

Lecture 10

Prototyping

CE346 – Microprocessor System Design
Branden Ghena – Fall 2021

Some slides borrowed from:

Josiah Hester (Northwestern), Prabal Dutta (UC Berkeley), Project Lead The Way

Administrivia

- Project Design Presentations
 - Next week Thursday in class
 - See Campuswire post for details

Today's Goals

- Discuss issues to consider when prototyping systems
- Understand how to use breadboards for prototyping
- Explore various components and how you might use them with a breadboard
- Also, understand process of capacitive touch sensing

Outline

- **Overview of Prototyping**
- Breadboarding Components
- Capacitive Touch Sensing

Prototyping goals

- Does this thing work at all?
 - Particular IC
 - Circuit layout
 - Software design
 - etc.
- Sometimes before doing something more serious with it
 - Design a PCB, Make a product, etc.
 - Not uncommon that the prototype is as far as you'll get

Isolating tests

- The goal when prototyping is to isolate the question at hand
- Do consider
 - New sensor/IC/component/whatever
- Do not consider
 - Power
 - Interference
 - Enclosure
 - Stable microcontroller
 - Soldering skills

Buying Parts

- Prototyping vendors

- Where you look for cool stuff to buy
- [Sparkfun](#)
- [Adafruit](#)

- Electronics vendors

- Where you buy parts when you know what you need
- [Digikey](#)
- [Mouser](#)

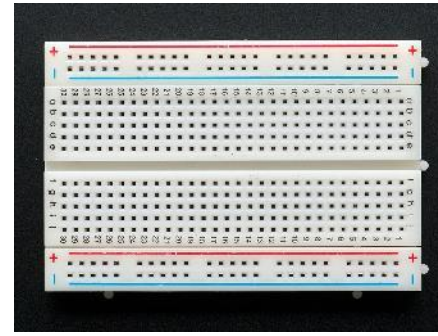
The screenshot shows the SparkFun website interface. At the top, there is a navigation bar with the SparkFun logo and the tagline "START SOMETHING". Navigation links include SHOP, LEARN, BLOG, and SERVICES. A shopping cart icon shows 0 items, and there are links for LOG IN and REGISTER. Below the navigation bar is a search bar with the placeholder text "find products, tutorials, etc..." and a magnifying glass icon. A "PRODUCT MENU" icon is on the left. The main content area features a large banner for the "Garmin LIDAR-Lite v4 LED" sensor, with the Qwiic logo and a description: "A high-performance, wireless optical distance measurement sensor with low resolution and 10 meter range." Below the banner is a category navigation bar with links for AUDIO, BRANDS, COMPONENTS, DEVELOPMENT TOOLS, E-TEXTILES, MISCELLANEOUS, ROBOTICS, SENSORS, TOOLS, and WIRELESS/IoT. A secondary navigation bar includes "New Products", "Top Sellers", "SparkFun Originals", "On Sale", and "SPARK X". The main product grid displays ten items with their names, product codes, and prices:

Product Name	Product Code	Price
SparkFun Analog MEMS Microphone Breakout - ICS-40180	BOB-18011	\$6.95
SparkFun LoRa Gateway - 1-Channel (ESP32)	WRL-18074	\$34.95
SparkFun Basic 16x2 Character LCD - White on Black, 5V (with Headers)	LCD-18160	\$16.95
SparkX Power Meter - ACS37800 (Qwiic)	SPX-17873	\$24.95
SparkX Distance Sensor - TMF8801 (Qwiic)	SPX-17716	\$19.95
SparkX Differential Pressure Sensor - SDP31 (Qwiic)	SPX-17874	\$44.95
Serial Flash Memory - CD25Q40CTIGR (4Mb, 120MHz)	COM-18076	\$0.40
SparkFun Machine Learning @ Home Kit for NVIDIA Jetson Nano	KIT-18157	\$114.95
SparkFun Thing Plus - ESP32-S2 WROOM	WRL-17743	\$19.95
Raspberry Pi IQAudio Codec Zero	DEV-17740	\$20.00

Prototyping methods

- Breadboarding

- Plug and connect components as needed
- Build up arbitrarily complex designs from nothing

