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

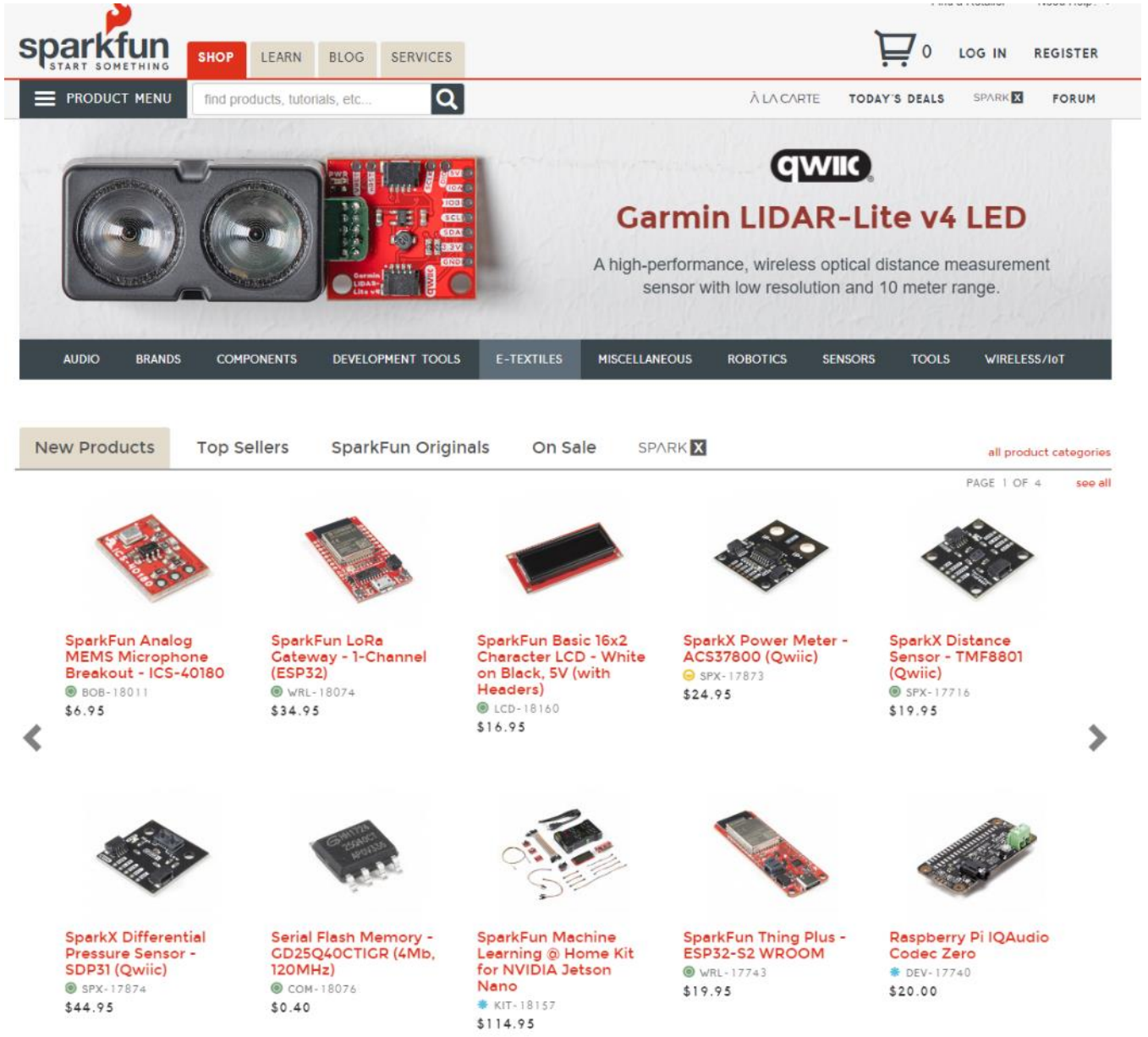
- Do consider
  - New sensor/IC/component/whatever

- Do not consider
  - Power
  - Interference
  - Enclosure
  - Stable microcontroller
  - Soldering skills

