

RC Circuit Lab

Objectives:

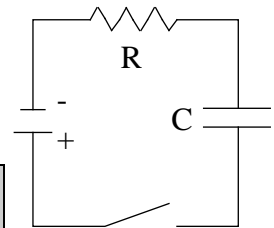
Students will be able to ...

- Use the *ScienceWorkshop* interface to investigate the relationship between the voltage remaining across a capacitor and the time taken for the discharge of the capacitor in an RC circuit;
- Calculate the capacitance based on the time to "half-max";
- Calculate the capacitive time constant based on the capacitance and resistance of the circuit;
- Compare the measured capacitance to the theoretical value as stated by the manufacturer.

Equipment Needed	Qty	From AC/DC Electronics Lab*	Qty
Voltage Sensor	1	Capacitor, 330 microfarad	1
Patch Cords	2	Resistor, 100 ohm	1

What Do You Think?

The voltage across a capacitor varies as it charges. How can you investigate this relationship? Capacitors also have what is known as the capacitive time constant. How can this constant be calculated?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

When a DC voltage source is connected across an uncharged capacitor, the rate at which the capacitor charges up decreases as time passes. At first, the capacitor is easy to charge because there is very little charge on the plates. But as charge accumulates on the plates, the voltage source must "do more work" to move additional charges onto the plates because the plates already have charge of the same sign on them. As a result, the capacitor charges exponentially, quickly at the beginning and more slowly as the capacitor becomes fully charged. The charge on the plates at any time is given by:

$$q = q_0 \left(1 - e^{-t/\tau} \right),$$

where q_0 is the maximum charge on the plates and τ is the capacitive time constant ($\tau = RC$, where R is resistance and C is capacitance). NOTE: The stated value of a capacitor may vary by as much as $\pm 20\%$ from the actual value. Taking the extreme limits, notice that when $t = 0$, $q = 0$ which means there is not any charge on the plates initially. Also notice that when t goes to infinity, q goes to q_0 which means it takes an infinite amount of time to completely charge the capacitor.

The time it takes to charge the capacitor to half full is called the half-life and is related to the capacitive time constant in the following way:

$$t_{1/2} = \tau \ln 2$$

In this activity the charge on the capacitor will be measured indirectly by measuring the voltage across the capacitor since these two values are proportional to each other: $q = CV$.

SAFETY REMINDER

- Follow all safety instructions.

**THINK SAFETY
ACT SAFELY
BE SAFE!**

For You To Do ++

Use the ‘Output’ feature of the *850 Interface* to supply a voltage to the resistor-capacitor circuit. Use the Voltage Sensor to measure the voltage across the capacitor as it charges and discharges. Record the voltage in the secondary coil for two configurations: one with an iron core inside the inner coil, and one without the iron core inside the inner coil.

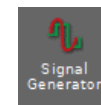
Use *DataStudio* to control the voltage output of the interface and to record and display the voltage across the capacitor. Finally, measure the time for the capacitor to charge to the ‘half-maximum’ voltage. Use the half-time constant and the known value of the resistance to calculate the capacitance of the capacitor.

Compare the calculated value of the capacitor to the stated value of the capacitor.

In this activity, the interface outputs a low frequency ‘positive-only’ square wave (0 to 4 V). This waveform imitates the action of charging and then discharging a capacitor by connecting and then disconnecting a DC voltage source.

