

Capacitance Measurements*

Object

To develop a method for capacitance measurement and then measure capacitances of various combinations of capacitors.

Theory

We shall be using capacitors and resistors in this experiment. The definitions and detailed analysis of such electrical circuit components will be dealt with in later lecture classes. However, for the purpose of this experiment we shall use the following working definitions:

- **A capacitor** consists of a pair of conducting plates. In electrical circuits it is used to store charge (temporarily). The two plates hold charges of equal magnitude (say q) but opposite sign. As a result, a potential difference (voltage) V develops between the plates. The capacitance of a capacitor is defined to be $C = q/V$ and its SI unit is a Farad (F). A more practical unit is a μF ($= 10^{-6}$ F).
- **A resistor** is an electrical circuit component that slows down the rate of flow of charges (current). If a potential difference (voltage) V is applied across a resistor to produce a current i in it then the resistance of the resistor is defined to be $R = V/i$. The SI unit for resistance is Ohm (Ω).

In the circuit shown below, the two short parallel lines represent a capacitor of capacitance C and the crooked line represents a resistor of resistance R .



The capacitor is charged by closing the switch. Then, opening the switch lets it discharge through the resistor. While discharging, if the voltage across the capacitor is V_0 at time $t = 0$, then at a later time t the voltage is

$$V = V_0 \exp(-t/\tau), \quad (1)$$

where $\tau (= RC)$ is called the time constant. If R is in Ohms and C in Farads, then τ is in seconds. Equation 1 will be derived later in theory. At present it is interesting to ponder over the qualitative aspects of this equation.

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The measurement method

First, setup the circuit shown above with a voltmeter in place of R . Besides measuring voltage, a voltmeter provides a large internal resistance (value stamped on meter). So, you will use this voltmeter resistance as R . Choose a value of C for a time constant of about 100 sec.. Charge the capacitor to about 5 V by closing the switch. Then open the switch to let the capacitor discharge through the resistor (voltmeter). Measure the voltage every 10 seconds. Plot a voltage versus time graph to observe the exponential discharging of the capacitor. You may use Excel for plotting and analyzing your graph. Find the time constant from this graph using equation 1. Compare with the chosen value for RC .

This method of measuring the time constant becomes impossible for shorter time constants unless a computer is used to measure the voltage at an appropriately rapid rate. The Vernier LabPro computer interface will allow your laboratory computer to do this. To use it, replace the voltmeter by the LabPro voltage probe. Like the voltmeter, the probe also provides an internal resistance R (1.0 M Ω). Start the “CapDisch” software. From the “Action” menu select “Sampling” (or click on the “samp” button). Choose appropriate values for sampling time and number of data points. Charge the capacitor as before for about a second, open the switch, and then click the “data” button. When data collection is complete, select a time range (using the mouse) on the graph starting after the onset of discharge and ending before the voltage drops to (roughly) 20% of its maximum value. Then, from the “Action” menu select “Curve Fit” (or click the “curve” button). A fitted graph is displayed along with the fitted value for time constant. If the fitted graph does not match the data points very well select another time range for fitting.

You can see that, if the resistance R in your circuit is known (voltmeter or probe), the measured time constant gives you the value of the capacitance ($C = \tau/R$). So, now you can use your setup as a capacitance measurement device.

Some trials

Connect up capacitors in combinations and measure their effective capacitances using the above method. Later you will learn to find the effective capacitances of such combinations using theoretical methods. Then you can compare your experimental values to the predictions of theory. For now, try to predict what combination methods would increase or decrease effective capacitances. Some combinations that you may try are as follows:

