LECTURE II

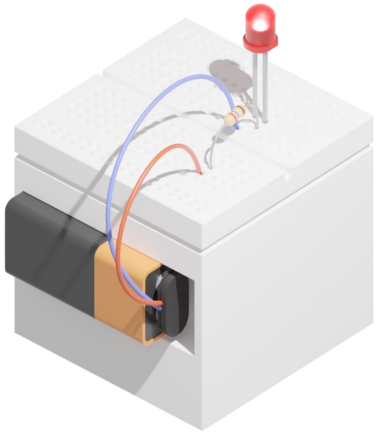
Circuit Analysis & Troubleshooting Techniques

SECTION I

Project I Review

Project I Review

- Official Due Date: Friday, November 1st by 11:59PM
- Ask questions and seek help (online or @Lab Hours), so you can finish it on time!
- Note: Your OPS membership is contingent on the completion of Project 1 by the end of Fall Quarter

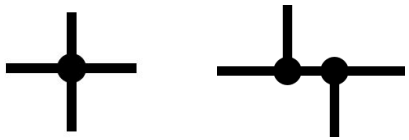


Learning Concepts:

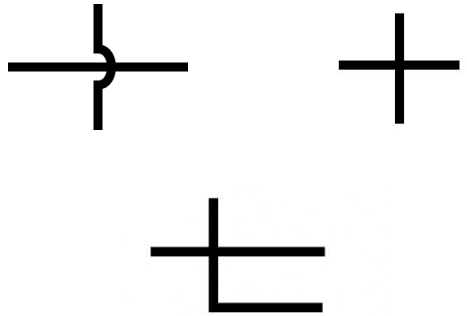
- Introduction to Circuits
- Ohm's Law (Voltage, Current, Resistance)
- Breadboarding
- Soldering

Schematic Connections Reminder

Connected Wires

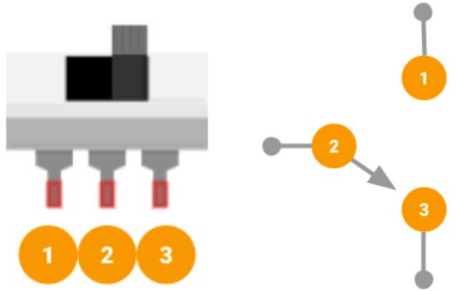


Unconnected Wires

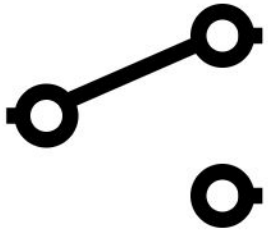


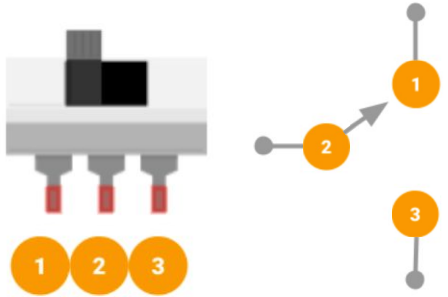
Slide Switch Review

- In project 1, we used the Slide Switch as a Toggle Switch



- We can also use the slide switch as a Changeover Switch





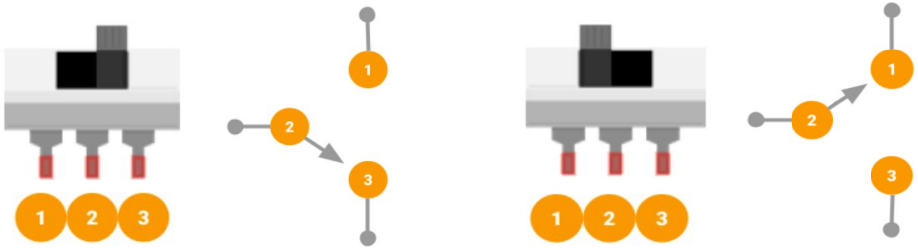
Breadboarding Quiz!

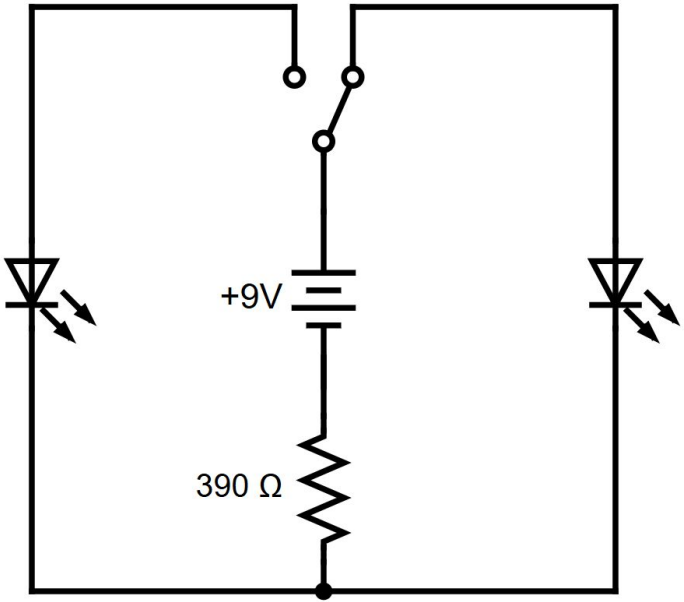
With the parts given in your OPS Kit, build this circuit on a breadboard.

Tips:

1. Resistor can go before or after the Battery (since you only want 1 LED, 1 Resistor, and 1 Battery in series)

2. A slide switch can be used as a Changeover Switch



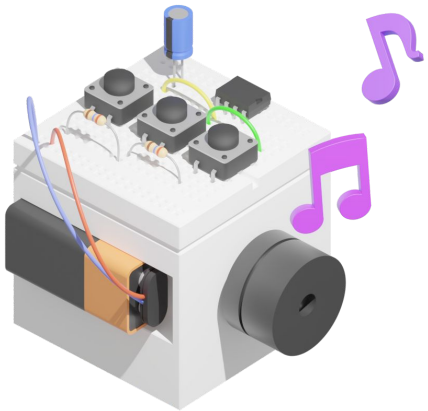


SECTION II

Project II

Project 2 Overview

- Create an **Electronic Piano** with the 555 Timer IC, and solder it to a printed circuit board.