PART I: Computer Setup

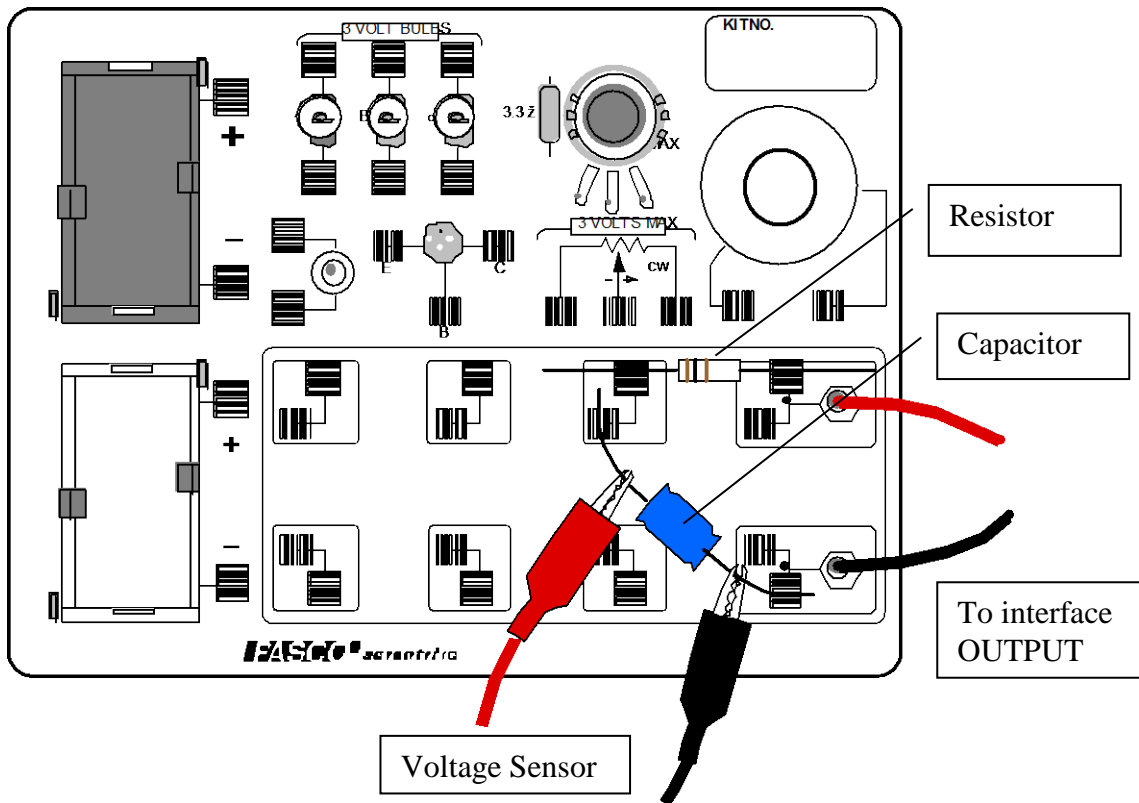
1. Insert the **100 Ω** resistor and the **330 μF** capacitor into the springs of the AC/DC Electronics Laboratory (as in the figure).
2. Plug the voltage sensor into port A of the 850 Universal Interface.
3. Using alligator clips, connect the ends of the voltage sensor wires to opposite ends of the capacitor (as in the figure).
4. Plug two patch wires (one red, one black) into the red and black plugs of the “OUTPUT” section of the 850 Interface.
5. Plug the other ends of the patch wires into the sockets as shown in the figure.
6. Double click the PASCO Capstone icon to start the software.
7. Click on the “Hardware Setup” icon.
8. You should see an image of the 850 box. Click on port A socket in “ANALOG INPUTS” and choose “Voltage Sensor.”
9. Click again on the “Hardware Setup” icon to dismiss it.
10. Click on the “Signal Generator” icon.
11. Change “Waveform” to Square.
12. Set “Frequency” to 0.5.
13. Set “Amplitude” to **1.0 V**.
14. Set “Voltage Offset” to **1.0 V**.
15. Click the “On” button.




16. Click again on the Signal Generator icon to dismiss it.
17. At the bottom of the window, change the sample rate to **1.00 kHz**.
18. Double click on the graph icon to produce a graph on which the data will plot.
19. Click <Select Measurement> and choose "Voltage (V)."
20. Now you're ready to start the experiment.

