LECTURE II

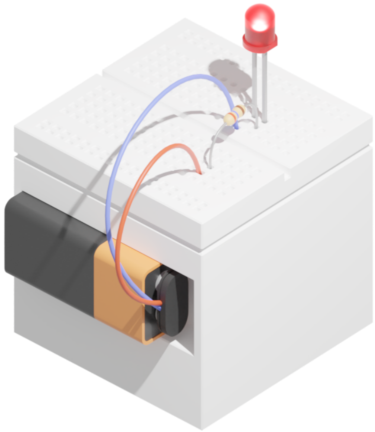
Circuit Analysis & Troubleshooting Techniques

SECTION I

Project I Review

Project I Review

- Official Due Date: Monday, October 27th by 11:59 PM
- 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 Monday, November 10th by 11:59 PM!!!**

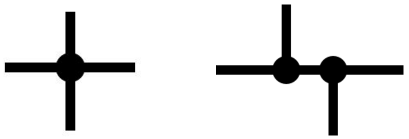


Learning Concepts:

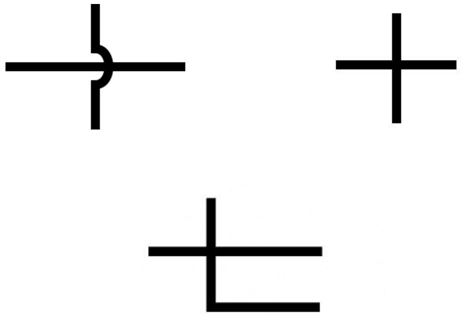
- Introduction to Circuits
- Ohm's Law (Voltage, Current, Resistance)
- Breadboarding
- Soldering

Schematic Connections Reminder

Connected Wires

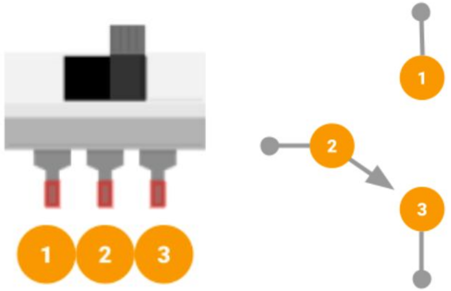


Unconnected Wires

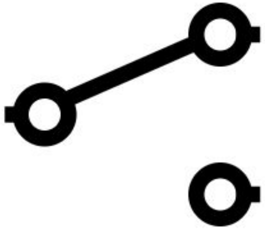


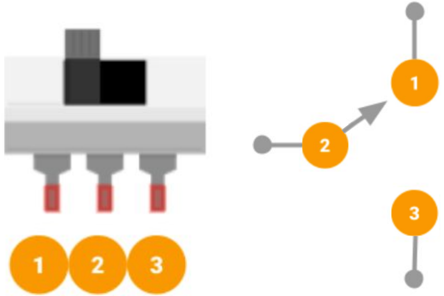
Slide Switch Review

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



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





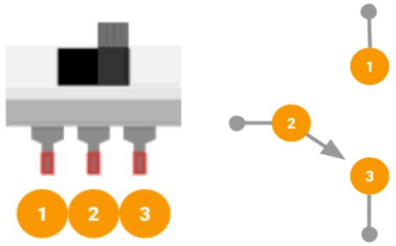
Breadboarding Quiz!

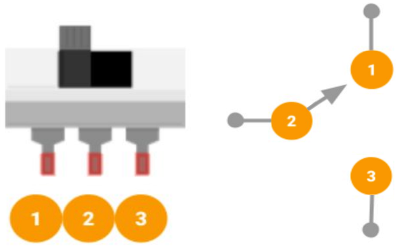
With the parts given in your OPS Kit, build this circuit on a breadboard.

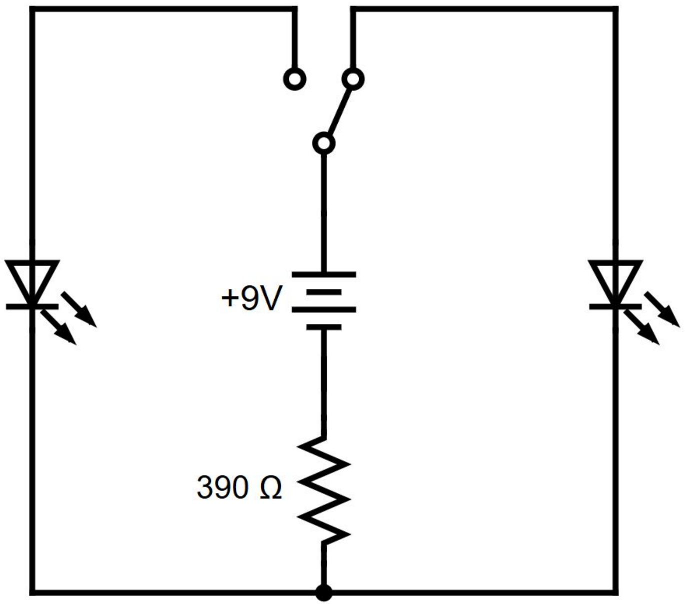
Tips:

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

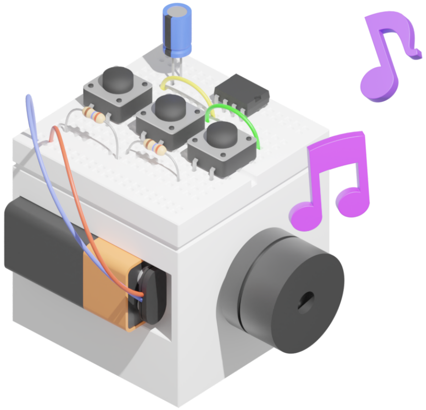
Project II

Project 2 Overview

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

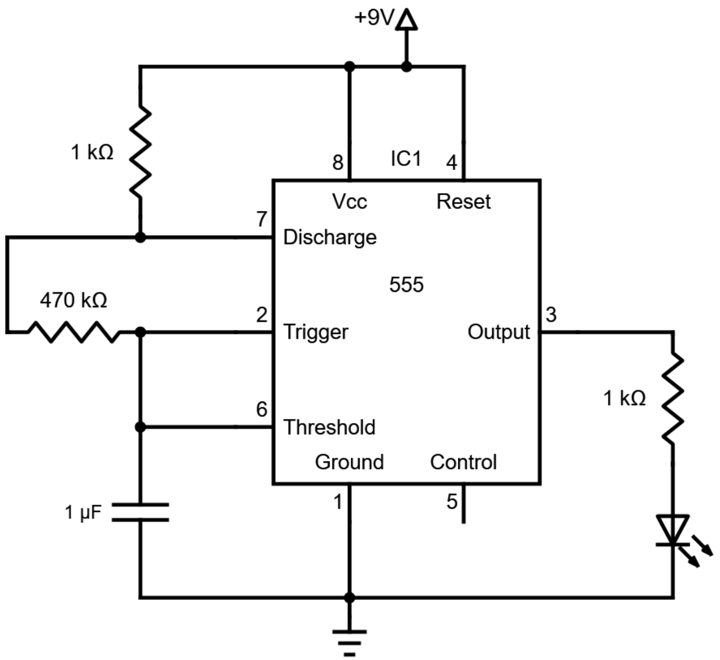
You will learn:

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

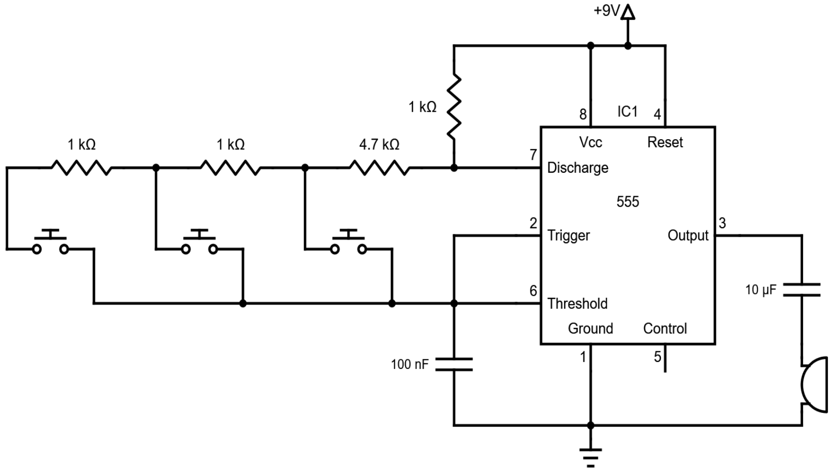


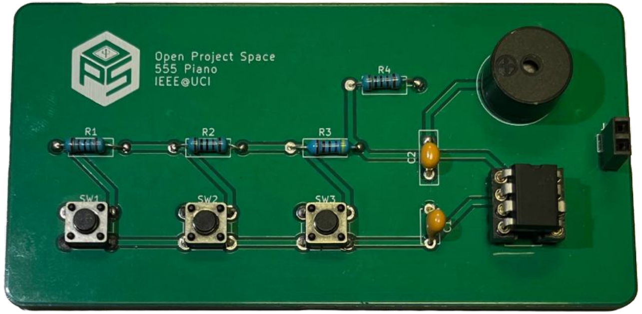
Checkpoint 1

- Create a **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



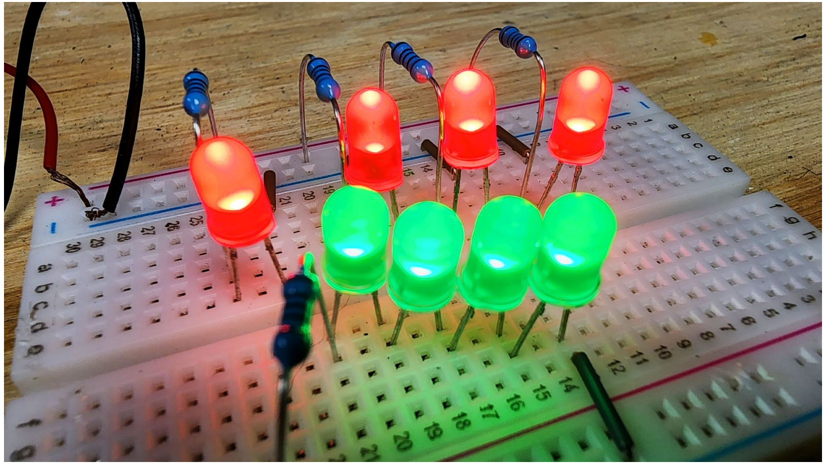


SECTION III

Circuit Topology

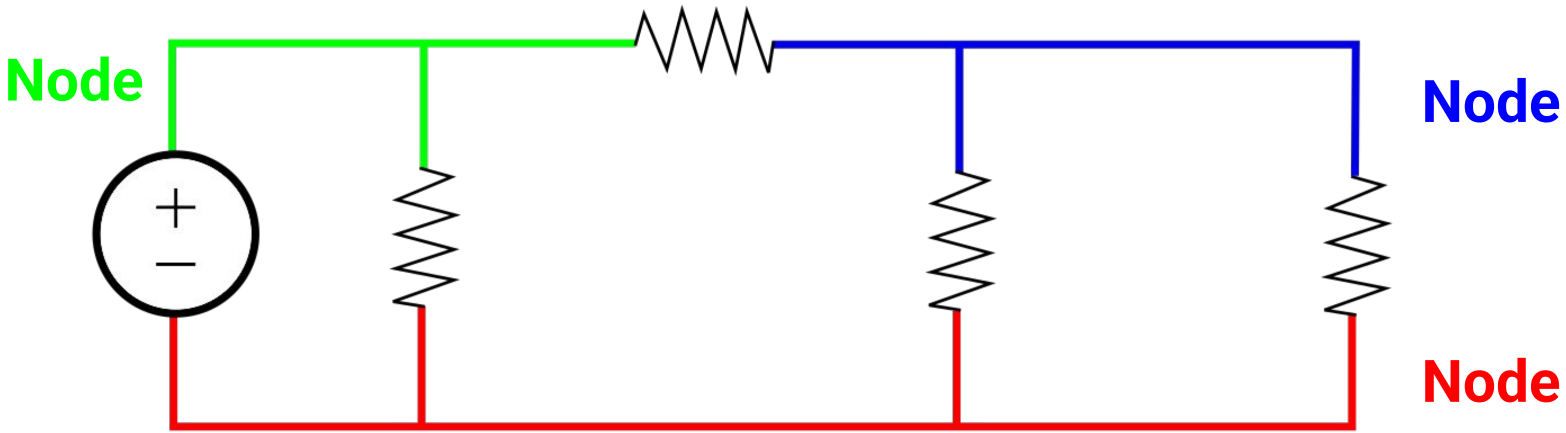
Circuits

- 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



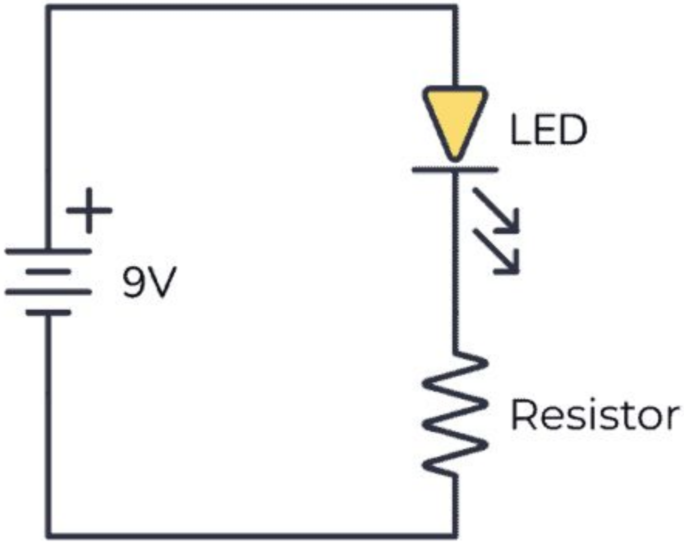
Nodes

- A **node** is a **connection** between two or more **components**
  - Though smaller nodes may exist within, nodes are typically defined by the largest continuous connection of components
- All points on the **same node** share the **<u>same voltage</u>**