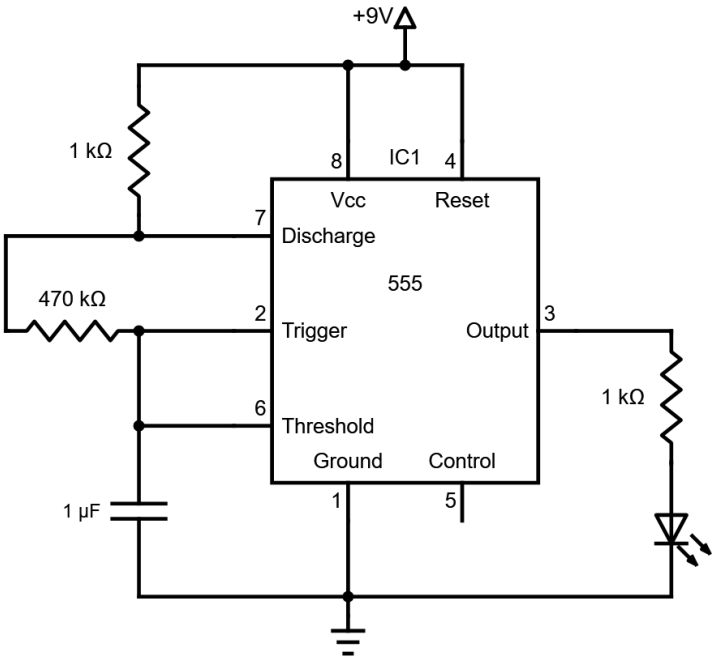


You will learn:

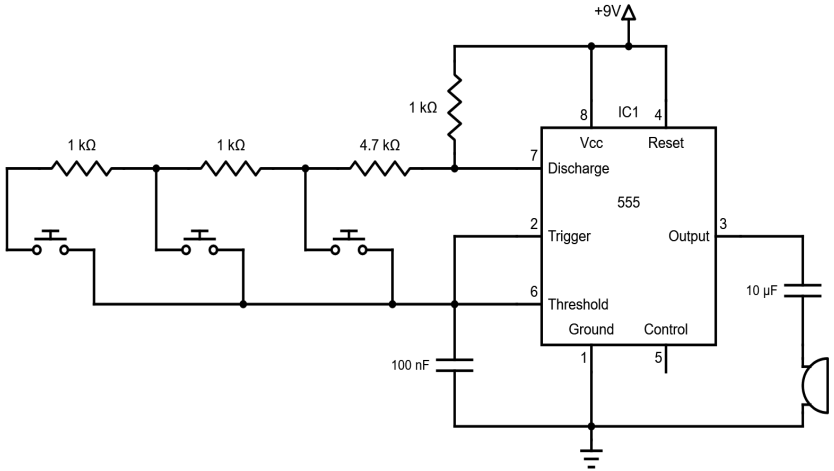
- Circuit Analysis (Nodes, Voltage Drop)
- Circuit Troubleshooting
- Multimeters
- 555 Timer
- Breadboarding
- Soldering

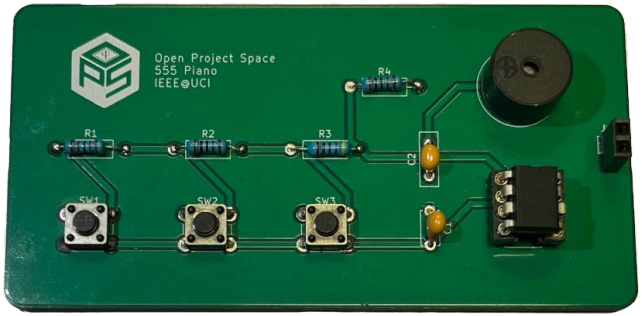
Checkpoint 1

- Create an **Blinking LED Circuit** with the 555 Timer IC
- Part of Project 2 Submission
- Timing of the blinking LED Circuit relies on the capacitor value
  - More on this later!



Project 2: 555 Piano



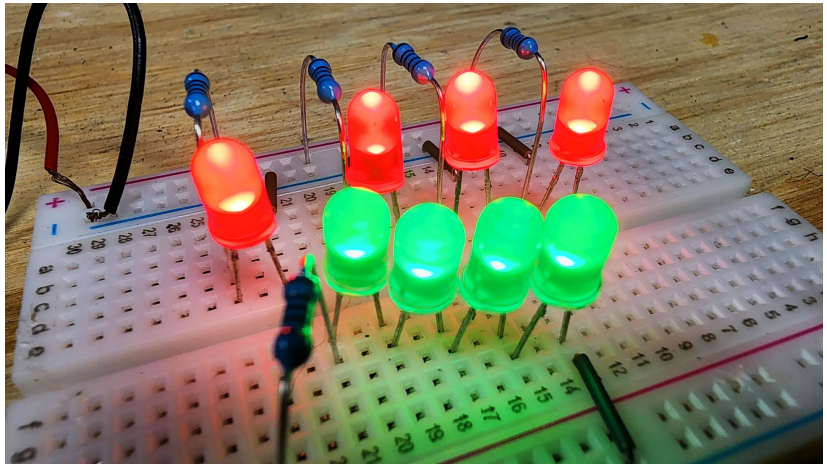


SECTION III

Circuit Topology

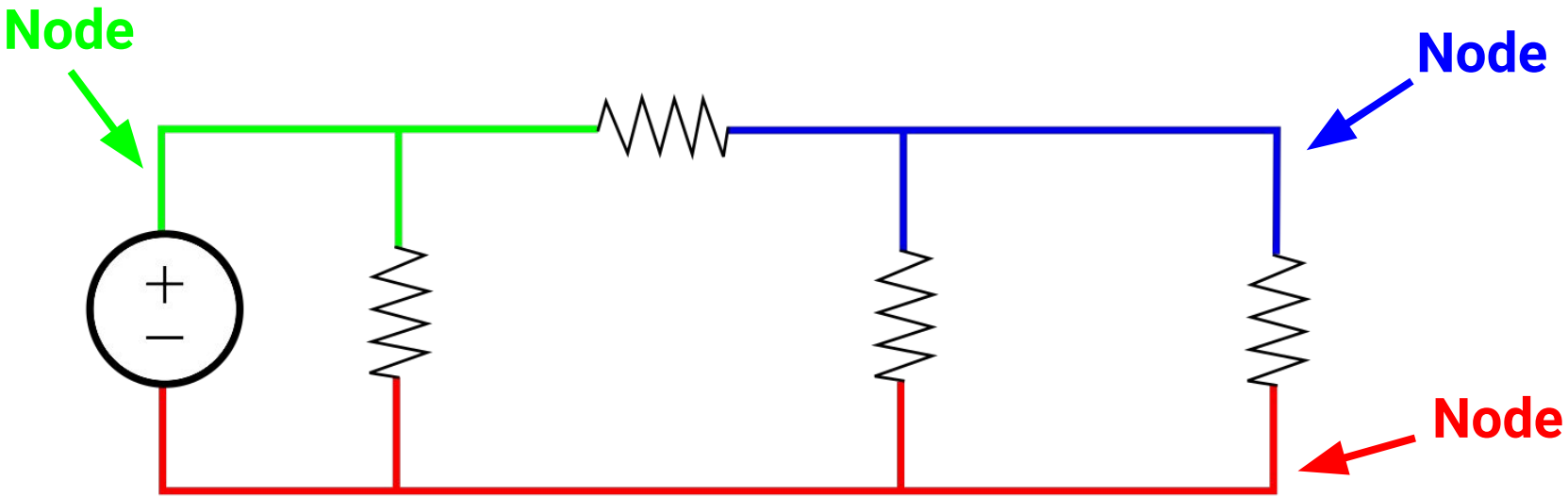
Circuits

- In project 1, we built a **circuit** with a single **closed loop** path where electrons can flow
- Circuits consist of **nodes** and **loops** to analyze the voltage, current, and resistance across segments of the circuit
    - **Why?** Circuit analysis enables us to design, **debug**, and test the performance of circuits



