

PH102 Lab IV: RC Circuits

Introduction

At this point you should have connected the lab box to a USB port and started the software.

Needed: 4 “banana” wires
1 capacitor
1 resistor
1 BamaLab source/measure box

In this experiment we will measure the charging and discharging of a capacitor in an RC circuit. This will allow us to determine the time constant of an RC circuit. Through an independent measurement of the value of the resistor, this will also allow us to determine the value of the capacitor. Figure 1 below shows the basic circuit we will consider.

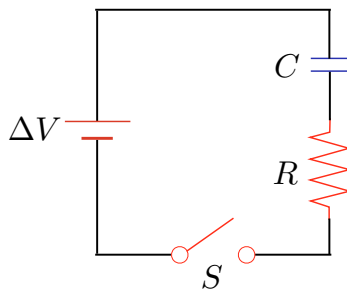


Figure 1: A basic “RC” circuit

In the actual lab, the switch S is controlled by the software, as is the value of the source voltage ΔV . If the capacitor C is discharged at time $t=0$, and we suddenly close switch S, the capacitor will start to charge up. While this happens, the potential difference on the capacitor will follow:

$$\Delta V_C(t) = \frac{Q}{C} \left(1 - e^{-t/RC}\right) = \Delta V \left(1 - e^{-t/RC}\right)$$

The quantity RC is the “time constant” of the circuit, and represents how long it takes to charge the capacitor.

If we wait long enough to fully charge the capacitor, and then suddenly close S, the capacitor will discharge through the resistor R. While this happens, the potential difference on the capacitor will follow:

$$\Delta V_C(t) = \Delta V e^{-t/RC}$$

In our experiment, we will use the lab software to charge and discharge the capacitor while simultaneously measuring the voltage, giving us our $\Delta V_C(t)$ curve directly.

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Part I: Charging & discharging the capacitor

This laboratory uses the tutorial software and hardware you were introduced to previously.

- a) Connect your resistor and capacitor in series by stacking the “banana” plugs.
- b) Connect the free end of the resistor to the “+Vout” terminal on your laboratory box, and the free end of the capacitor to “-Vout” to complete the circuit as shown above. This is for applying a voltage to the R and C in series.
- c) Connect wires from “+Vin” and “-Vin” to either end of the capacitor. Keep the polarity preserved, i.e., connect the “-Vin” to the same point that “-Vout” is connected. This is for measuring the voltage on the capacitor..
- d) In the tutorial software, choose “Voltage vs. Time” from the “ac Circuits” menu.

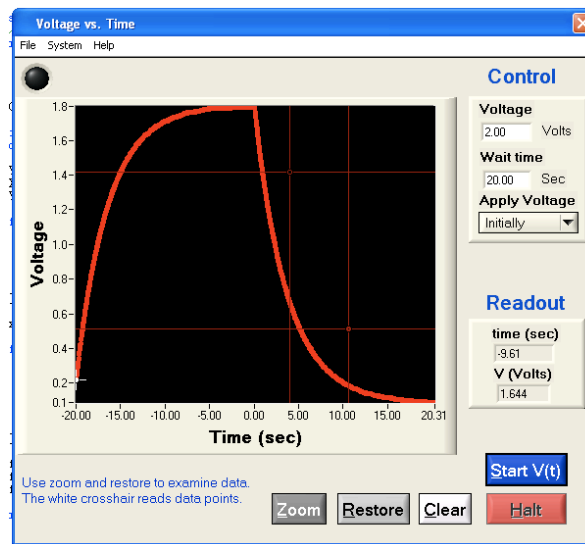


Figure 2: The voltage vs. time panel.

- e) We first want to apply a potential difference ΔV for a set amount of time, and then remove it. On the right side of the window, set the “Wait time” to 10 seconds, and choose “**Initially**” from the “Apply Voltage” pull-down menu. (You can change the voltage if you like, but 2 Volts works well.)