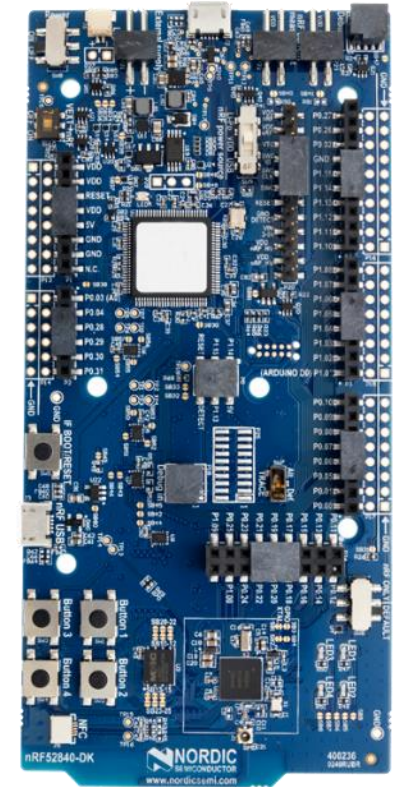


- Development kits

- Pre-fabricated systems design for testing components

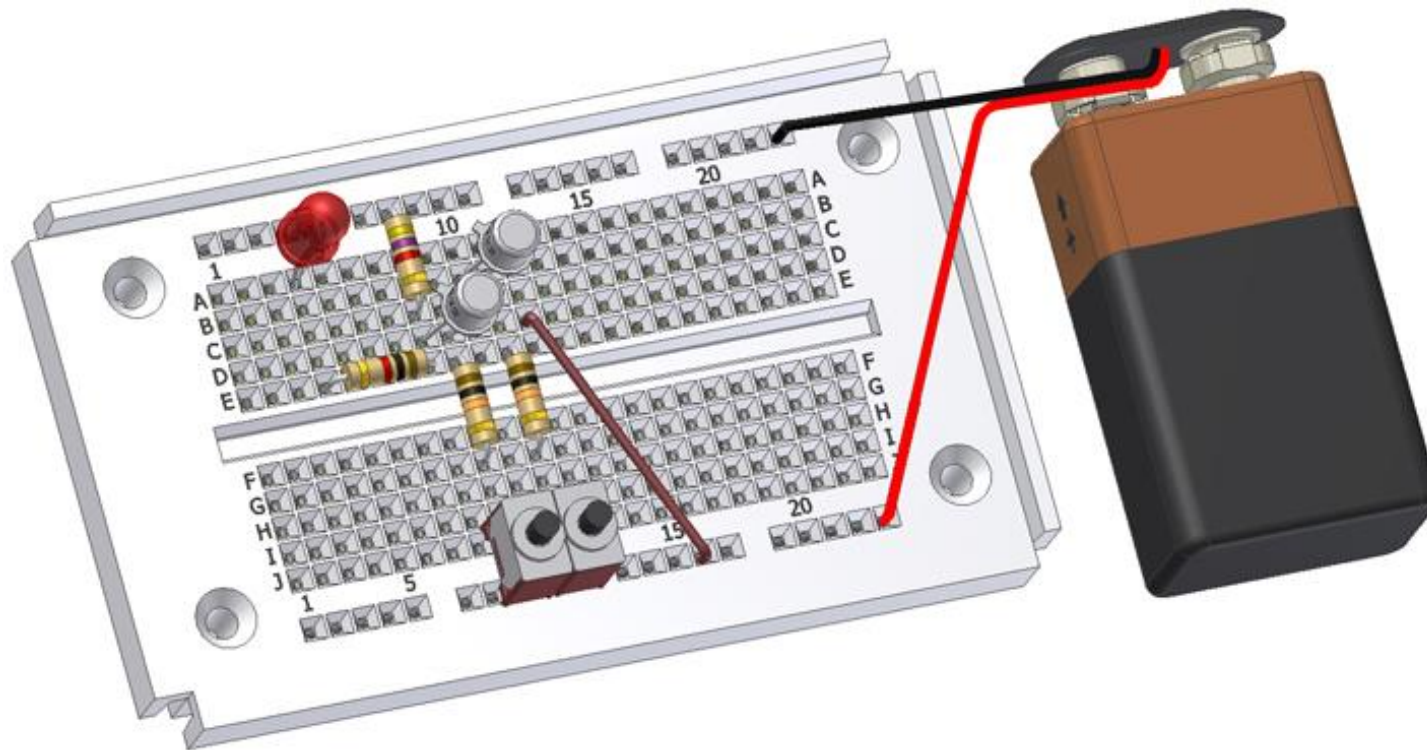
- Small-scale test PCBs

- Design a PCB that demonstrates the thing you're interested in
 - Making a PCB is less hard than some might think (Eagle, [Fritzing](#), etc.)
 - \$20-30 for small, low-speed PCBs from batch services like [OSHPark](#)



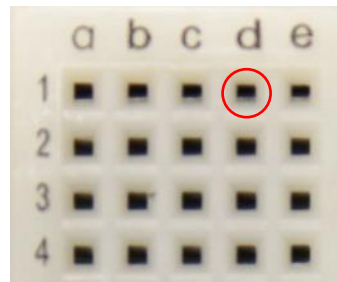
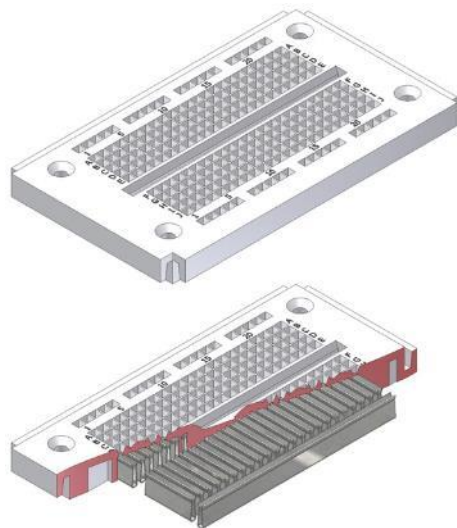
Breadboards for prototyping

- Reusable platform for temporary circuits
- Plug in jumper wires and through-hole components

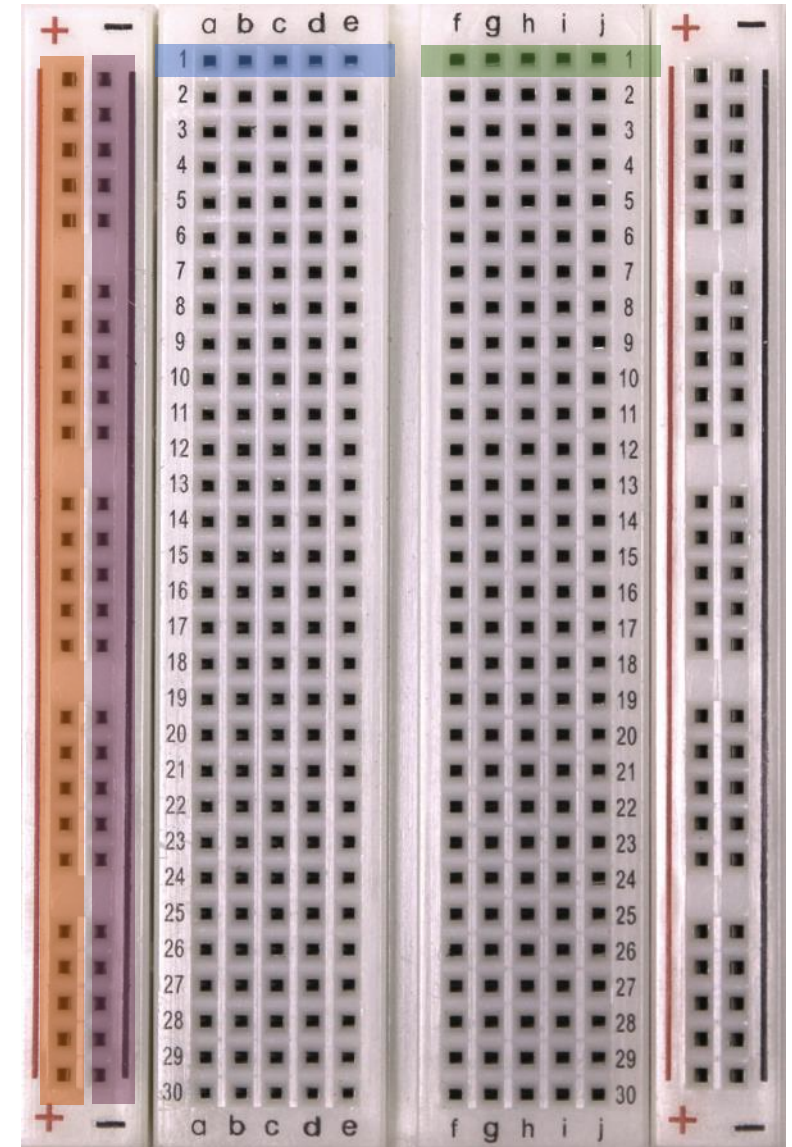


How a breadboard works

- Component leads and wires are inserted into holes in the breadboard
- Half-rows of five holes are connected
- Vertical columns are connected for power/ground

