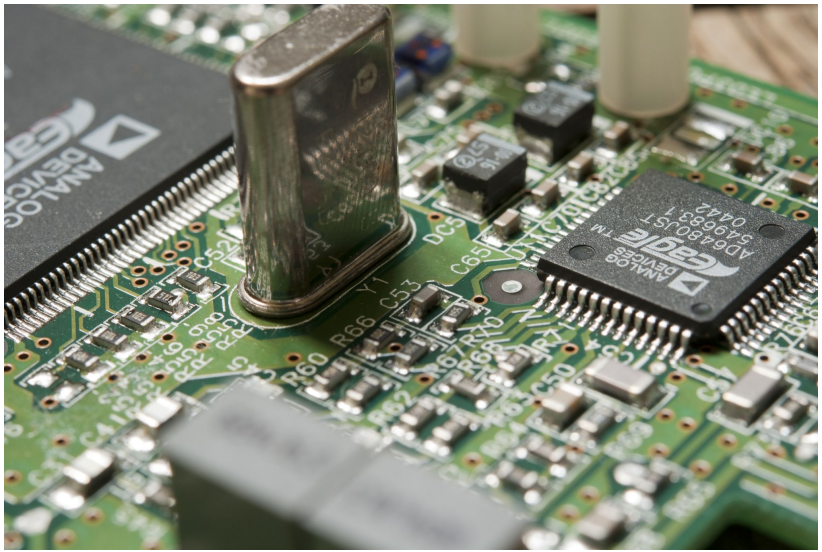
Embedded System Workshops

05. Electronics Theory and Review
CCA Girls Who Code

Workshop Overview

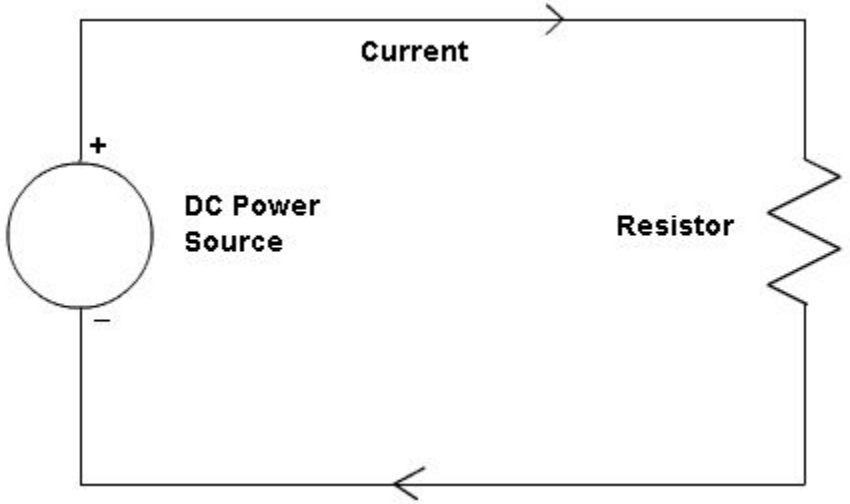
- Purpose
  - Learn about the theory behind Direct Current circuits and circuit elements
  - Review the components we have used in previous workshops, like the LED light, Button, LCD Screen, and Servo Motor

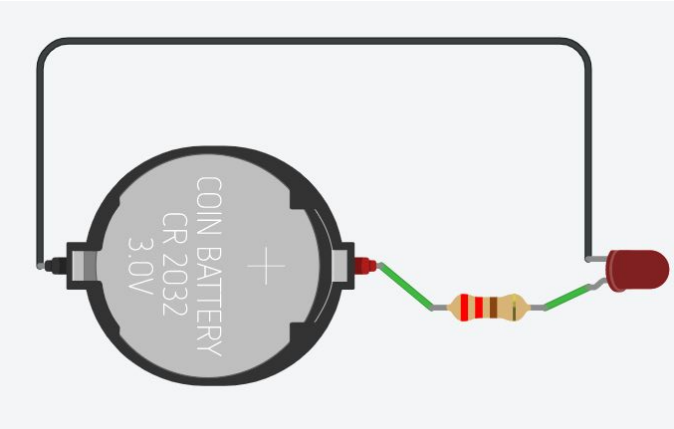


Electronics Theory

Basic DC Circuit

- The most basic DC circuit comprises a power source and a load.
- Current Flows from the positive terminal of the power source to the load, then into the negative terminal of the power source





