards often mean some type of connector)



This gets 5V

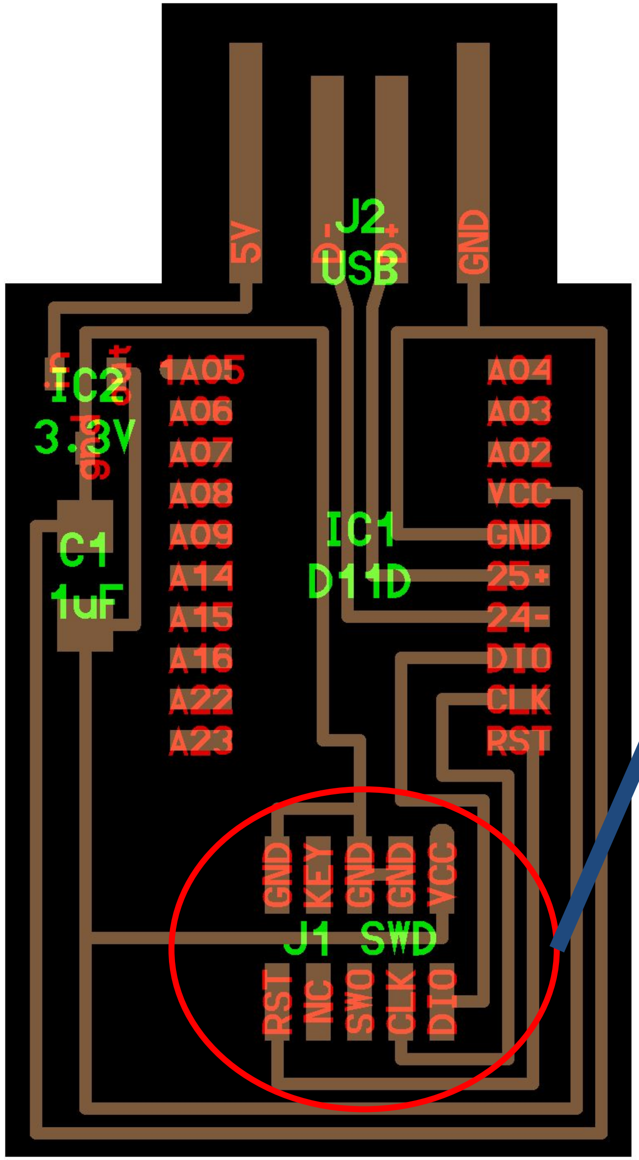
So this (voltage regulator)
Drops it to 3.3V for this
microcontroller

Most of the microcontrollers you will encounter in this class will run at either 3.3V or 5V – Be careful about not cooking a 3.3V micro with 5V!



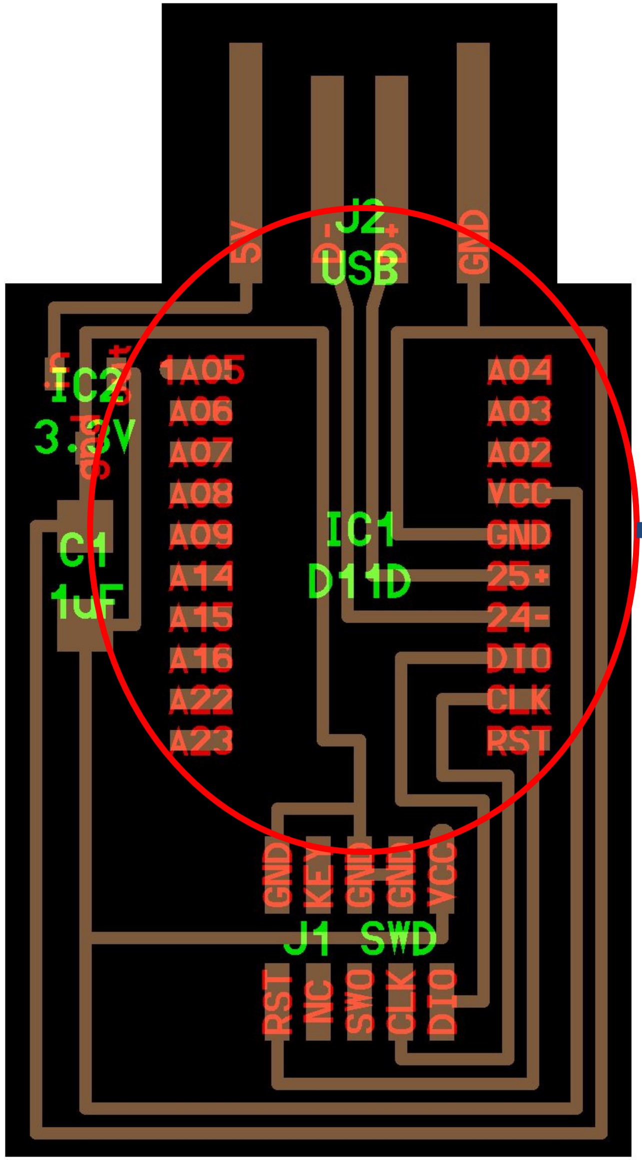
Bypass capacitor as we discussed!