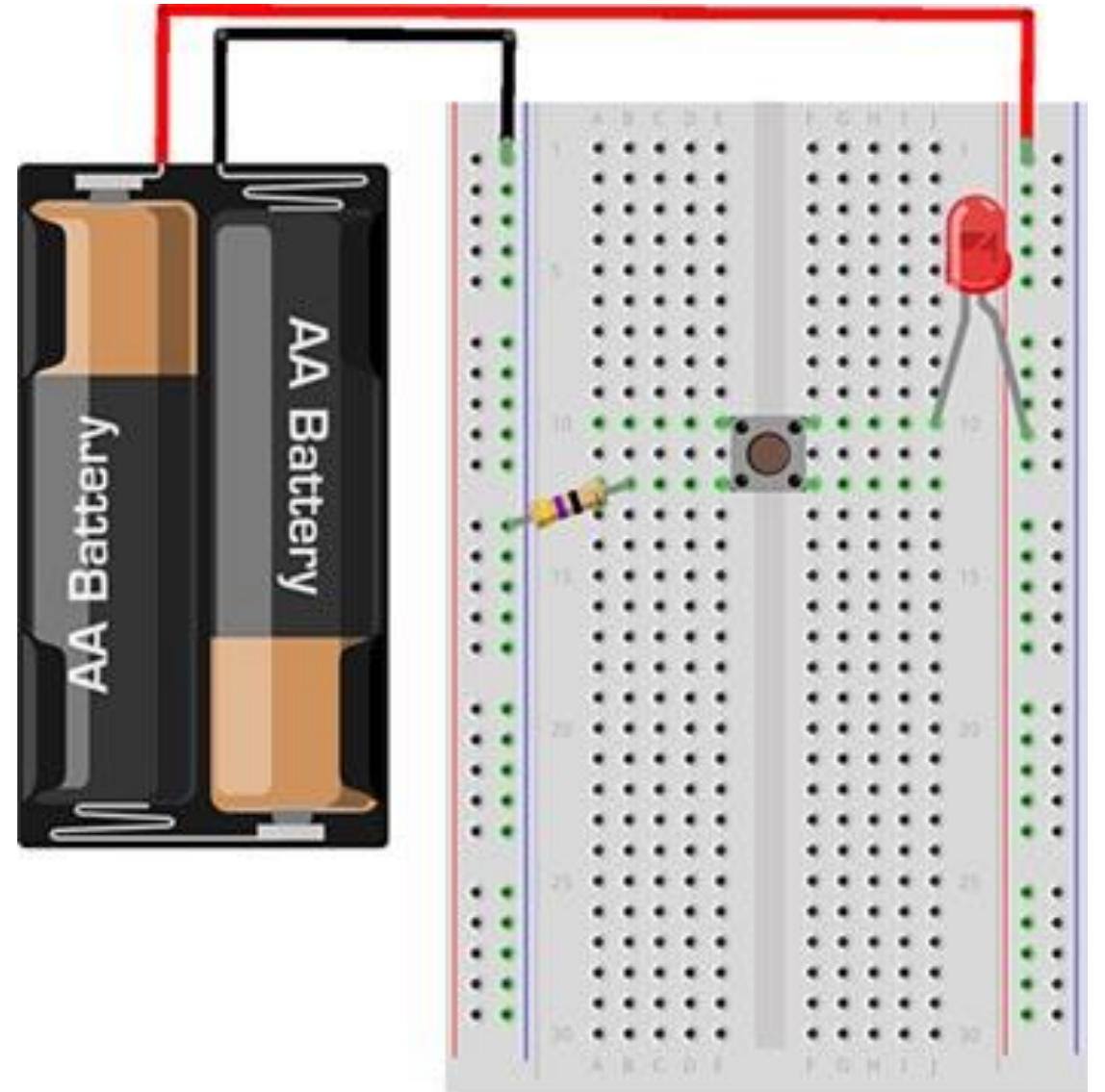


Holes to
insert wires



Breadboard LED example

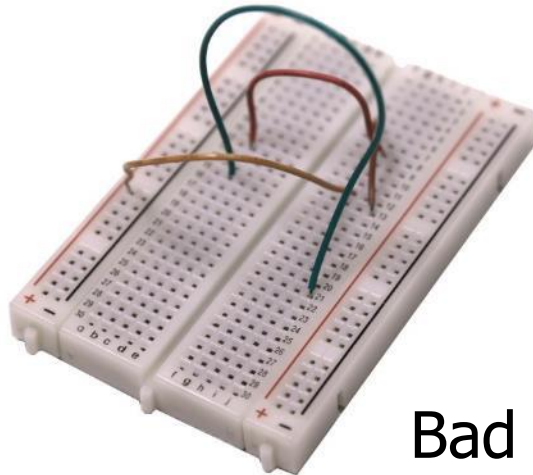
- Uses button to control LED



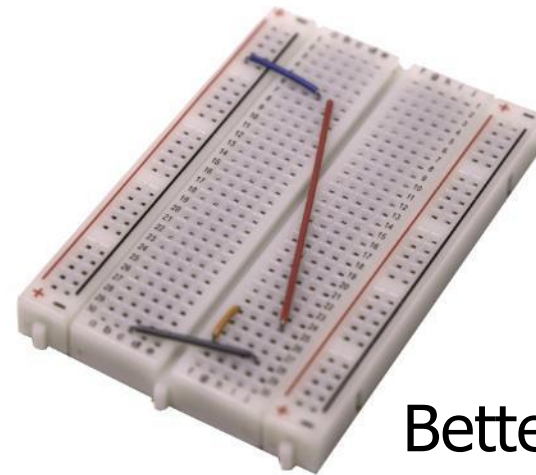
fritzing

Breadboard guidelines

- Long wires in large bird nests makes debugging very difficult
 - Shorter, constrained wires are easier to understand
 - In this class, we'll only have large jumper wires though...
- Use the minimum jumpers necessary, mostly use breadboard for connections