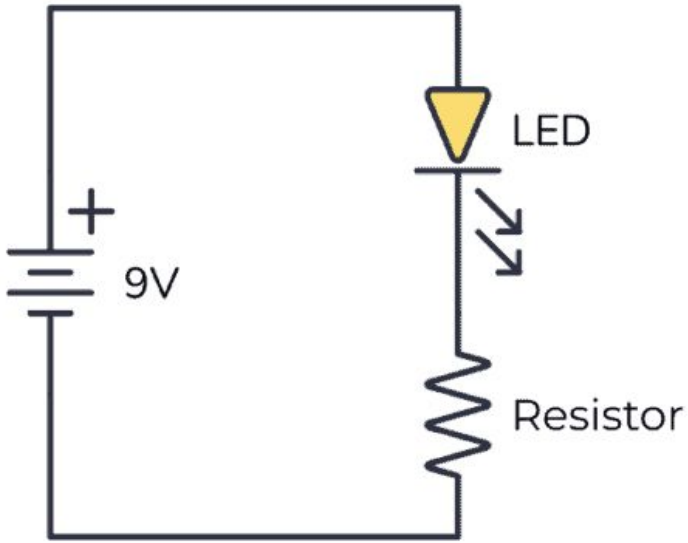
Nodes

- A **node** is a **connection** between two or more **components**
- All points on the **same node** have the **same voltage**



Node Exercise

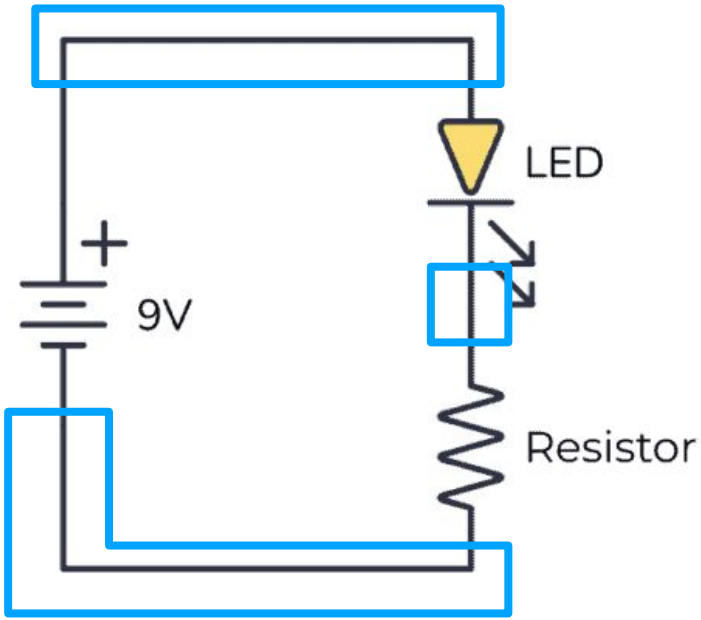
Exercise: How many nodes are in this schematic?



Node Exercise

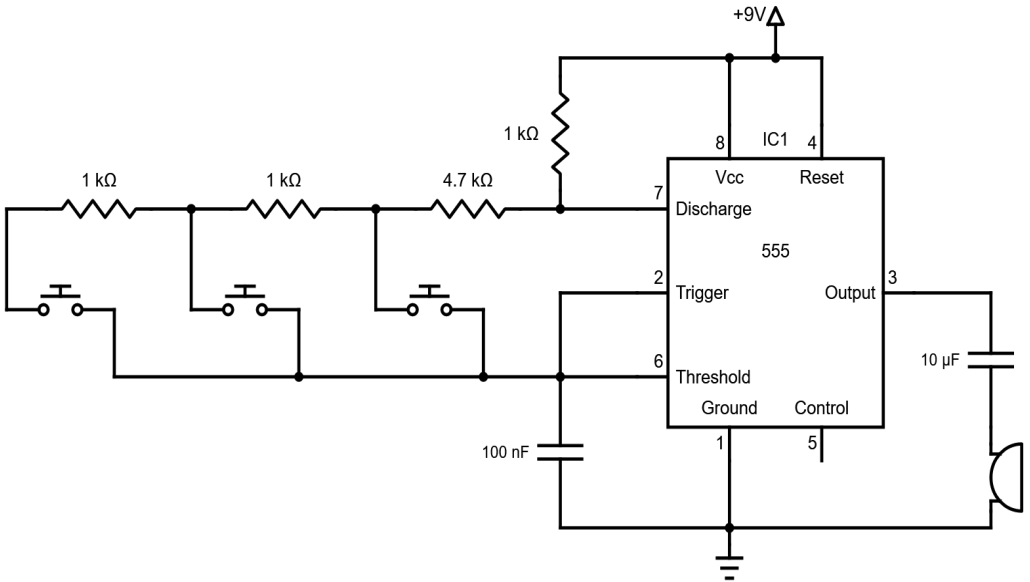
Exercise: How many nodes are in this schematic?

Answer: 3 Nodes



Node Exercise

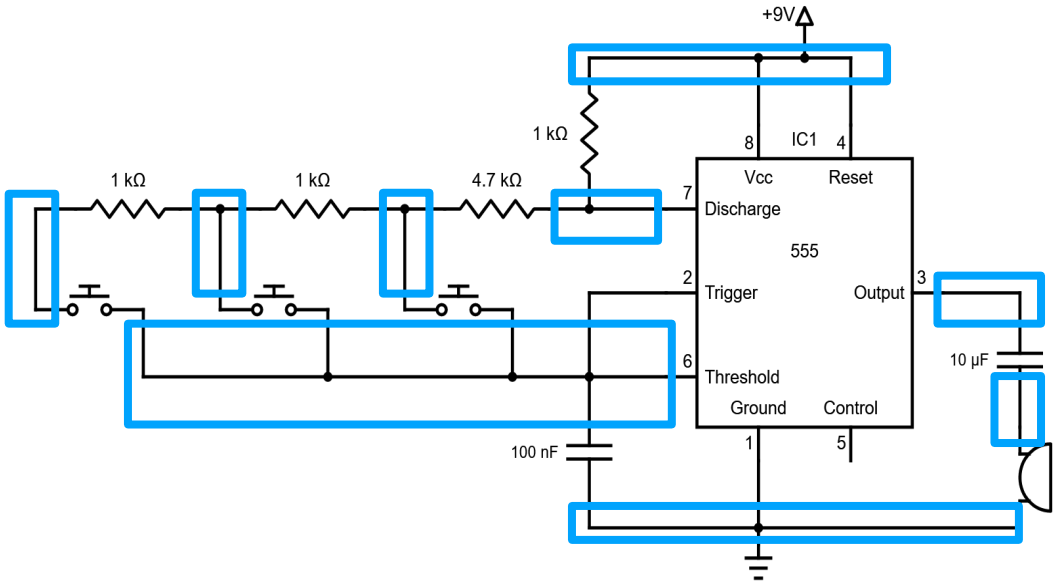
Exercise: How many nodes are in Project 2 (if the buttons are pressed)?