Terminology

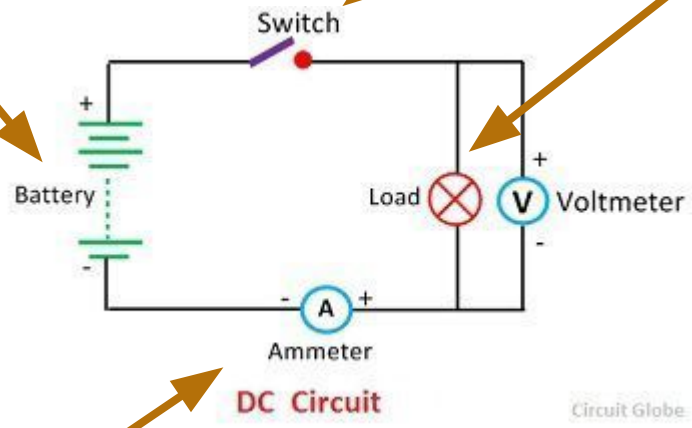
- Voltage (V)
  - Voltage is the potential difference between two points on a circuit, measured in Volts (V). For instance, a 5V battery has 5 volts of potential difference between its positive and negative terminals.
- Resistance (R)
  - As the name suggests, this is the resistance applied to the circuit, measured in Ohms (Ω).
- Current (I)
  - Current is the flow of charge through the circuit, measured in Amps (A). 1 amp of current is equal to one coulomb of charge per second.

Circuit Elements!

A **switch** acts as an on/off device. Closing the switch completes the circuit, allowing current to flow.

A **load** is simply whatever applies resistance to the circuit, whether it be a resistor, light bulb, motor, etc.

The **battery** acts as the power source by supplying voltage to the circuit



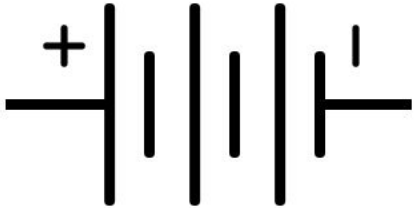
An **ammeter** is a device that measures the current in the circuit in Amps.

A **voltmeter** is a device that measures the potential difference in Volts between two points on the circuit

Basic Circuit Elements

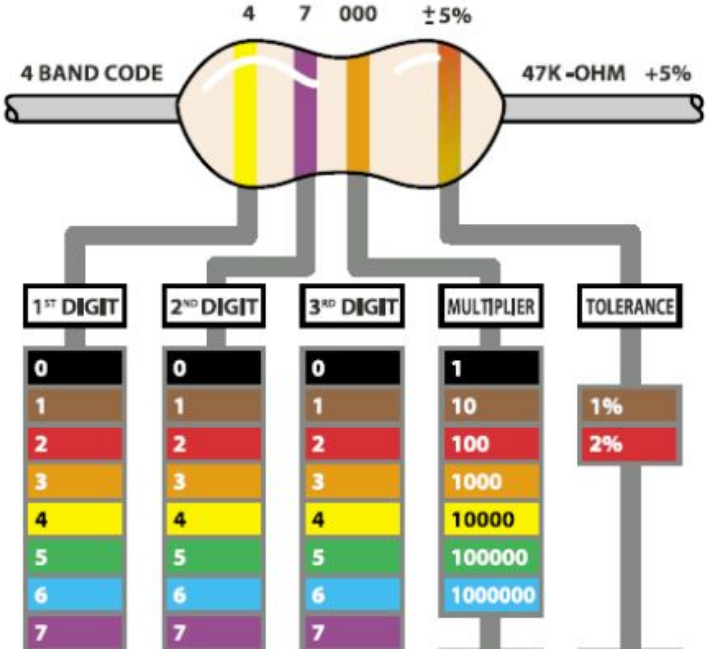
Power Source

- The power source of a circuit is simply what provides a voltage (i.e. potential difference) that causes electricity to flow.
- A common example of a power source is a battery