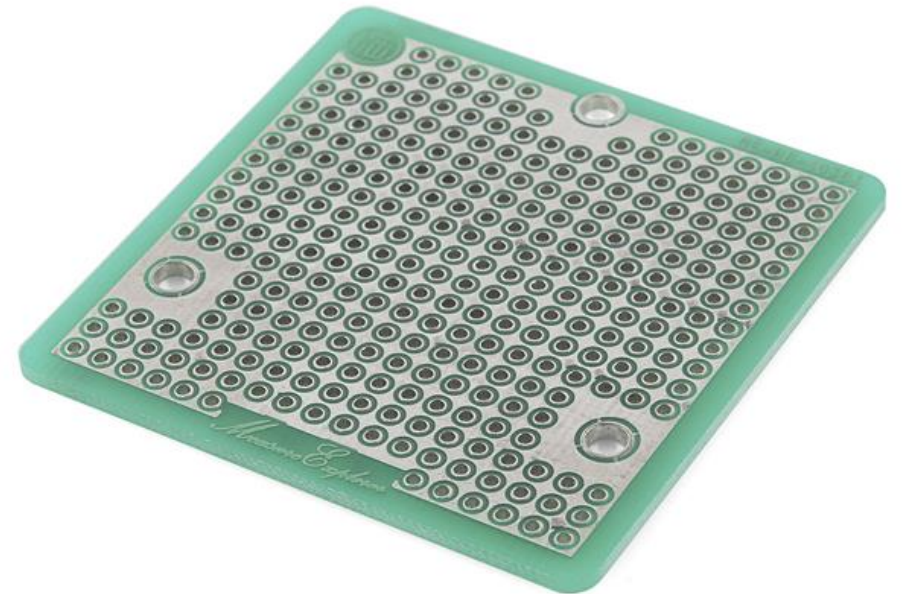
Bad



Better

More permanent breadboards

- Breadboards are also known as “Solderless Breadboards”
- Protoboard allows configurable circuits
 - Solder jumper wires between locations
 - Solder adjacent pads to form connection
- Usually not worth it (just make a PCB)
 - Does solve core problem of breadboards: things getting unintentionally unplugged
 - Might be useful for some projects!



When to not use breadboards

- Breadboards work great for digital circuits and simple analog!
- High voltage/current are bad for breadboards
 - Honestly, anything above 12 volts DC shouldn't be in a breadboard
 - Also avoid high-power applications above a few Watts
 - Never put AC in a breadboard
- Sensitive analog circuits
 - Particularly anything sensitive to capacitance may not work right
 - Sets of metal holes with strips connecting them function as capacitors
- Anything in long term use

Outline

- Overview of Prototyping
- **Breadboarding Components**
- Capacitive Touch Sensing

Prototyping with a breadboard

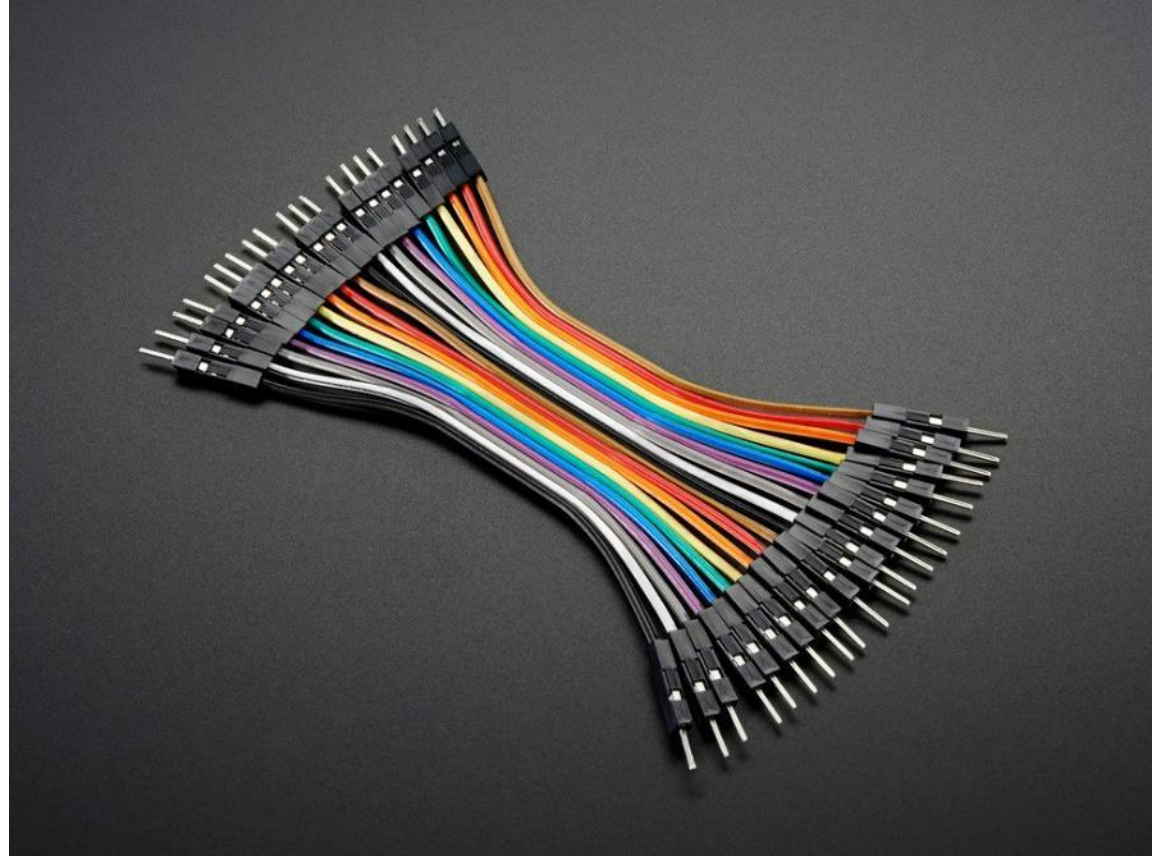
- What kinds of things might you use with a breadboard?
- Jumper wire
- Microbit!
- Resistors/Capacitors
- LEDs
- Buttons/Switches
- Analog Sensors
- Various other through-hole components
 - Transistors, Op-Amps, other ICs



