RC Circuit

Lab #3

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RC Circuit

Objective

Infer the relationship between the time constant τ, resistance R, and capacitance C of an RC circuit.

1 Introduction

An RC circuit is a type of circuit made of a resistor and a capacitor connected in series, like so:

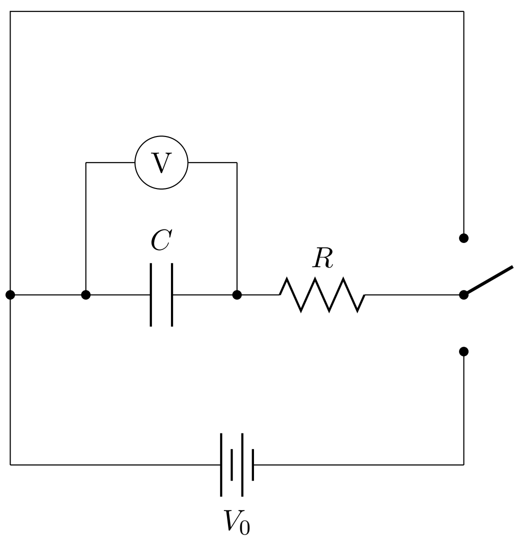

Figure 1: RC circuit

When a constant DC voltage V_0 is applied to the circuit, an electric field builds up inside the capacitor as it gradually charges. By Kirchhoff's voltage law, the circuit's behavior as a function of time is given by the first-order differential equation

$$V_0 - \frac{Q}{C} - R\dot{Q} = 0 \tag{1}$$

The solution to this equation is

$$V(t) = V_0\,(1 - e^{-t/RC}) \tag{2}$$

As t approaches infinity, $V(t)$ approaches V_0.

The time constant τ of an RC circuit is defined such that

$$V(\tau) = V_0\,(1 - e^{-1}) \approx 0.63\,V_0. \tag{3}$$

Therefore,

$$\tau = RC. \tag{4}$$

Note that τ does not depend on V_0: the greater the applied voltage, the faster the capacitor charges.

When a capacitor is discharging into an RC circuit, it produces an exponentially decaying direct current. As a function of time, this is

$$V(t) = V_0\, e^{-t/\tau} \tag{5}$$

Substituting $t = \tau$,

$$V(\tau) = V_0\, e^{-1} \approx 0.37\, V_0. \tag{6}$$

2 Procedures and Results

We set up the circuit shown in Figure 1. We set V_0 to 4.5 V, R to $1.6\,\mathrm{k\Omega}$, and C to $27\,\mu\mathrm{F}$. We turned on the power and took voltage measurements every 5 seconds for 45 seconds.

Table 1: Charging from a 4.5-V DC power source.

Time (s)	Voltage (V)	% of V_0
0	0	0.00%
5	1.01	22.44%
10	2.04	45.33%
15	2.93	65.11%
20	3.27	72.67%
25	3.31	73.56%
30	3.26	72.44%
35	3.22	71.56%
40	3.2	71.11%
45	3.18	70.67%

Next, we turned off the power and quickly disconnected the DC power source, so that the capacitor began to discharge. We took voltage measurements every 5 seconds for 60 seconds.

Table 2: Discharging after a 45-s charge.

Time (s)	Voltage (V)	% of V_0
0	3.18	100.00%
5	2.39	75.16%
10	2.11	66.35%
15	1.88	59.12%
20	1.69	53.14%
25	1.53	48.11%
30	1.38	43.40%
35	1.24	38.99%
40	1.12	35.22%
45	1.02	32.08%
50	0.92	28.93%
55	0.84	26.42%
60	0.72	22.64%

Then, we repeated these steps with a $200-\Omega$ resistor and $V_0 = 12$V.

Table 3: Charging with a $200-\Omega$ resistor for 60 s.

Time (s)	Voltage (V)	% of V_0
0	0	0.00%
5	6.14	51.17%
10	8.92	74.33%
15	10.33	86.08%
20	10.98	91.50%
25	11.34	94.50%
30	11.53	96.08%
35	11.62	96.83%
40	11.67	97.25%
45	11.71	97.58%
50	11.73	97.75%
55	11.74	97.83%
60	11.75	97.92%

Table 4: Discharging for 70 s.

Time (s)	Voltage (V)	% of V_0
0	11.76	100.00%
5	5.05	42.94%
10	2.36	20.07%
15	1.24	10.54%
20	0.67	5.70%
25	0.35	2.98%
30	0.2	1.70%
35	0.13	1.11%
40	0.08	0.68%
45	0.06	0.51%
50	0.04	0.34%
55	0.03	0.26%
60	0.02	0.17%
65	0.02	0.17%
70	0.02	0.17%

3 Discussion

We know from Eq. 3 that during charging, the voltage rises to about 63% of its maximum level after one time constant.

Similarly, by Eq. 6, during discharging, the voltage drops to about 37% of its original level after one time constant.

4 Conclusion

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