The RC Series Circuit

Purpose: To study some of the characteristics of an RC series circuit

Equipment Needed: Low voltage power supply, 90 volt power supply, Lab Pro, Voltage Pro, stop watch, various capacitors and resistors (both decade and individual), square wave generator, oscilloscope, neon bulb, small breadboard

Introductions: An RC series circuit is shown in Figure 1. When the switch is closed, the capacitor will begin to charge. At any instant, the sum of the voltage drops around the loop will equal zero (Kirchhoff's Loop Theorem):

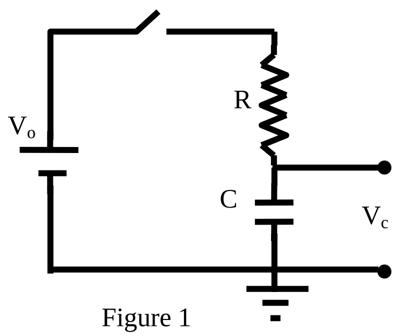

Figure 1

$$V_o - IR - Q/C = 0$$

or $$V_o = Q/C + R\, dQ/dt \quad \text{since } I = dQ/dt$$

This is a differential equation whose solution is

$$Q(t) = CV_o(1 - e^{-t/RC})$$

where we have assumed that the capacitor is initially uncharged. Since the voltage, V_c, across the capacitor is Q/C we can write V_c as a function of time as

$$V_c(t) = Q(t)/C = V_o(1 - e^{-t/RC})$$

The product RC is called the time constant of the circuit since for t = RC, $V_c = V_o(1 - e^{-1}) = 0.63\ V_o$. In other words, the voltage across the capacitor rises to 63 percent of the battery voltage in one time constant.

Procedure I:

A. Set up the circuit shown in Figure 1 with C = 1 F and R = 50 ohms. Use a battery voltage (V_o) of no more than 4 volts. Have your instructor check your circuit to be sure that you have the polarity of the capacitor correct (black band is the negative terminal of the capacitor). Load the **Logger Pro** software. Open the **Electricity and Magnetism** folder and then open **RC Series Circuit** file. Close the switch to begin charging the capacitor and, and the same time click **Collect** key to record and plot voltages, collect data for five minutes. Select **Analyze/Curve Fit** and see if your data conforms to the exponential function given above. Label your graph appropriately and obtain a printout.

B. From the graph determine the time that it took for the voltage to rise to 63 percent of its maximum value. This time is the time constant for this circuit. Compare with the theoretical value for the time constant.

Procedure II:

A. Set up the circuit of Figure 1 again, but this time replace the battery and switch with a square wave generator so that the capacitor can charged and discharged many times each second (equivalent to opening and closing the switch many times each second). Also, set R = 10k ohms and C = 0.01 μF. Adjust the frequency of the square wave generator to about 1 kHz. With the help of your instructor, observe the square wave output of the generator and the voltage across the capacitor with an oscilloscope.

B. Determine as accurately as possible the value for the time constant from the oscilloscope. Make a careful sketch of the oscilloscope waveform. Record the horizontal and vertical scales and explain how the time constant was determined. Compare with the calculated value. Vary the frequency of the square wave generator to see what effect this has on the shape of the waveform seen on the oscilloscope. Similarly, vary the values for R and C and observe the effect.

Procedure III:

Note: The voltage in this part is high enough to cause injuries. If you have questions ask for help.

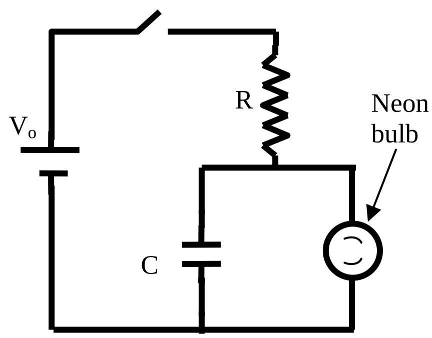

Figure 2

A. Your instructor will explain the operation of the relaxation oscillator circuit shown in Figure 2. Before wiring the circuit, connect the neon bulb across the power supply and slowly increase the voltage (V_2) until the bulb fires. Now decrease the voltage (V_1) until the bulb turns off. Record these firing and cutoff voltages.

B. In the following, **DO NOT connect or turn on the power supply until your instructor has checked your circuit**. Set up the circuit shown in Figure 2 using the small bread board for making connections. Use a resistance of 1 or 2 Mohms and a capacitance of 0.82MFD or 2.2 μF. The voltage of the power supply will be adjusted, by your instructor, so that V_o = 100 volts. Once your circuit has been checked out, get the circuit operating and observe the flashing neon bulb. The bulb should flash at a rate of one flash for every one or two seconds. Carefully determine the period for the flashing neon bulb by measuring twenty or so periods and averaging.

C. The formula (without proof) for calculating the time T, between flashes of the neon bulb is

$$T = RC \ln[(V_0 - V_1)/(V_0 - V_2)]$$

Using the above values for V_o, C, and R, calculate T and compare with the value measured in part B.