<https://www.adafruit.com/product/2975>

Jumper wires

- Connect two rows in the breadboard together
- Recommendation:
 - Peel off sets of 2-4 wires and keep them stuck together
 - Often want to run multiple at once

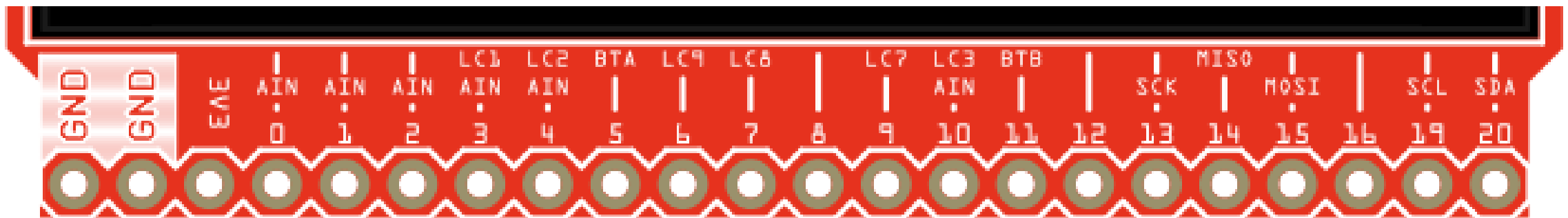
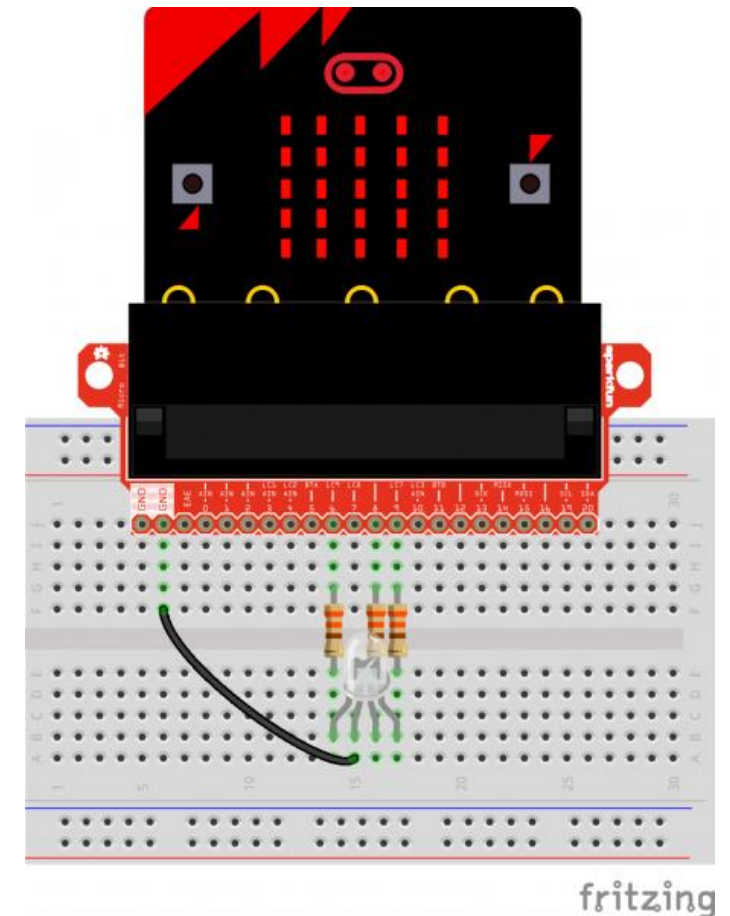


Microbit

- Always connect LED matrix side up
- Breaks out various pins from board
 - Need to consult table to know which pins
 - <https://tech.microbit.org/hardware/schematic/>

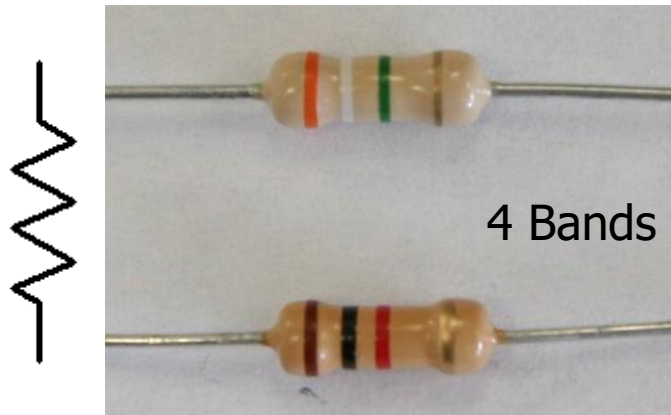
<https://www.sparkfun.com/products/13989>