Node Exercise

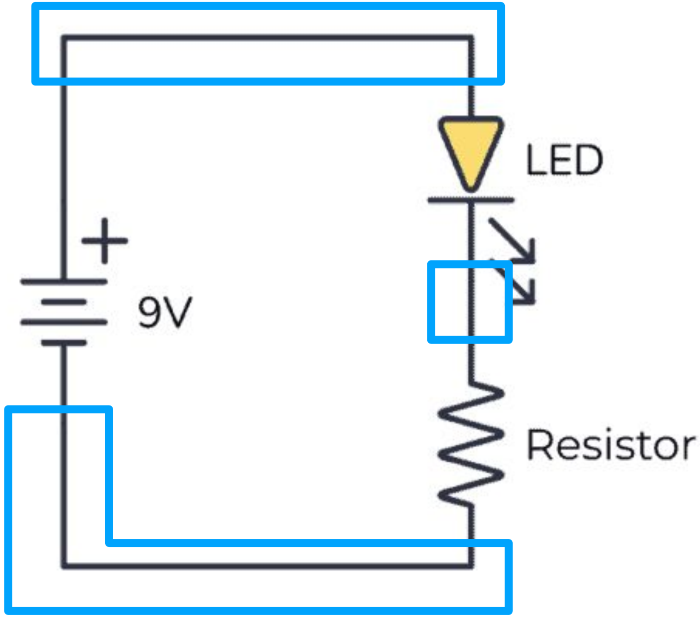
Exercise: How many nodes are in this schematic?



Node Exercise

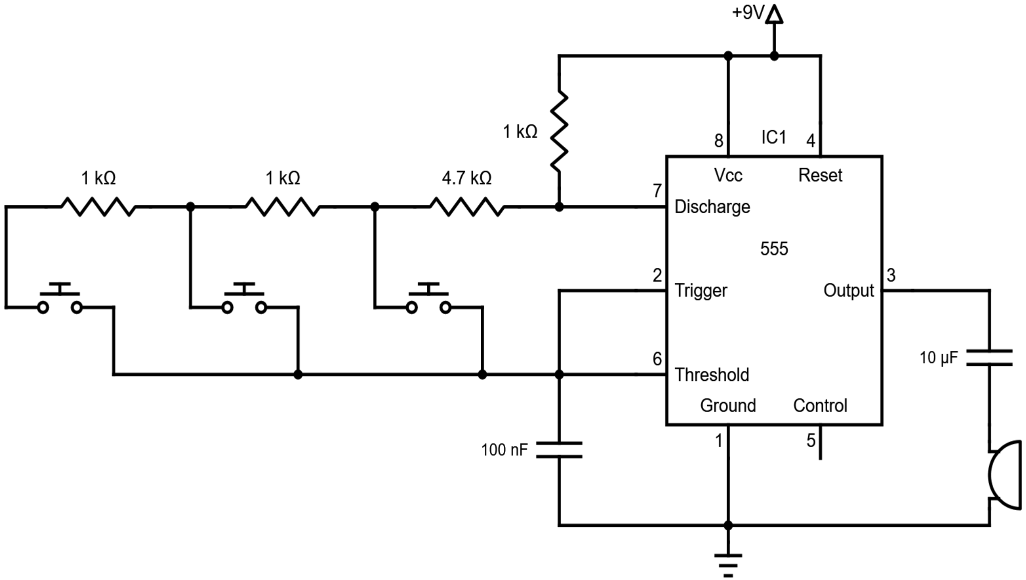
Exercise: How many nodes are in this schematic?

Answer: 3 Nodes



Node Exercise

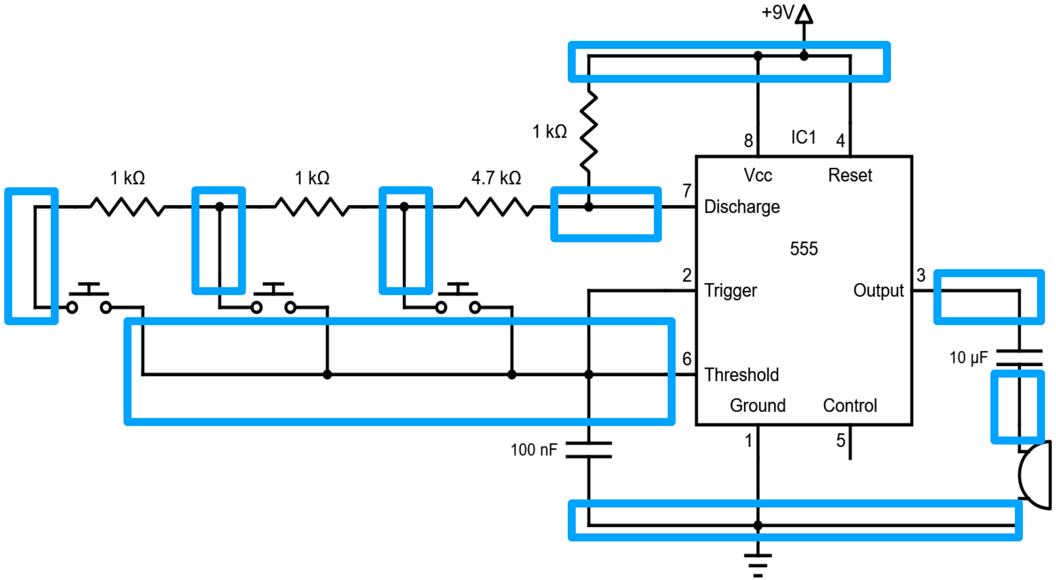
Exercise: How many nodes are in Project 2 (if the buttons are not pressed)?



