# Electronics and Electromagnetism

**Lab 5: Capacitors and its applications**

## Purpose

In this Lab, we will be discussing about the **Capacitor's I-V characteristics & its configurations**. We will then learn about components such as buzzers and push buttons to create interesting circuits with capacitors.

## Capacitors

In a resistor, the voltage is determined by the resistance and the current flowing through the resistor. In the case of a capacitor, the current through the capacitor at any given moment is the product of **capacitance(C)** and the rate of change (i.e., the derivative with respect to time) of the **voltage(v)** across the capacitor.

$$I = C\frac{dV}{dt}$$

Because we are using a **linear voltage sweep**, the current through the capacitor is constant when the voltage is increasing or decreasing. When the voltage changes from a positive slope (shown in blue in Figure 1) to a negative slope (orange), the direction of the current reverses.

this is represented in the current vs time plot as a change from the positive-current section of the graph to the negative-current section of the graph.

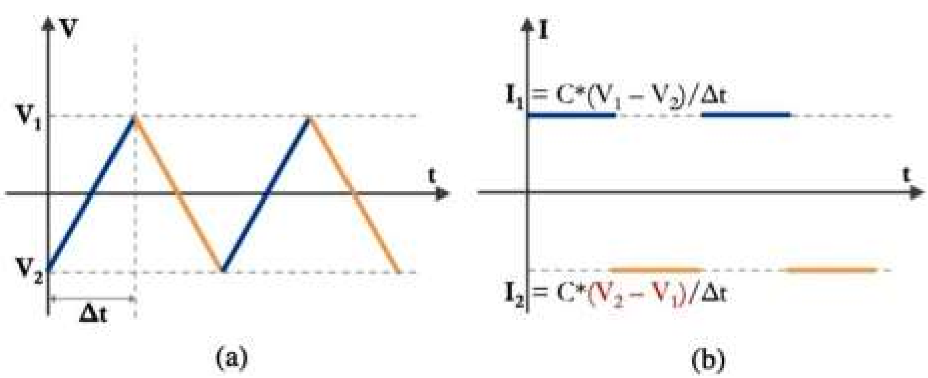



**Figure 1:** (a) Linear voltage sweep and (b) the corresponding capacitor current vs time

The I-V relationship of an ideal capacitor is shown in Figure 2. The magnitude of the current is constant, however the direction of the current changes depending on whether the voltage is moving from V1 to V2 or V2 to V1. When the voltage has a positive rate of change, the current is positive (indicated by the blue arrowhead); when the voltage has a negative rate of change, the current is negative (indicated by the orange arrowhead).

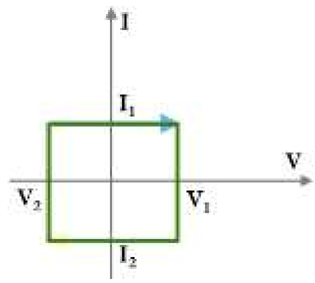



**Figure 2:** I-V curve for an ideal capacitor based on the voltage sweep shown in **Figure 1**

**Capacitance**

Capacitance is the ability of a component or circuit to collect and store energy in the form of an electrical charge. In other words, **capacitance (C)** of an electrostatic system is the ratio of the quantity of charge separated **(Q)** to the potential difference applied **(V)**.

The SI unit of capacitance is the **farad [F]**, which is equivalent to the **coulomb/volt [C/V]**.

$$C = \frac{Q}{V} \qquad \boxed{C = Q/\Delta V} \qquad \left[F = \frac{C}{V}\right]$$

**Parallel Plate Capacitor**

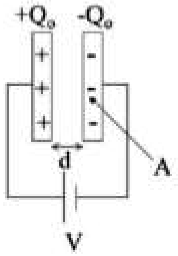
Capacitors are energy-storing devices. Shape of the capacitor is proportional to the capacitance value.(Higher the Capacitance, Larger the area of Capacitor). They consist of two parallel plates of conducting material (usually a thin metal) sandwiched between an insulator made of ceramic, film, glass, or other materials, even air

Capacitance of a parallel plate capacitor

• directly proportional to the **area (A)** of one plate,

• inversely proportional to the **separation (d)** between the plates, and

• directly proportional to the **dielectric constant** $\mathscr{E}$ of the material between the plates.




$$C_o = \frac{Q_o}{V} = \frac{\varepsilon_o A}{d} \quad (\text{unit} = \text{Farad})$$