Node Exercise

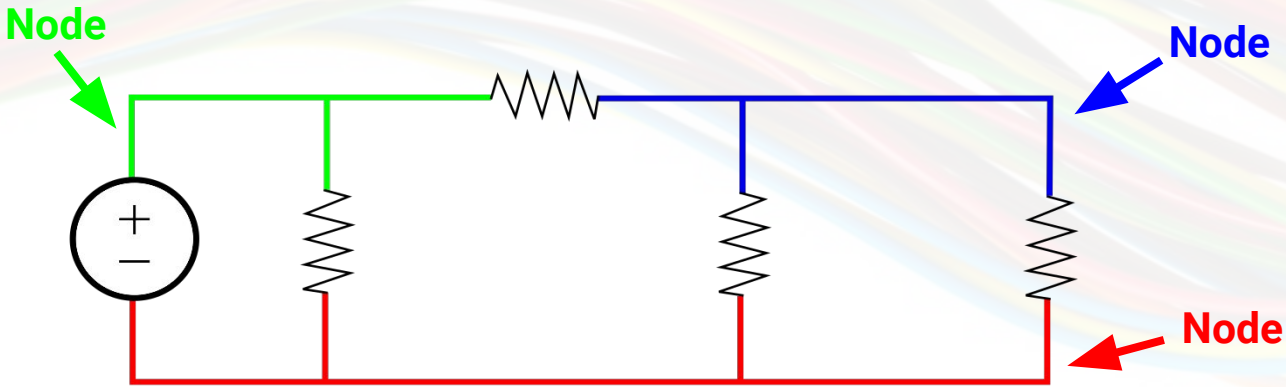
Exercise: How many nodes are in Project 2 (if the buttons are not pressed)?

Answer: 9 Nodes



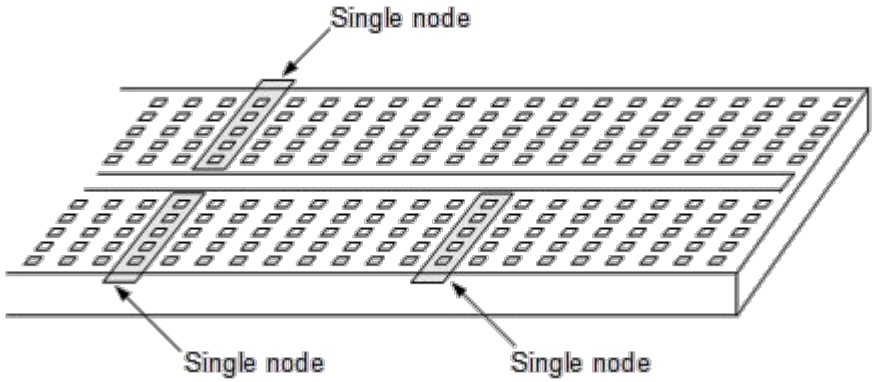
Nodes (Cont'd)

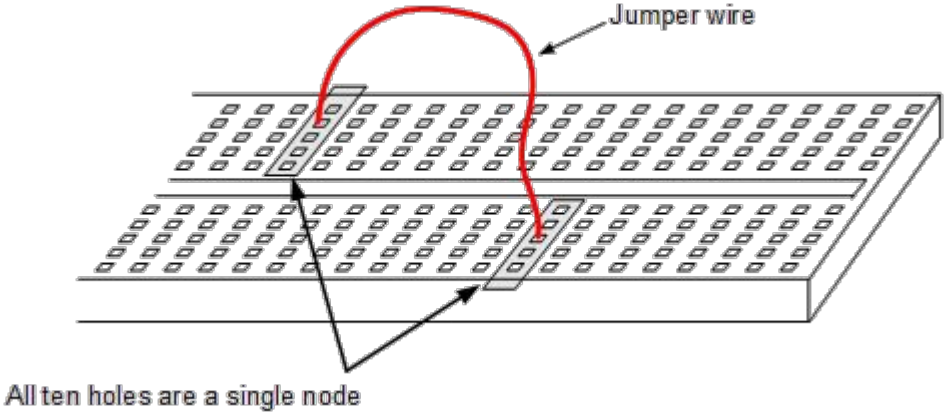
- **Wires** can be treated as **nodes**
  - .. if we assume that the wire has **no resistance** and there is **no voltage change** across the wire
    - This is acceptable for our course projects



Nodes (Cont'd)

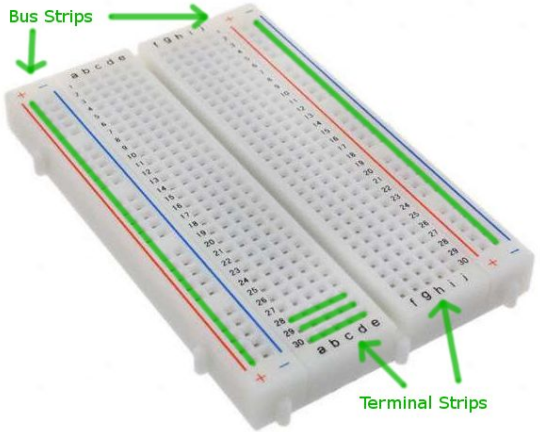
- A breadboard horizontal **strip** be treated as a **single node**
- Connecting two strips with a jumper wire creates a larger **single node**
- Gap in the middle (called a **channel**) separates the left and right nodes on a breadboard





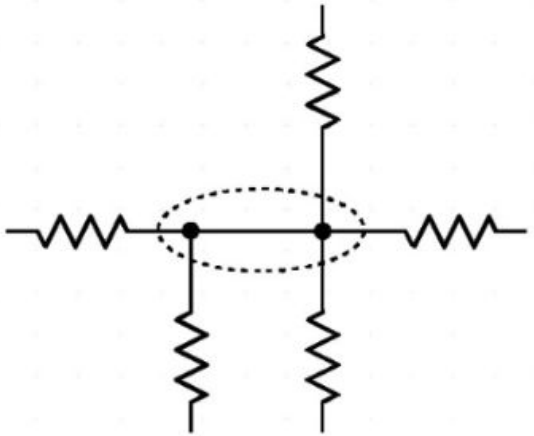
Nodes (Cont'd)

- A bus (vertical strip) on the breadboard is one long node
- Generally used for connecting a power source to the breadboard
  - (ex. Battery, power supply, etc.)
- Connect the positive terminal to the **power strip** (denoted by the + sign), and the negative terminal to the **ground strip** (denoted by the **- sign**)



Nodes (Cont'd)

What is the voltage difference between these two points?

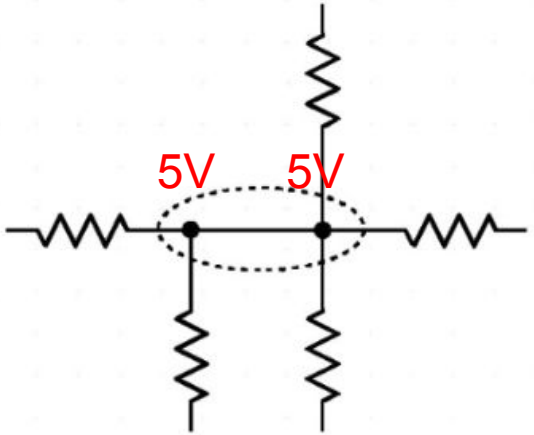


Nodes (Cont'd)

What is the voltage difference between these two points?