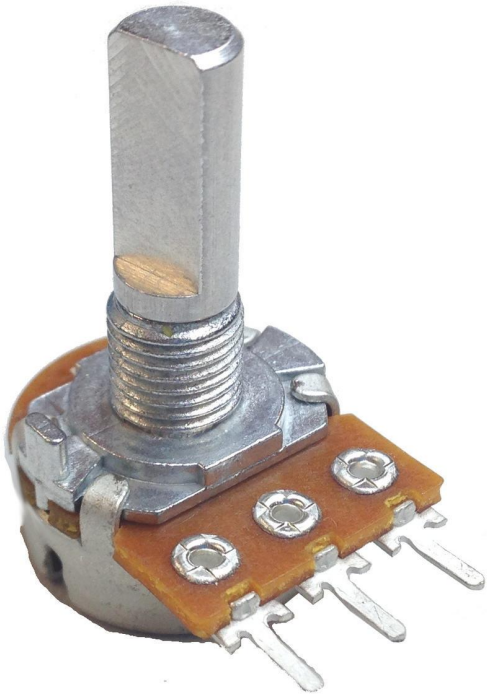
Resistors

- Resistors slow the electric current, and control where and how fast the current flows
- Resistance value is measured in ohms Ω, which is represented by colored stripes on the body of the resistor
- Each stripe has a different value depending on the color and location as shown in the reference chart



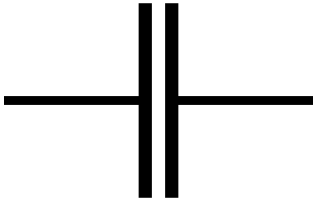
Potentiometers

- A potentiometer is essentially a variable resistor: you can change how much resistance is applied by twisting the knob
- This is useful for adjusting brightness, power, etc.



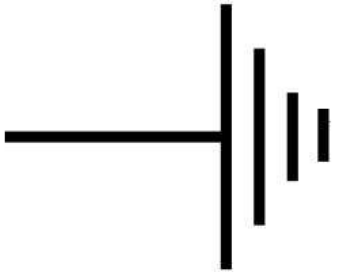
Capacitors

- A Capacitor is a circuit element that stores charge, similar to a battery.
- The main strength of a Capacitor is its ability to rapidly charge and discharge, making them useful as a buffer between a power source and a load, particularly one with varying power requirements
- A Capacitor's ability to store charge is measured in Farads (F), with one farad being equal to 1 coulomb of charge per volt of potential difference.