Node Exercise

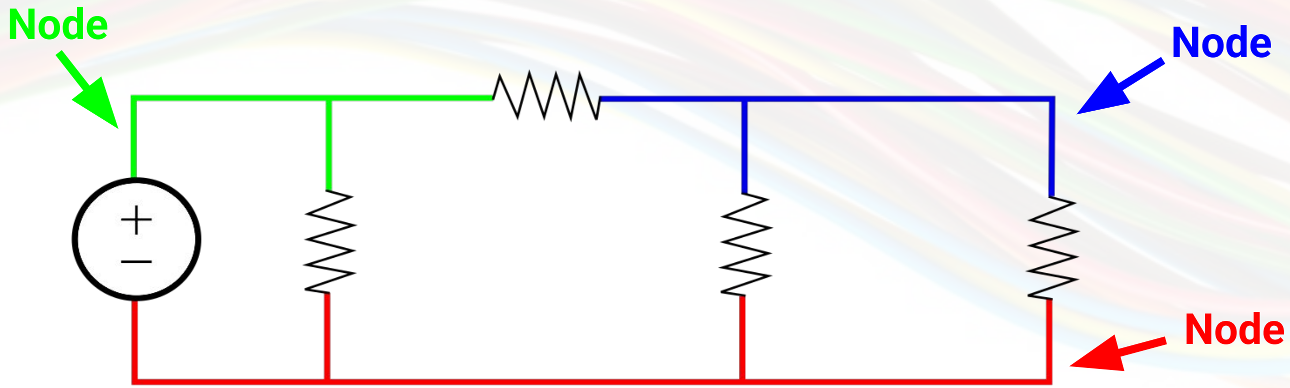
Exercise: How many nodes are in Project 2 (if the buttons are not pressed)?

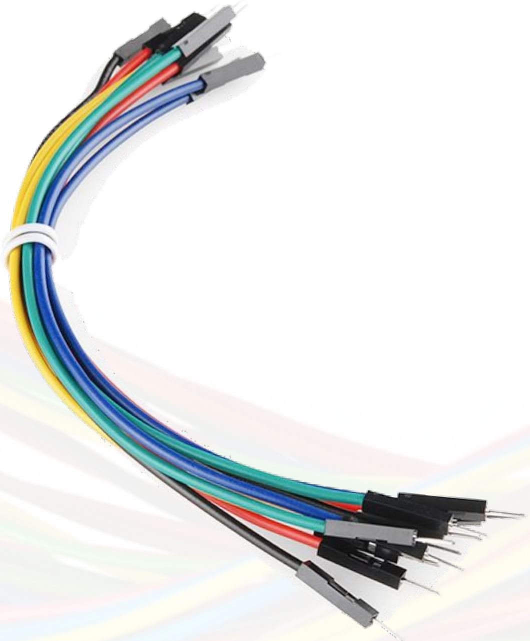
Answer: 9 Nodes



Nodes (Cont'd)

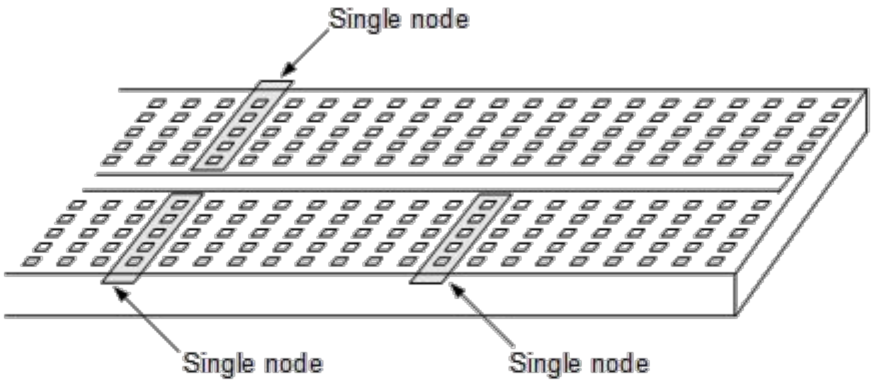
- **Wires** can be treated as **nodes**
  - .. if we assume that the wire has **no resistance** and there is **no voltage change** across the wire
    - This is acceptable for our course projects

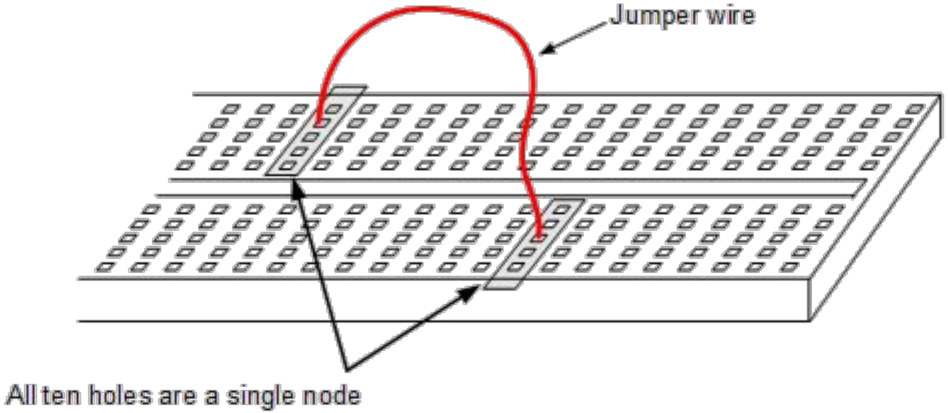




Nodes (Cont'd)

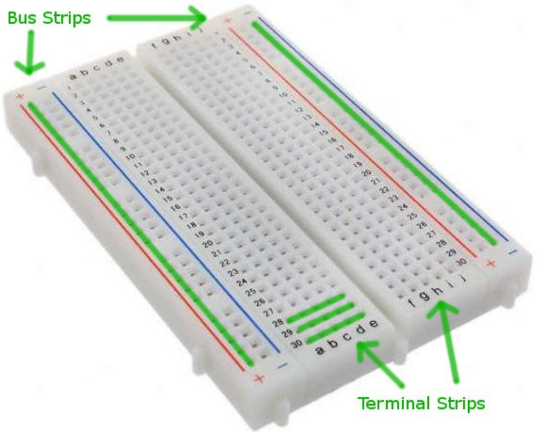
- A breadboard horizontal **strip** be treated as a **single node**
- Connecting two strips with a jumper wire creates a larger **single node**
- Gap in the middle (called a **channel**) separates the left and right nodes on a breadboard





Nodes (Cont'd)

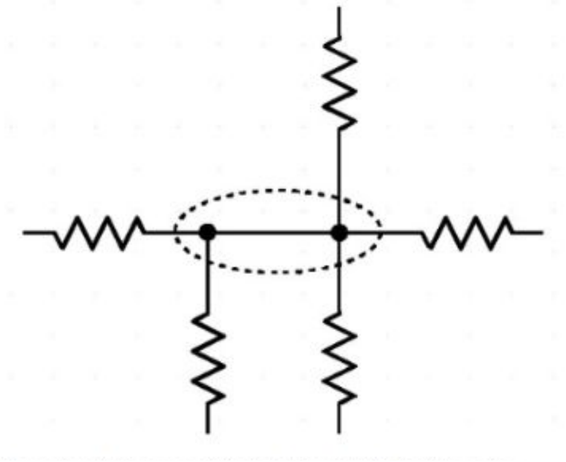
- A bus (vertical strip) on the breadboard is one long node
- Generally used for connecting a power source (like batteries) to the breadboard
  - Note: can also connect circuit boards and/or extend power/ground signals
- Connect the positive terminal to the **power strip** (denoted by the + sign), and the negative terminal to the **ground strip** (denoted by the **- sign**)



Nodes (Cont'd)

I/A

What is the voltage difference between these two points?