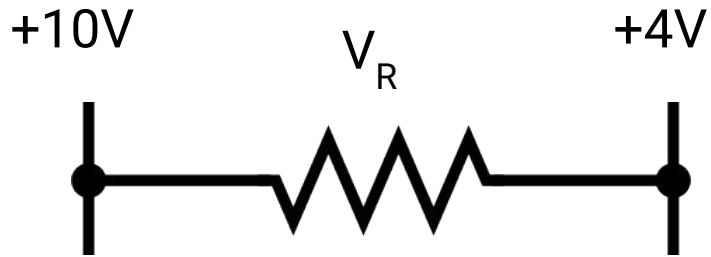
Ex. 5V – 5V = 0V

Answer: 0V

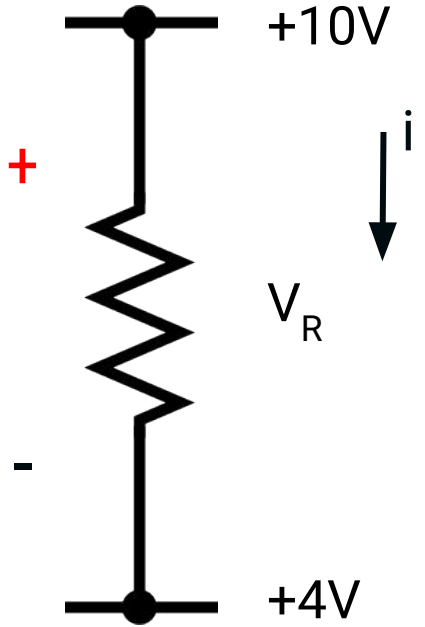


Voltage Drop

- **Voltage drop** is the **difference of electric potential** (Volts) along the path of current flowing in a circuit
    - An LED experiences a voltage drop because it expends energy to emit light
- We can calculate the voltage drop between two nodes (across a circuit component)



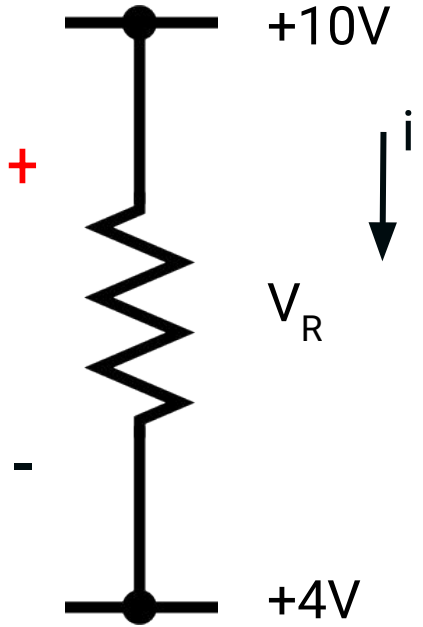
Calculating Voltage Drop



Find voltage drop $\mathbf{V_R}$

1. Calculate $\mathbf{V_R}$ as the **difference in volts** between terminals, following the direction of current

Calculating Voltage Drop (Cont'd)

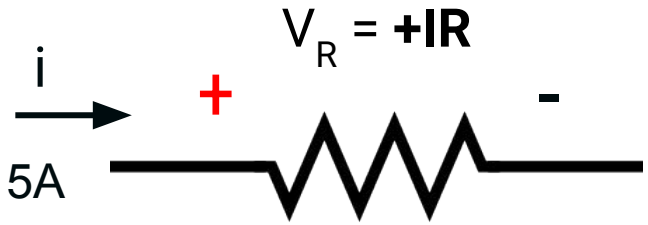


Find voltage drop $\mathbf{V_R}$

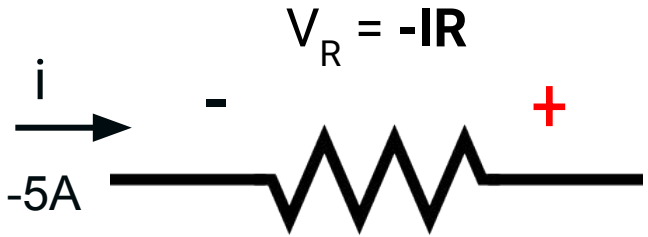
1. Calculate $\mathbf{V_R}$ as the **difference in volts** between terminals, following the direction of current

$$V_R = 10V - 4V = \boxed{6V}$$

Voltage Drop Sign Convention (Cont'd)



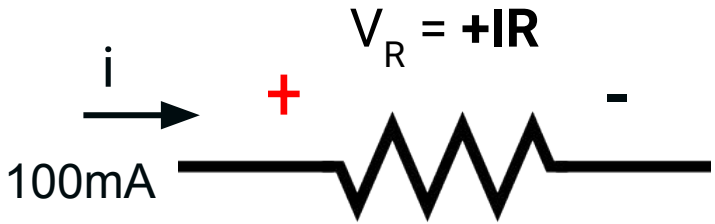
- The sign of the voltage drop is **positive** if current flows from **+** to **-** terminals
  - Conventional current flows from **+** to **-** terminals

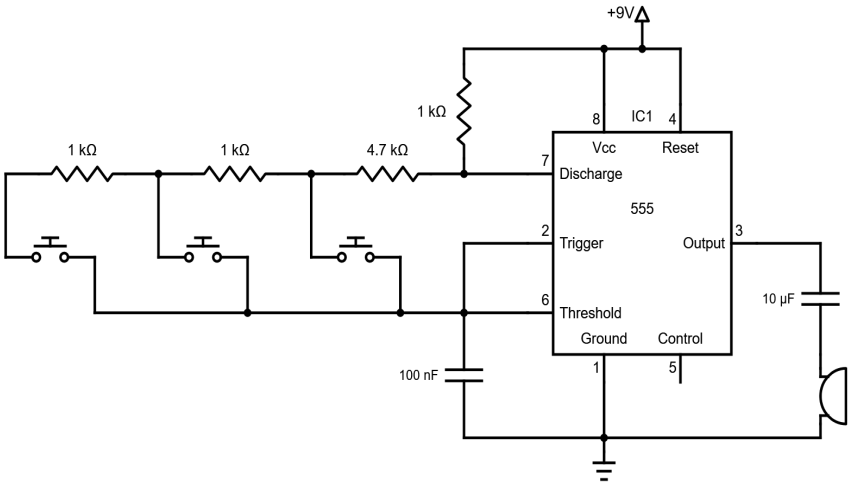


- The sign of the voltage drop is **negative** if current flows **-** to **+** terminals

Voltage Drop for Project 2

- By using different resistance values, we can vary the voltage drop across the resistors connected in series to produce 3 different sounds on the Piezo buzzer.