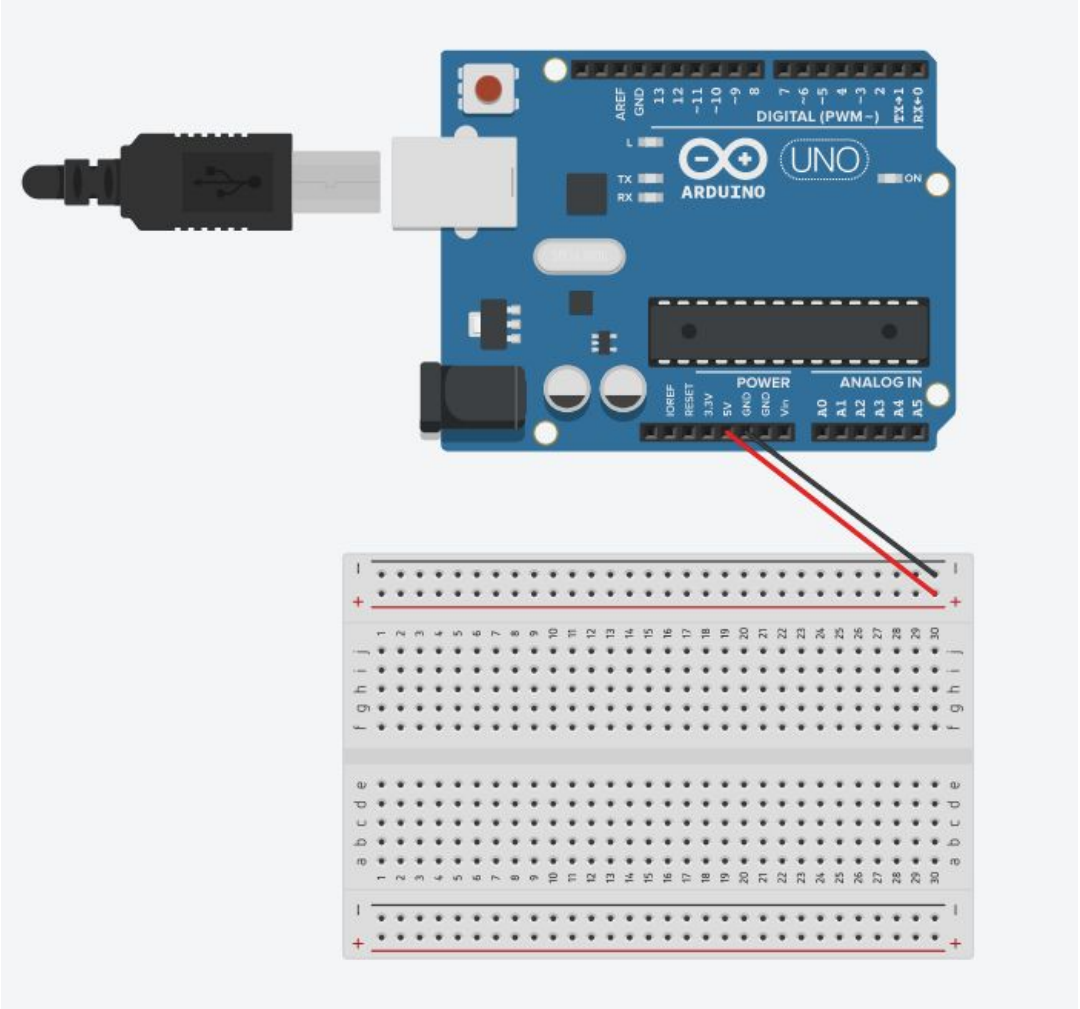
Electrical Ground

- The Electrical Ground (GND) is the reference voltage for the circuit.
  - Essentially, this is a point with zero potential, and all other voltages are calculated with the ground being 0V.
- In practice, the electrical ground may take the form of a return path for current or sometimes a physical connection to the Earth.



Power and Ground on Arduino

- Red wire connects to 5V pin, which is power
- Black wire connects to GND pin, which is ground



Equations!

- Ohm's Law: I = V/R
  - Current (in Amps) is equal to Voltage (in Volts) divided by Resistance (in Ohms)
- Power: P = IV
  - The power of the circuit (in watts) is equal to the current times the potential difference.
- Capacitance: Q = CV
  - The charge a capacitor can store per volt of potential difference is equal to the capacitance times voltage

Exercises!

1. 5 amps of current passes through a 10 ohm resistor. What is the voltage drop across this resistor?
2. A particular light bulb will blow if receives receive more than 20mA (milliamps) of current. With a voltage of 5V, what is the smallest resistor that we can safely use with the LED?
3. A 10V battery supplies 2 amps of current to a motor. How much power does the motor use?

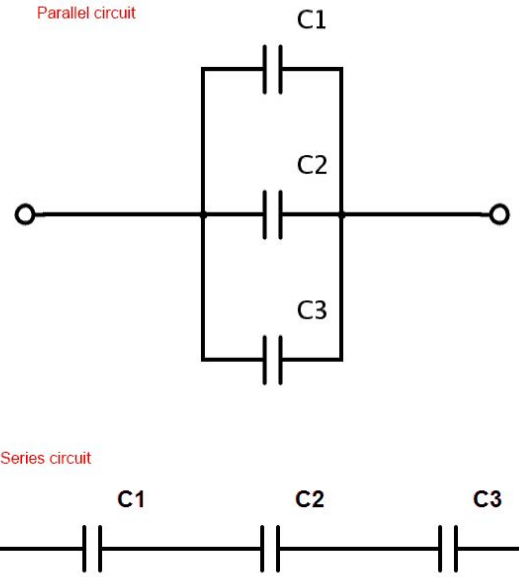
Series and Parallel

Two circuit elements are in parallel if they allow more than one path for current to flow. Two circuit elements are in series if current can only flow through one path.

The equivalent resistances of a group of resistors in a circuit are as follows:

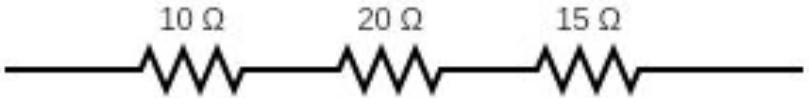
- In Series:
  - $R_{eq} = R_1 + R_2 + R_3 + \ldots + R_n$
- In Parallel
  - $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n$

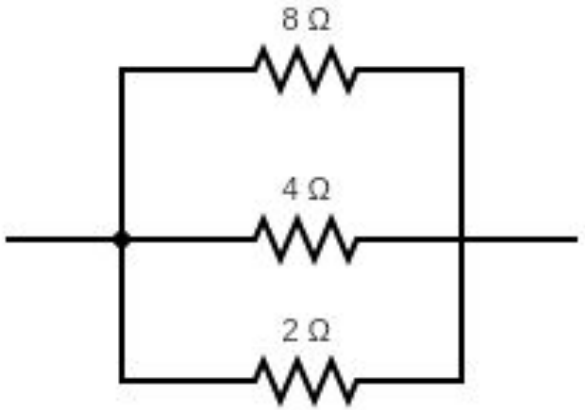
For Capacitors, the reverse applies.



Exercises!