$C_o$ = capacitance of a parallel plate capacitor in free space
$Q_o$ = charge on the plates
$V$ = voltage
$\varepsilon_o$ = absolute permittivity (8.854 pF/m or pC/(V m)
A = area of a plate
d = distance of the space between the plates

## Energy Storage of a Capacitor

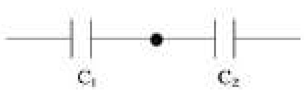
Energy storage is equal to the work done to charge a Capacitor.

$$U = \int_0^Q V\,dq = \int_0^Q \frac{q}{C}\,dq = \frac{1}{2}\frac{Q^2}{C}$$

Since $Q = CV$, and also since $C = Q/V$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV$$

## Capacitors in Series Connection

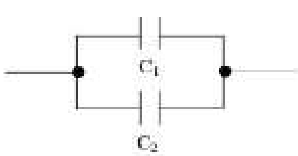



For a series connection, the charge on each capacitor will be the same and the voltage drops will be added. We are able to define the equivalent **capacitance Ceq**, from

$$Q \cdot 1/C_{eq} = \Delta V = \Delta V_1 + \Delta V_2 = Q/C_1 + Q/C_2 = Q\,[1/C_1 + 1/C_2]$$

$$\boxed{1/C_{eq} = 1/C_1 + 1/C_2}$$

## Capacitors in Parallel Connection




For a parallel connection, the voltage drops will be the same, but the charges will be added. Then the equivalent capacitance can be calculated by adding the charges:

$$C_{eq}\,\Delta V = Q = Q_1 + Q_2 = C_1\Delta V + C_2\Delta V = [C_1 + C_2]\,\Delta V$$

$$\boxed{C_{eq} = C_1 + C_2}$$

## Buzzers

Buzzers are electronic devices that can generate sounds. Normally powered by DC voltages and they can be categorized into 2 types as Piezo buzzers and magnetic buzzers. They have different design concepts and due to that it may produce different sounds as well.

**Figure 3:** Commercial Buzzers by SIEMENS

## Piezo Buzzers

As the name suggests, a Piezo-type buzzer's core consists of a piezoelectric element. The piezoelectric element is made from a piezoelectric ceramic as well as the metal plate, they are held together in place by the adhesive. Piezo buzzers are constructed by placing the electrical contacts on the two faces of a disk of piezoelectric material and then supporting the disk at the edges in an enclosure. When a voltage is applied across the two electrodes, the piezoelectric material mechanically deforms due to the applied voltage. This movement of the piezo disk within the buzzer creates sound.

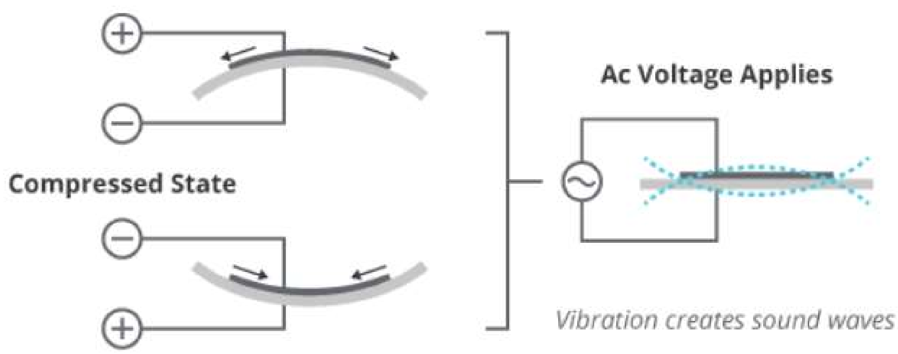



**Figure 4:** Working principle of a piezo buzzer

## Magnetic Buzzers

In a magnetic buzzer, a current is driven through a coil of wire which produces a magnetic field. A flexible ferromagnetic disk is attracted to the coil when the current is present and returns to a "rest" position when the current is not flowing through the coil.

