UNIVERSITY OF MIAMI
Department of Electrical and Computer Engineering
EEN 203

Name: ____________________
Section: ____________________
Date: ____________________

EXPERIMENT 3

TRANSIENT ANALYSIS OF SIMPLE RC CIRCUITS

PURPOSE: In this experiment we shall study two simple circuits containing resistors and capacitors. When circuits contain only capacitors and inductors and no active elements (i.e., diodes, transistors, op-amps, etc) they are referred to as *RC* or *RL* circuits. The application of Kirchhoff's laws to these circuits gives rise to first order differential equations. The solutions give insight into the behavior of circuits in response to the sudden application of current or voltage signals. In general, these responses tell us how fast a circuit can respond to external inputs. When sources are suddenly connected to these circuits, they produce two kinds of responses. The first is the *natural response* that is characterized by the nature of the circuit itself and is of exponential nature for *RC* and *RL* circuits. The second response is the *forced response* and depends on the forcing or driving function and the steady state behavior of capacitors and inductors. From the natural responses, we will be able to determine charging and discharging times (*time constants)* for a particular circuits. When the circuit is pure RC or RL, the charging and discharging times are generally equal (see parts a and b in the preliminary work). Some circuits utilize active components in order to have different charging and discharging times.

Equipment

2 Variable resistance boxes
1 0.1 μF capacitor
1 Digital Oscilloscope
1 Frequency Generator
1 1N4001 Diode

Preliminary Work

a) Assuming the source of Fig. 3.1 to be a step voltage of V_o volts, show that the capacitor voltage builds up according to the relationship

$$V_c(t) = V_o\,(1 - e^{-t/\tau})$$

Where the initial capacitor voltage is $V_c(0^+) = 0$ V and $\tau = RC$ is the time constant.

b) After a sufficient time, a short circuit is placed across the source. Show that the capacitor voltage decreases according to

$$V_c(t) = V_o\, e^{-t/\tau}.$$

c) Show that the charging and discharging time constants are given by the expressions $V_c(\tau_c)=0.632V_o$ and $V_c(\tau_d)=0.368V_o$ respectively.

Experimental Procedure

I. RC Circuit with Square Wave Input:

a) Set up the circuit shown in Fig. 3.1. Adjust the input voltage to vary from **0 to 5 V** and a frequency of 500 Hz (make sure that there is no dc offset in the waveform by viewing the waveform in the DC mode of the oscilloscope and varying the DC level knob in the signal generator). Make R = 1 kΩ and C = 0.1 μF. Note that you must account for the internal resistance of the signal generator for the theoretical calculations.

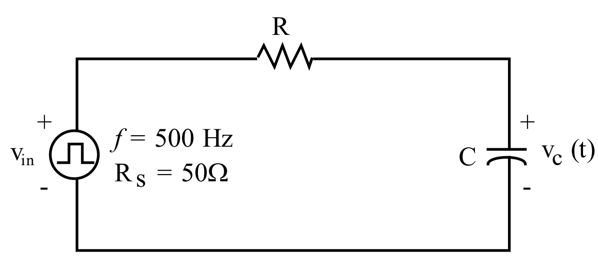

Figure 3.1 Driven *RC* network.

b) Calculate the time constant of the charging path, $(R_S+R)C$ τ_c = ___________

c) Calculate the time constant of the discharging path, RC τ_d = ___________

d) Sketch the waveform of the voltage across the capacitor, $V_c(t)$. Indicate the **maximum voltage, minimum voltage**, and the charging and discharging times.

e) Measure the charging time constant, τ_c = ___________

f) Measure the discharging time constant, τ_d = ___________

g) Calculate the % error for τ_c, % error τ_c = ___________

h) Calculate the % error for τ_d, % error τ_d = ___________

i) Vary R and *f* according to the values given in Table 3.1. Measure and calculate τ_c, τ_d, and the % errors. Use fixed resistance instead of the resistance boxes.

		Measured		**Calculated**		**% Error**	
R (Ω)	***f* (Hz)**	**τ_c (ms)**	**τ_d (ms)**	**τ_c (ms)**	**τ_d (ms)**	**τ_c**	**τ_d**
470	300						
	500						
	1000						
1000	300						
	500						
	1000						

Table 3.1 Measured and Calculated data for time constants of circuit in Fig. 3.1.

Note that the time constant is independent of frequency for the range considered in this experiment.

II. RC Circuit with Active Element:

a) Set up the circuit shown in Fig. 4.2. Adjust the input voltage to vary from **0 to 5 V** and a frequency of 500 Hz (use the procedure explained in I(a) to remove any DC offsets from the signal). Choose C = 0.1 μF. Measure τ_c and τ_d in each of the cases below and sketch the waveform of the voltage across the capacitor, $V_c(t)$. Indicate the **maximum voltage, minimum voltage**, and the charging and discharging times.

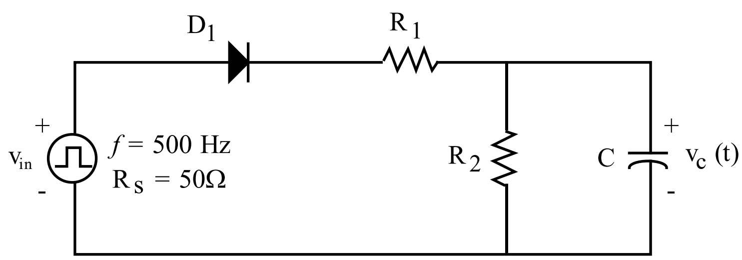

Figure 4.2 RC circuit wit different charging and discharging times.

(b) Set $R_1 = 470\ \Omega$, $R_2 = 470\ \Omega$.

$\tau_c =$ ____________

$\tau_d =$ ____________

(c) Set $R_1 = 1\ k\Omega$, $R_2 = 470\ \Omega$.

$\tau_c =$ ____________

$\tau_d =$ ____________

(d) Set $R_1 = 470\ \Omega$, $R_2 = 1\ k\Omega$.

$\tau_c =$ ____________

$\tau_d =$ ____________

Discussion of Results

a) Why would the measurements be inaccurate if higher frequencies were to be used?

b) In part II, why doesn't the capacitor voltage build up to the source maximum voltage?

c) In part II, explain the difference in τ_c and τ_d by deriving the necessary circuit equations.

d) Calculate the theoretical values of τ_c and τ_d for parts II.b, II.c, and II.d and find the % errors. Present the calculations in tabular form. Show one example calculation.

e) From the results of part II.b, estimate the forward drop across the diode. Assume a constant voltage drop across the diode when forward biased.

f) Write a conclusion.