<https://learn.sparkfun.com/tutorials/microbit-breakout-board-hookup-guide>

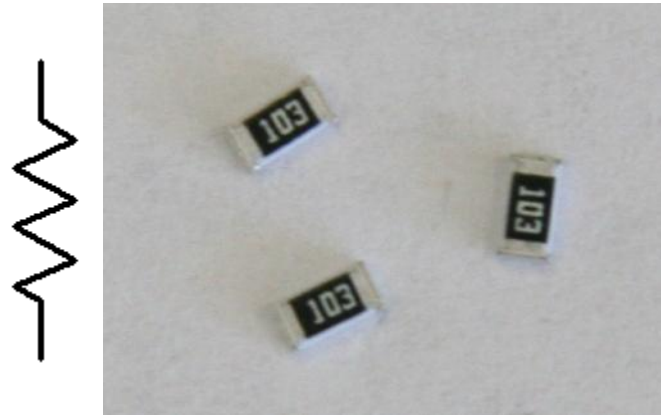


Resistors

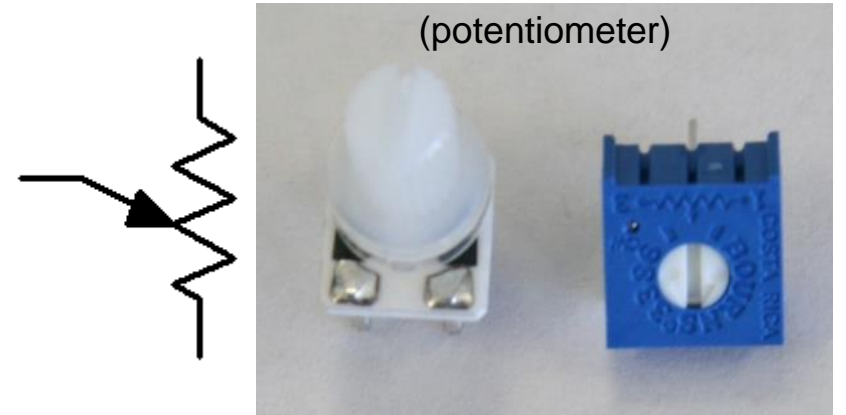
Carbon Film Resistors



Surface Mount Resistors

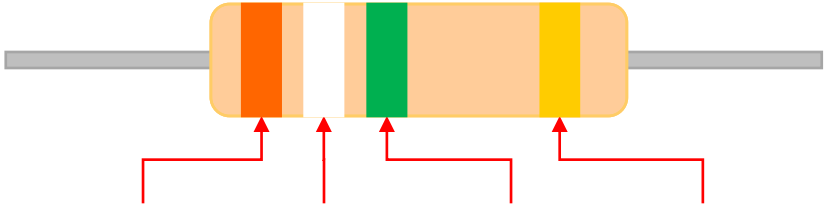


Variable Resistors



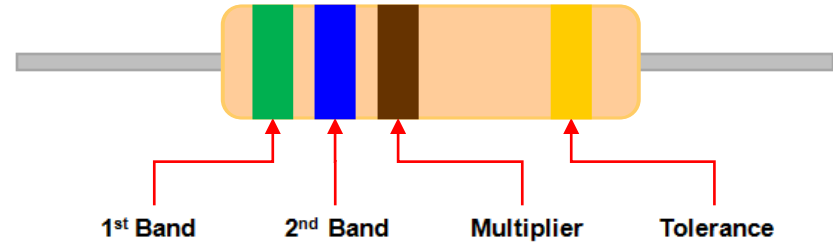
Resistor color codes

- Colored bands on resistors label the resistance value of the part
- First and second bands are the digits
- Third band is multiplier
- Fourth band is tolerance
 - Usually gold: +/- 5%



	1 st Band	2 nd Band	Multiplier	Tolerance
NONE				20%
Silver			0.01	10%
Gold			0.1	5%
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1K	
Yellow	4	4	10K	
Green	5	5	100K	
Blue	6	6	1M	
Violet	7	7	10M	
Gray	8	8	100M	
White	9	9	1000M	

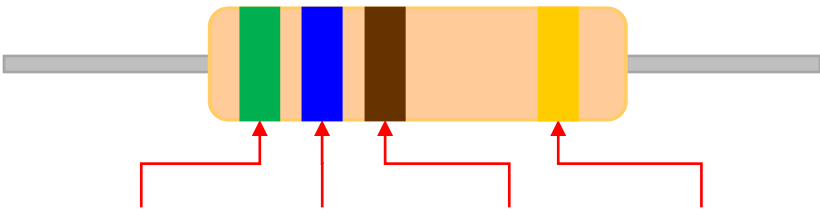
Example: determine the resistor



	1 st Band	2 nd Band	Multiplier	Tolerance
NONE				20%
Silver			0.01	10%
Gold			0.1	5%
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1K	
Yellow	4	4	10K	
Green	5	5	100K	
Blue	6	6	1M	
Violet	7	7	10M	
Gray	8	8	100M	
White	9	9	1000M	

Example: determine the resistor

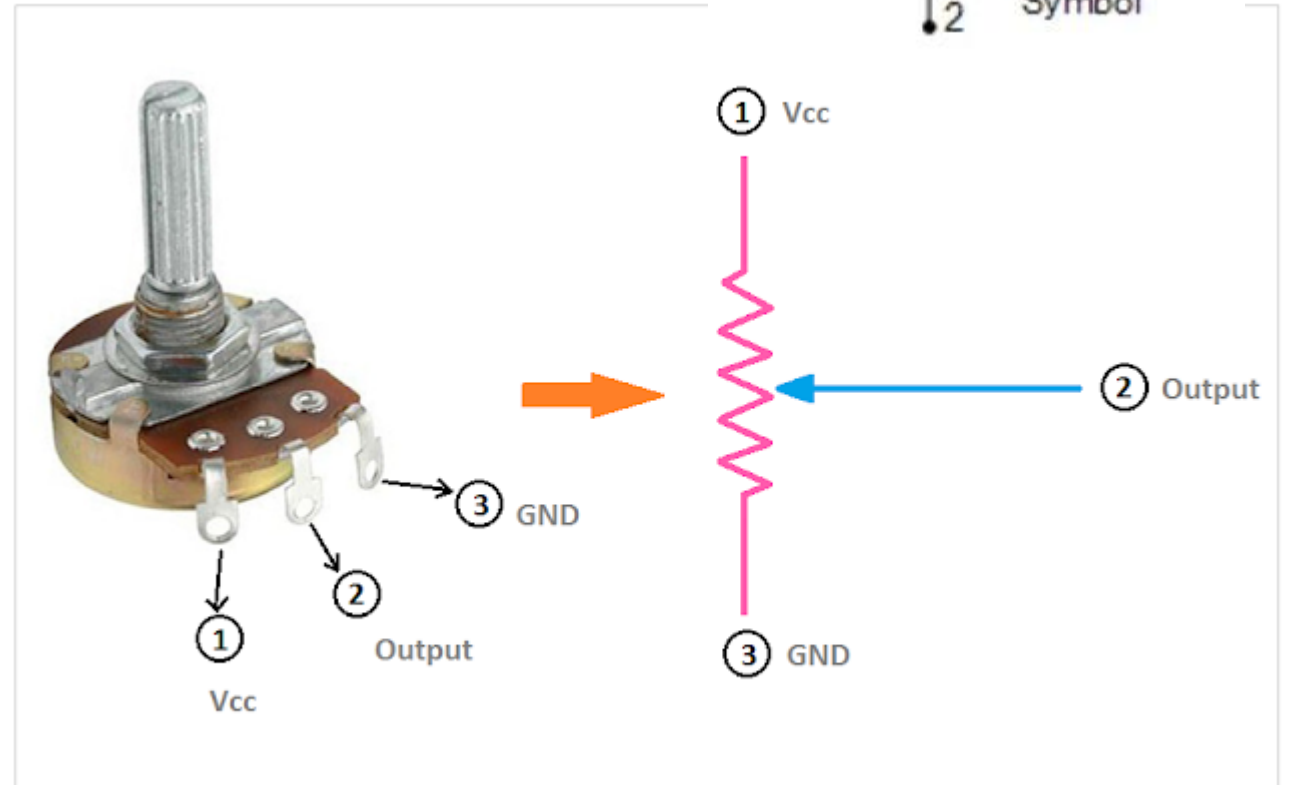
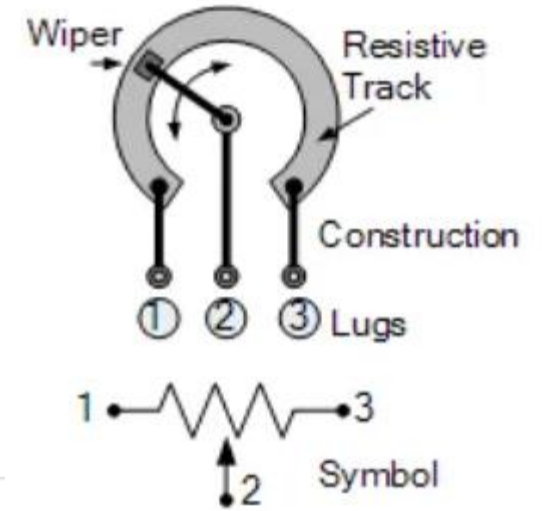
- $56 \times 10 \Omega = 560 \Omega (\pm 5\%)$



