102L/104L EXPERIMENT 4
ANALYZING RC CIRCUITS

4.1 Purpose

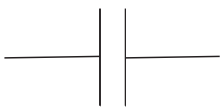
The purpose of the experiment is to analyze the characteristics of RC circuits and to learn the usage of capacitors.

4.2 Apparatus

Lab manual, stopwatch, DC power supply, resistors, capacitor, multimeters, cables, breadboard and graph paper.

4.3 Brief Description

A capacitor is a passive electric circuit device consisting of a pair of conductors separated by an insulator. A capacitor stores electrical potential energy and electrical charge. The capacitors are represented as in figure 4.1 in circuit diagrams. The picture of a commonly used capacitor is given in figure 4.2.



C

Figure 4.1: The circuit representation of a capacitor.

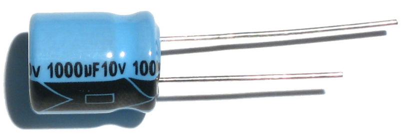


Figure 4.2: A picture of a commonly used capacitor.

The potential difference between the plates of the capacitor is given by

$$V = \frac{Q}{C}, \tag{4.1}$$

where Q is the charge stored on the capacitor. In fact the total net charge stored in a capacitor is zero since $+Q$ and $-Q$ are stored in single plates. In equation 4.1, C is defined as the capacitance of a capacitor.

While working with capacitors, keep in mind that the polarity of the capacitors are important. Connecting a capacitor in wrong polarity may explode it.

A resistor-capacitor circuit (RC circuit), or RC filter or RC network, is an electric circuit composed of resistors and capacitors driven by a voltage or current source. The 1st order RC circuit composed of one resistor and one capacitor, is the simplest example of an RC circuit. The schematic representation of a simple RC circuit is given in figures 4.3 and 4.3. When an external power supply is connected to the circuit, the capacitor stores energy and this circuit is called charging RC circuit.

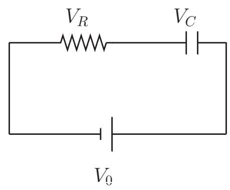


Figure 4.3: The circuit representation of an RC circuit(charging).

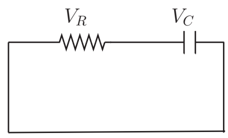


Figure 4.4: The circuit representation of an RC circuit(discharging).

While **charging**, the behavior of the capacitor can be calculated as follows:

$$\begin{aligned} V_0 &= V_R + V_C \\ &= R.I + \frac{Q}{C} \\ &= R\frac{dQ}{dt} + \frac{Q}{C}. \end{aligned} \tag{4.2}$$

Solving this differential equation, one gets the time behavior of the charge on a capacitor as

$$Q(t)_{\text{charging}} = Q_f\,(1 - e^{-\frac{t}{RC}}), \tag{4.3}$$
$$I(t)_{\text{charging}} = I_0\,e^{-\frac{t}{RC}}, \tag{4.4}$$
$$V_C(t)_{\text{charging}} = V_0(1 - e^{-\frac{t}{RC}}), \tag{4.5}$$

where $I_0 = V_0/R$ and $Q_f = V_0 C$.

While **discharging**, the behavior of the capacitor can be calculated as follows:

$$\begin{aligned} 0 &= V_R + V_C \\ &= R.I + \frac{Q}{C} \\ &= R\frac{dQ}{dt} + \frac{Q}{C}. \end{aligned} \tag{4.6}$$

Solving this differential equation, one gets the time behavior of the charge on a capacitor as

$$Q(t)_{\text{discharging}} = Q_f\, e^{-\frac{t}{RC}}, \tag{4.7}$$
$$I(t)_{\text{discharging}} = -I_0\, e^{-\frac{t}{RC}}, \tag{4.8}$$
$$V_C(t)_{\text{discharging}} = -V_0\, e^{-\frac{t}{RC}}. \tag{4.9}$$

For an RC circuit, a characteristic parameter is the time constant, which is defined as

$$\tau = RC. \tag{4.10}$$

Note that when $t = \tau$, the current on the RC circuit is

$$I(\tau) = \pm I_0 \times e^{-1} = \pm 0.37\ \mathrm{I}_0 \tag{4.11}$$

In this experiment you are going to measure the time constant of a RC circuit from I vs t graph.

4.4 Procedure

1. Construct the circuit given in figure 4.5.

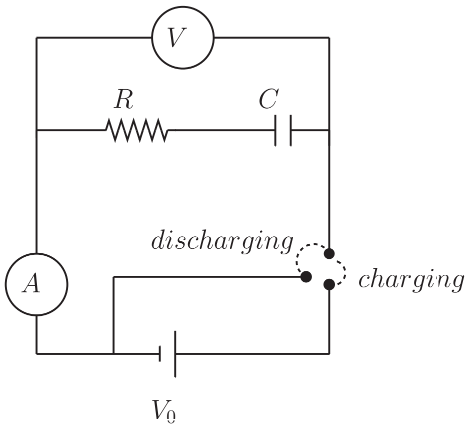


Figure 4.5: The circuit you are going to construct in this experiment.

2. By connecting a cable over the capacitor (i.e. shortcutting the capacitor), fully discharge the capacitor and measure I_0.
3. Place the switch in charging position and start the stopwatch, take $I(t)$ vs t data for the charging circuit.
4. **Without discharging the capacitor**, reset the stopwatch, disconnect the power supply.
5. Place the switch in discharging position and start the stopwatch, take $I(t)$ vs t data for the discharging circuit.
6. Plot I vs t graph for charging and discharging circuits.
7. By finding the time corresponding to the value of $I_0 \times 0.37$ from the graphs, find the experimental value of the time constant and compare with the theoretical value.

Name Surname	Section	Quiz	EXP	Grade

4.5 Data and Results

1. Record the values of R, C, V_0 and I_0 below.

R	
C	
V_0	
I_0	

2. After constructing the circuit given in 4.5, take I vs t data for both charging and discharging circuits and record below.

t_{charging}(s)	I(mA)	$t_{\text{discharging}}$(s)	I(mA)

3. Plot I vs t graphs and record the values of the time constant you obtained from the charging and discharging circuits.

τ_{charging}	
$\tau_{\text{discharging}}$	
$\tau_{\text{theoretical}}$	

4. Find the charge stored on the capacitor.

$$
\begin{aligned}
Q(t=\infty) &= V_0C = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
Q(t=t_{final}) &= V_0C(1-e^{-t_{final}/RC}) = \ldots\ldots\ldots\ldots\ldots\ldots
\end{aligned}
$$