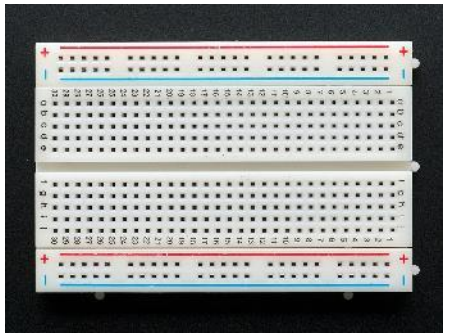
Buying Parts

- 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



Prototyping methods

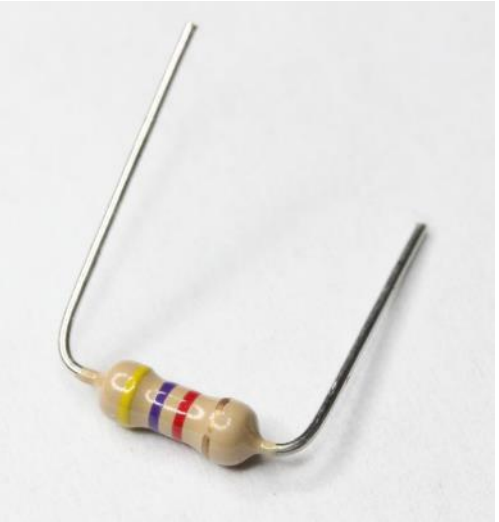


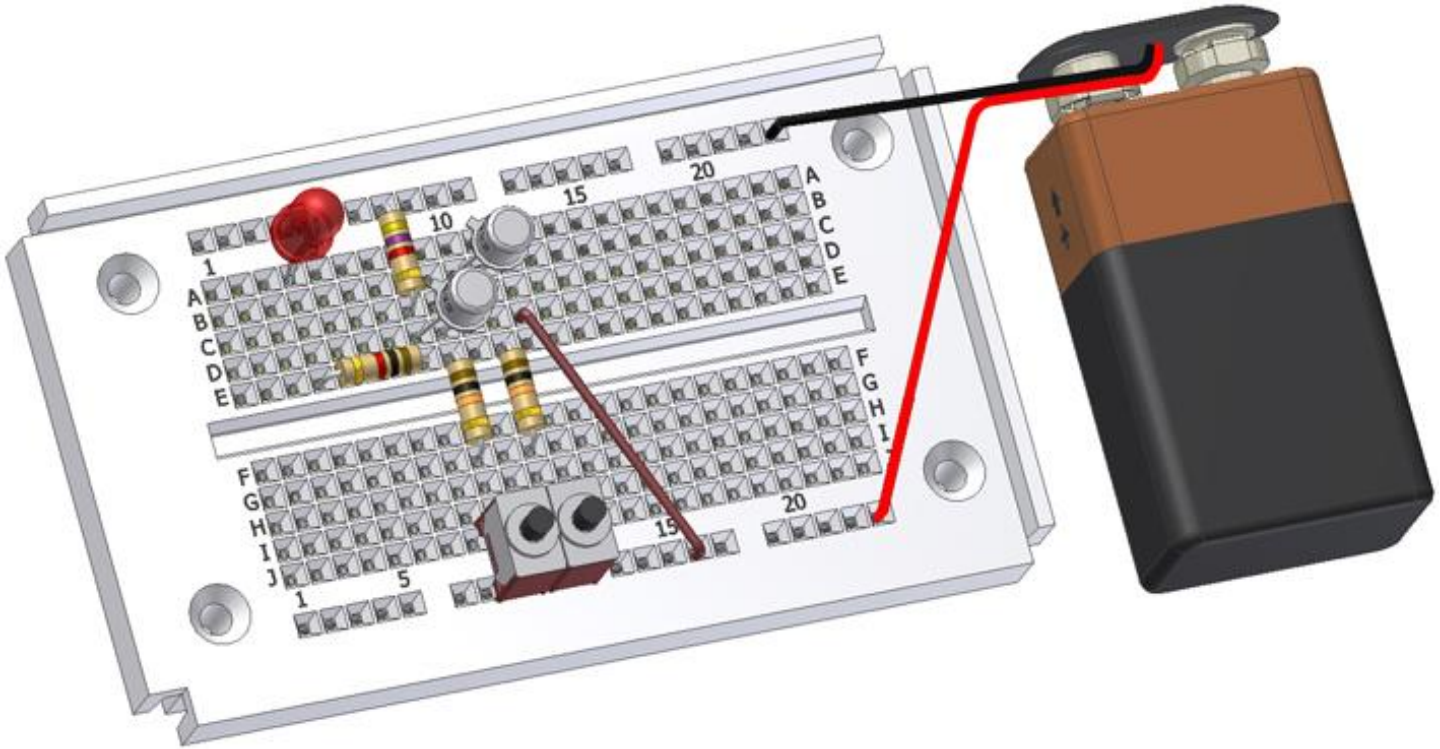
- Breadboarding
  - Plug and connect components as needed
  - Build up arbitrarily complex designs from nothing
- Development kits
  - Pre-fabricated systems design for testing components
- Small-scale test PCBs
  - Design a PCB that demonstrates the thing you're interested in
    - Making a PCB is less 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-hold components

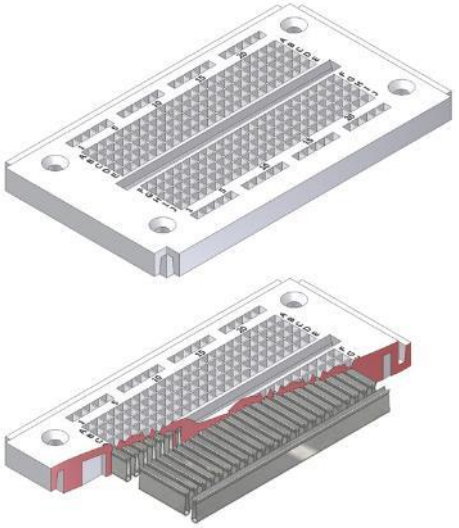


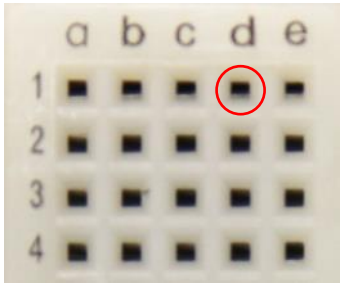


How a breadboard works

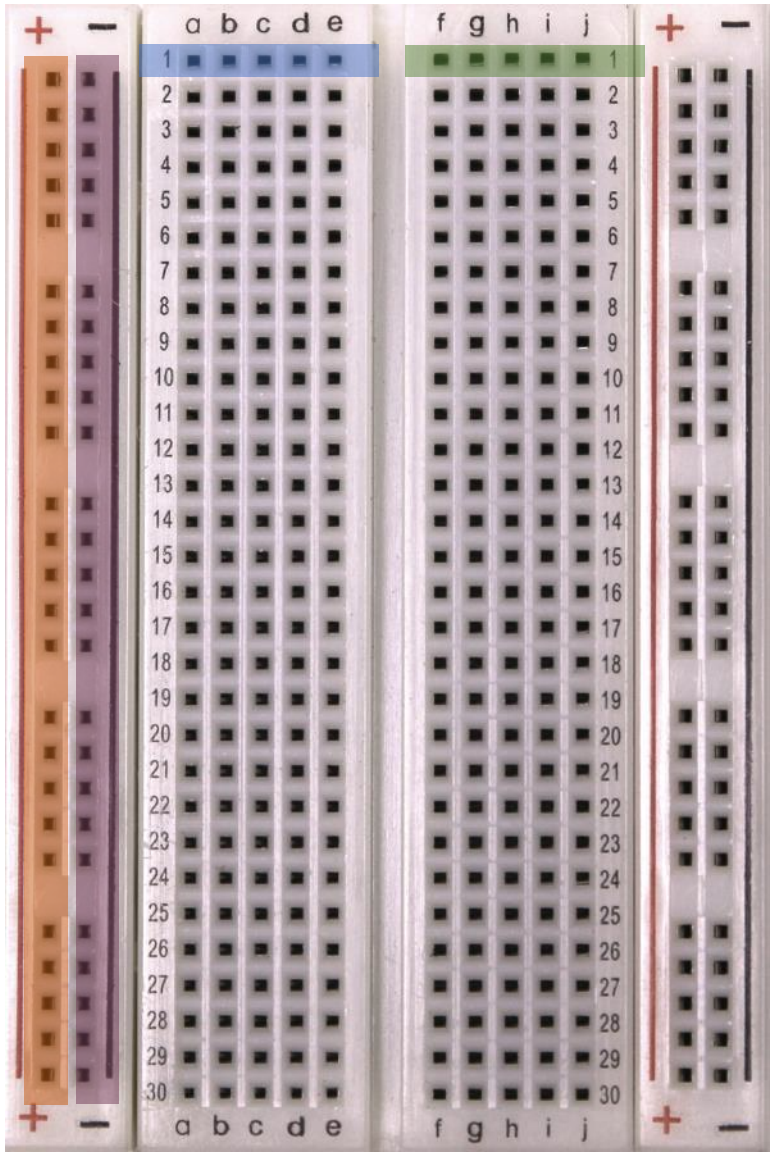
- Component leads and wires are inserted into holes in the breadboard

