UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 10 – TIME CONSTANT OF AN RC CIRCUIT

OBJECTIVES

The purpose of this experiment is to measure the time constant of an RC circuit experimentally and to verify the results against the values obtained by theoretical calculations.

MATERIALS/EQUIPMENT NEEDED

Digital Multimeter
DC Power Supply
Alligator (Clips) Jumper
Resistor: 20kΩ
Capacitor: 2,200 µF (rating = 50V or more)

INTRODUCTION

The time constant of RC circuits are used extensively in electronics for timing (setting oscillator frequencies, adjusting delays, blinking lights, etc.). It is necessary to understand how RC circuits behave in order to analyze and design timing circuits.

In the circuit of Figure 10-1 with the switch open, the capacitor is initially uncharged, and so has a voltage, V_c, equal to 0 volts. When the single-pole single-throw (SPST) switch is closed, current begins to flow, and the capacitor begins to accumulate stored charge. Since Q=CV, as stored charge (Q) increases the capacitor voltage (V_c) increases. However, the growth of capacitor voltage is not linear; in fact it is an exponential growth. The formula which gives the instantaneous voltage across the capacitor as a function of time is

$$V_c = V_S\left(1 - e^{\left(-t/\tau\right)}\right)$$

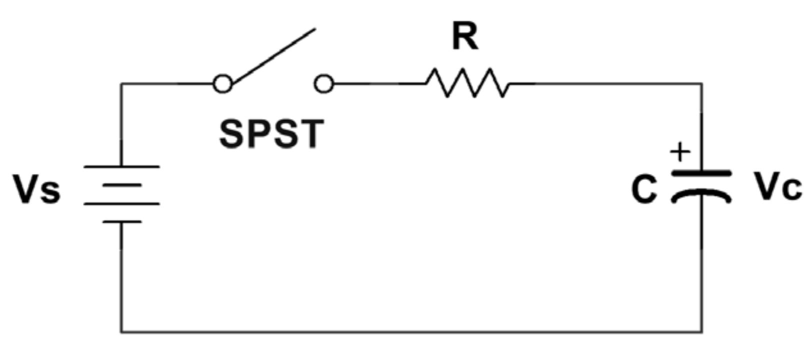

Figure 10-1 Series RC Circuit

This formula describes exponential growth, in which the capacitor is initially 0 volts, and grows to a value of near V_s after a finite amount of time. It is important to understand each term in this formula in order to be able to use it as a tool. The following definitions describe each of these symbols:

V_s: The limiting value of capacitor voltage as t approaches infinity. The capacitor voltage will reach 99% of this value during a time lapse of five time constants.

t: The lapsed time in seconds that the circuit voltages and currents have been changing.

τ: The time constant of the circuit. The symbol is the Greek lower case letter TAU. τ is the product of R and C ($\tau = RC$) in ohms and farads, and the unit is seconds. R is the total resistance in series with the capacitor and C is the total capacitance of the circuit.

V_c: The capacitor voltage at any instant of time after the switch closes.

e: The base of natural logarithms, a constant which equals about 2.7183.

It is important to mention that for an RC circuit after five time constants the circuit is assumed to be in the “steady state” condition. While in theory it takes an infinite time for “steady state” conditions to be reached, in practical terms, after five time constants it is nearly impossible to observe further changes.

PRELAB

1. Use Figure 10-1 and the equation for the capacitor voltage to derive an expression for current in terms of time, τ, e and initial current.

PROCEDURE

1. Construct the circuit in Figure 10-2 below. Let R = 20 kΩ, C = 2,200 μF (rating = 50V or more), Vs = 35 V. Use an alligator lead jumper as the short circuit across the capacitor.