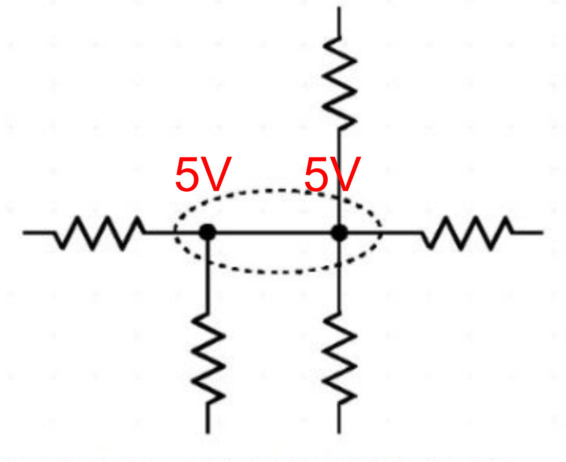
Nodes (Cont'd)

I/A

What is the voltage difference between these two points?

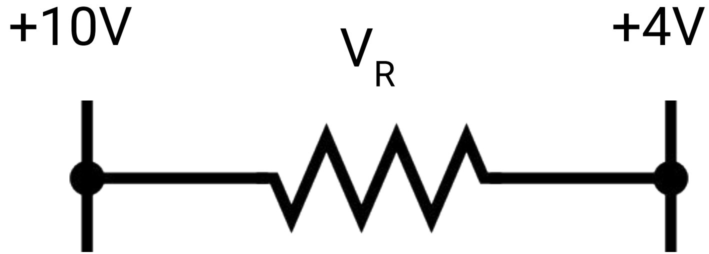
Ex. 5V – 5V = 0V

Answer: 0V

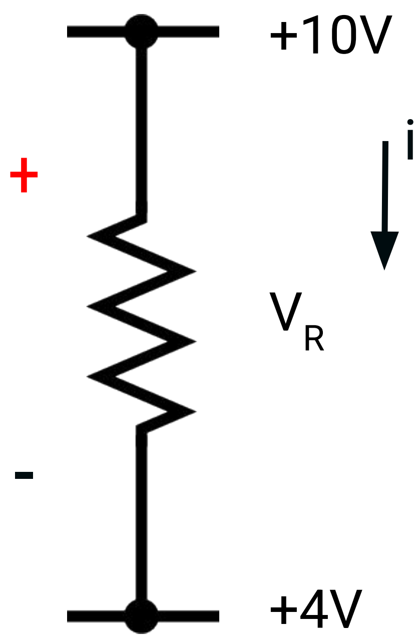


Voltage Drop

- **Voltage Drop** is the **difference of electric potential** (in Volts) **between two positions,** following the path of current flowing in a circuit
  - An LED experiences a voltage drop because it expends energy to emit light
  - A resistor experiences a voltage drop because electrons lose potential energy as they go through it
- We can calculate the voltage drop between two nodes (across a circuit component)



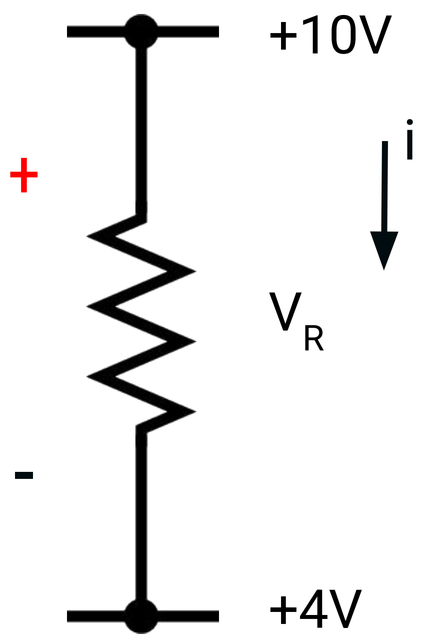
Calculating Voltage Drop



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)

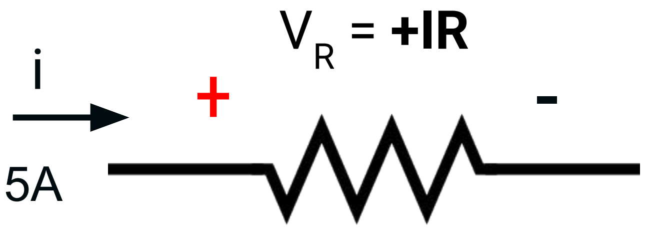


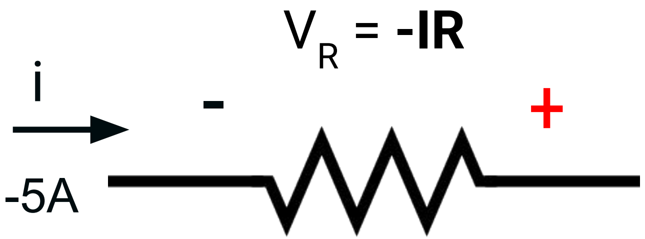
Find voltage drop $\mathbf{V_R}$

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)

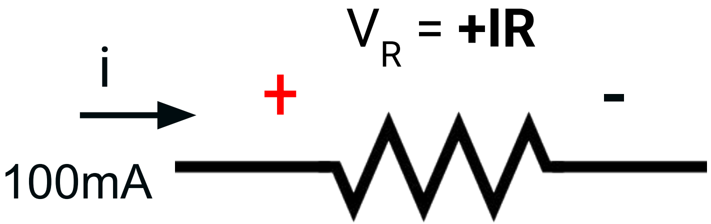


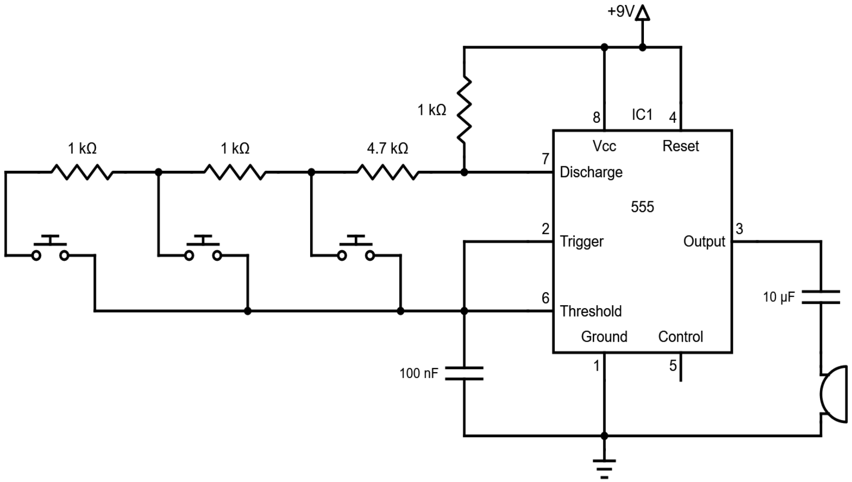


- The voltage drop is **positive** if current flows from **+** to - terminals
  - Conventional current flows from **+** to - terminals (even though in reality it is the opposite)
- The voltage drop is **negative** if current flows - to **+** terminals

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.