- Half-rows of five holes are connected
- Vertical columns are connected for power/ground



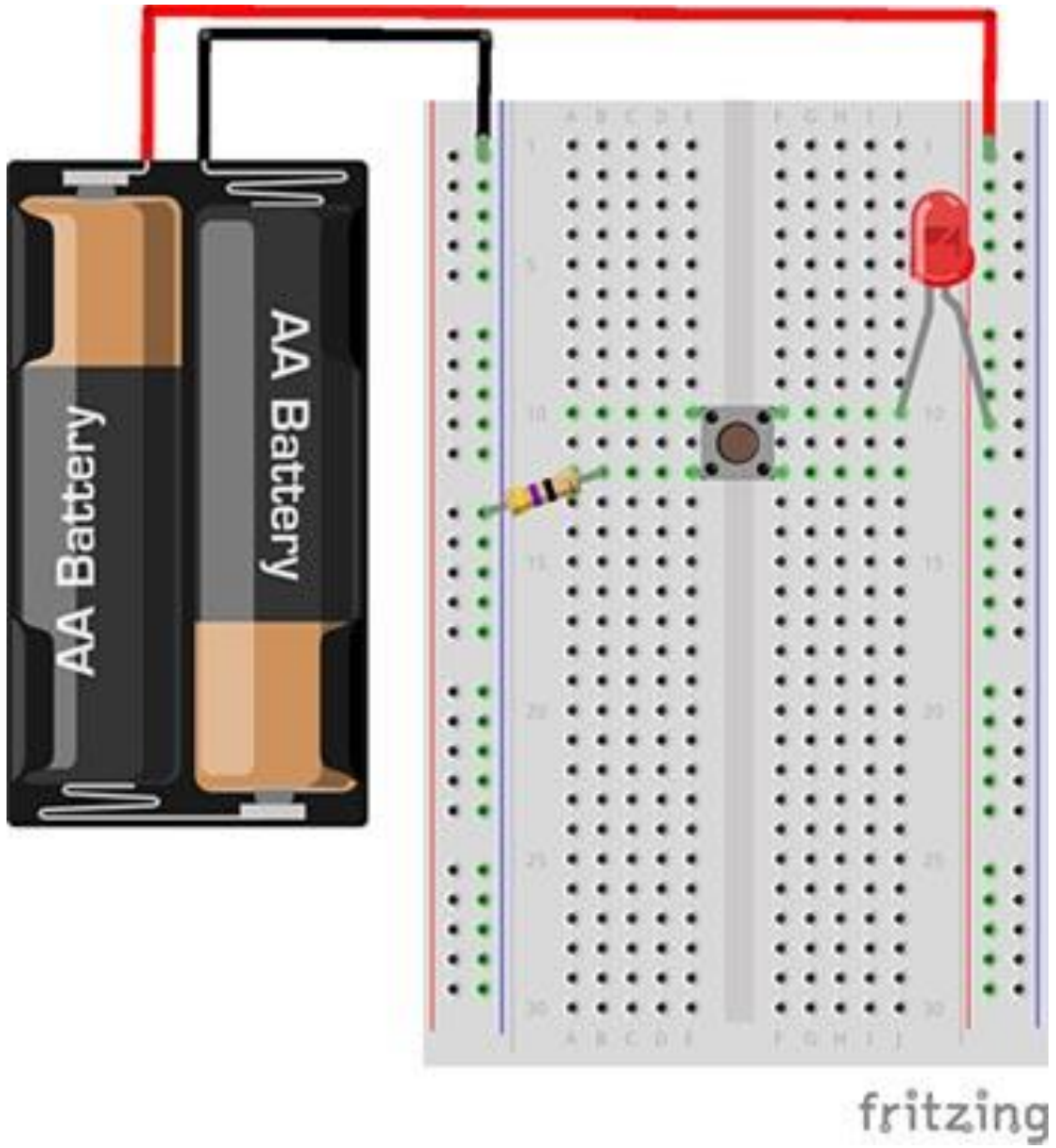


Holes to insert wires



Breadboard LED example

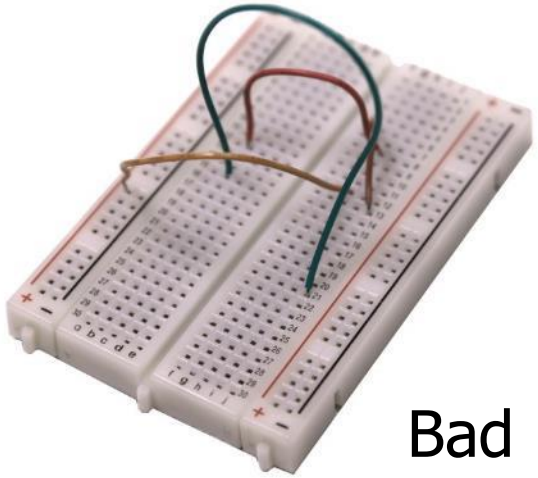
- Uses button to control LED



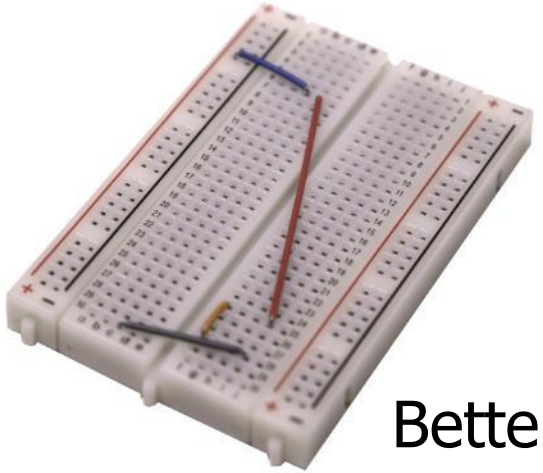
Breadboard guidelines

- 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