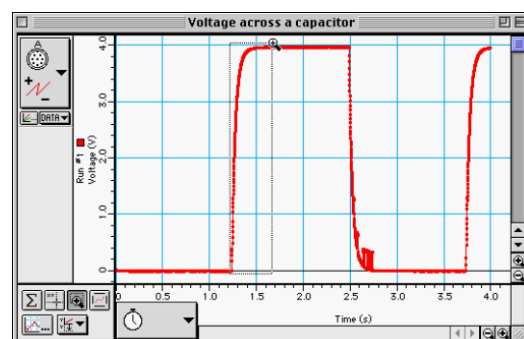
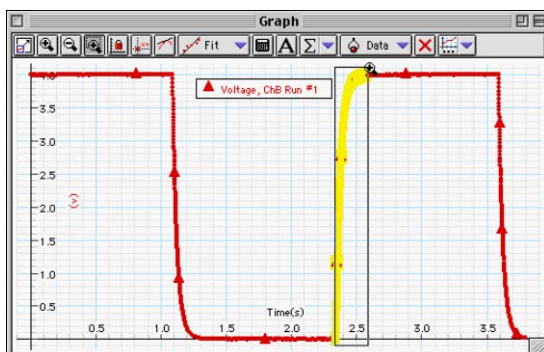
Part III: Data Recording

1. Start measuring data. The Signal Generator output will automatically start when data recording begins.
 - Watch the plot of voltage versus time in the Graph display.
2. Data recording will continue for four seconds and then stop automatically.
 - 'Run #1' will appear in the Data list.




Analyzing the Data

1. Rescale the Graph display if needed.
2. Expand a region of the Graph display. Use the 'Highlight' tool  to click-and-draw a



rectangle over a region of the plot of Voltage versus Time that shows the voltage rising from zero volts to the maximum volts.

- **Result:** Your selected region expands to fill the Graph display.
3. Use the built-in analysis tools in the Graph display to find the time to ‘half-max’.
 - a. To measure the charge/discharge half-life.
 - b. Click on the icon shown here and choose “Add Multi-coordinates Tool.” 
 - c. You can drag this tool along the horizontal axis with the tab at the bottom in order to read the time at a particular point.
 - d. Using this, find the time at which the voltage begins to rise. The time is read out on the tab that is on the time axis.
 - e. Move the tab again to find the time at which the voltage reaches half its maximum value.
 - f. The half-life is the difference between these times.

4. Use $t_{\frac{1}{2}} = \tau \ln 2 = 0.693 RC$ to calculate the capacitance (C) of the capacitor.

Put your results in the Lab Report section

Lab Report: RC Circuit Lab

What Do You Think?

The voltage across a capacitor varies as it charges. How can you investigate this relationship? Capacitors also have what is known as the capacitive time constant. How can this constant be calculated?

Data

Time to half-max ($t_{1/2}$) = _____ s

Capacitance = _____ F = _____ μ F

(Remember, $C = \frac{t_{\frac{1}{2}}}{\ln 2} \div R$)

Percent Difference between stated capacitance value of 330 microfarad = _____

1. The time to half-maximum voltage is how long it takes the capacitor to charge halfway. Based on your experimental results, how long does it take for the capacitor to charge to 75% of its maximum?

2. After four “half-lives” (i.e., time to half-max), to what percentage of the maximum charge is the capacitor charged?

3. What is the maximum charge for the capacitor in this experiment?

4. What are some factors that could account for the percent difference between the stated and experimental values?

5. Show that the capacitive time constant, RC , has the dimensions of time in *seconds* when R is in ohms and C is in farads.

6. During the initial charging of this capacitor up to the max voltage, V_o , the initial energy stored in the capacitor is $\frac{1}{2}CV_o^2$. Show mathematically that this energy is equal to the total energy dissipated as heat in the resistance through which discharging the current flows. (You may attach a separate sheet).

7. A charged 2- μF capacitor is connected in parallel with 0.5-M Ω resistor. (a) How long after the connection is made will the voltage across the capacitor fall to 75% of its maximum value? (b) How much thermal energy will be dissipated across the resistance after three time constants?