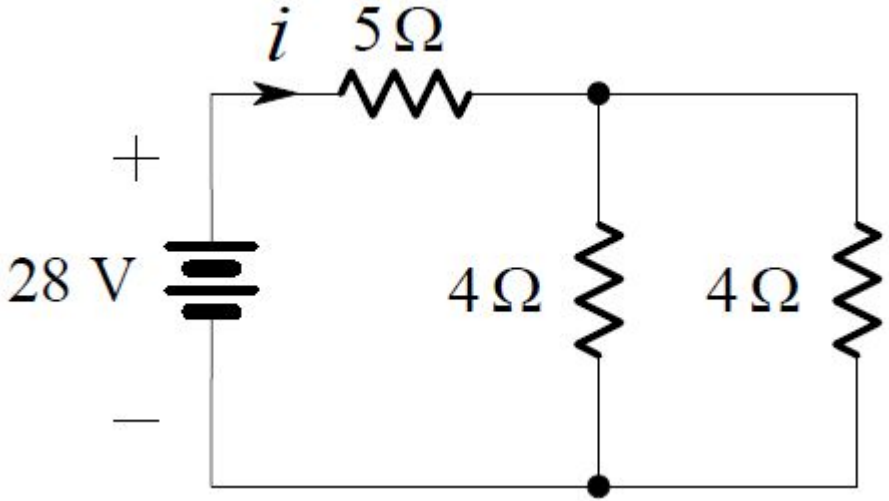
4. Calculate the equivalent resistance of these two circuits





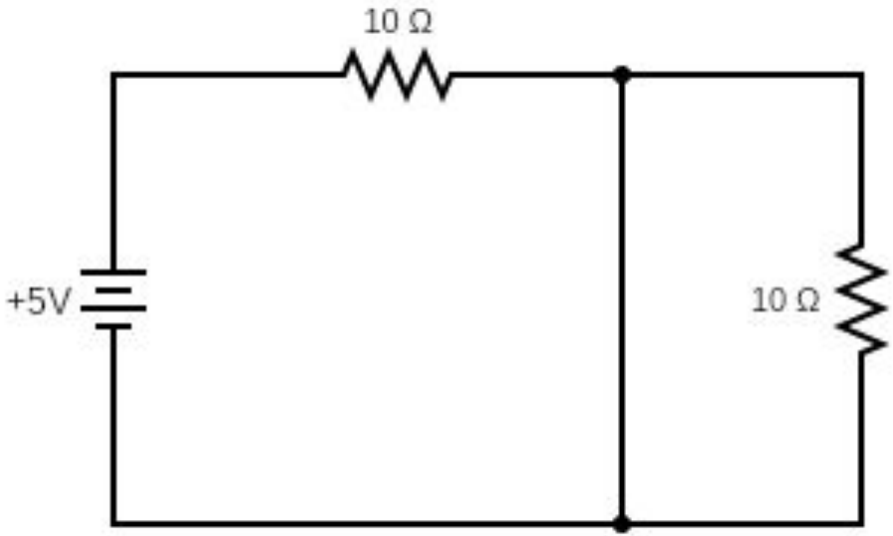
Exercises! (this one is a little more complex)

5. Calculate the current *i* through this circuit.



Exercises!

6. What is the equivalent resistance of this circuit? Explain your answer



Solutions

1. 50V
2. 250 ohms
3. 20 Watts
4. 45 ohms, 8/7 ohms
5. 4 amps
6. 10 ohms. A short circuit parallel to the second 10 ohm resistor gives that part of the circuit an equivalent resistance of 0 ohms