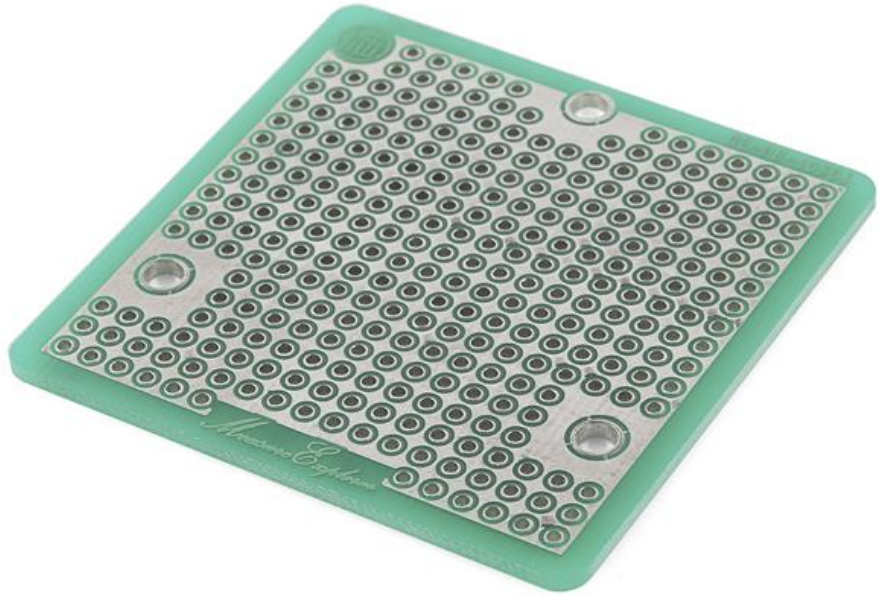


Better

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

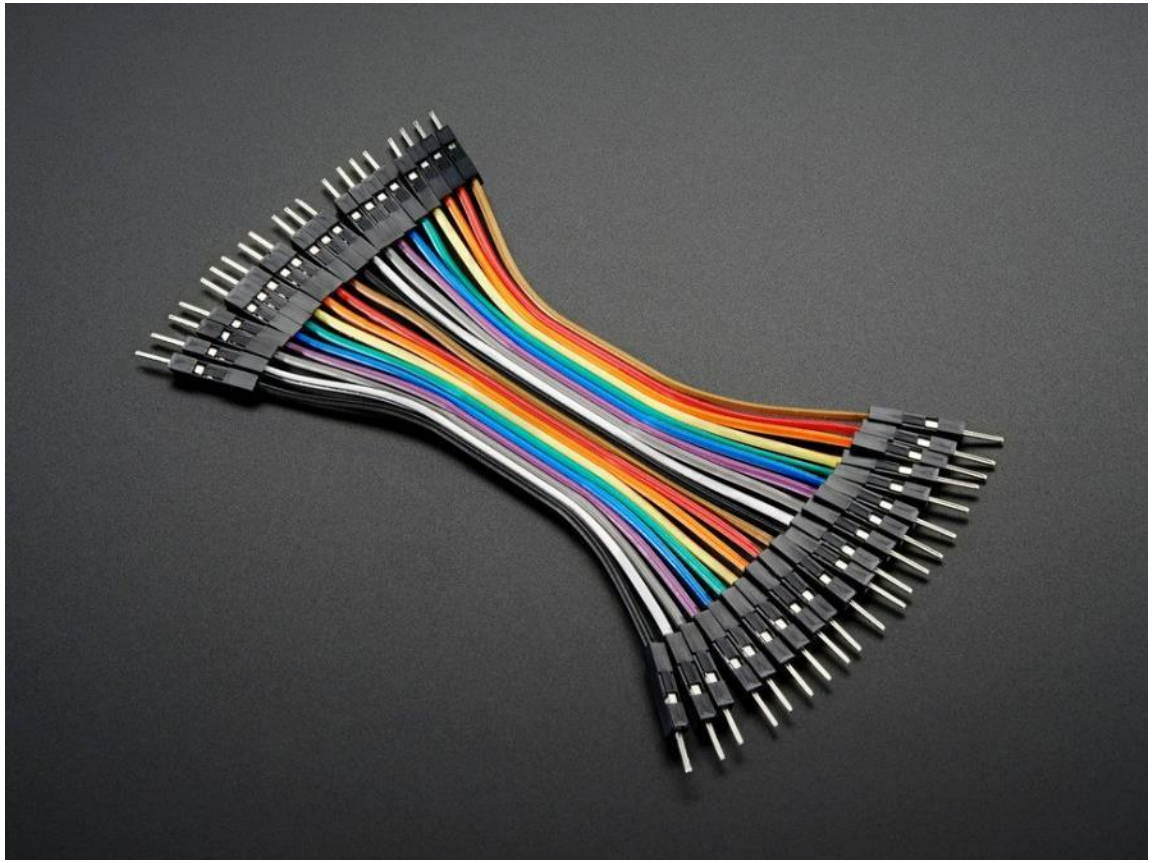
- What kinds of things might you use with a breadboard?
- Jumper wire
- Microbit!
- Resistors/Capacitors
- LEDs
- Buttons/Switches
- Analog Sensors
- Various other through-hole components
  - Transistors, Op-Amps, other ICs

