

RC Circuits

Equipment

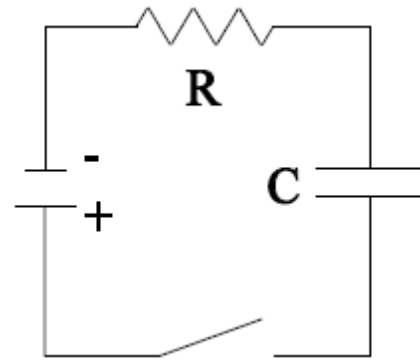
Qty	Items	Part Number
1	AC/DC Electronics Laboratory	CI-6503
2	Banana Plugs, Patch Cord	
1	330 μF Capacitor	
1	1000 Ω resistor	

Purpose

The purpose of the first part of this activity is to examine some of the basic properties, and behavior of a simple circuit that contains a resistor, and a capacitor that are connected to each other in series. The other two standard components of an RC circuit are a voltage source, and a switch to open and close the circuit.

Theory

When a DC voltage source is connected across an uncharged capacitor, a current begins to flow in the circuit, and capacitor begins to gain electrical charge. The rate at which the capacitor gains electrical charge decreases as time goes on till eventually the capacitor is said to be fully charged, and there is no longer any current flowing in the circuit. This occurs because as electrical charges accumulate on the plates of the capacitor the voltage source must do more and more work to cause additional charge to build up on the plates. Which results in the charges building up at slower, and slower rates till the voltage source can't do enough work to get anymore charge to build up, the current is said to stop flowing, and the capacitor is said to be full. **The amount of electrical charge in a capacitor, as a function of time, that is being charged by a voltage source is given by the equation;**



$$q(t) = q_{max} \left(1 - e^{-t/\tau} \right)$$

In this equation it is assumed that time is set to zero $t = 0$ when you begin to charge the capacitor, and that the capacitor is initially 'empty' of charge $q(0) = 0$. Also, q_{max} is the maximum charge the plates can hold, and τ (tau) is the **Time Constant of the RC circuit itself $\tau = RC$ where R is the resistance, and C is the capacitance.** The Time Constant has the SI units of seconds. The Time Constant is considered to be the fundamental characteristic of an RC circuit due to an interesting physical result that occurs when the amount of time spent charging a capacitor is equal to the Time Constant $t = \tau$. inserting this into our equation for charging a capacitor gives the following;

$$q(\tau) = q_{max} \left(1 - e^{-\tau/\tau} \right)$$

$$q(\tau) = q_{max}(1 - e^{-1})$$

$$q(\tau) = q_{max} \cdot 0.63$$

As you can see, regardless of the values of either the resistance, or capacitance of the circuit the capacitor will be 63% charged when the amount of time spent charging it is equal to the Time Constant of the circuit.

When a DC voltage is removed from a fully charged capacitor, while the circuit remains closed, the electric charge that is contained on the capacitor starts to redistribute itself, which results in a current beginning to flow through the circuit. As time goes on the rate at which the charge redistributes itself gets slower, and slower till finally the electric charge is said to be full discharged from the capacitor, and the current is said to stop flowing. **Assuming we start with a fully charged capacitor $q(t) = q(0) = q_{max}$ then the amount of electric charge still in a discharging capacitor, as a function of time, is given by;**

$$q(t) = q_{max} \cdot e^{-t/\tau}$$

Just like when charging a capacitor, when discharging a RC circuit, something interesting occurs when the amount of time spent discharging it is equal to the Time Constant of the circuit. Inserting $t = \tau$ yield;

$$q(\tau) = q_{max} \cdot e^{-\tau/\tau}$$

$$q(\tau) = q_{max}e^{-1}$$

$$q(\tau) = q_{max} \cdot 0.37$$

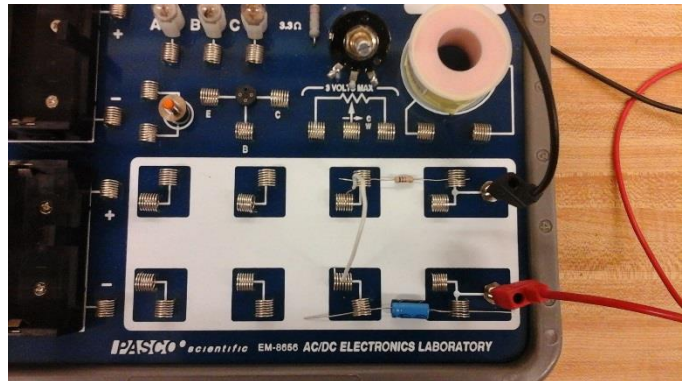
As you can see, regardless of the values of either the resistance, or the capacitance of the circuit the capacitor will only have 37% of the maximum charge left in it when the amount of time spent discharging it is equal to the Time Constant of the circuit.