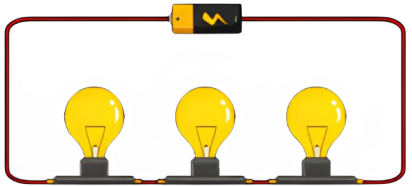




Series and Parallel Circuits

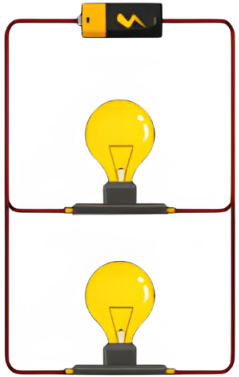
Series

- Two or more elements are in **series** if they exclusively are connected in one line
- Elements in series carry the **same current**



Parallel

- Two or more elements are in **parallel** if they are connected to they share the same two nodes
- Elements in parallel have the **same voltage** across them

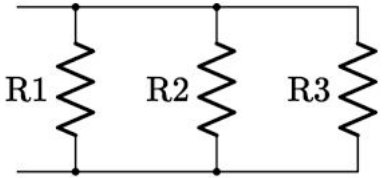


Series and Parallel Circuits

- If **multiple resistors** are arranged **in series or parallel**, we can treat them as having a **single equivalent resistance**

Parallel

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Series

$$R_{eq} = R_1 + R_2 + R_3$$

Resistors in Series

Ex) Given R_1 = 10Ω, R_2 = 30Ω, and R_3 = 70Ω, we will find the equivalent resistance.

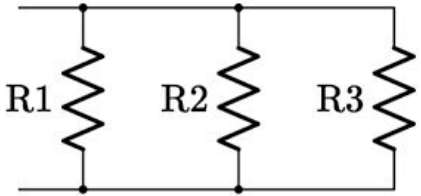
$$R_{eq} = R_1 + R_2 + R_3$$

$$R_{eq} = 10\Omega + 30\Omega + 70\Omega$$

$$\boxed{R_{eq} = 110\Omega}$$

Resistors in Parallel

Ex) Given R_1 = 10Ω, R_2 = 30Ω, and R_3 = 70Ω, we will find the equivalent resistance.



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{10\Omega} + \frac{1}{30\Omega} + \frac{1}{70\Omega}$$

$$\frac{1}{R_{eq}} = \frac{31}{210}\Omega$$

$$R_{eq} = \frac{210}{31}\Omega$$

$$R_{eq} \simeq 6.77\Omega$$

SECTION IV

Multimeters

What is a Multimeter?

- A **multimeter** is an instrument used to measure the electrical properties of a circuit, including…
  - Voltage
  - Current
  - Resistance
  - Continuity
  - And More!

Multimeter Probes

- The multimeter has **two probes**:
  - The **red probe** is associated with the positive side of a component/connection
    - Plug it into the **red V** multimeter port
  - The **black probe** is associated with **COM**
    - Plug it into the **COM** multimeter port
    - **COM** or **common** is the reference point from which the red probe measures voltage, current, etc.
      - **Common is not ground**

Measuring Voltage

How to **measure DC voltage** with an auto-ranging multimeter:

1) Connect the probes to **VΩmA** and **COM**
2) Set the dial to **DC Voltage**
3) Place the **red probe** on one node and the **black probe** on the node to be used as the reference point
4) Read the display
    - The display value is the voltage drop from the node at the **red probe** to the node at the **black probe**

Measuring Resistance

How to **measure resistance** with an auto-ranging multimeter:

1) Connect the probes to **VΩmA** and **COM**
2) Set the dial to **Ohms**
3) **Disconnect the component** from the live circuit
4) Place a probe on each terminal of the component
5) Read the display

Measuring Current

How to **measure DC current** with an auto-ranging multimeter:

1) Connect the probes to **A** and **COM**
2) Set the dial to **DC Current**
3) Place the probes in **series** with components in the circuit
4) Read the display

Testing Continuity

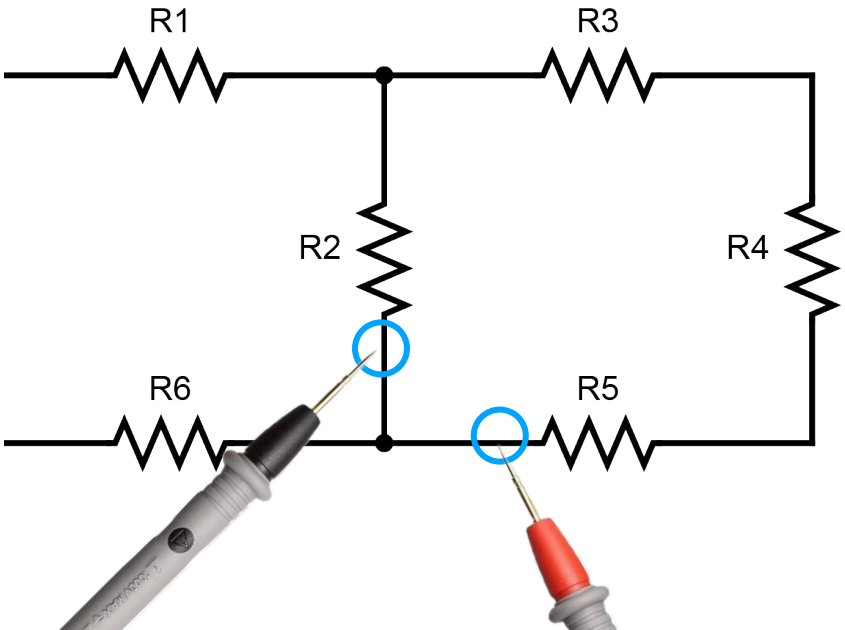
How to **test continuity** with an auto-ranging multimeter:

1) Connect the probes to **VΩmA** and **COM**
2) Set the dial to **Continuity**
3) **Disconnect the power source** from the circuit
4) Place the probes on the circuit
5) The DMM **beeps** if there is a continuous path between the probes

Testing Continuity (Cont'd)

I/A

You can test the continuity across any two points on a circuit which lie on the same node. The DMM should beep



SECTION V

Troubleshooting Circuits

How To Troubleshoot a Circuit

Circuit not working? Follow these steps to **find the issue**:

1) Check the **power supply** and **ground**
    - Is the power supply is providing the correct voltage?
        - Use a DMM to **measure voltage**
    - Check the power and ground connections to the circuit
2) Visually **inspect the circuit**
    - Look for loose connections, damaged components, cold solder joints, etc.
        - Use a DMM for **continuity tests**

How To Troubleshoot a Circuit (Cont'd)

Circuit not working? Follow these steps to **find the issue**:

3) Verify the **schematic diagram**
   - Make sure you understand the circuit's functionality based on the schematic
   - The circuit should match the **schematic diagram**. Go node-by-node and make sure every component is properly connected
   - Check the component values against the schematic

How To Troubleshoot a Circuit (Cont'd)

Ideally, at this point, you have found the *potential issue*.
Here's how you verify the issue:

- Suspect a faulty component?
  1) **Replace the component** and test the circuit again
  2) Circuit still not functioning? Test the "faulty" component on a working circuit
     - If the "faulty" component works on another circuit, then go back to the start. Try to identify a new issue.
     - If it doesn't work, then use the replacement component. However, there's still work to be done:Your circuit still functions, so there must be another issue.