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

Jumper wires

- Connect two rows in the breadboard together

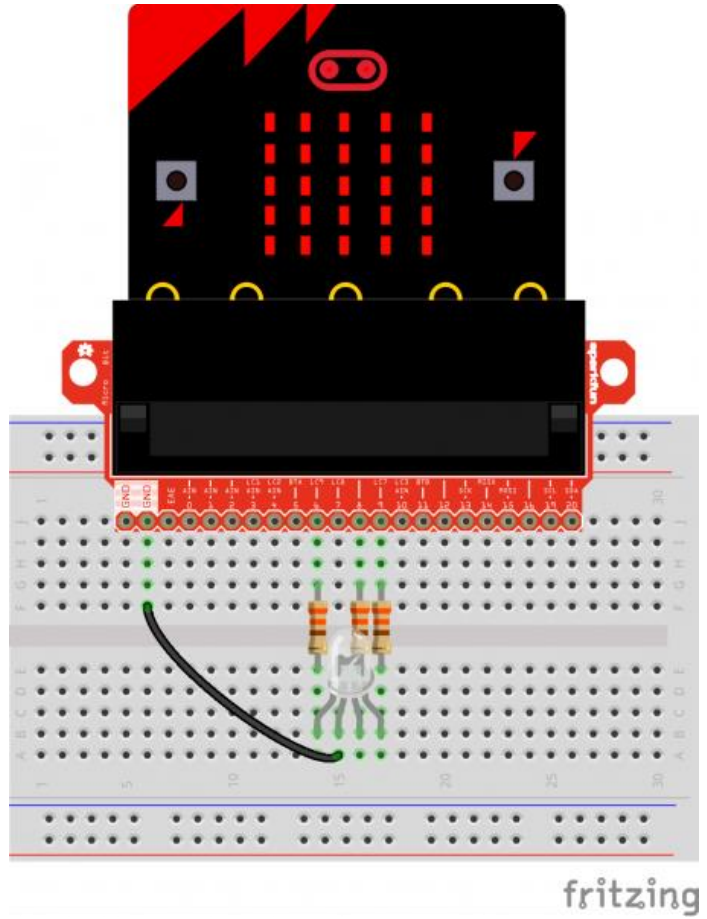
- Recommendation:
  - Peel off sets of 2-4 wires and keep them stuck together
  - Often want to run multiple at once



Microbit

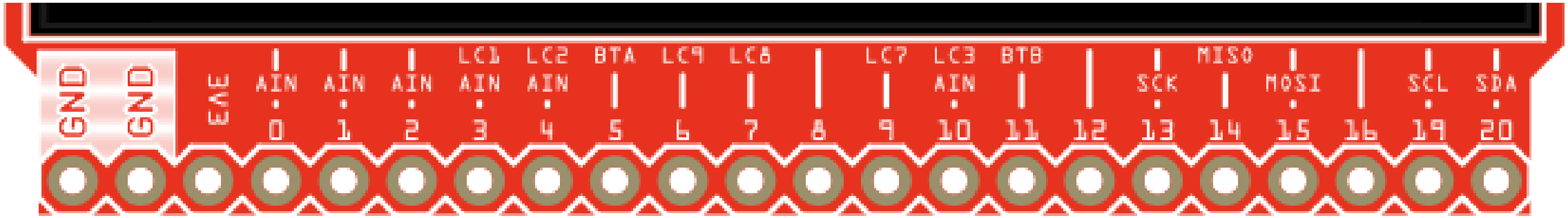
- Always connect LED matrix side up

- Breaks out various pins from board
  - Need to consult table to know which pins
  - https://tech.microbit.org/hardware/schematic/