	1 st Band	2 nd Band	Multiplier	Tolerance
NONE				20%
Silver			0.01	10%
Gold			0.1	5%
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1K	
Yellow	4	4	10K	
Green	5	5	100K	
Blue	6	6	1M	
Violet	7	7	10M	
Gray	8	8	100M	
White	9	9	1000M	

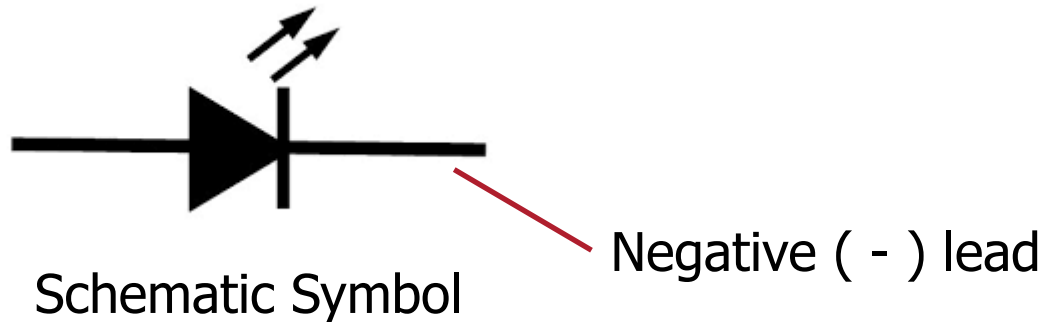
Potentiometers

- Vary resistance between zero and some maximum
 - 1 k Ω , 10 k Ω , 100 k Ω common
- Connect middle and an edge for just a changeable resistor
- Middle terminal is a movable resistor divider
 - Knob changes middle output if outer pins are VCC and Ground



LEDs

- Directional component: only allows current to flow one way
- Shorter side is the negative one
 - i.e. where current flows to



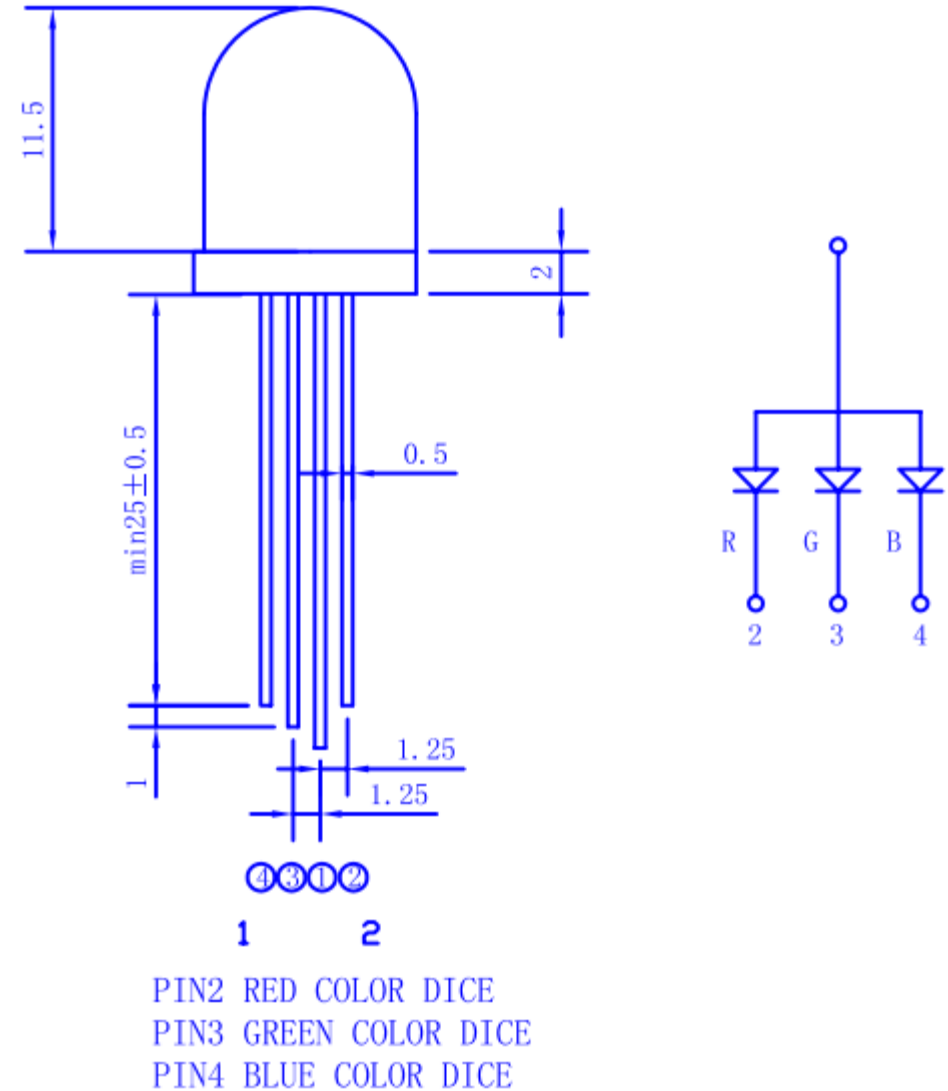
Larger metal component inside of case or case flat spot is cathode or negative (-) lead

