**UNIVERSITY OF MIAMI**

Department of Electrical and Computer Engineering

EEN 203

*Name:*

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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 Vo volts, show that the capacitor voltage builds up according to the relationship

Vc(t) = Vo (1 − e−t/τ)

Where the initial capacitor voltage is Vc(0+) = 0 V and τ = 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

Vc(t) = Vo e−t/τ.

c) Show that the charging and discharging time constants are given by the expressions

Vc(τc)=0.632Vo and Vc(τd)=0.368Vo 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, (RS+R)C τc =

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

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

e) Measure the charging time constant, τc =

f) Measure the discharging time constant, τd =

g) Calculate the % error for τc, % error τc =

h) Calculate the % error for τd, % error τd =

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

|  |  | **Measured** | | **Calculated** | | **% Error** | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **R (Ω)** | ***f* (Hz)** | **τc (ms)** | **τd (ms)** | **τc (ms)** | **τd (ms)** | **τc** | **τd** |
|  | 300 |  |  |  |  |  |  |
| 470 | 500 |  |  |  |  |  |  |
|  | 1000 |  |  |  |  |  |  |
|  | 300 |  |  |  |  |  |  |
| 1000 | 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 τc and τd in each of the cases below and sketch the waveform of the voltage across the capacitor, Vc(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 R1 = 470 Ω, R2 = 470 Ω.  τc =  τd =  (c) Set R1 = 1 kΩ, R2 = 470 Ω.  τc =  τd =  (d) Set R1 = 470 Ω, R2 = 1 kΩ.  τc =  τd = |  |
| --- | --- |

***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 τc and τd by deriving the necessary circuit equations.

d) Calculate the theoretical values of τc and τd 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.