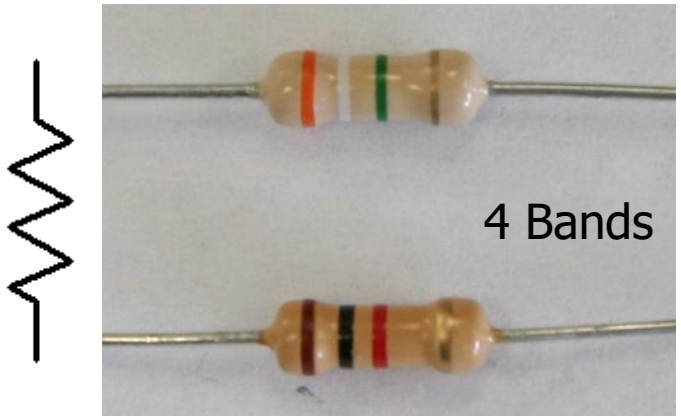
https://www.sparkfun.com/products/13989

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

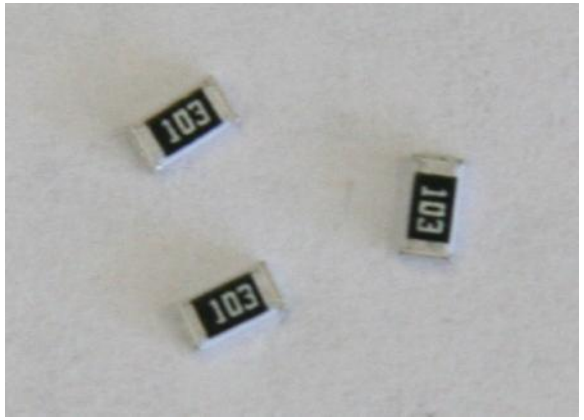


Resistors

Carbon Film Resistors

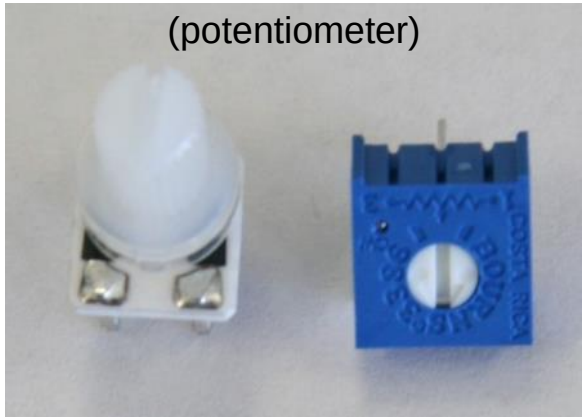


Surface Mount Resistors



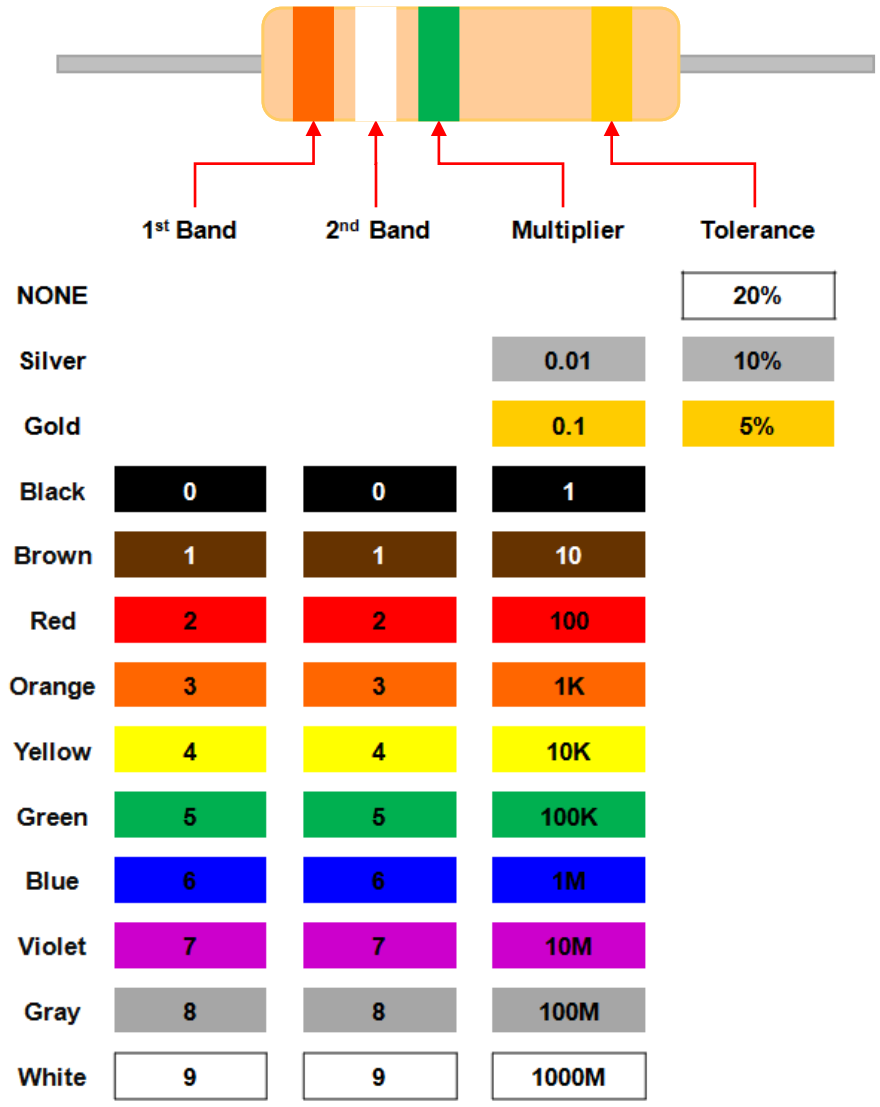
Variable Resistors

(potentiometer)