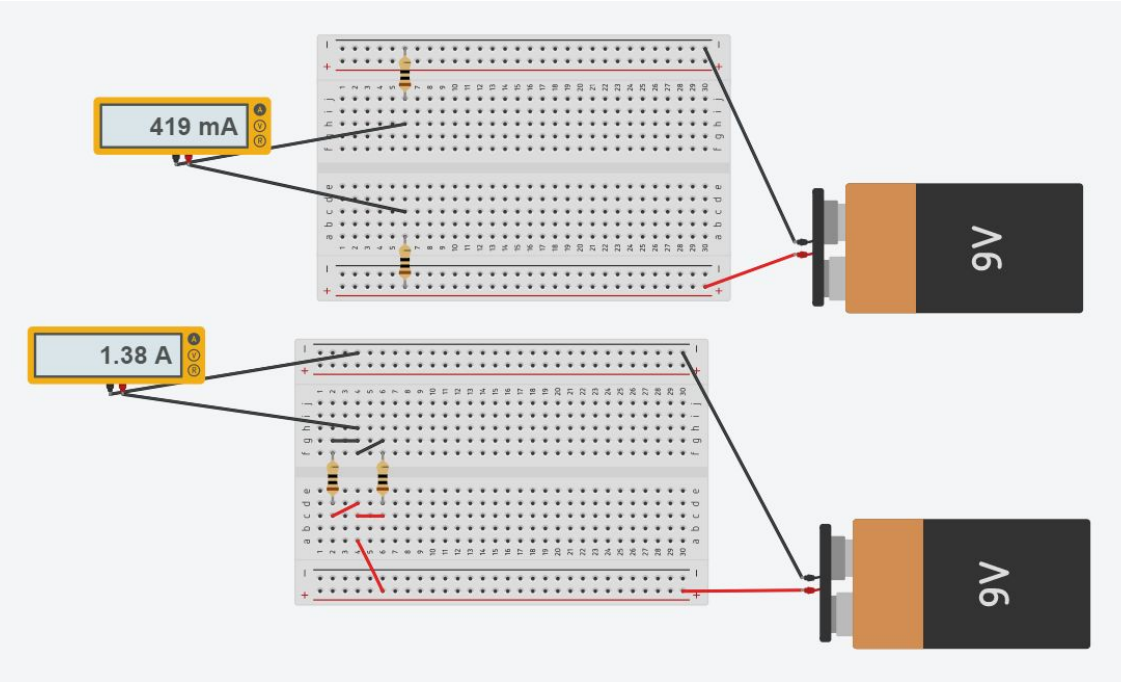
Demonstrations

TinkerCad Demonstrations

- Go to TinkerCad if you want to try any of these yourself. You may need to create an account, which can also be made by signing in with your Google Email
  - https://www.tinkercad.com/
- What will be demonstrated:
  - Each of the components that were discussed previously
  - Circuits in series and parallel
  - Resistors in series and parallel
  - Things to avoid doing (i.e. short circuits, swapping power and ground, etc)