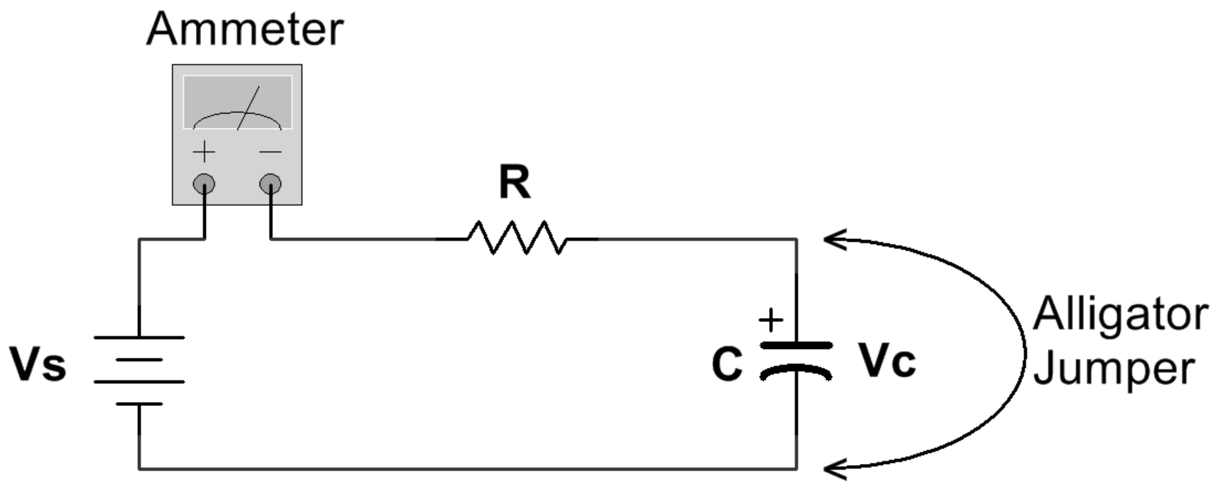

Figure 10-2 Series RC Circuit for Experimental Setup

Note to Instructor: *Source voltage Vs, R and C are chosen to give a maximum current just under 2.000 mA, and a time constant of about 45 seconds to 1 minute. Other values of R, C and Vs may be used, as needed, depending on the equipment and components available.*

2. Record the initial current reading of the milliammeter; it should be closed to “full-scale” for a digital meter on the 2 mA range (I = [35 V/20 kΩ]). Express the current in units of mA. Write the value in Table 10-1, for t = 0, columns Trial One and Trial Two.
3. Calculate the values of τ and 5τ. Recall that it takes a time of 5τ for a capacitor to substantially reach fully charge. You may need to extend your data table to ensure that data is taken for a time of no less than 5τ.
4. Now get ready to collect the data. This is best done with your partner, but can be done successfully by one person. You will need a stopwatch (you can use your phone), or an analog clock with a second hand.
5. The instant you remove the alligator jumper, the current (which had been flowing through the jumper) flows through the capacitor. This is time = 0, and you will begin recording data every 15 seconds after that instant.
6. Every 15 seconds, record the current under the Trial One column in Table 10-1, until you have reached 5τ or beyond.
7. Now repeat steps 4 to 6 under Trial 2. Be sure to replace the alligator jumper before starting Trial Two. There will be a significant spark the moment you put the jumper across the capacitor, resulting from the rapid discharge of the energy stored in the capacitor, which brings its voltage back to 0 volts.

8. The results of Trial One and Trial Two will then be averaged, because obtaining accurate repeatable readings when the current is changing is difficult.
9. Average the currents (Trial one and Trial two) for each row in the data table, and enter that average current in the table. At each time in the table using the average current at that time, calculate the resistor voltage using $V_R = IR$ (ohm's law). Be sure to use the measured value of R.
10. Now for each time in the table using the calculated resistor voltage, calculate the capacitor voltage using $V_c = (V_s – V_R)$. Be sure to use the measured value of R. This is just Kirchoff's voltage law applied: The sum of the resistor voltage and the capacitor voltage must equal the source voltage.

DATA/OBSERVATIONS

Table 10-1: Data Table for RC Time Constant

τ = **Initial Current =**

5τ =

Time (min:sec)	Current (mA)			Resistor Voltage (V)	Capacitor Voltage (V)
	Trial 1	Trial 2	Average		
0:00					
0:15					
0:30					
0:45					
1:00					
1:15					
1:30					
1:45					
2:00					
2:15					
3:30					
3:45					
4:00					
4:15					
4:30					
4:45					
5:00					
5:15					
5:30					
5:45					
6:00					

INSTRUCTOR'S INITIALS: ____________ DATE: ____________

POST-LAB

1. From the data obtained in this experiment in a single graph;
   a. Plot V_R vs. time
   b. Plot V_c vs. time

2. After the graphs have been completed, do the following:
   a. Describe the capacitor voltage behavior from 0 through 5τ, in terms of initial and final voltage magnitude, linearity and rate of change.
   b. Describe the resistor voltage behavior from 0 through 5τ, in terms of initial and final voltage magnitude, linearity and rate of change.
   c. To how many volts has V_c charged in one time constant?
   d. To what % has the capacitor charged to at this point?
   e. Using the equation in the introduction section of this experiment, show the calculation of V_c for a time equal to one time constant.
   f. How many volts are across the resistor at the end of one time constant? What % is this of the total possible voltage change?
   g. From the graphs read the values of capacitor and resistor voltage at 4 minutes.
   h. Calculate the values of capacitor and resistor voltage at 4 minutes.
   i. From the results of g and h above, what do you conclude about the accuracy of your graphs?

Be sure to include all items from the post-lab exercise above in your written lab report.