LAB 8. RC CIRCUITS

Problem

How does a capacitor's votage change as it charges and discharges?

Equipment

DC power supply, breadboard, switch, large capacitor, connector wires, precision resistor box, voltmeter, timer

Background

A capacitor in series with a resistor charges and discharges in an exponential decay. If the capacitor is charging up to voltage V_f from an initial charge of 0, its voltage theoretically obeys $V = V_f (1 - e^{-t/\tau})$. If it is discharging from an initial voltage of V_0, its voltage theoretically obeys $V = V_0 e^{-t/\tau}$. Here, τ is the time constant of the system.

In this lab, you will measure the voltage across the resistor that is in series with the capacitor while the capacitor charges and discharges. From the data, you will determine the time constants of the circuits, and from those you will estimate the capacitance of the capacitor.

Activity

Use a single capacitor and two different resistances. Measure the progress of the charging and discharging twice for each capacitor-resistance combination.

Charging the capacitor

1. Measure and record the resistance of the resistor. Read and record the nominal capacitance of the capacitor.
2. Discharge the capacitor by shorting it. Set up a circuit so that the capacitor is in series with a resistor and the switch. **Make sure that the capacitor is connected so that its (+) terminal is at higher potential than its (−) terminal**. When you are ready to begin, turn on the DC power supply and verify its voltage with the voltmeter. Then set up the voltmeter to measure the voltage across the resistor.
3. Close the switch. At the same time, start the timer. Every five seconds, record the voltmeter reading.
4. Continue until the voltage reading is no more than 10% of its original reading.
5. When you are finished, short the capacitor to discharge it.

Discharging the capacitor

1. Set up the circuit so that the capacitor is in series with the resistor and switch. Connect the DC power source to the capacitor (If the capacitor has labeled polarity, connect

positive to positive, negative to negative) and power up the capacitor. Verify that the capacitor is charged.

2. Set up the voltmeter to measure the voltage across either the resistor or the capacitor.
3. Disconnect the power source from the capacitor.
4. Quickly close the switch. At the same time, start the timer. Every five seconds, record the voltmeter reading.
5. Continue until the voltage reading is no more than 10% of its original reading.
6. When you are finished, short the capacitor to discharge it.

Data Processing

Theoretically, all of your data should follow the relationship $V = V_0\, e^{-t/\tau}$. If that is true, a plot of V (vertical axis) vs. t (horizontal axis) will be an exponential decay with an asymptote of zero. However, taking the natural logarithm of both sides of the equation yields $\ln(V) = \ln(V_0) - t/\tau$. Plotting the *transformed* data—$\ln(V)$ (vertical axis) vs t (horizontal axis)—should give a straight line with a y-intercept of $\ln(V_0)$ and a slope of $-1/\tau$. A linear trend line to the plot of this transformed data provides a way to estimate the time constant τ.

Transform your data (measured voltages) by taking logarithms. Plot $\ln(V)$ vs. t for each experiment and find the best-fit slope for each graph to estimate τ. Use the theoretical relation $\tau = RC$ to find the capacitance of the capacitor.

Lab Report

Report your observations and findings in a written report with sentences and paragraphs.

- Report your measurements of the resistances of the resistors you used. Report the nominal capacitance of the capacitor, if you could find it.
- Display the plots of observed V (vertical axis) vs. time (horizontal axis).
- Display the corresponding linearized plots, their trend lines, and trend line equations.
- Discuss whether the observations support the theoretical model of exponential decay. (Are the linearized data plausibly linear?)
- Discuss the similarity of the estimated capacitances to each other and to the nominal capacitance.