CAPACITORS

Introduction: In this lab, we use a "charge-sharing" technique to determine the capacitance of various conductor-dielectric geometries. Text Reference: Y&F 24.1-2.

Procedure: You will use a power supply to charge a capacitor, then carefully touch that capacitor's leads to the leads of a second capacitor (uncharged in most cases) so that the charge on the first capacitor is shared with the second.

Before beginning the formal experiment, you must learn how to measure the voltage across a charged capacitor. Digital voltmeters, due to finite internal resistance, always draw some current when connected across a charged capacitor, thereby leaking charge. To overcome this problem, we will use a custom-built unit which draws less than one picoamp, and which gives identical input and output voltages; we call this device a "voltage follower."

IMPORTANT: The RED input on the voltage follower is connected directly to a sensitive semiconductor device. It is designed to measure voltages from -10 V to +10 V. It is easy to destroy this device by exposing it to a high voltage like the one you might generate if not grounded properly. So be sure that one hand is touching the metal case of the unit while manipulating the RED input.

Mount a 0.1 μF capacitor (the smaller blue capacitor) on the styrofoam block. Use the power supply to charge this capacitor to a voltage of 5.0 V, then disconnect the power supply. Attempt to measure the capacitor voltage directly with a digital voltmeter (DVM). You should observe the voltage on the DVM dropping rather quickly to zero.

Now mount the 0.1 μF capacitor across the input of the voltage follower. Connect the DVM to the output of the unit. (Make sure the computer interface is turned on; this powers the voltage follower.) Again use the power supply to charge the capacitor to a voltage of 5.0 V; this time the DVM should read a constant 5.0 V. Now discharge the capacitor by shorting the input of the voltage follower with a wire lead (or touch both capacitor leads simultaneously with an alligator clip). Once again the voltage on the DVM should drop rather quickly to zero. You may observe some short-lived "rebound" in the DVM voltage due to lingering polarization in the dielectric of the capacitor.

For the formal experiment, begin with a pair of capacitors in parallel. Leave the 0.1 μF capacitor mounted across the input of the voltage follower and mount a 1.0 μF capacitor (the larger blue capacitor) on the styrofoam block; connect the two capacitors (the connectors with small hooks are useful here) to create a 1.1 μF capacitor. Make sure that the 1.1 μF capacitor is completely discharged. Charge a second 1.0 μF capacitor to 5.0 V (you can do this by holding the second capacitor by its plastic cover and inserting its leads into the power-supply outlets) and touch it to the uncharged 1.1 μF capacitor (to protect the voltage follower, please connect positive to positive). For safety, discharge the "charge-transfer" capacitor before putting it down. Compare the measured voltage (the DVM reading) to what is expected from a theoretical calculation.

Now discharge the 1.1 μF capacitor, then repeat the above steps using a 0.1 μF capacitor as the charge-transfer capacitor (instead of a 1.0 μF capacitor). Once again, compare the DVM reading to what is expected from a theoretical calculation.

This time, do not discharge the 1.1 μF capacitor. Recharge the 0.1 μF charge-transfer capacitor to 5.0 V and connect it again across the 1.1 μF capacitor, taking care to maintain the proper polarity. You should observe that the DVM voltage increase is a little less this time. Compare the DVM reading to what is expected from a theoretical calculation and explain why the increase in voltage is a little less for the second charge transfer. What do you expect for a third charge transfer without discharging the 1.1 μF capacitor? Do the experiment and report your results.

Now charge the 1.1 μF capacitor to 5.0 V. Share the charge on this capacitor with an uncharged capacitor of unknown capacitance (the capacitor covered with black electrical tape), and from the final DVM reading determine the unknown capacitance. You can share the charge by holding the uncharged capacitor and touching its leads to the leads of the charged 1.1 μF capacitor. Report this "measurement" of capacitance and compare with a second measurement taken directly with the capacitance capability of the DVM.

Finally, we wish to measure the capacitances of a length of coaxial cable and of a parallel-plate capacitor. Construct the parallel-plate capacitor by inserting the wax paper between the aluminum plates; press the combination together by putting a 1.0 kg weight on top of the top plate. Both of these capacitances are quite small, so we will need to alter our standard capacitor. Remove the 0.1 μF capacitor and mount a 0.01 μF capacitor (the smaller brown capacitor) across the input of the voltage follower; disconnect the second capacitor mounted on the styrofoam. We must now take into account the small capacitance of the voltage follower, which we have thus far ignored. Use the capacitance capability of the DVM to measure the combined capacitance of the 0.01 μF capacitor and the voltage follower (it should be approximately twice the capacitance of the 0.01 μF capacitor alone); this is our standard capacitor. Reconnect the DVM to the output of the voltage follower and then charge the standard capacitor to 5.0 V using the power supply. Use the charge-sharing method to determine the two unknown capacitances. Compare your results to "direct" measurements of those capacitances with the capacitance capability of the DVM (the DVM internally performs a similar experiment). How would pressing the two parallel plates together more tightly affect their capacitance? Try it and report your results.

Prelab Quiz PHY132
Capacitors

Name
Section Time and Day

1. A capacitor stores 53 μC of charge when connected to a 6.0 V battery. How much charge would the capacitor store when connected to a 9.0 V battery?

2. What voltage is required to store 72 μC of charge on the plates of a 6 μF capacitor?

3. Suppose after charging a 1 μF capacitor to 10.0 V, you connect it to another already-charged capacitor of 4.7 μF and 5.0 V (the connection is made with matching polarity). What is the resulting voltage across the two capacitors?