Value: 1uF



Programming header—how you (initially) load code onto this microcontroller!

We see the J prefix again—this is a header — and SWD denotes the interface



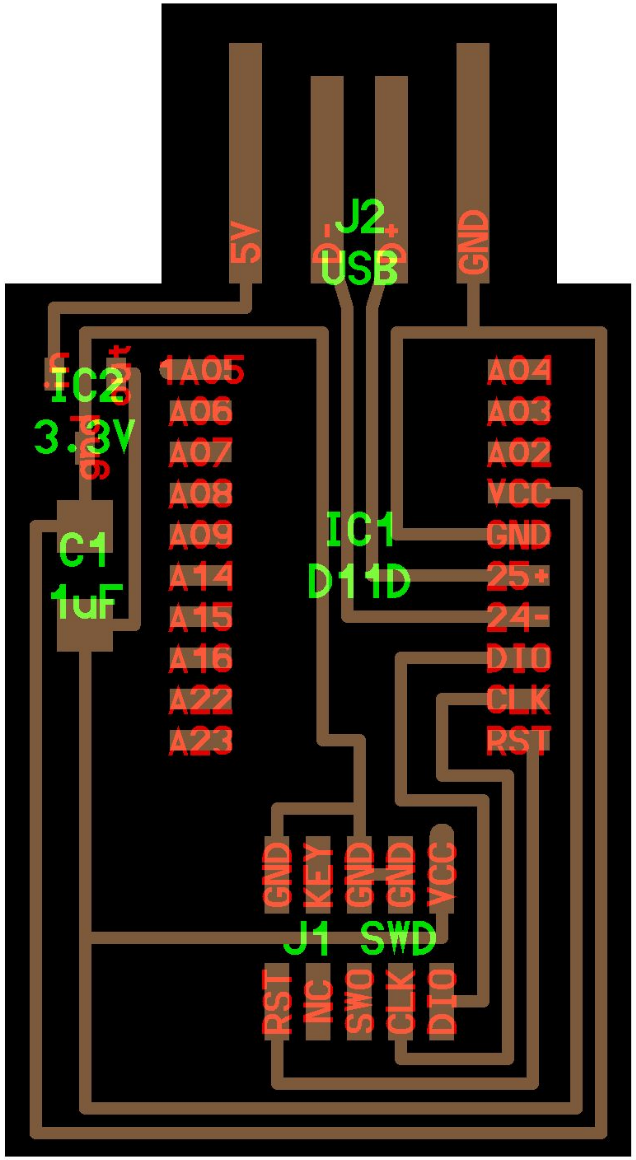
Microcontroller

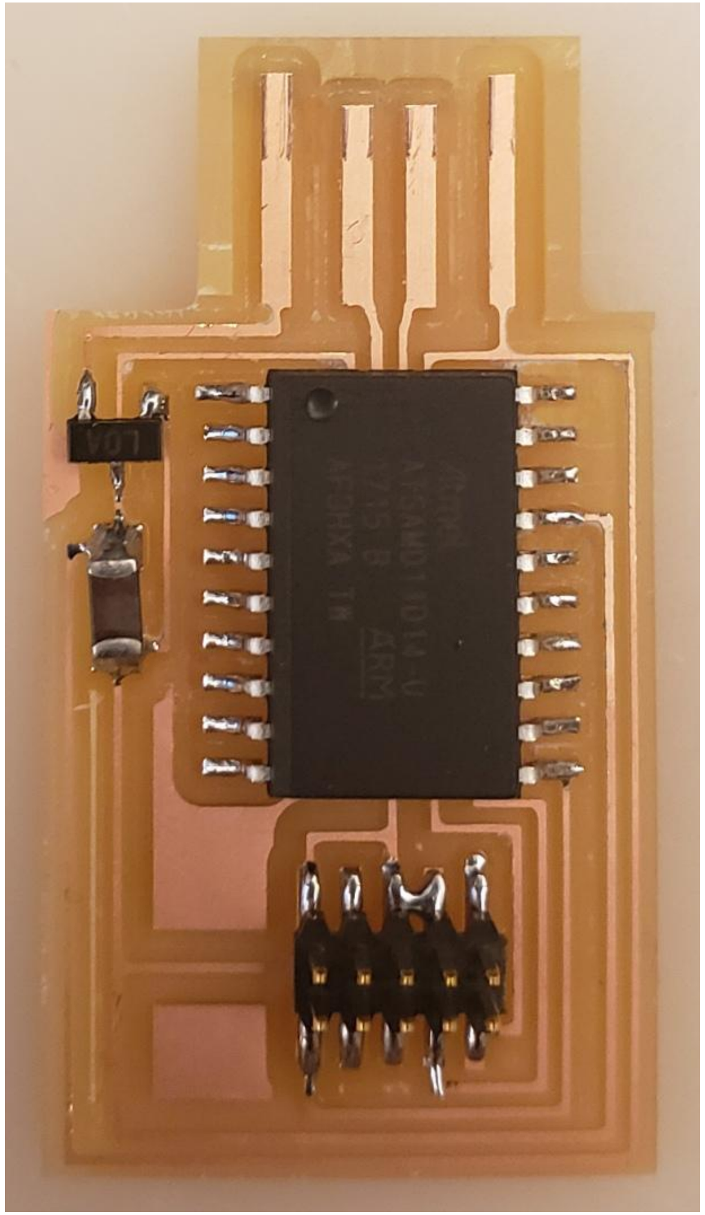
SAMD11D

This is a SAMD11 in the D package

We also stock SAMD11C, which has less pins but the same package.

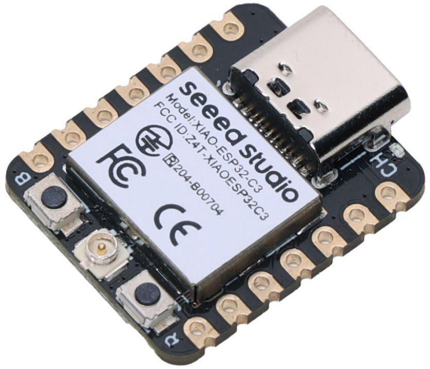
Neil uploads photos of these boards to the components link— check this if you're not sure what you're looking for.



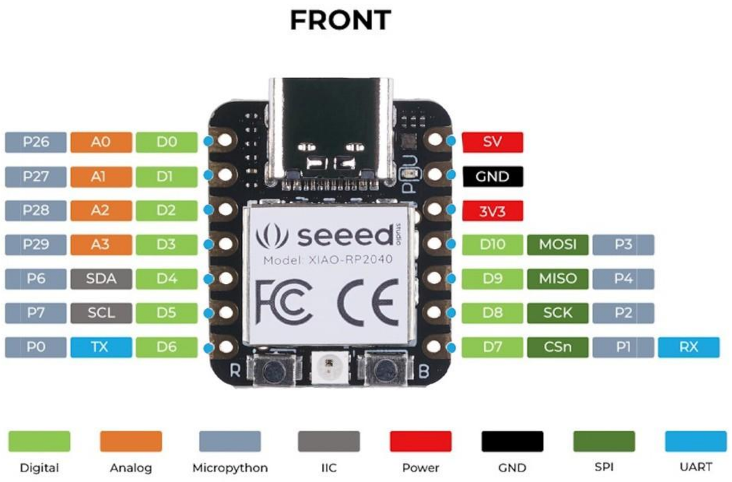


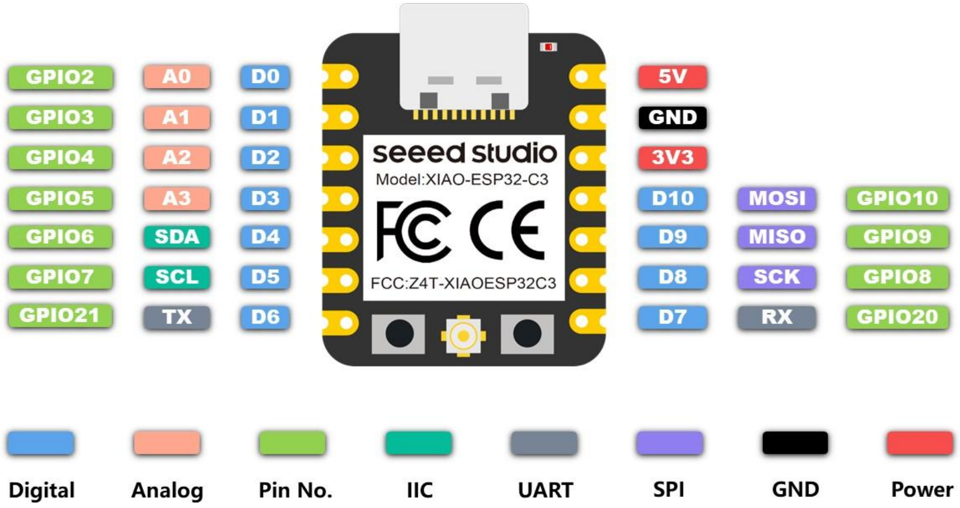
Seeed XIAO ("小”： means ”small”)

RP2040



ESP32C3





Seeed XIAO ("小"： means "smal