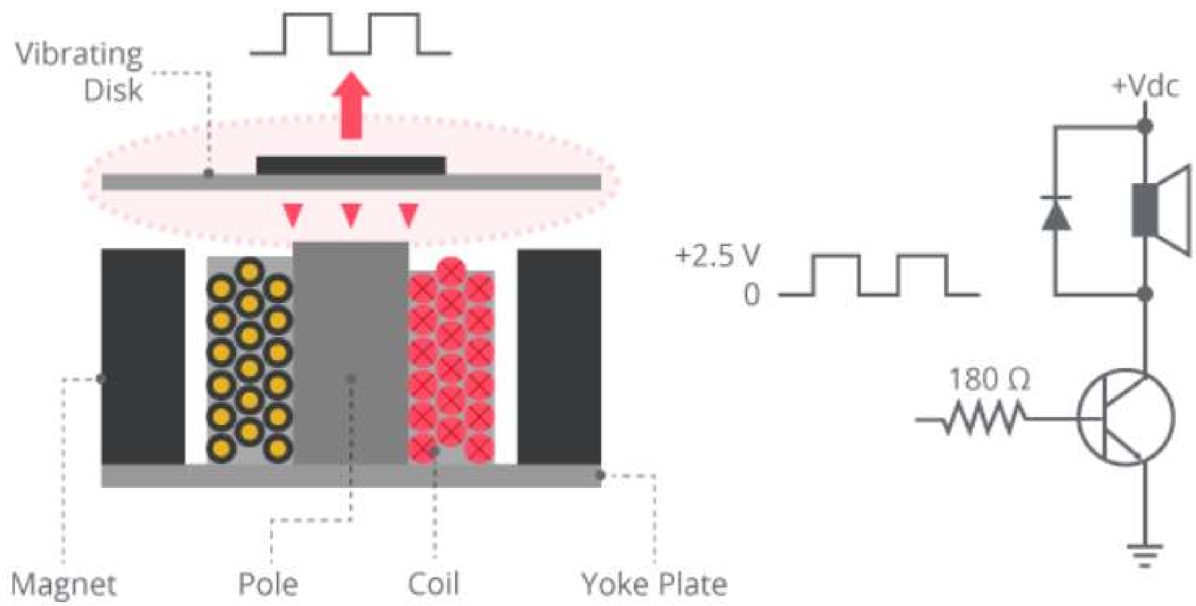



**Figure 5:** Working principle of a magnetic buzzer

Magnetic buzzers operate at lower voltages and higher currents (1.5~12 V, > 20 mA) compared to piezo buzzers (12~220 V, < 20 mA), while piezo buzzers often have greater maximum sound pressure level (SPL) capability than magnetic buzzers. Furthermore, the piezoelectric buzzer is a simple and durable in structure, but it has a single tone and peak sound quality. Therefore, it is feasible for alarms and other equipment. On the other hand, the magnetic buzzer is mostly used for voice, music, and other equipment due to its constant sound quality.

(a) (b)

**Figure 6:** Piezo (a) & magnetic buzzers (b)

## Push buttons

A push-button is a switch equipped with a spring which can stand in two states: pushed or released. Thanks to the spring, normally the button is released. From a circuital point of view, a push-button is a two terminal device which acts as a short circuit when pushed and as an open circuit when released.

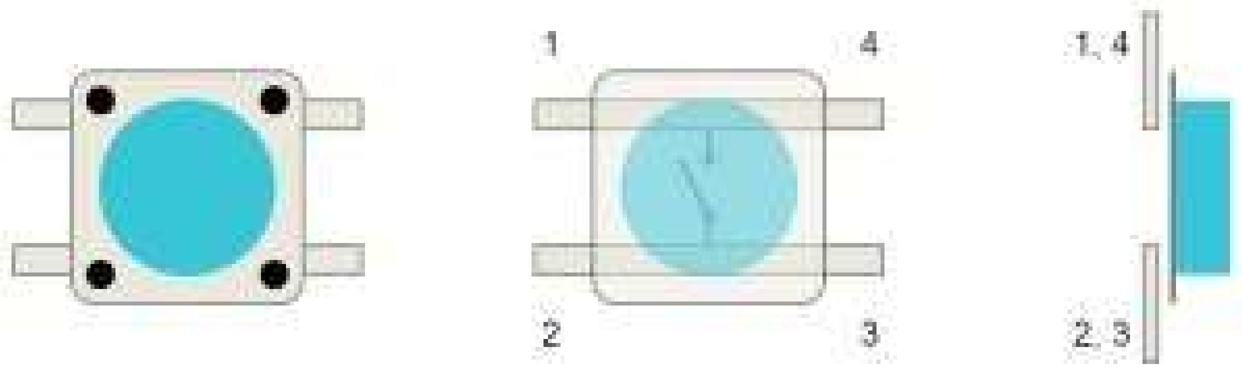
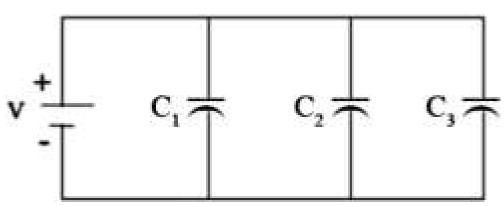



