CAPACITORS EXPERIMENT

Short description:
In this experiment you will determine how voltages are distributed in capacitor circuits and explore series and parallel combinations of capacitors.

Equipment:
- AC power supply (set to 10V)
- Three 0.1 µF capacitors, one 0.01 µF capacitor, one unknown capacitor
- Multimeter
- 4 cables

Theory:
Capacitors are 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, \( \Delta V \):

\[
C = \frac{Q}{\Delta V}
\]  

(1)

The schematic symbol of a capacitor is has two vertical (or horizontal) lines a small distance apart (representing the capacitor plates) connected to two lines representing the connecting wires or leads).

\[ \]

There are two ways to connect capacitors in an electronic circuit - series or parallel connection.

Series:
In a series connection the components are connected at a single point, end to end as shown below:

\[ C_1 \quad \bullet \quad C_2 \]

For a series connection, the charge on each capacitor will be the same and the voltage drops will add. We can find the equivalent capacitance, \( C_{eq} \), from

\[
Q \cdot \frac{1}{C_{eq}} = \Delta V = \Delta V_1 + \Delta V_2 = \frac{Q}{C_1} + \frac{Q}{C_2} = Q \left[ \frac{1}{C_1} + \frac{1}{C_2} \right]
\]

(2)

\[
\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}
\]

(3)
Parallel:
In the parallel connection, the components are connected together at both ends as shown below:

\[
\begin{align*}
\text{For a parallel connection, the voltage drops will be the same, but the charges will add. Then the} \\
equivalent capacitance can be calculated by adding the charges: \\
C_{eq} \Delta V &= Q = Q_1 + Q_2 = C_1 \Delta V + C_2 \Delta V = [C_1 + C_2] \Delta V \quad (5) \\
C_{eq} &= C_1 + C_2 \quad (6)
\end{align*}
\]

Procedure:

1. Turn on the power supply and set the AC voltage to 10 V. Measure the actual power supply voltage with the multimeter and record it below:

\[V_{PS} = \text{_______________________V}\]
2. Connect two 0.1 µF capacitors in **series**. Measure \( V_2 \) (across \( C_2 \)) and record it below.

\[
V_2 \text{ (measured)} = \underline{\underline{\underline{\underline{}}} \text{ V}}
\]

3. Compute the expected value of \( V_2 \) using \( V_{PS} \), the values of \( C_1 \) and \( C_2 \) with equations 1 and 3. Remember that Eq. 1 is true for each capacitor, including the combined \( C_{12} \).

\[
V_2 \text{ (expected)} = \underline{\underline{\underline{\underline{}}} \text{ V}}
\]

\[ \% \text{ difference} = \frac{|\text{measured} - \text{expected}|}{\text{measured}} \times 100 \% = \underline{\underline{\underline{\underline{}}}} \]

4. Connect a third 0.1 µF capacitor in **parallel** with \( C_2 \). Compute their equivalent capacitance \( C_{23} \).

\[
C_{23} = \underline{\underline{\underline{\underline{}}} \text{ µF}}.
\]

Measure and compute the voltage across \( C_2 \). [Hint: is this the same as the voltage across the equivalent capacitor \( C_{23} \)? You may want to compute the total equivalent capacitance seen by the power supply, \( C_{123} \)]

\[
V_2 \text{ (measured)} = \underline{\underline{\underline{\underline{}}} \text{ V}},
\]

\[
V_2 \text{ (expected)} = \underline{\underline{\underline{\underline{}}} \text{ V}},
\]

\[ \% \text{ difference} = \underline{\underline{\underline{\underline{}}}} \]

5. Now remove the third capacitor \( C_3 \) and replace it with a 0.01 µF capacitor. Compute their equivalent capacitance \( C_{23} \).

\[
C_{23} = \underline{\underline{\underline{\underline{}}} \text{ µF}}.
\]

Measure and compute the voltage across \( C_2 \)

\[
V_2 \text{ (measured)} = \underline{\underline{\underline{\underline{}}} \text{ V}},
\]

\[
V_2 \text{ (expected)} = \underline{\underline{\underline{\underline{}}} \text{ V}},
\]

\[ \% \text{ difference} = \underline{\underline{\underline{\underline{}}} \text{ %}} \]
6. Now connect the 0.1 µF and the 0.01 µF capacitor in **series**, as C₂ and C₃. Compute the equivalent capacitance C₂₃

\[ C_{23} = \text{________} \mu\text{F}. \]

Measure and compute the voltage across the equivalent capacitance C₂₃.

\[ V_{23} \text{ (measured)} = \text{______} \text{ V}, \]

\[ V_{23} \text{ (expected)} = \text{______} \text{ V}, \]

\[ \% \text{ difference} \quad = \text{______} \]

7. This method can be used to find an unknown capacitance. Replace C₂ with the unknown value capacitor and determine its capacitance by measuring V₂ and using equations 1 and 3.

\[ V_2 = \text{______} \text{ V}, \]

\[ C_2 = \text{______} \mu\text{F}. \]