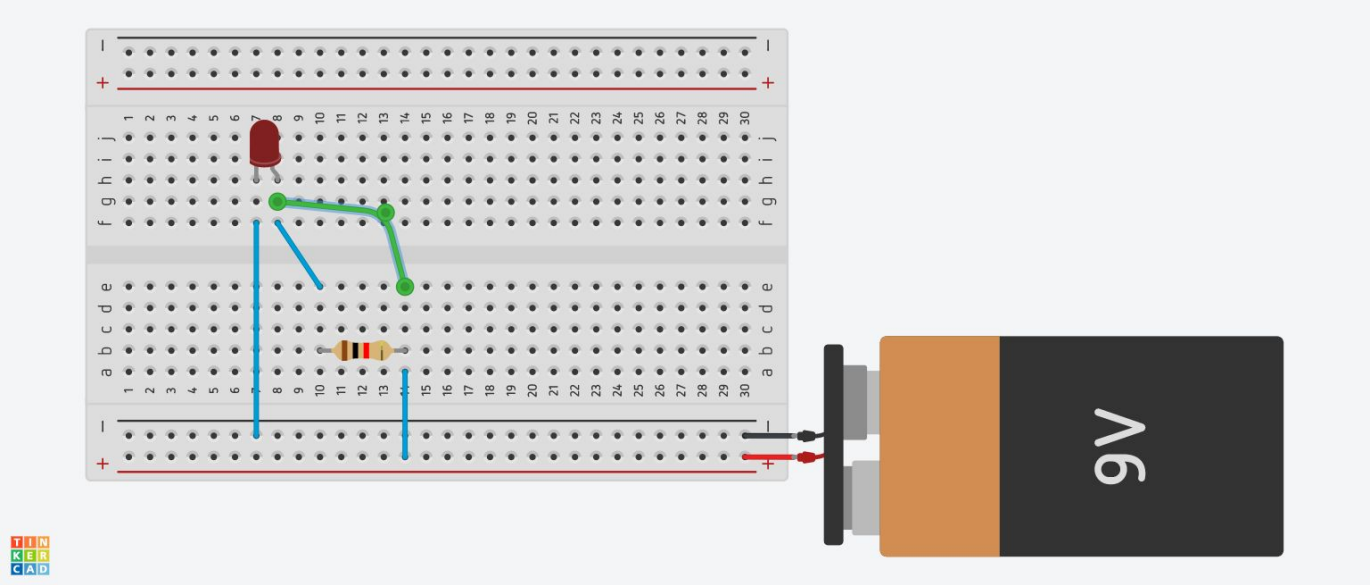
Series and Parallel Demo

All resistors shown have a value of 10 ohms



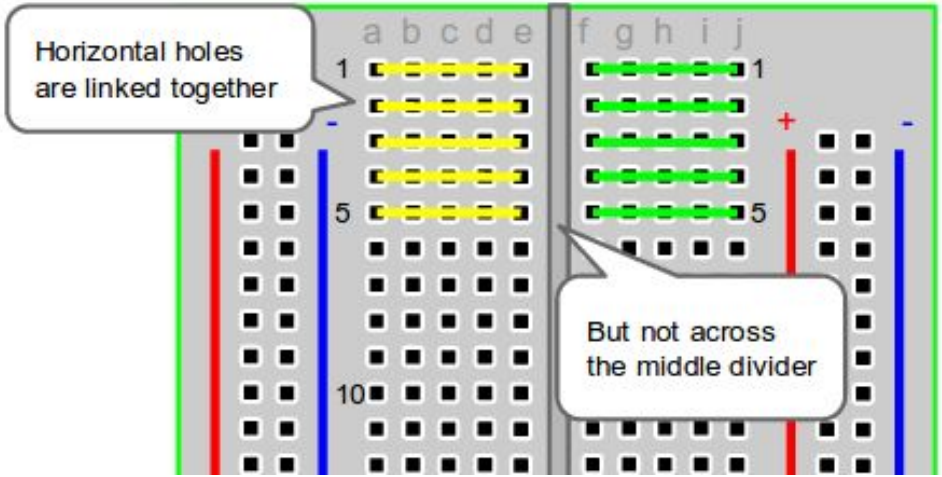
Short Circuit Demo

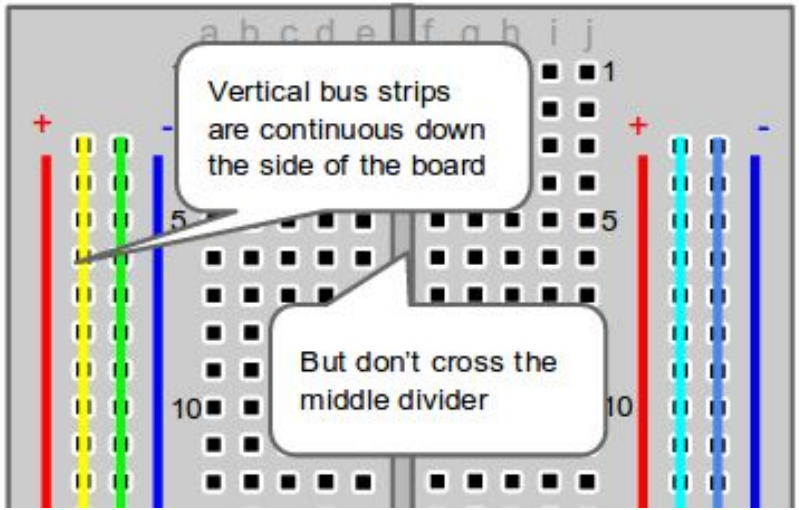
The GREEN wire in this schematic will induce a short circuit and blow the LED



Review of Previous Projects

Review: Breadboards





Tip: It is good practice to have your power input connected to the red/positive rail and your ground pin connected to the blue/negative rail.

Review: Switches

A switch is a device that you can use to open or close a circuit at will. A closed circuit allows current to flow through it. An open circuit has a gap in the circuit, preventing current from flowing through it.

Why is this relevant?

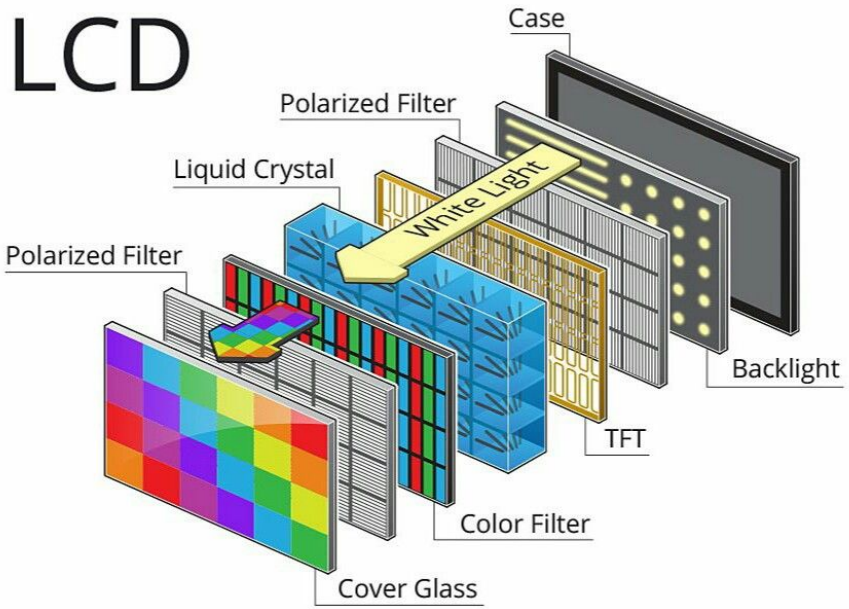
A button is a type of switch that closes the circuit when pressed down and opens it when released.

