

Lab 3 – RC Time Constants

Equipment:

2 Resistors	2 Digital Multimeters
1 DC Power Supply	1 Breadboard
1 Capacitor	1 Stopwatch

Objectives:

To observe the natural response discharge behavior of a series RC circuit.

Theory:

Circuits containing only resistors connected to voltage sources have constant currents through the resistors and constant voltage drops across the resistors. However, if a capacitor is placed in series with a resistor, the current through the elements and the voltage across the elements becomes time dependent.

If we assume that the switch in the circuit shown below in Figure 1 has been closed for a “long” period of time, the voltage across the capacitor (V_c) will be equal to the voltage V_s . We define a “long” period of time as being at least 5τ , where $\tau = RC$, the time constant of the circuit.

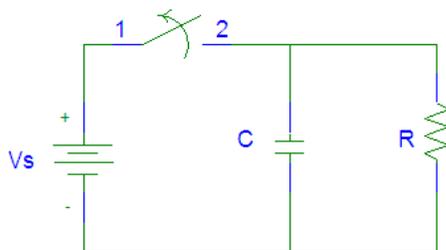


Figure 1: RC Circuit

Once the switch is open, the capacitor will begin to discharge through the resistor. Applying Kirchhoff's Current Law (KCL) to the top junction connecting the capacitor to

the resistor, we find an expression for the natural response of V_c as a function of time:

$$V_c = V_0 e^{-\left(\frac{t}{RC}\right)} \quad \text{Eq. (1)}$$

Where V_0 is the voltage across the capacitor at the instant the switch is open (in this case, the initial voltage $V_0 = V_s$). This equation is called the natural response of the RC circuit because current flow in the circuit is only a result of the discharge of stored energy in the capacitor.

Procedure:

Caution: Do not switch on power at any time during this experiment until your lab instructor has approved your circuit.

1. Construct the circuit shown in Figure 1 with $R = 470 \text{ k}\Omega$ and $C = 47 \text{ }\mu\text{F}$. For the switch, just use a wire that can be easily disconnected from the power supply. If your capacitors are electrolytic, they must be placed in the circuit with the negative side of the capacitor on the negative side of the power supply. Place the Wavetek multimeter in parallel with the capacitor, and set it to the 20 V DC setting.

2. Turn on the power supply and charge the capacitor until there is a 10 V potential difference across the capacitor as measured by the voltmeter. Simultaneously start your stopwatch while disconnecting the wire connecting the capacitor to the power supply

(effectively opening your switch). Record the times when the voltage across the capacitor is 37%, 14%, 5%, 2%, and 1% of your initial voltage V_0 . These times are your experimental 1, 2, 3, 4, and 5 time constant values, respectively.

3. Repeat Step 1 and 2 above, but replace the Wavetek multimeter with the Beckman multimeter, set to the 20 V DC setting.

4. Repeat Steps 1 through 3 above with $R = 2.2 \text{ M}\Omega$.

5. Have your lab instructor measure the actual values of all the resistors. Record these values.

Calculations:

1. Calculate the 1, 2, 3, 4, and 5 time constants for both circuits from $\tau = RC$ using the measured values of resistance and capacitance. Take these values to be your theoretical values.

2. For the data sets collected with the Wavetek multimeter, calculate the percent error between the theoretical and experimental time constants (these errors may be high).

3. For the data collected with the Beckman multimeter, calculate the percent error between the theoretical and experimental time constants.

Questions:

1. When you measured the voltage across the capacitor, you placed a voltmeter (a Wavetek or a Beckman) in parallel with the capacitor and resistor. Draw a circuit showing a parallel connection of the capacitor, resistor, and voltmeter for all of the configurations you tested in lab (there should be four). Use a $1 \text{ M}\Omega$ resistor to represent the Wavetek multimeter and a $22 \text{ M}\Omega$ resistor to represent the Beckman multimeter. Based on these circuits, what is

the most logical explanation for the high percent errors associated with the measurements made with the Wavetek multimeter?