Capacitors in Parallel Connection

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April 2019

1 Theoretical Background

In this experiment we will investigate the serial connection of two capacitors. To read more about the fundamental features about the capacitors you may check Ref [1]. Please remember that the capacitance value of a parallel plate capacitor is,

$$C = \epsilon_0 \frac{A}{d}, \tag{1}$$

where C, ϵ_0, A and d are the capacitance, electrical constant, area of one plate and separation of two plates respectively. Electrical potential between two plates are determined by the capacitance as,

$$V = \frac{Q}{C}, \tag{2}$$

where V and Q are the electrical potential between plates and the absolute value of total charge on one plate. Imagine we have a circuit part of two capacitors connected in parallel. When we would replace the two parallel-connected capacitors with only one capacitor so that the replaced capacitance is equivalence of the parallel connected capacitors, then the total current over the two capacitors is equal to the current over the equivalence capacitor.

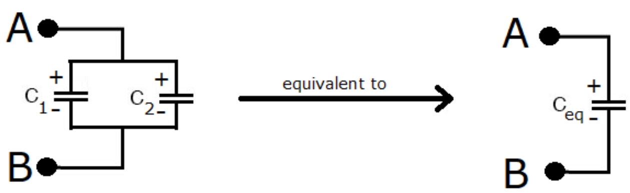

Figure 1: (Left) Two capacitors connected in serial. (Right) Equivalent of the circuit on the left.

$$I = I_1 + I_2, \tag{3}$$

$$Q_{eq} = Q_1 + Q_2 \tag{4}$$

and using Eqn.(2) we get,

$$V_{eq}C_{eq} = V_1C_1 + V_2C_2. \tag{5}$$

Because the capacitors are connected in parallel and because the third capacitor is the equivalence of them, the voltage values on them should be equal to one another.

$$V_{eq} = V_1 = V_2 \quad \Rightarrow \quad C_{eq} = C_1 + C_2. \tag{6}$$

The time constant of RC circuit which has two serial-connected capacitors is,

$$\tau = RC_{eq}. \tag{7}$$

Due to Eqn.(6), the equivalence capacitance is less then the capacitance values of the components. This should increase the time constant of a RC circuit and make the total duration of charging and discharging increased.

2 Procedure

2.1 Experimental Procedure

1. By using the power supply and a multimeter, adapt the source voltage 5V and immediately turn it off. Perform this step very quickly!
2. Set the circuit given in Fig (2) with a and $10k\Omega$ resistor and two $2200\mu F$ capacitors.
3. Calculate the time constant and seven times of the time constant of the circuit. Write these values down in Section 3.
4. Place a chronometer next to the voltmeter and ammeter. By using small pieces of paper, write the names of the multimeters (write which one is the voltmeter and which one is the ammeter.)
5. By using your phone's video feature, start recording the circuit while source is turned off and read the specifics of the circuit verbally so that the video can record your voice.* DO NOT STOP RECORDING.
6. Turn on the chronometer and the source simultaneously while recording. Record for you see approximately zero in ammeter and approximately source voltage in V_{eq}. DO NOT STOP RECORDING.But reset your chronometer.
7. After charging, turn off the source and turn on the chronometer simultaneously.
8. Keep recording until you see ≈ 0 at the voltmeter. When you see zero, you may stop recording.
9. Repeat steps 2-8 with $10k\Omega$ resistor, $1000\mu F$ capacitor and $2200\mu F$ as Part B.

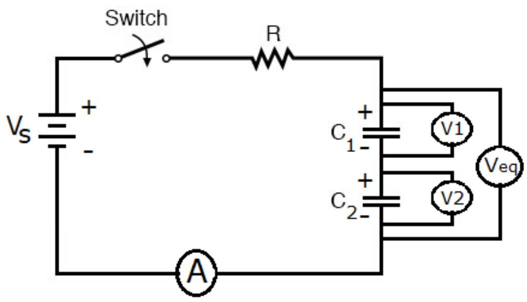

Figure 2: Circuit for the experiment.

2.1.1 Analysis Procedure

1. By watching the recordings fill all the tables in Section 3.
2. Plot the $V_{eq} - t$, $V_1 - t$ $V_2 - t$ on the same millimetric paper using different colored pens for both charging and discharging in all parts. You should have 4 compact coltage plots.
3. Plot $I - t$ graphs for both charging and discharging in all parts. You should plot 4 current graphs in total.
4. Using the source voltages, calculate 63% of it to analyze $V_{eq} - t$ plots during charging. Write them in Section 3.
5. Find the $0.63V_s$ value at the $y - axis$ and read the corresponding time value from $x - axis$ for the V_{eq} curve. This is your experimental τ value for $V_{eq} - t$ plots during charging.
6. Using the source voltages, calculate 37% of it to analyze $V_C - t$ plots during discharging. Write them in Section 3.
7. Find the $0.37V_s$ value at the $y - axis$ and read the corresponding time value from $x - axis$ for the V_{eq} curve. This is your experimental τ value for $V_{eq} - t$ plots during discharging.