How To Troubleshoot a Circuit (Cont'd)

Ideally, at this point, you have found the *potential issue*.
Here's how you verify the issue:

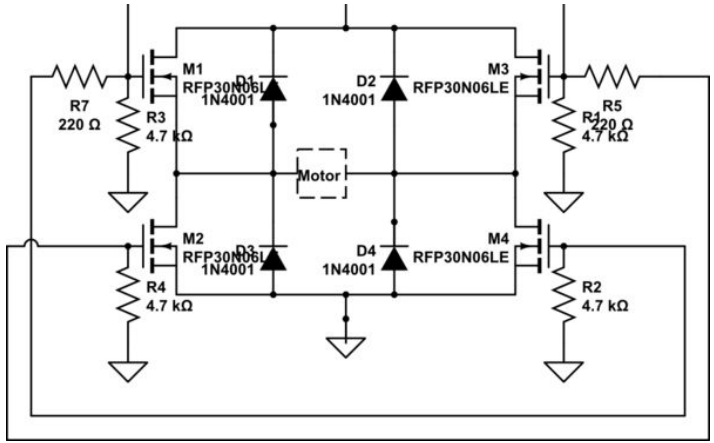
- Loose wire? Poor connection?
    1) Re-solder or replace connections as needed and test the circuit again
    2) If the circuit still fails, **test the connections again** with the multimeter. It's possible to solder poorly on even the second or third try.

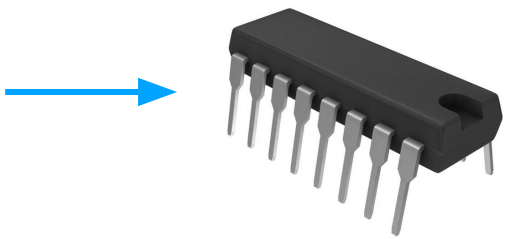
SECTION VI

Integrated Circuits

Integrated Circuits

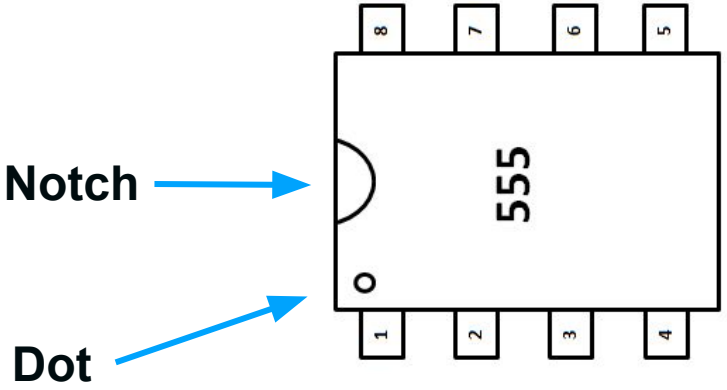
- An **integrated circuit** (**IC, chip**, **microchip**) is a set of electronic circuits on one small flat piece of semiconductor material
  - Electronic components are **integrated** on the chip
  - Complex circuits can be **scaled down** and **mass-produced**





Integrated Circuits

- The **functions** and **pin layout** of an IC are specified in its **datasheet**
- The **notch/dot** on the IC indicates its **orientation**



6 Pin Configuration and Functions

Pin Functions

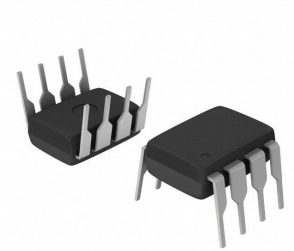
PIN			I/O	DESCRIPTION
NAME	D, P, PS, PW, JG	FK		
	NO.			
CONT	5	12	I/O	Controls comparator thresholds, Outputs 2/3 VCC, allows bypass capacitor connection
DISCH	7	17	O	Open collector output to discharge timing capacitor
GND	1	2	–	Ground
NC		1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	–	No internal connection
OUT	3	7	O	High current timer output signal
RESET	4	10	I	Active low reset input forces output and discharge low.
THRES	6	15	I	End of timing input. THRES > CONT sets output low and discharge low
TRIG	2	5	I	Start of timing input. TRIG < ⅓ CONT sets output high and discharge open
V_{CC}	8	20	–	Input supply voltage, 4.5 V to 16 V. (SE555 maximum is 18 V)

SECTION VII

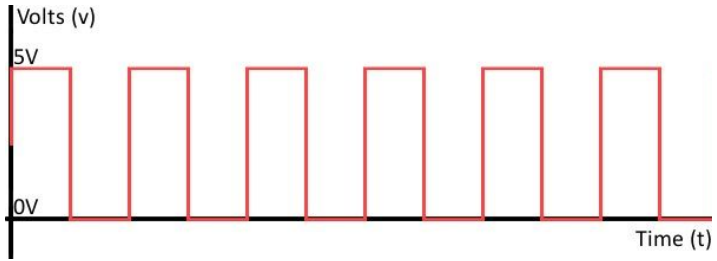
555 Timer IC

555 Timer IC

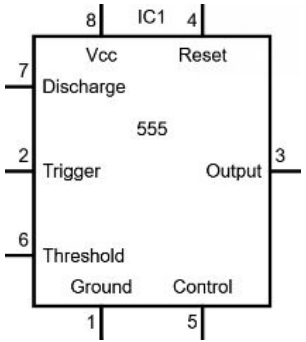
- The **555 Timer** is a chip used in various modes as a timer, pulse generator, wave oscillator, and an analog-to-digital signal converter
- In this course, the 555 Timer will be used in **astable mode** to generate an **oscillating digital wave**



555 Timer DIP Package



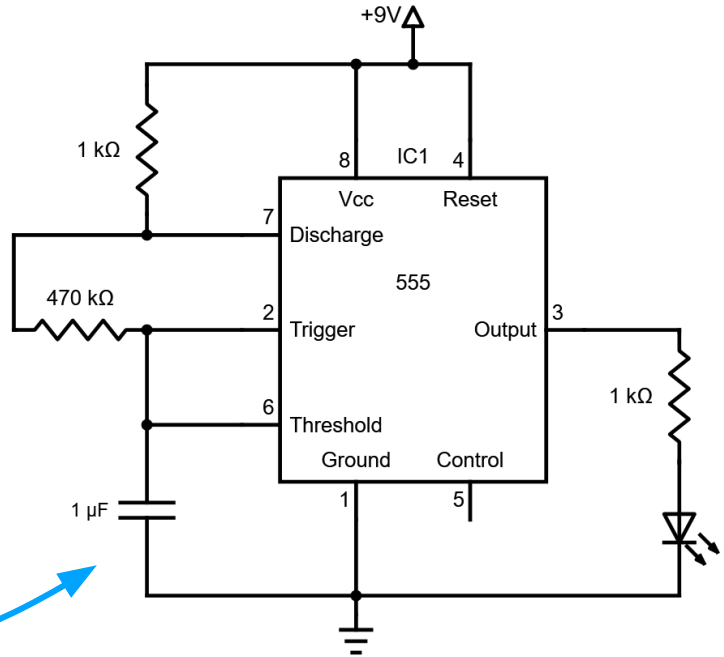
Oscillating Digital Waveform



555 Timer Schematic Symbol

Blinking LED Circuit

- To further examine the astable-mode behavior of the 555 Timer, we will use it in a **blinking LED circuit** as an example
- The function of the the circuit is to **cycle an LED** ON and OFF at a constant frequency
- The circuit's timing relies on a the value of the **capacitor**

