LAB 7. RC CIRCUITS

Problem

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

Equipment

DC supply: DC Power supply, breadboard, switch, large capacitor, connector wires, resistors, voltmeter, timer

Square wave supply: Signal generator (computer with DataStudio installed, ScienceWorkshop 750 Interface), connector wires, precision resistor box, oscilloscope, capacitor, resistor

Background

A capacitor in series with a resistor charges and discharges in an exponential decay. If the capacitor's starting voltage is V_1 and the input voltage is switched to V_2 at time $t = 0$, the capacitor's voltage decays as $V = V_2 + (V_1 - V_2)\, e^{-t/\tau}$, where τ is the time constant of the system.

Activity

There are two activities. You may complete them in any order. However, we have only one oscilloscope and signal generator, so you may have to wait for it.

DC Supply

Repeat the charging and discharging experiments three times for good statistics.

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 (**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 the resistor.
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.

Square wave and oscilloscope

1. Set the signal generator to produce square wave output with an amplitude of 1 V. Connect the ground of the oscilloscope to the ground of the signal generator. Also connect the negative terminal of the circuit to the ground of the signal generator.
2. Connect the Channel 1 probe of the oscilloscope to the signal output of the signal generator. Verify that the output is a square wave, and verify the vertical (voltage) and horizontal (time) scales. (If the horizontal scale is off, you can adjust it using the "Horizontal Var Sweep" knob.
3. On the breadboard, make a series circuit in the order signal generator – resistor– capacitor – ground. Place the oscilloscope (Channel 1) probe at the input to the capacitor. Adjust the frequency and resistance to show good decay progress. Sketch the trace. Note the amplitude and period of the signal.

4. Exchange the capacitor and resistor so that the order is signal generator – capacitor – resistor – ground. Place the oscilloscope probe at the input to the resistor. Sketch the trace. Note the amplitude and period of the signal.

5. Measure and record the half-life $t_{½}$, the time for the signal to decay to ½ its initial value.
6. Repeat measuring the half-life with two more resistances. You may need to adjust the frequency of the signal and the parameters of the oscilloscope.

Data Processing

DC Source

Use a transformed linear fit to find the time constant τ from each charging and discharging trace. From this value and the measured resistance, find the capacitance of the capacitor.

Square Wave

Calculate the time constant τ from each measured half-life. From the resistance and the time constant, determine the capacitance of the capacitor.

Lab Report

Report your observations and findings in a written report with sentences and paragraphs. Make one section for the DC activity and one for the square wave activity.

DC source

Show the plots of observed *V* (vertical axis) vs. time (horizontal axis). Show the corresponding linearized plots, their trendlines, and equations. Discuss the similarity of the estimated capacitances to each other and to the nominal capacitance.

Square Wave

Report the qualitative shapes of the voltage signals across the capacitor and resistor, along with their periods and amplitudes. Describe your experimental approach. Report your decay half-lives and estimated capacitance. Discuss the agreement of the estimated capacitances with each other and with the nominal capacitance of the capacitor (if you could find it).