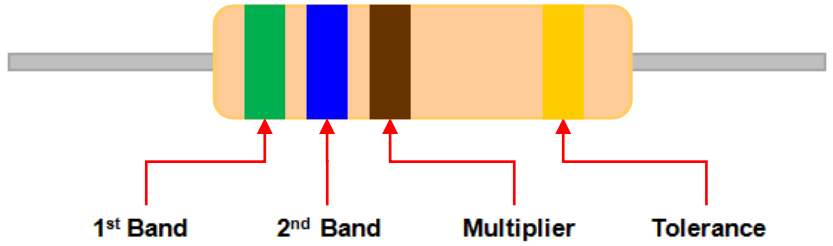


Resistor color codes

- 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%



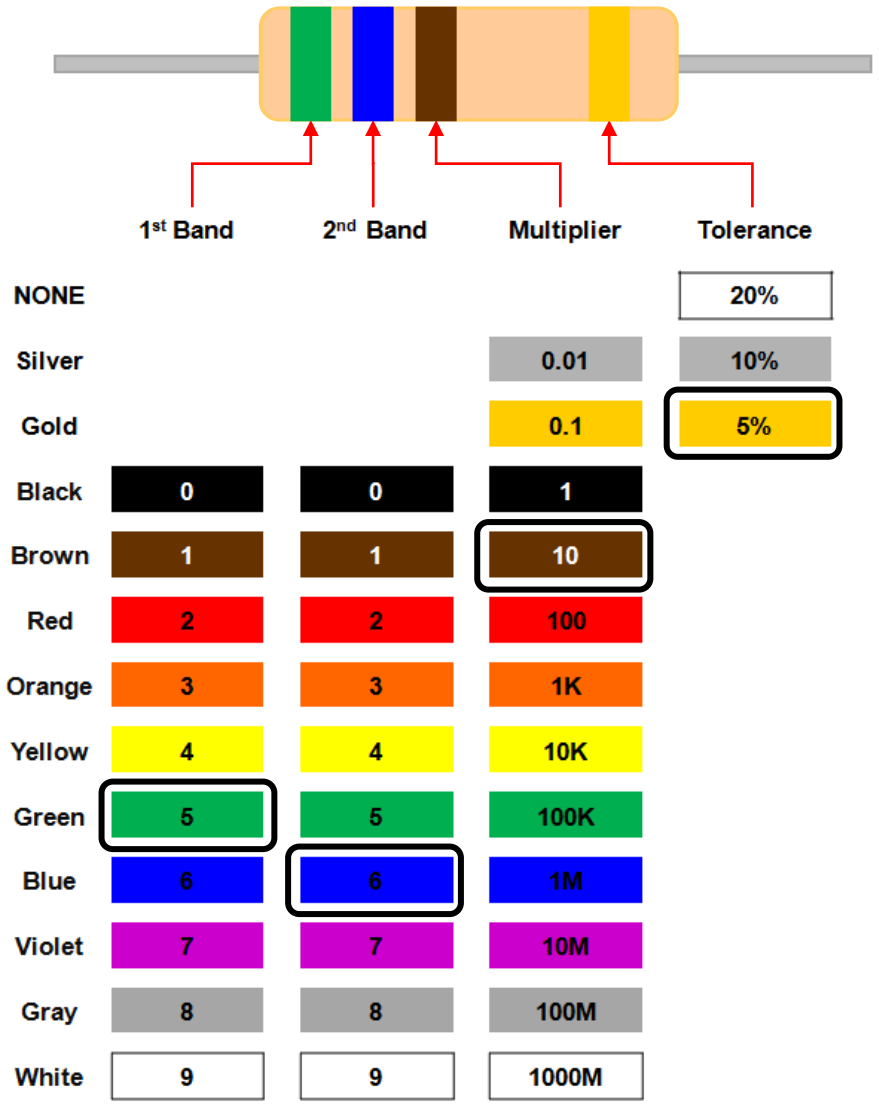
Example: determine the resistor



	1st Band	2nd 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	

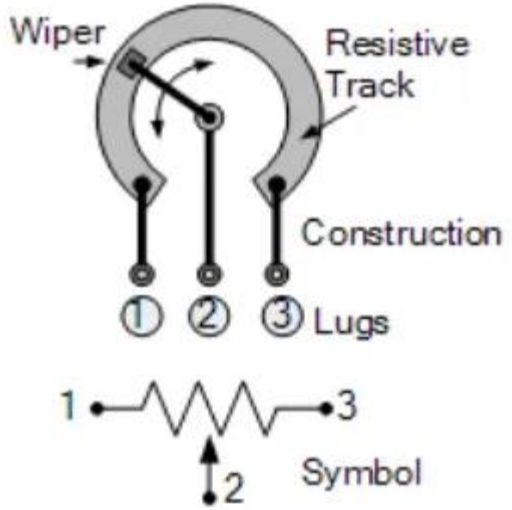
Example: determine the resistor

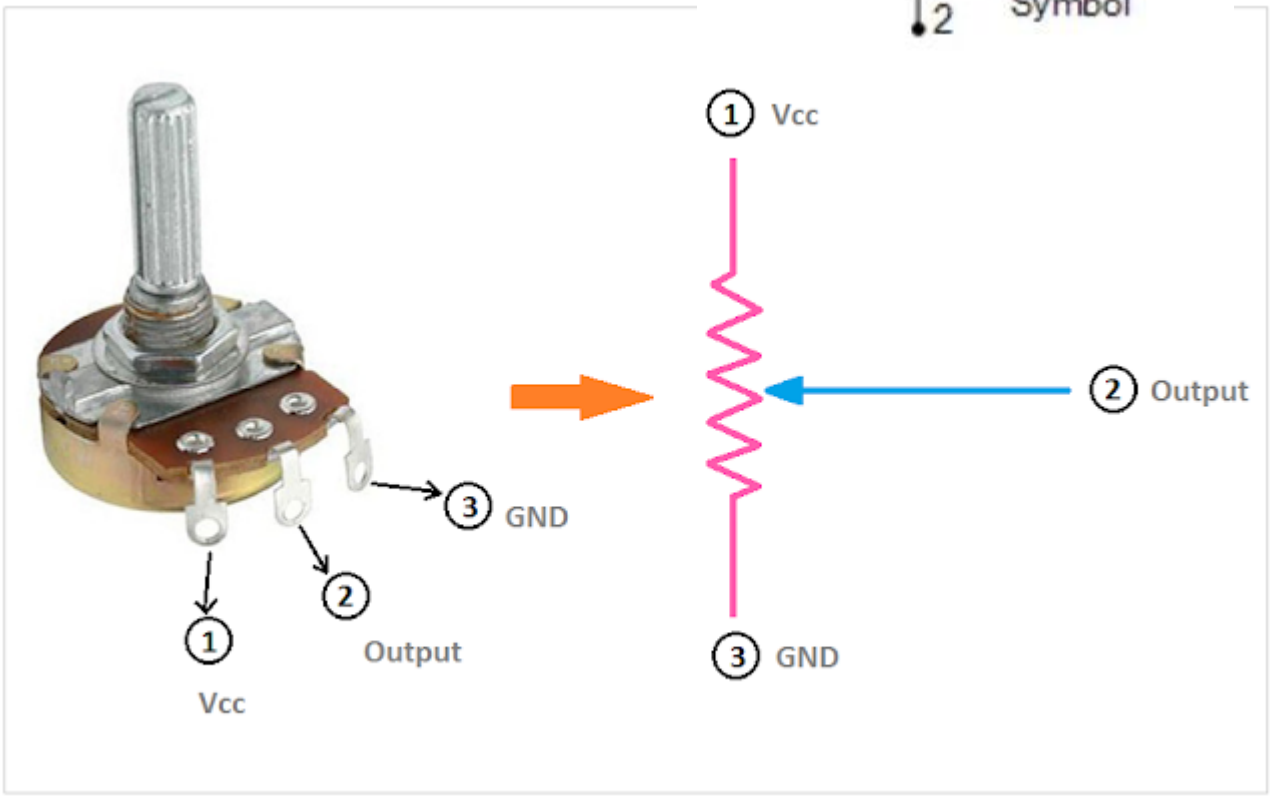
- 56 x 10 Ω = 560 Ω (±5%)



Potentiometers

- Vary resistance between zero and some maximum
  - 1 kΩ, 10 kΩ, 100 kΩ 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

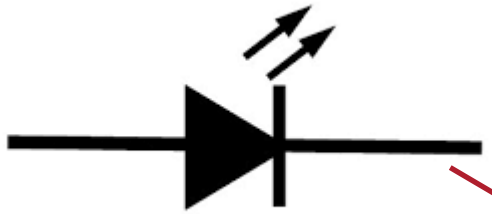




LEDs

- Directional component: only allows current to flow one way

- Shorter side is the negative one
  - i.e. where current flows to



Schematic Symbol

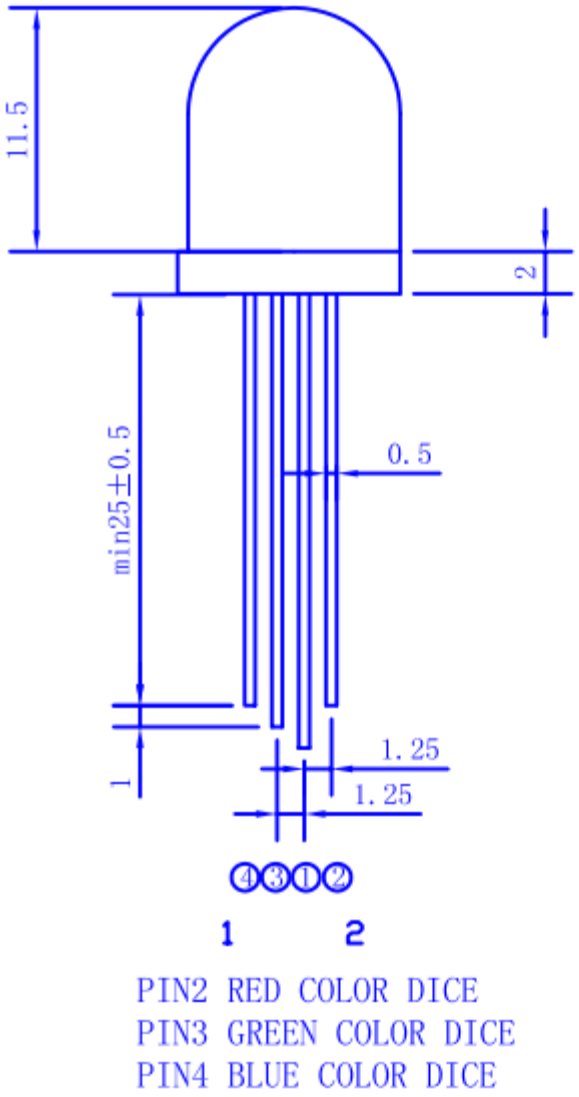
Negative (-) lead

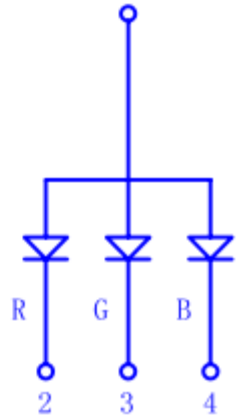
Larger metal component inside of case or case flat spot is cathode or negative (-) lead

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!

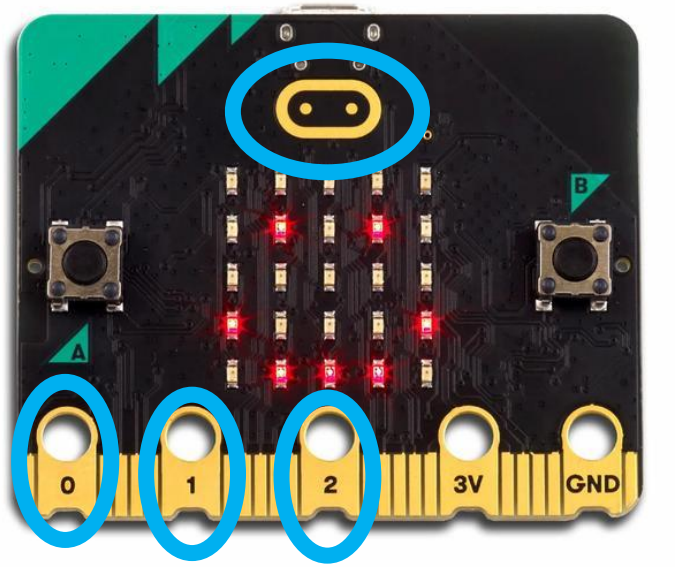
- RGB LED
  - Plus resistors
- Control LED with
  - Switch
  - Potentiometer
  - Photoresistor

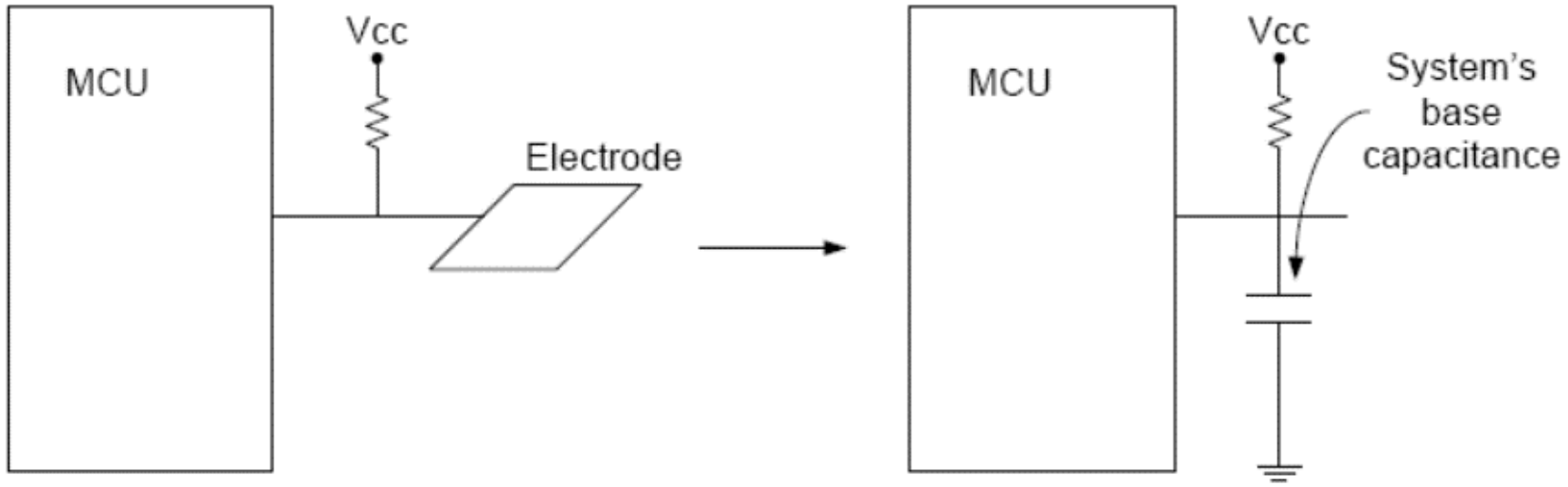
Outline

- 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
     - ~70 µs with no finger, milliseconds with finger
     - Needs to timeout after a few milliseconds

3. Repeat periodically

Sudden large increase in rise time ⇨ 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

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- Breadboarding Components
- Capacitive Touch Sensing