Shorter wire is cathode or negative (-) lead



RGB LED

- Three different colors of LED in a single large diffuser
- Short leads are negative ends
 - One for each color
- Long lead is common power
 - Common anode
- Combinations of LEDs give other colors
 - Cyan, Yellow, Violet, White



<https://cdn-shop.adafruit.com/datasheets/FLR-100WAS-RGB.pdf>

Sensors

- Thermistor



- Photoresistor



Breadboard demo!

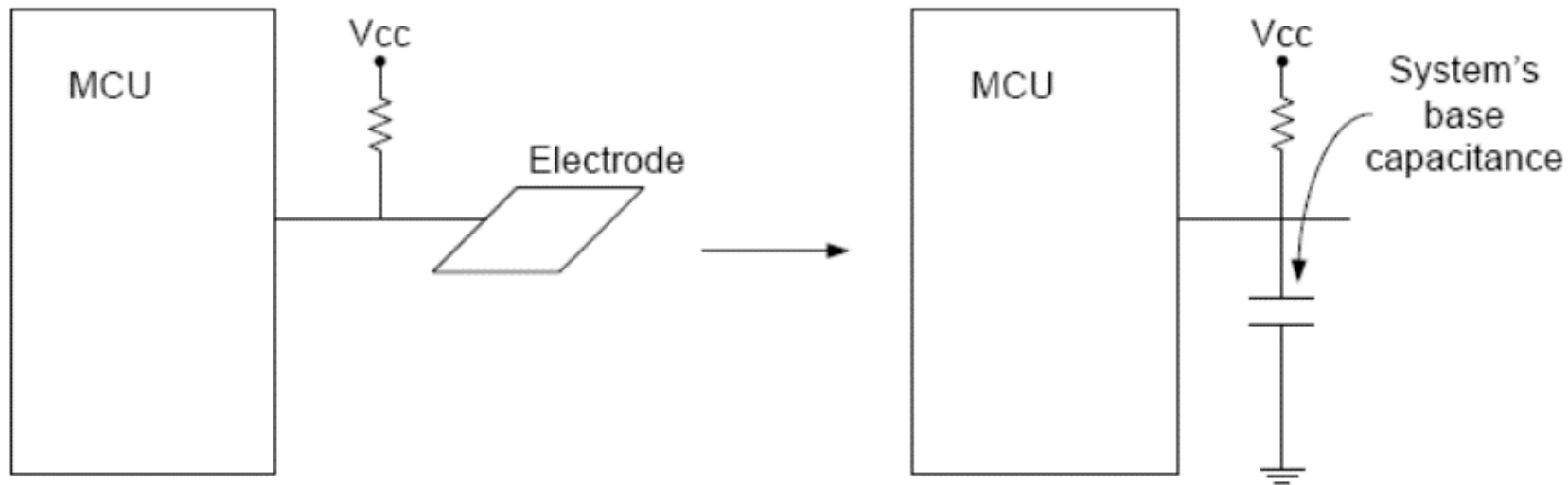
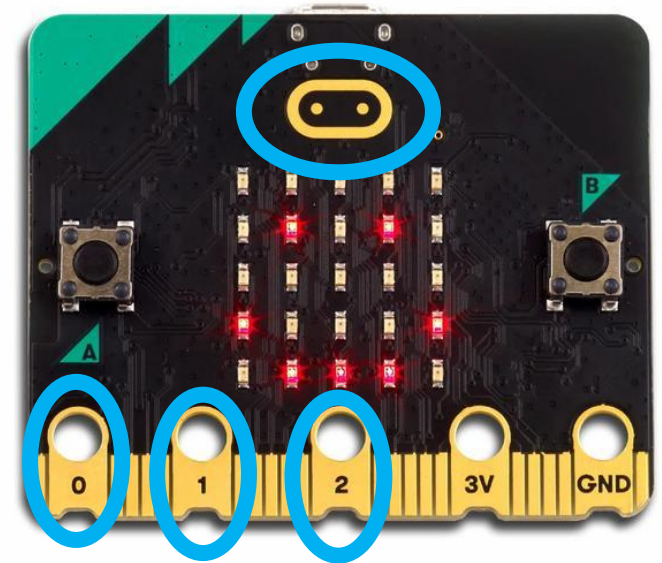
- RGB LED
 - Plus resistors
- Control LED with
 - Switch
 - Potentiometer
 - Photoresistor

Outline

- Overview of Prototyping
- Breadboarding Components
- **Capacitive Touch Sensing**

Capacitive Touch Sensor

- Pull-up resistors connected to metal pads
 - Also connected to GPIO pin
- Acts as a capacitor connected to ground



Capacitive touch sensing method

1. Drive GPIO pin low
 - Connects the pad to ground
2. Set GPIO pin as input and enable low-to-high interrupt
 - Pad is pulled high. This takes time based on capacitance
 - Use a timer to determine time until interrupt
 - $\sim 70 \mu\text{s}$ with no finger, milliseconds with finger
 - Needs to timeout after a few milliseconds
3. Repeat periodically

Sudden large increase in rise time \Rightarrow someone is touching!

- Finger acts as a large capacitor

Capacitive touch works on any metal surface

- Idea: Microbit door handle sensor
- Connect a wire and a pull-up resistor to a metal door handle to sense when someone is touching it!
 - Timing will be very different from capacitive pad, but should be repeatable and distinguishable from human touch

Outline

- Overview of Prototyping
- Breadboarding Components
- Capacitive Touch Sensing