

Lab 4 – RC Circuits

Name _____

Partner's Name _____

I. Introduction/Theory

Consider a circuit such as that in Figure 1, in which a potential difference is applied to the series combination of a resistor and a capacitor. During any interval in which a constant potential difference is applied to the RC combination, the capacitor charges or discharges exponentially and the current to the capacitor and resistor has the form

$$I(t) = I_o e^{-\frac{t}{RC}} \quad (1)$$

The quantity RC is called the time constant of the RC combination. It has the dimensions of a time; in effect, it is an estimate of the time required to make a change in the potential differences in the circuit. From (1), the time of one time constant, RC , will lower the current or voltage by ~38%.

$$\text{i.e. } I(t = RC) = I_o e^{-\frac{t=RC}{RC}} = I_o e^{-1} \cong I_o 0.38$$

The current through the resistor will be directly proportional to the voltage across the resistor, therefore

$$V_R(t = RC) \cong V_o 0.38 \quad (2)$$

By measuring the time it takes for the voltage across the resistor to drop to ~0.38 of its original value, the circuit's time constant is being measured. Alternatively, the time constant can be determined by measuring the time it takes to for the voltage to drop to 50% of its original value, $\tau_{1/2}$. Where

$$\tau_{1/2} = \ln(2)RC \cong 0.69RC \quad (3)$$

The voltage source in the experiment is a 1 - 2 Hz square wave produced by a function generator, providing a constant voltage for 250 - 500 ms in each half-cycle. This is a charging RC circuit when the voltage is positive (see Figure 2a) and a discharging RC circuit when the voltage is zero (see Figure 2b). For each corresponding time interval, the current in the circuit, and accordingly the voltage across the resistor, will depend on time according to (1). While the value of the circuit's time constant, RC , will depend on (2) and (3). *You will use this property to determine the capacitance of each circuit.*

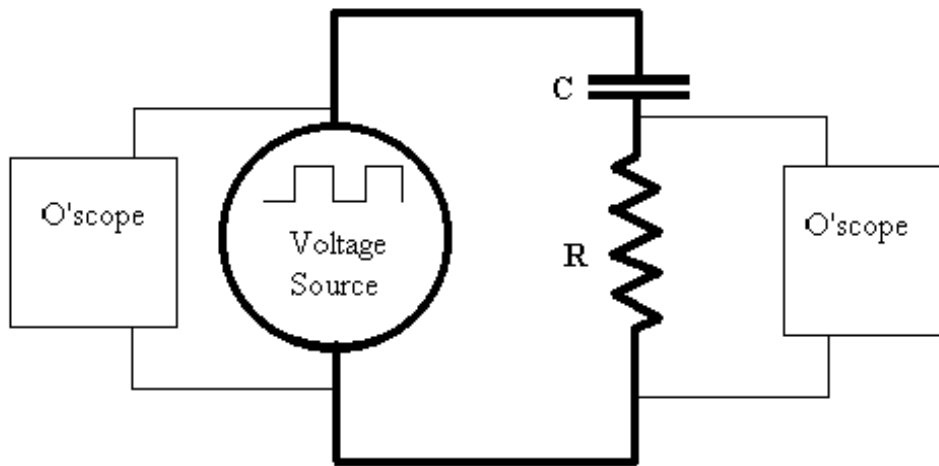


Figure 1

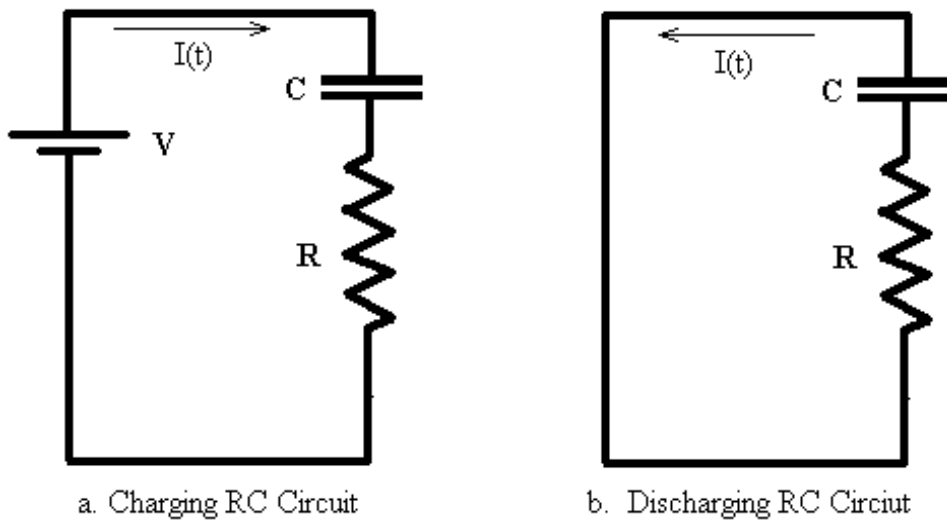


Figure 2

II. Equipment

Wave Function Generator

Oscilloscope

~500 and ~150 Ω resistors

~1000 and ~3300 μF capacitors

Clip leads with connectors and BNC connectors

Multimeter

III. Procedure/Data

1. Use the digital voltmeter to measure the value of the resistance of each resistor at your station. Be sure to use a scale that permits at least three significant figures. The two resistors look similar and have similar resistance, label each one to verify which is which. Record the resistance.

1. _____ Ω

2. _____ Ω

2. Configure a complete RC circuit with the $\sim 1000 \mu\text{F}$ capacitor and one $\sim 500 \Omega$ resistor as per Figure 1. The function generator should have a square wave form from 0 volts to a peak voltage of 2 - 4 volts and a frequency of 2 Hz.
3. Adjust the oscilloscope until the charging (and discharging) resistor voltage is clearly visible. Determine and record the time constant RC via (2) and/or (3). The function generator may need to be adjusted to a frequency of 1 Hz. Verify setup with instructor!

RC = _____ sec.

4. Repeat steps 2 and 3 with the $\sim 3300 \mu\text{F}$ capacitor. Verify setup with instructor.

RC = _____ sec.

5. Repeat steps 2 and 3 with the ~ 1000 and $\sim 3300 \mu\text{F}$ capacitors in series. Verify setup with instructor!

RC = _____ sec.

6. Repeat steps 2 and 3 with the $\sim 3300 \mu\text{F}$ capacitor and two $\sim 500 \Omega$ resistors in parallel. Verify setup with instructor!

RC = _____ sec.

7. Repeat steps 2 and 3 with the $\sim 1000 \mu\text{F}$ capacitor and two $\sim 500 \Omega$ resistors in parallel. Verify setup with instructor.

RC = _____ sec.

8. Repeat steps 2 and 3 with the $\sim 3300 \mu\text{F}$ capacitor and two $\sim 500 \Omega$ resistors in series. Verify setup with instructor!

RC = _____ sec.

9. Repeat steps 2 and 3 with the $\sim 1000 \mu\text{F}$ capacitor and two $\sim 500 \Omega$ resistors in series. Verify setup with instructor.

RC = _____ sec.

3. From the two values of capacitance in analysis steps 1 and 2, calculate the effective capacitance in procedure step 5. Include the calculation of the uncertainty in this effective capacitance.

4. From the observed time constants in procedure step 5 and the measured resistance, the effective capacitance for the two capacitors can be determined. Statistically compare this effective capacitance with the effective capacitance and uncertainty of the previous step.

- V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)