Setup

1. Open the Capstone software. On the left side of the main screen is the Tool Bar. Click on the Hardware Setup icon. This will open the Setup window.
 - Click on Channel A of the picture of the 850 Universal Interface in the Setup window, and then scroll down, and add the 'Voltage Sensor'.
2. On the bottom center left of the main screen the Sample Rate Tab should now say 'Voltage Sensor'.
 - Set the sample rate to 50 Hz.
3. Right to the right of the Sample Rate Tab is the Recording Conditions Icon. Click on it, and the Recording Conditions window should open.
 - Click on 'Stop Conditions'.

- Change 'Conditions Type' to 'Time Based'.
 - Set 'Record Time' to 20 seconds.
 - Click 'ok', and the window should close.
4. In the Tool Bar, now click on the Signal Generator Icon. This will open the Signal Generator window.
 - In the Signal Generator window click on the tab "850 output 1" tab. This will open up the options window for the output generator 1.
 - Set the Waveform to 'Positive Square Wave'.
 - Set the frequency to 0.100 Hz.
 - Set the Amplitude to 1 Volt.
 - Set the Generator to 'Auto', so that it will start and stop automatically when you start and stop collecting data.
 5. Close the Tool Bar.
 6. On the right side of the main screen is the Display Bar.
 - Left click, and hold on the Graph Icon. Then drag out to the middle of the main screen, and release.
 - Click on the y-axis 'select measurement' tab, and select Voltage. The computer should automatically select time for the x-axis.

7. Plug in the Voltage Sensor to Analog Channel A of the 850 Universal Interface.
8. Plug in to Patch Cords to the Output Generator 1 of the 850 Universal Interface (top right of the interface). Then plug the other ends of the Patch Cords to the AC/DC Electronics Laboratory.
9. Using a 1000 Ω resistor, and a 330 μF capacitor, and one jumper cable, construct the simple RC circuit shown in the picture. Make sure the capacitor is pointing towards the negative terminal.
10. Attach a Banana Clip to each of the two ends of the Voltage Sensor.



11. Then Connect the Voltage Sensor to the capacitor with one end of the Voltage Sensor on either side of the capacitor as shown in the picture.



Procedure

1. At the bottom of the main screen click on “Record”, then wait for the 20 seconds it takes for the experiment to run its course.
2. Expand a region of the graph display so that you can easily see a region of the plot of Voltage vs. Time graph that shows the voltage rising from zero volts to the maximum voltage.
3. Use the coordinate tool to find the time value of the time where the voltage starts to increase from zero. Record this time in the Table as t_o for charging.
4. Then use the coordinate tool to find the time that the voltage is 63% of the maximum voltage. Record this time the Table as τ'_{exp} for charging.
5. Expand a region of the graph display so that you can easily see a region of the plot of Voltage vs. Time graph that shows the voltage falling from maximum volts to zero volts.
6. Use the coordinate tool to find the time value of the time where the voltage starts to decrease from maximum voltage. Record this time in the Table as t_o for discharging.
7. Then use the coordinate tool to find the time that the voltage is 37% of the maximum voltage. Record this time in the Table as τ'_{exp} for charging.
8. Save the graph so it can be turned in with your lab report.

Analysis of RC Circuits Lab

Name _____ Group# _____

Course/Section _____

Instructor _____

Table 1 (20 points)

	Charging	Discharging
t_o		
τ'_{exp}		
τ_{exp}		

1. Calculate your experimental value of the Time Constant, τ_{exp} , obtained by both charging and discharging the capacitor by taking the difference of $\tau'_{exp} - t_o$ and record it as τ_{exp} in Table 1, under charging and then discharging. Show work. (15 points)

2. Calculate the theoretical value for τ . Show work. (15 points)

3. Calculate the % errors for the Time Constant for both the charging and discharging values. Show work. (15 points)

4. Calculate the % difference between your experimental values of the Time Constant. Show work. (15 points)

5. Does the time constant, τ , depend on the voltage from the power supply? Explain your answer. (10 points)

6. Did our experiments confirm the theory? Explain your answer. (10 points)