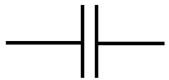


SECTION VIII

Other Project 2 Components

Capacitors

- A **capacitor** stores electrical energy which it charges and discharges
  - The ability of a capacitor to store energy is its **capacitance**, measured in **Farads** (**F**)
- Unlike a battery, a capacitor can only briefly store a small amount of energy
- When a capacitor is connected to a voltage source, it charges until it reaches the **same voltage** as the voltage source

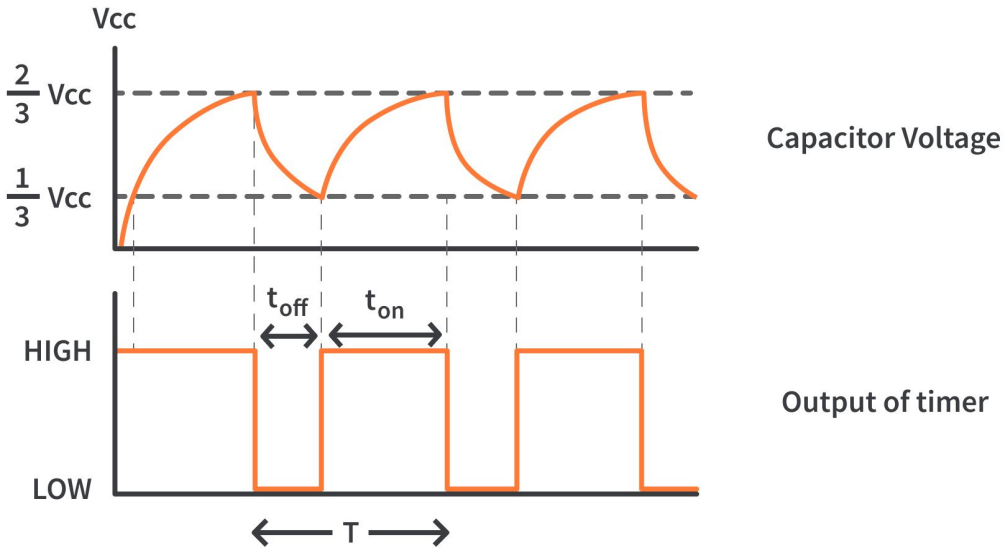


Capacitor Timing Diagram

Timing Diagram

- As the capacitor charges…
  - Output = **HIGH** voltage
- As the capacitor discharges…
  - Output = **LOW** voltage

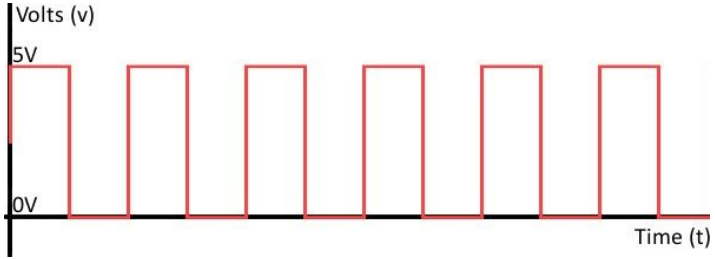
- The output waveform is a **rectangular wave**



Piezo Buzzers

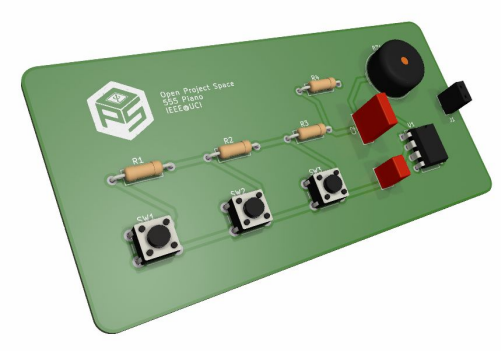
- A piezoelectric buzzer is a component used to emit sound

- We will be using Passive Piezo Buzzers
  - They have to be fed an oscillating signal
  - Make sure to have the correct polarity



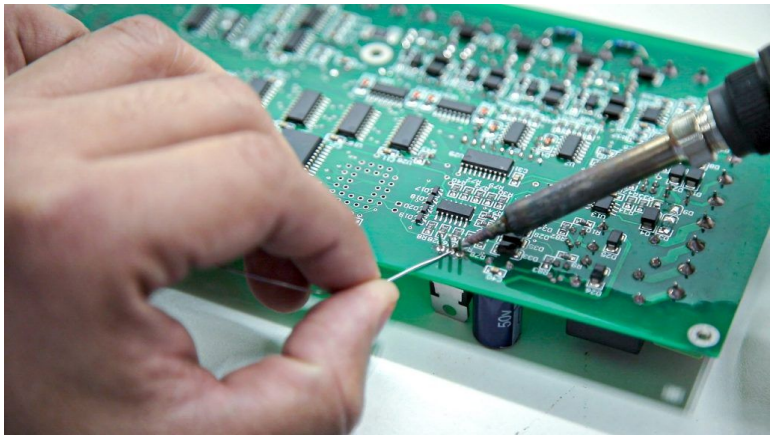
Printed Circuit Board (PCB)

- Breadboards and protoboards are great for prototyping simple circuits



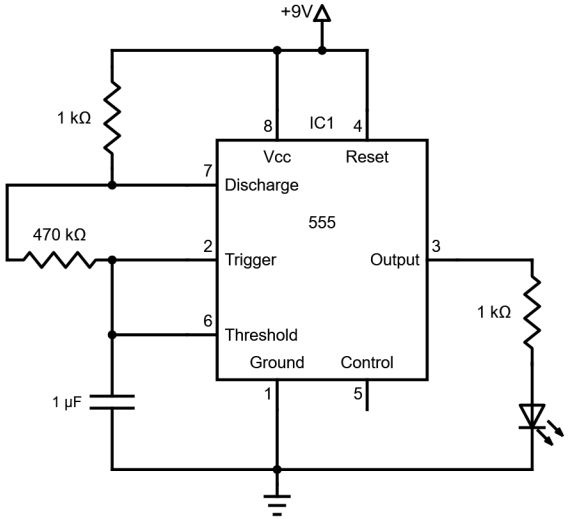
- When electronics are more complex or are ready for production, we typically use printed circuit boards or PCBs.

- We will be using Passive Piezo Buzzers
  - They have to be fed an oscillating signal
  - Make sure to have the correct polarity



Sign-Up for the Workshop

- Thank you for attending the second lecture!
- The remainder of time will be to work on Project 2, Checkpoint 1: Blinking LED Circuit
- To solder your Project 2 PCBs, RSVP for a soldering workshop here:



SCAN ME

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