*You should read the resistance, capacitance and source voltage values.

8. Using the source voltages, first calculate the initial current values and then calculate 37% of it to analyze $I-t$ plots during both charging and discharging. Write them in Section 3.

9. Find the $0.37I_0$ value at the $y-axis$ and read the corresponding time value from $x-axis$. This is your experimental τ value for $I-t$ plots during both charging and discharging.

<u>NOTE:</u> You may check Fig. (3) to grasp the details about analysis.

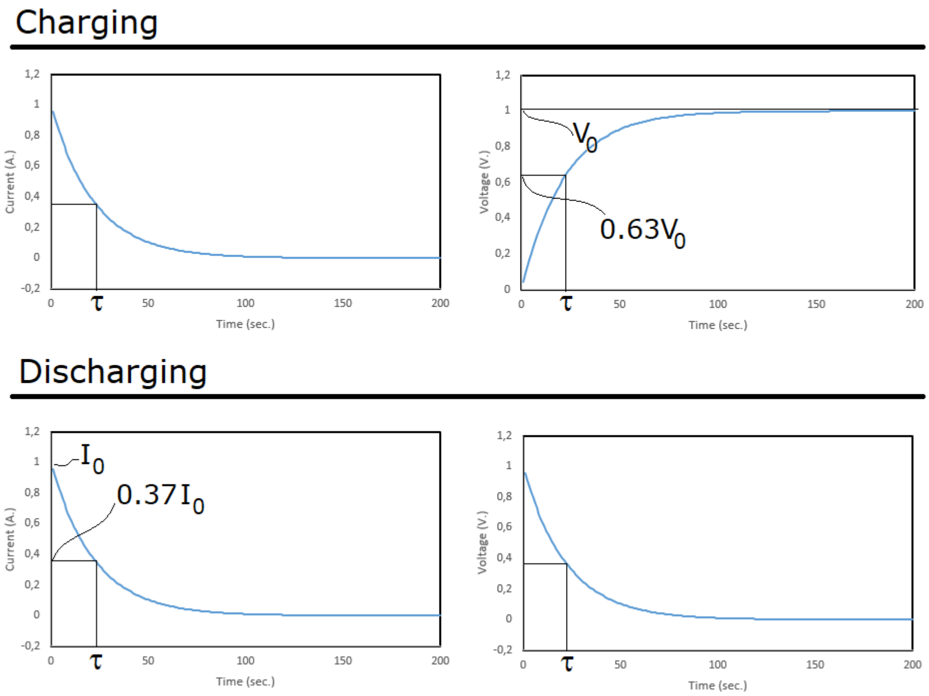

Figure 3: Templet plots for current and voltage during charging and discharging.

3 Data & Analysis

3.1 Part A: $C_1 = C_2 = 2200\mu F,\ R = 10k\Omega$

Calculate the following values in detail.

$$\tau = \text{--} \quad (8)$$

$$7\tau = \text{--} \quad (9)$$

Charging

Table 1: Table of time, voltage and current values during charging for $C_1 = C_2 = 2200\mu F$, $R = 10k\Omega$, $V_s = 5V$.

#	t ($s.$)	I (---)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)	#	t ($s.$)	I (---)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)
1	1					31	45				
2	2					32	50				
3	3					33	55				
4	4					34	60				
5	5					35	65				
6	6					36	70				
7	7					37	75				
8	8					38	80				
9	9					39	85				
10	10					40	90				
11	11					41	95				
12	12					42	100				

13	13					43	110				
14	14					44	120				
15	15					45	120				
16	16					46	130				
17	17					47	140				
18	18					48	150				
19	19					49	160				
20	20					50	170				
21	22					51	180				
22	24					52	200				
23	26					53	220				
24	28					54	240				
25	30					55	260				
26	32					56	280				
27	34					57	300				
28	36					58	320				
29	38					59	350				
30	40					60	400				

- Analysis details of $V_{eq} - t$ plot during charging.

$$63\% \text{ of } V_s = \text{------------------------------} \quad (10)$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{------------------------------} \quad (11)$$

$$\tau_{the} = \text{------------------------------} \quad (12)$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{--------------------} \quad (13)$$

- Analysis details of $I - t$ plot during charging.

$$I_0 = \text{------------------------------} \quad (14)$$

$$37\% \text{ of } I_0 = \text{------------------------------} \quad (15)$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{------------------------------} \quad (16)$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{--------------------} \quad (17)$$

Discharging

Table 2: Table of time, voltage and current values during discharging for $C_1 = C_2 = 2200\mu F$, $R = 10k\Omega$, $V_s = 5V$.