A button

Review: LCD Screens

An LCD, or Liquid Crystal Display, is a type of screen that can display images by varying the brightness and color of the light shining from its backlight using a set of filters.

These screens are extremely widespread on TV's, computer monitors, phone and tablet screens, basically anything that requires a screen.



Review: Servos

A Servo is a type of motor designed to allow precise rotation within a fixed range of rotational positions. The servos we are using can go from 0 to 180 degrees depending on the input signal.

Servos differ from traditional motors in that they do not provide continuous rotation.

Servo Components

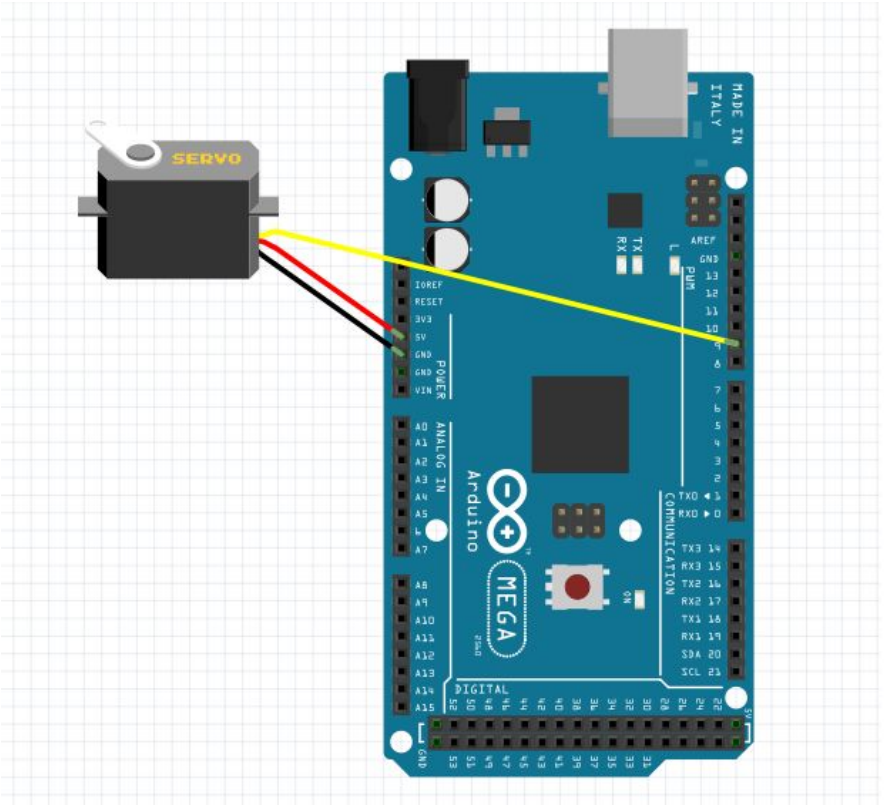
The servo has three wires: red, brown, and orange.

- The Red wire connects to the 5v power supply.
- The Brown wire connects to Ground (GND).
- The Orange wire connects to one of the numbered pins and provides the signal to the servo.

Servo Diagram

NOTE:
On this diagram, the orange wire is replaced by a yellow wire, and the brown wire is replaced by a black one.

Assemble the servo by attaching the servo horn to the servo itself (any of the three types is fine). Use a small screwdriver to securely fasten the two parts together.



Other Appliances

Ammeters and Voltmeters

- Ammeters measure the amount of current in a circuit.
- Voltmeters measure the potential difference between two points on a circuit.
- A multimeter (shown here) can perform both functions, using the dial to switch between modes

- An ammeter must be placed in **series**, while a voltmeter must be placed in **parallel**

Thank you!

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