**Figure 7:** Push button connections

## Task 1

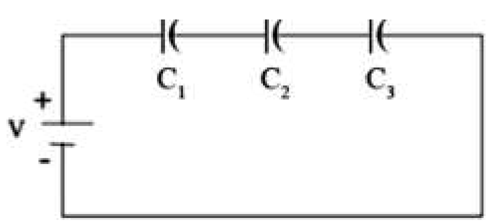
Construct the parallel circuit for the given C1,C2,C3 values (choose any). Set your power supply to be 6V connect the DMM in parallel with each capacitor and measure the voltage then record in the below table (Read the Capacitor value using Lab 2 knowledge)




| Capacitor (uF) | Measured value (Voltage :V) | Calculated Q value (Coulomb :C) |
|---|---|---|
| $C_1$= | $V_{c1}$= | $Q_{c1}$= |
| $C_2$= | $V_{c2}$= | $Q_{c2}$= |
| $C_3$= | $V_{c3}$= | $Q_{c3}$= |

***Find the Theoretical equivalent capacitance, also check the current value for each capacitor and total current

## Task 2




Construct the series circuit for the given C1,C2,C3 (choose the same capacitor values you used above) values. Set your power supply to be 6V connect the DMM in parallel with each capacitor and measure the voltage then record in the below table

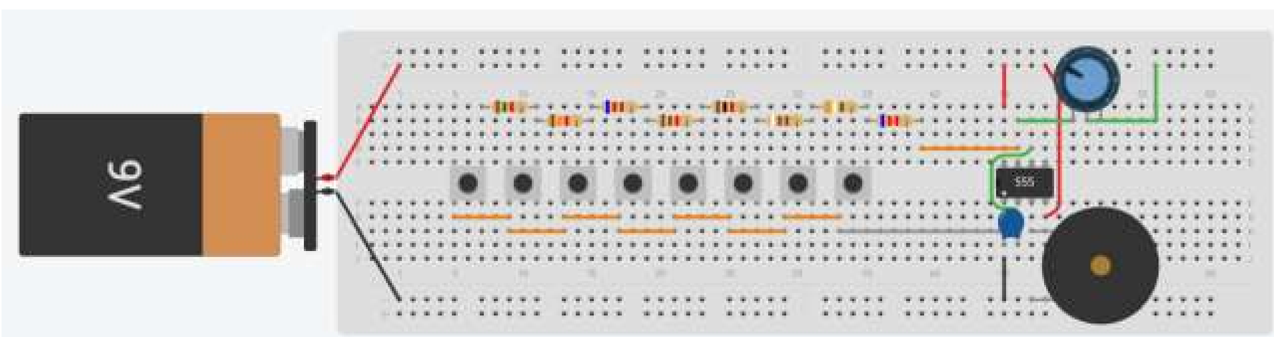
Find the Theoretical equivalent capacitance

| Capacitor (uF) | Measured value (Voltage :V) | Calculated Q value (Coulomb :C) |
|---|---|---|
| $C_1$= | $V_{c1}$= | $Q_{c1}$= |
| $C_2$= | $V_{c2}$= | $Q_{c2}$= |
| $C_3$= | $V_{c3}$= | $Q_{c3}$= |

***Note :*** *Be careful and discharge the capacitors before each time of use.*

### Task 3

Create the following simple circuit using TinkerCad. Then analyze the circuit by measuring voltages at the buzzer with each push button press (Using DMM or Oscilloscope). Then also, observe and describe the effect of sound when you use the potentiometer (use at least 3 situations; min, medium and max ohm values). *****Why do we use the capacitor here?**




**Necessary items:**
1. 555(NE 555) Timer IC – 1
2. Piezo Buzzer – 1
3. 100nf Capacitor – 1
4. Push Buttons – 7
5. Resistor 6.2KΩ -1
6. Resistor 1.5KΩ -1
7. Resistor 1.3KΩ-1
8. Resistor 1.1KΩ-1
9. Resistor 1KΩ -1

10. Resistor 910Ω -1 11. Resistor 620Ω -1 12. Resistor 390Ω -1

13. 9V Battery 14. 10KΩ potentiometer

***** You can decide on a proper setup for the resistors (order of placing them)!!!**