#	t ($s.$)	I (___)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)	#	t ($s.$)	I (___)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)
1	1					31	45				
2	2					32	50				
3	3					33	55				
4	4					34	60				
5	5					35	65				
6	6					36	70				
7	7					37	75				
8	8					38	80				
9	9					39	85				
10	10					40	90				
11	11					41	95				
12	12					42	100				
13	13					43	110				
14	14					44	120				
15	15					45	120				
16	16					46	130				

17	17					47	140				
18	18					48	150				
19	19					49	160				
20	20					50	170				
21	22					51	180				
22	24					52	200				
23	26					53	220				
24	28					54	240				
25	30					55	260				
26	32					56	280				
27	34					57	300				
28	36					58	320				
29	38					59	350				
30	40					60	400				

- Analysis details of $V_{eq} - t$ plot during discharging.

$$37\% \text{ of } V_s = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{18}$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{19}$$

$$\tau_{the} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{20}$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \% \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{21}$$

- Analysis details of $I - t$ plot during discharging.

$$I_0 = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{22}$$

$$37\% \text{ of } I_0 = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{23}$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{24}$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \% \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{25}$$

3.2 Part B: $C_1 = 1000\mu F, C_2 = 1000\mu F,\ R = 10k\Omega$

Calculate the following values in detail.

$$\tau = \text{---} \quad (26)$$

$$7\tau = \text{---} \quad (27)$$

Charging

Table 3: Table of time, voltage and current values during charging for $C_1 = C_2 = 1000\mu F$, $R = 10k\Omega$, $V_s = 5V$.

#	t (s.)	I (---)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)	#	t (s.)	I (---)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)
1	1					31	45				
2	2					32	50				
3	3					33	55				
4	4					34	60				
5	5					35	65				
6	6					36	70				
7	7					37	75				
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9	9					39	85				
10	10					40	90				
11	11					41	95				
12	12					42	100				

13	13					43	110				
14	14					44	120				
15	15					45	120				
16	16					46	130				
17	17					47	140				
18	18					48	150				
19	19					49	160				
20	20					50	170				
21	22					51	180				
22	24					52	200				
23	26					53	220				
24	28					54	240				
25	30					55	260				
26	32					56	280				
27	34					57	300				
28	36					58	320				
29	38					59	350				
30	40					60	400				

- Analysis details of $V_{eq} - t$ plot during charging.

$$63\% \text{ of } V_s = \text{---} \quad (28)$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{---} \quad (29)$$

$$\tau_{the} = \text{---} \quad (30)$$

$$\text{P.E.} = \%\frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{--------------------} \quad (31)$$

- Analysis details of $I - t$ plot during charging.

$$I_0 = \text{---} \quad (32)$$

$$37\% \text{ of } I_0 = \text{---} \quad (33)$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{---} \quad (34)$$

$$\text{P.E.} = \%\frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{--------------------} \quad (35)$$

Discharging

Table 4: Table of time, voltage and current values during discharging for $C_1 = C_2 = 1000\mu F$, $R = 10k\Omega$, $V_s = 5V$.

#	t ($s.$)	I (___)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)	#	t ($s.$)	I (___)	V_C^1 (V)	V_C^2 (V)	V_C^{eq} (V)
1	1					31	45				
2	2					32	50				
3	3					33	55				
4	4					34	60				
5	5					35	65				
6	6					36	70				
7	7					37	75				
8	8					38	80				
9	9					39	85				
10	10					40	90				
11	11					41	95				
12	12					42	100				
13	13					43	110				
14	14					44	120				
15	15					45	120				
16	16					46	130				

17	17					47	140				
18	18					48	150				
19	19					49	160				
20	20					50	170				
21	22					51	180				
22	24					52	200				
23	26					53	220				
24	28					54	240				
25	30					55	260				
26	32					56	280				
27	34					57	300				
28	36					58	320				
29	38					59	350				
30	40					60	400				

- Analysis details of $V_{eq} - t$ plot during discharging.

$$37\% \text{ of } V_s = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{36}$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{37}$$

$$\tau_{the} = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{38}$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{39}$$

- Analysis details of $I - t$ plot during discharging.

$$I_0 = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{40}$$

$$37\% \text{ of } I_0 = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{41}$$

$$\tau \text{ corresponds to it(i.e. } \tau_{exp}) = \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{42}$$

$$\text{P.E.} = \% \frac{|\tau_{the} - \tau_{exp}|}{\tau_{the}} \times 100 = \%\text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_} \tag{43}$$

4 Conclusions

5 Notes

References

[1] Saba Arife Karakaş. Capacitors. [Marmara University, Physics Laboratory II Lab Manuals].