LAB 5. 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, resistors, multimeter, timer

Background

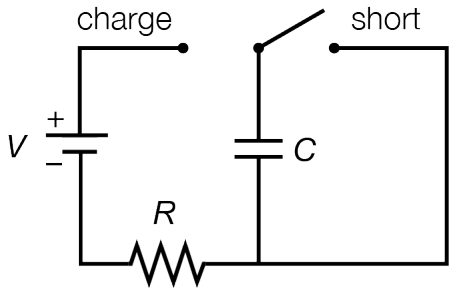
A capacitor in series with a resistor charges and discharges as a decaying exponential. If the capacitor's starting voltage is V_1 and the voltage across the capacitor + resistor is switched to V_2 at time $t = 0$, the capacitor's voltage V decays as $V = V_2 + (V_1 - V_2)\, e^{-t/\tau}$, where τ is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

Activity

Repeat the charging and discharging experiments at least twice for good statistics. Ideally, examine at least two capacitors, each combined in series separately with at least two different resistors. If time is short (isn't it always?), you may run the charging experiments with just one Capacitor-Resistor combination, and run discharges only with the others.

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. **If the capacitor is polarized, make sure that it is connected so that its (+) terminal is at higher potential than its (−) terminal**.



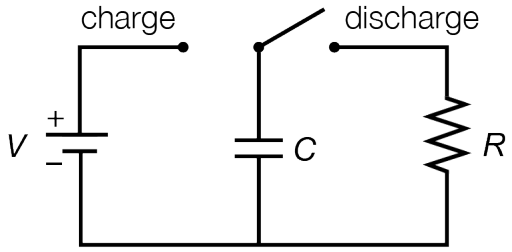
   When you are ready to begin, turn on the DC power supply and verify its voltage with the voltmeter. Then set up the voltmeter to measure the voltage across the resistor.

3. Close the switch. At the same time, start the timer. Every five seconds, record the voltmeter reading. It may be helpful to observe the decay informally a few times to get an idea of the time interval you should allow between measurements.
4. Continue until the voltage reading is no more than 10% of its original reading (unless the discharge is really slow).
5. When you are finished, short the capacitor to discharge it.

Charging the Capacitor again

1. Set up and run this the same as the previous activity, but this time monitor the voltage across the *capacitor*.

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. Switch from charging to discharging the capacitor. 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.

Other questions to ponder

Does the capacitor "leak," that is, do charges equilibrate through the capacitor itself, without linking the terminals to a circuit? If so, how can you determine that it is happening? How can you characterize and model this?

Is the voltmeter infinitely resistive, or does it allow some current to flow? If it does allow current to flow, how could we detect and model that?

How will the voltage across a capacitor behave if the capacitor is connected in series or parallel with another capacitor?

Data Processing

Enter your (*t*, *V*) data from V_R of the charging experiments and V_C of the discharging experiments into a spreadsheet. Calculate a new column of ln *V*. Use the spreadsheet to fit a straight line to the (*t*, *V*) values. The equation for the straight line will be in the form $\ln V = \ln V_0 - {}^{t}/_{\tau}$; that is, a straight line with a slope of $-1/\tau$ and a *y*-intercept of $\ln V_0$. From the fitted straight line, you can find the initial voltage and the time constant τ of the system. From the time constants and resistances, you can estimate the capacitance of the capacitors.

Checking Out

Show your instructor your spreadsheet of data, graphs, and calculations. Answer any clarifying questions they ask.