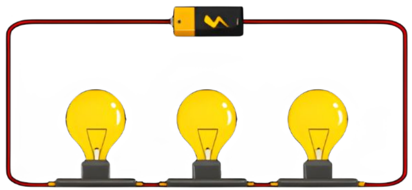




Series and Parallel Circuits

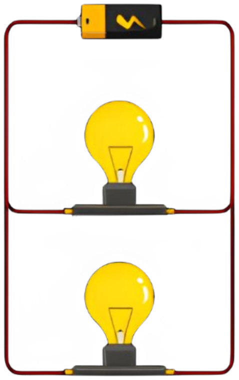
Series

- 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 share the same two nodes
- Elements in parallel have the **same voltage** across them

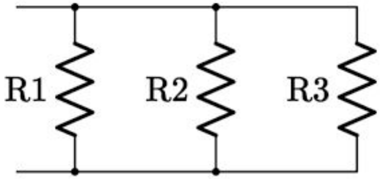


Series and Parallel Circuits

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

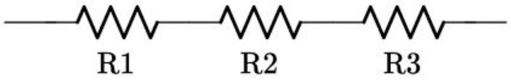
Parallel

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



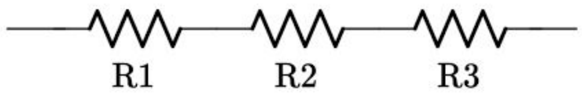
Series

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



Resistors in Series

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



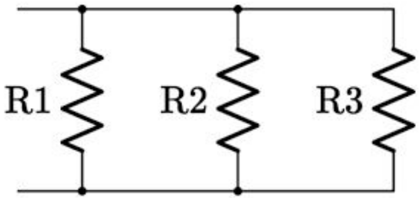
$$R_{eq} = R_1 + R_2 + R_3$$

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

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

Resistors in Parallel

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



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

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

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

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

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

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 Video

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**, the reference for red probe measurements
    - Plug it into the **COM** multimeter port

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 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

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

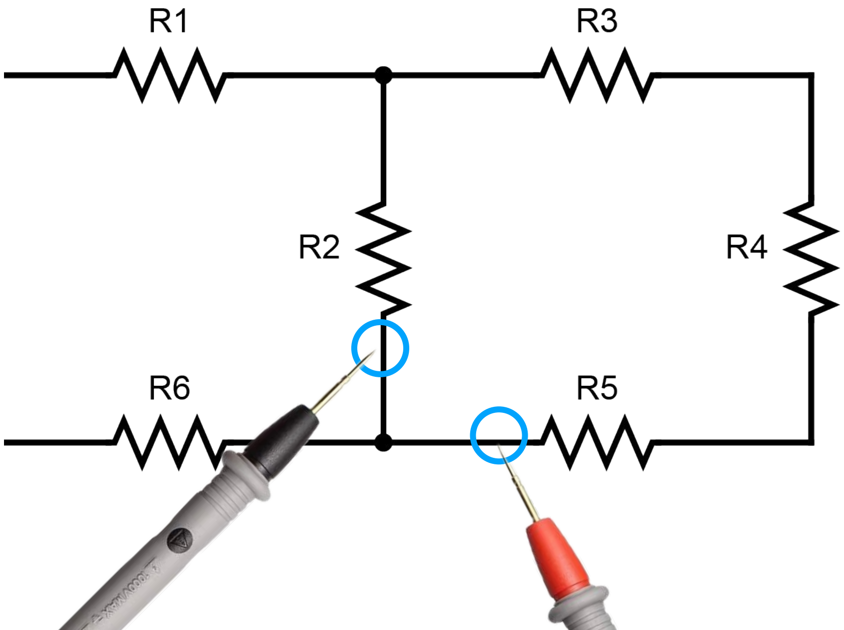
Testing Continuity

How to **test continuity** (whether there is a continuous path between the probes) 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 multimeter **beeps** if there is continuity between the probes

Testing Continuity (Cont'd)

You can test the continuity across any two points on a circuit which lie on the same node. The multimeter 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 providing the correct voltage?
        - Use a multimeter 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 multimeter 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: if your circuit still malfunctions, 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:

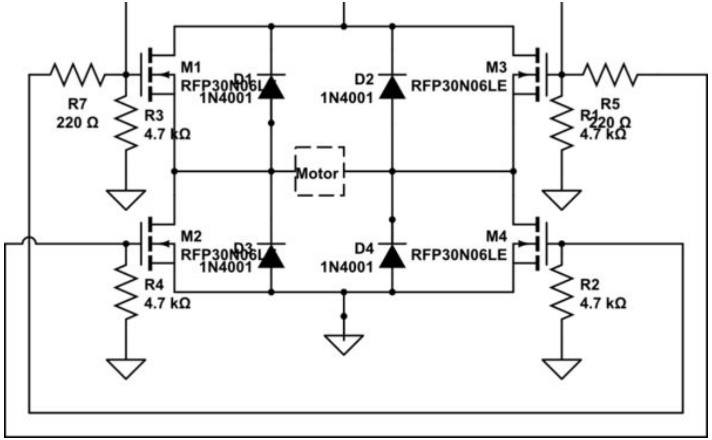
- Loose wire? Poor connection?
    1) Re-solder or replace connections as needed and test the circuit again
    2) If the circuit still fails, **test the connections again** with the multimeter. It's possible to solder poorly on even the second or third try.

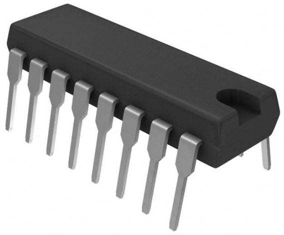
SECTION VI

Integrated Circuits

Integrated Circuits

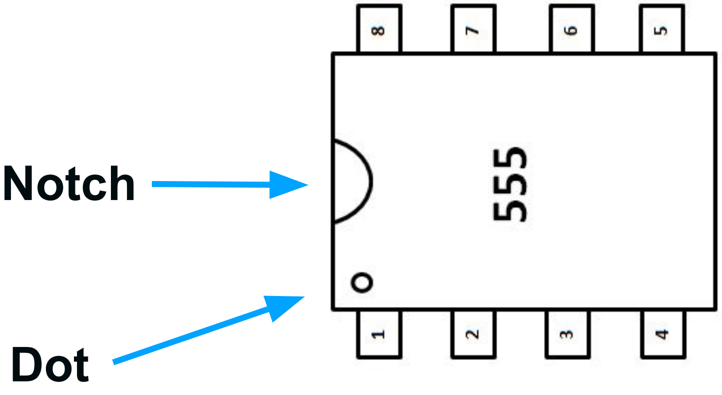
- An **integrated circuit** (**IC, chip**, **microchip**) is a set of electronic circuits on one small flat piece of semiconductor material
    - Electronic components are **integrated** on the chip
    - Complex circuits can be **scaled down** and **mass-produced**





