

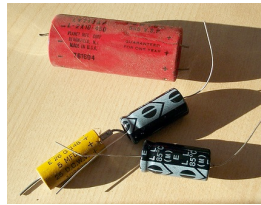
PH102 Capacitors Lab

Introduction

In this experiment we will determine how voltages are distributed in capacitor circuits and explore series and parallel combinations of capacitors. The capacitance is a measure of a device's ability to store charge. Capacitors are passive electronic devices which have fixed values of capacitance and negligible resistance. The capacitance, C , is the charge stored in the device, Q , divided by the voltage difference across the device, ΔV :

$$C = \frac{Q}{\Delta V}$$

The SI unit of capacitance is the farad, $1 \text{ F} = 1 \text{ C/V}$. Capacitance can be calculated from the geometry of a device. For most practical devices, the capacitor consists of capacitor plates which are thin sheets of metal separated by a dielectric (insulating) material. For this reason, the schematic symbol of a capacitor is has two vertical lines a small distance apart (representing the capacitor plates) connected to two lines representing the connecting wires, as shown below at left. Also shown is what your capacitor might look like, at right.



(left) Circuit diagram symbol for a capacitor. (right) Various real-life capacitors.

Sometimes the sheets are rolled up in a spiral to increase the overall area while keeping the device compact - this is why your capacitors are cylindrical. In any case, so long as the device consists of two parallel conductors much larger in extent than their separation, the capacitance is:

$$C = \frac{\kappa \epsilon_0 A}{d}$$

Here κ is the dielectric constant of the spacer material, ϵ_0 is the permittivity of free space, A is the surface area of the metal sheets, and d is the thickness of the dielectric. The capacitors used in this lab mostly use mylar sheet as a dielectric, with $\kappa = 3.2$ and a thickness $d = 10\mu\text{m}$.

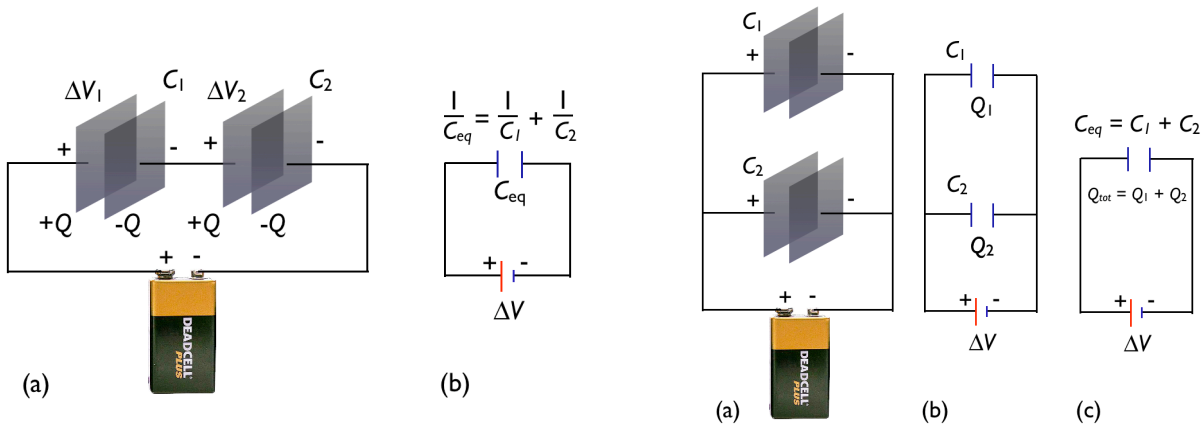
There are two ways to connect two passive (no polarity) components in an electronic circuit: in series or in parallel. In a series connection, the components are connected at a single point, end to end as shown below. **For a series connection, the charge on each capacitor will be the same.** Conservation of energy dictates that the total potential difference of the voltage source will be split between the two capacitors - if both capacitors are identical, each would have half the voltage of the source. In class, we calculated the equivalent capacitance, C_{eq} , for two capacitors in series:

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$$\frac{Q}{C_{eq}} = \Delta V_{source} = \Delta V_1 + \Delta V_2 = \frac{Q}{C_1} + \frac{Q}{C_2} \quad \Rightarrow \quad \frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

In the parallel case, the components are connected at both ends as shown at left. Thus, **for parallel capacitors, the voltage on each capacitor will be the same**, but the charges will add together. Then the equivalent capacitance can be calculated by adding the charges:

$$\begin{aligned} Q_1 &= C_1 \Delta V \\ Q_2 &= C_2 \Delta V \\ Q_{total} = Q_1 + Q_2 &= C_1 \Delta V + C_2 \Delta V = (C_1 + C_2) \Delta V \quad \Rightarrow \quad C_{eq} = C_1 + C_2 \end{aligned}$$



Two capacitors in series. (a) Schematic illustration. (b) Equivalent circuit diagram.

Two capacitors in parallel. (a) schematic illustration. (b) Circuit diagram. (c) Circuit diagram with equivalent capacitance.

Procedure

1. Turn on the power supply and set the AC voltage (rightmost knob) at 5 or 10 V. Measure this voltage with the multimeter (in ac volts mode, labeled V~) and record it below:

$$V_{source} = \underline{\hspace{2cm}} \text{ Volts}$$

2. Connect two capacitors in series, and connect the free end of one capacitor to the positive **AC terminal** on the power supply, and the free end of the other capacitor to the negative terminal. *The AC terminals are on the right side of the power supply, do not use the terminals on the left side.* Measure the voltage across the first capacitor (V_1) with the meter and record it below.

$$V_1 \text{ (measured)} = \underline{\hspace{2cm}} \text{ Volts}$$

3. Compute the expected value of V_1 using the measured value of the power supply voltage and the values of the capacitors C_1 and C_2 . Note that the meter is measuring V_1 as described above.

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$$V_1 \text{ (expected)} = \underline{\hspace{2cm}} \text{ Volts}$$
$$\% \text{ difference} = 100\% \times |\text{measured} - \text{expected}| / \text{measured} = \underline{\hspace{2cm}}$$

4. Connect a third capacitor (C_3) in *parallel* with C_1 . What is the equivalent capacitance of C_1 and the third capacitor?

$$C_{eq} = \underline{\hspace{2cm}} \mu\text{F (calculated)}$$

Measure and compute the voltage across C_1 and C_3 in parallel.

$$V_{eq} \text{ (measured)} = \underline{\hspace{2cm}} \text{ Volts,}$$
$$V_{eq} \text{ (expected)} = \underline{\hspace{2cm}} \text{ Volts } \% \text{ difference} = \underline{\hspace{2cm}}$$

5. Remove the third capacitor. Now connect a different fourth capacitor (C_4) in *series* with C_1 . What is the equivalent capacitance of C_1 now?

$$C_{eq} = \underline{\hspace{2cm}} \mu\text{F (calculated)}$$

Measure and compute the voltage across C_1 and C_3 in series.

$$V_{eq} \text{ (measured)} = \underline{\hspace{2cm}} \text{ Volts,}$$
$$V_{eq} \text{ (expected)} = \underline{\hspace{2cm}} \text{ Volts,}$$
$$\% \text{ difference} = \underline{\hspace{2cm}}$$