UNIVERSIDADE DA MADEIRA

Experimental Science
P9: Capacitor charge and discharge

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1. Purpose

- Experimental verification of an exponential dependency between two physical quantities.
- Perform numerical evaluations.

2. Introduction

The simplest capacitor one can imagine is made with two parallel (conducting) flat plates A and B separated by an insulating medium:
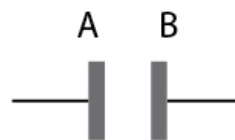

Figure 1.

Initially both plates are neutral (that is, they have an equal number of positive and negative charges).

Suppose that by some process we are able to get an excess of positive charges in one of the plates (for instance A). In spite of the impossibility of charge transfer to B, the positive charge excess in A will attract an excess of negative charges in B to the vicinity of A. This process is termed electrostatic influence.

Figure 2.

The two conductors are separated by an insulating medium, therefore this situation can persist "*ad eternum*". The capacitor is *charged*.

A capacitor may be charged by directly applying a constant voltage difference to its terminals V_0. The electric charge Q stored in a capacitor is directly proportional to the voltage difference V at its terminals:

$$Q = CV_0$$

The C constant is termed the capacitor capacity. That is, the capacity of a capacitor is the charge it contains when subject to a voltage difference of 1 V. This means that when one studies the voltage difference at its terminals, one is actually also studying the electric charge variation. The capacity SI unit is the farad (F) and the capacitor symbol is:

$\dashv\vdash$.

There is a capacitor value coding similar to that of the resistor's colour code: three digits ABC correspond to a capacity of AB x 10^C pF.

If a capacitor is charged by the direct application of a voltage V_0, the charge time will be very small (so small it is non measurable by the equipment we're using). We have to slow down the process by intercalating a resistor R into the circuit. This way, the charge (or discharge) becomes measurable over time. This is the reason we will assemble the following RC circuits RC:
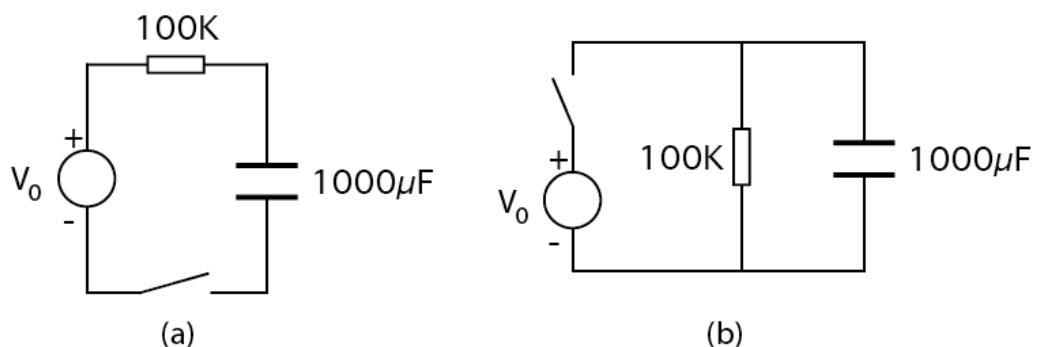

Figure 3: Capacitor charge through a resistor circuit (a) and capacitor discharge through a resistor circuit (b).

When a capacitor is charged through a resistor (figure 3a), by a constant voltage supply, the capacitor voltage V increases (as does the charge) over time t. The capacitor voltage is a function of time given by:

$$V = V_0\left(1 - e^{-\frac{t}{RC}}\right)$$

(1)

where V_0 is the power supply voltage. The amount $RC = \tau$ is termed the RC circuit time constant.

When a fully charged capacitor is discharged through a resistor (figure 3b), the capacitor voltage decreases exponentially according to the formula

$$V = V_0 e^{-\frac{t}{RC}}$$

(2)

The capacitor discharge time is given by the time constant $RC = \tau$.