Integrated Circuits

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



TEXAS INSTRUMENTS

NA555, NE555, SA555, SE555

www.ti.com SLFS022I – SEPTEMBER 1973 – REVISED SEPTEMBER 2014

6 Pin Configuration and Functions

Pin Functions

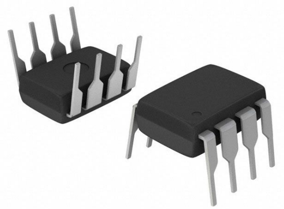
NAME	PIN D, P, PS, PW, JG (NO.)	PIN FK (NO.)	I/O	DESCRIPTION
CONT	5	12	I/O	Controls comparator thresholds, Outputs 2/3 VCC, allows bypass capacitor connection
DISCH	7	17	O	Open collector output to discharge timing capacitor
GND	1	2	–	Ground
NC		1, 3, 4, 6, 8, 9, 11, 13, 14, 16, 18, 19	–	No internal connection
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 < ½ 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

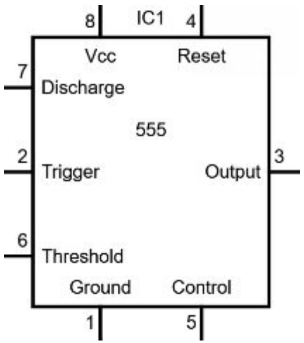
555 Timer IC

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**
  - Astable mode means the circuit oscillates continuously
  - Stable mode means the circuit has at least one stable state, and requires an external trigger to change from that state



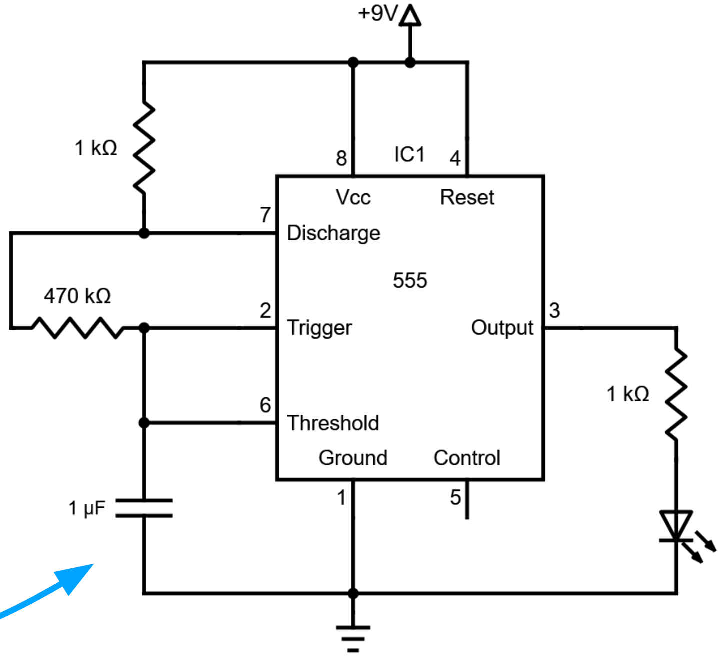
555 Timer DIP Package



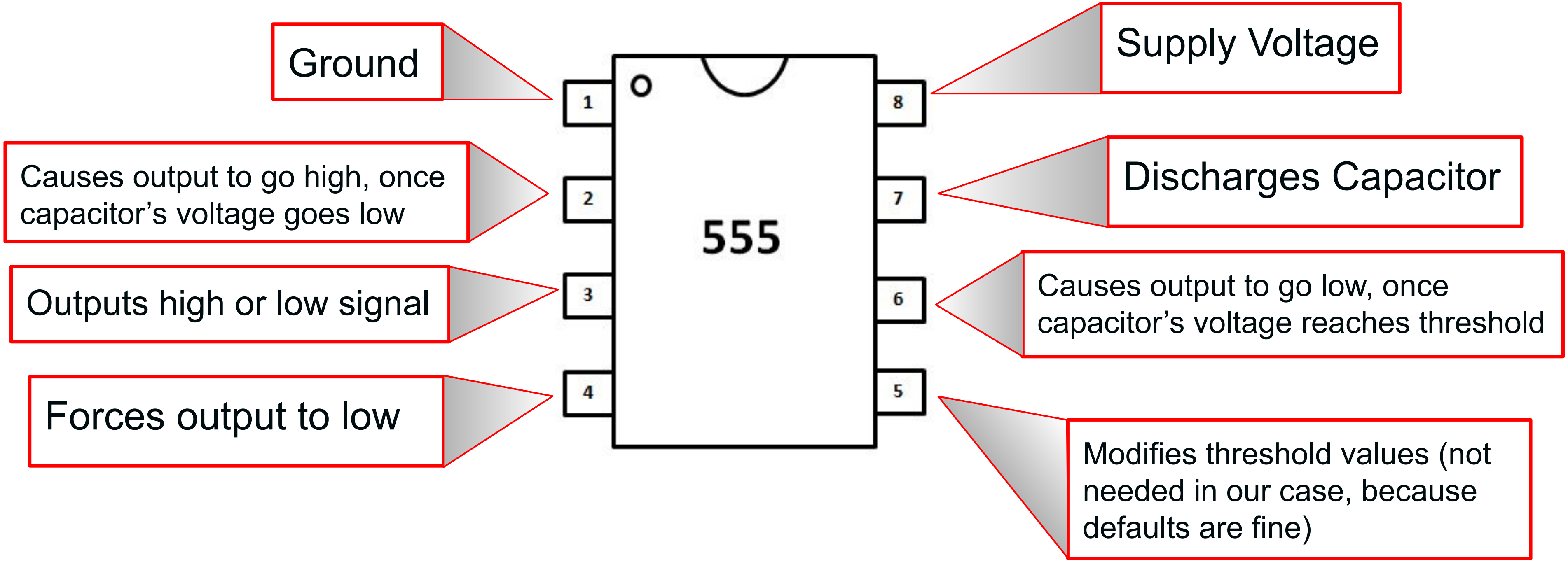
555 Timer Schematic Symbol

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 circuit is to **cycle an LED** ON and OFF at a constant frequency
- The circuit's timing relies on the value of the **capacitor**



555 Timer Pins (astable)

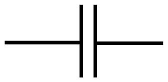


SECTION VIII

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

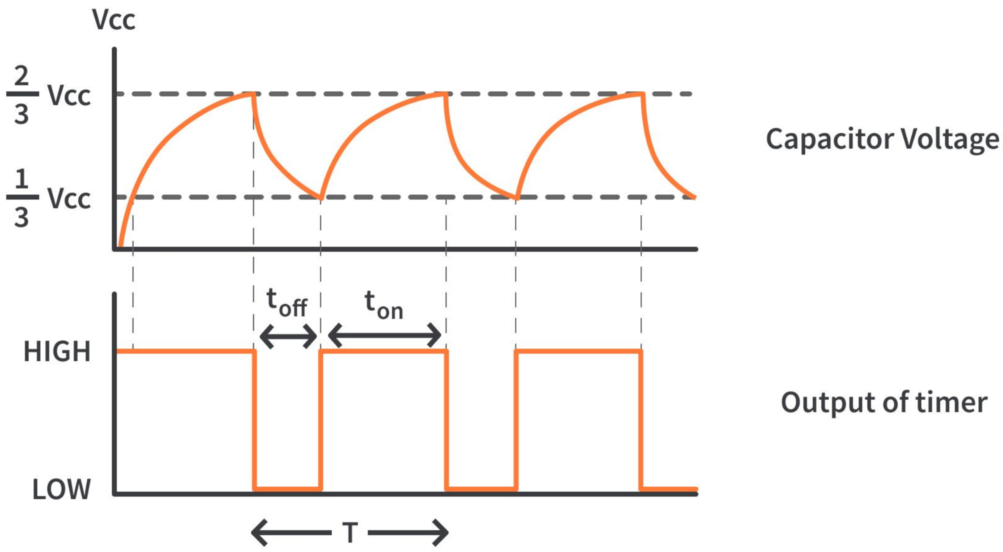


Capacitor Timing Diagram

Timing Diagram

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

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



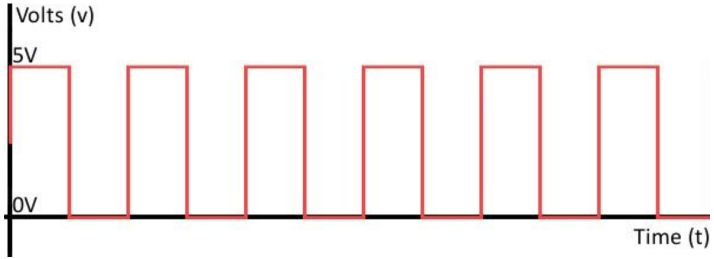
Piezo Buzzers

- A piezoelectric buzzer is a component used to emit sound

- There are two types of buzzers:
    - **Active buzzers** have a built-in oscillator, use DC voltage, and produce one tone
    - **Passive buzzers** do not have built-in oscillators, use AC voltage, and can produce a variety of tones

Piezo Buzzers (Cont'd)

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



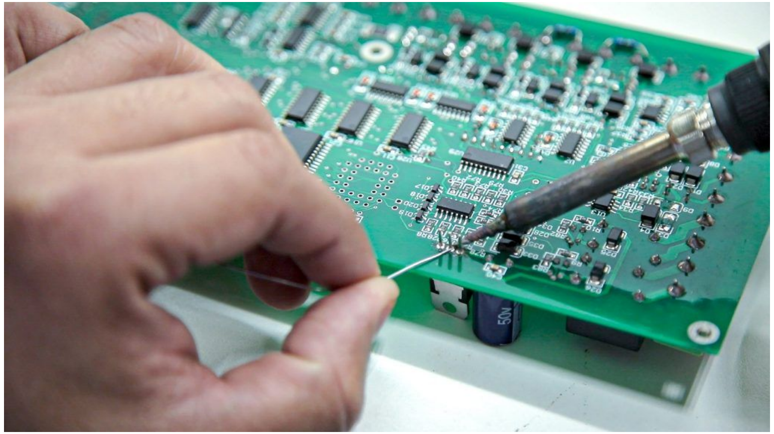
- The voltage waveform is relevant because the frequency is what controls the buzzer's pitch, and the amplitude controls the volume!

Printed Circuit Board (PCB)

- Breadboards and protoboards are great for prototyping simple circuits

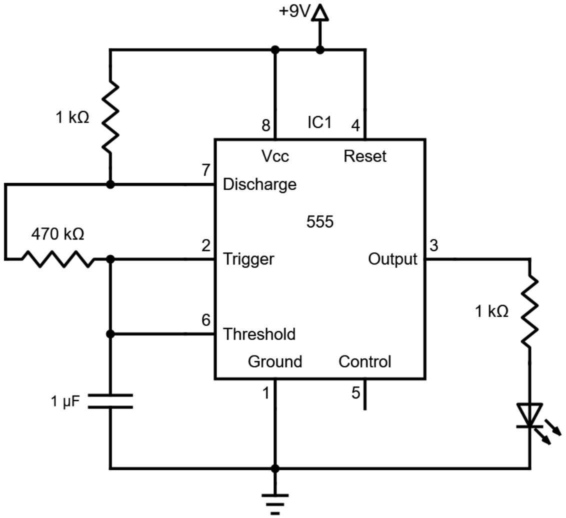
- When electronics are more complex or are ready for production, we typically use **printed circuit boards or PCBs**

- In a PCB, wiring is built into the circuit board, so only the components need to be soldered on

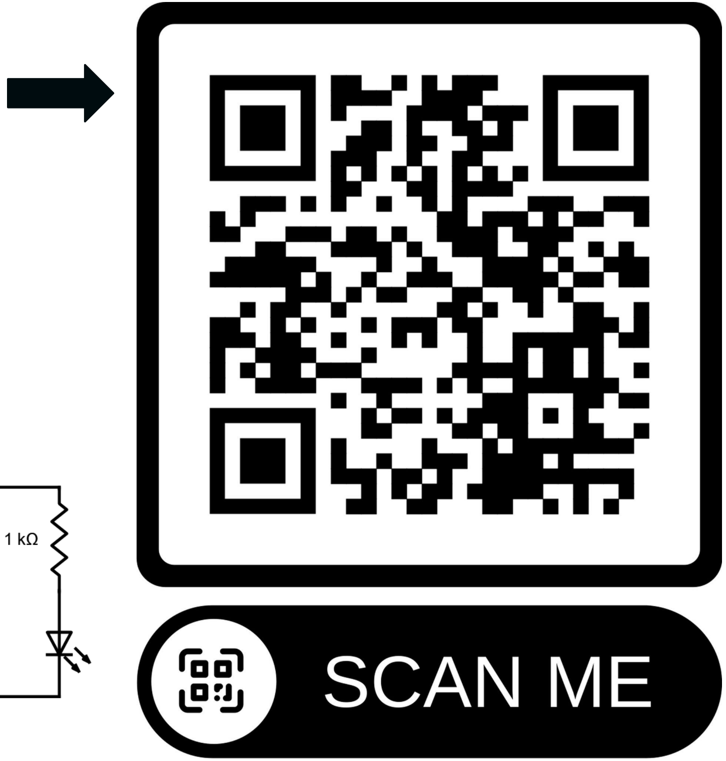


Sign-Up for the Workshop

- 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:



Sign up here



OPS Halloween Social

- Hot chocolate making, games, movie, snacks, and MORE!
- Friday 5:00-6:30 PM @ EH 2430
- Be there or be SCARED

Sign up here →

SCAN ME

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