3. Previous questions

1. What type of dependence is there between the difference $V_0 - V$ and the capacitor charge time through a resistor?
2. What type of dependence is there between the capacitor voltage and the capacitor discharge time?
3. Verify that for the capacitor charging process: $V(t = \tau) = 0.63V_0$.
4. Verify that for the capacitor discharging process: $V(t = \tau) = 0.37V_0$.
5. Calculate the time constants for both circuits.
6. Calculate the charge percentage a capacitor will have when $t = 5\tau$. Do you think the capacitor is practically charged?

4. Experimental activity

4.1 Material

1 multimeter, 1 voltage supply, 1 capacitor (1000 μF), 1 resistor (100 kΩ), 1 GLX Xplorer, connection wires, crocodile connectors, pen-drive.

<u>Material the students should bring</u>: pen-drive.

4.2 Additional information

Relating to any device you may use:

• Always use the most sensitive scale.
• Record the maximum device error for each chosen scale.

4.3 Procedure

4.3.1 Initial requisites

1. Measure and record the resistor resistance.
2. **ATENTION:** Electrolytic capacitors have to be powered with the correct polarity. The negative side is marked. If the polarization is inverted there is the possibility of an explosion. So before you close the circuit ask the teacher to confirm the connections.

3. Verify the GLX Xplorer may work as a stopwatch. Select *Home* and then *Stopwatch*.

4. Verify the GLX Xplorer may work as a voltmeter. Select *Home* and then *Digits*.

4.3.2 Capacitor charge

The capacitor charge will be studied by two different methods.

Method 1

1. Discharge the capacitor. Assemble the figure 3a circuit. Set the multimeter to the voltmeter function and connect it in parallel with the capacitor.

2. Construct a table with the following head line:

t (s)	V (V)

3. Connect the 5 V voltage and start measuring and recording right away the capacitor voltage. Make the measurements in 10 s intervals until the capacitor is fully charged (this process may take a few minutes). Write your measurements into the previous table. This task should be done by two students (one records the time and the other the corresponding capacitor voltage).

Method 2

1. Discharge the capacitor. Assemble the figure 3a circuit. Connect the GLX Xplorer to the capacitor terminals.

2. Before connecting the 5 V, start acquiring the capacitor voltage with the GLX Xplorer (select *Home* and then *Graph*).

3. Wait at least 3 min.

4. Save the file into your pen-drive (select *Home* and then *Data Files*). Save the file with the name *chargeP??G??* (ask the teacher what to place in the ??). Connect your pen-drive to the GLX Xplorer. On the top of the screen select *RAM* and select the file you want to transfer. On the *Files* menu select *Copy File*. Select the destination on the top of the screen: FAT16.

4.3.3 Capacitor discharge

The capacitor discharge will be studied by two different methods.

Method 1

1. Discharge the capacitor. Assemble the figure 3b circuit. Set the multimeter to the voltmeter function and connect it in parallel with the capacitor.

2. Choose a 5 V voltage. The voltage supply's task is to charge the capacitor.

3. Verify with the multimeter that the capacitor charge time is instantaneous. Explain this fact with the previous equations.

4. Construct a table with the following head line:

t (s)	V (V)

5. Once the capacitor is fully charged, disconnect the voltage supply from the circuit and start measuring and recording right away the capacitor voltage. Make the measurements in 10 s intervals until the capacitor is completely discharged (this process may take a few minutes). As in 4.3.2 this task should be done by two students.

Method 2

5. Discharge the capacitor. Assemble the figure 3b circuit. Connect the GLX Xplorer to the capacitor terminals.

6. Repeat items 2 and 3 from the previous method.

7. Once the capacitor is charged, start acquiring the capacitor voltage with the GLX Xplorer (select *Home* and then *Graph*). Right away, disconnect the voltage supply terminals. Start by disconnecting the positive pole.

8. Wait at least 3 min since the supply was removed and stop the acquisition.

9. Save the file into your pen-drive (select *Home* and then *Data Files*). Save the file with the name *dischargeP??G??* (ask the teacher what to place in the ??). Connect your pen-drive to the GLX Xplorer. On the top of the screen select *RAM* and select the file you want to transfer. On the *Files* menu select *Copy File*. Select the destination on the top of the screen: FAT16.