These settings mean the program will immediately apply a voltage of 2.00 Volts (or whatever you choose) once you press “Start V(t)”, leave it on for 10 seconds, and then turn it off. Time “t=0” is defined as the point when the voltage is turned off.

- f) Adjust the delay time until you see a curve like the one above, such that the curve rises and is nearly flat before $t=0$.
- g) Have an instructor verify that your graph is OK and **INITIAL HERE** _____
(there is no need to print any plots)

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Part II: Conservation of energy

a) Now switch the “+Vin” and “-Vin” connections to measure the voltage on the resistor instead of the capacitor. **Without pressing “Clear”**, run the measurement again. We want to get $V(t)$ from the capacitor and $V(t)$ from the resistor on the screen at the same time, like this:

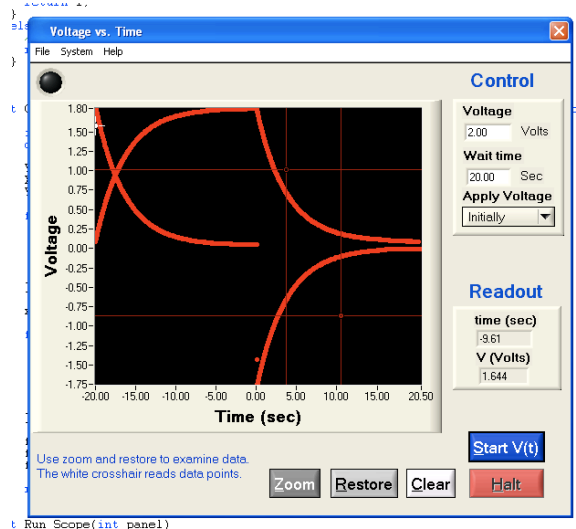


Figure 3: $V(t)$ curves for the resistor and capacitor on the same screen

Have an instructor verify that your graph is OK and **INITIAL HERE** _____

b) Using the white crosshair tool, verify for at least 6 different times that the $V_C + V_R$ is a constant. *At times less than zero, there is an actual voltage applied. For times greater than zero, the source voltage is off.*

t (sec)	V_C (Volts)	V_R (Volts)	$V_C + V_R$ (Volts)

Q1: Does your data support conservation of energy? What does our simple analysis not account for that could lead to a deviation?

Q2: What should $V_C + V_R$ equal?

Q3: How can the voltage be negative on the resistor for some times?

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Part III: Finding the time constant RC

a) Leave the connections as they were in the last part - applying voltage across the R and C together, measuring voltage across R.

b) Choose “After Delay” from the “Apply Voltage” pull-down menu. Set the “Wait Time” to 0.1 seconds. Run the measurement.

This will, after a short 0.1sec delay, apply a voltage to your circuit and just leave it on. Measuring the voltage on the resistor measures the current in the circuit, which should steadily decrease as the capacitor charges (finally reaching zero when the capacitor is “full”).

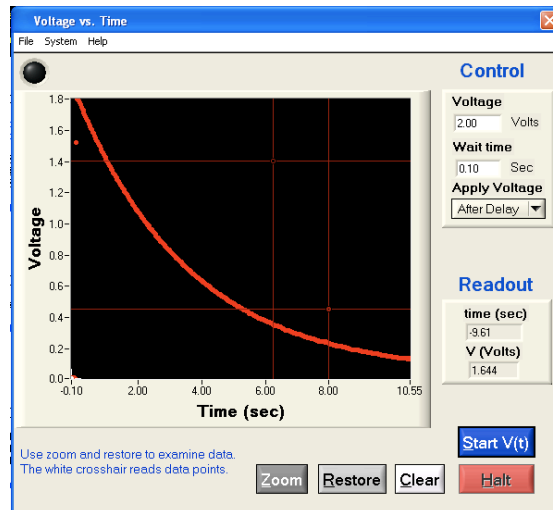


Figure 4: Discharging of a capacitor

c) Save this data (File/Save), **preferably into “My Documents.”** Open it in Excel.

d) Plot the data, and add **an exponential trendline, $y(x) = Ae^{bx}$** . Do this only for data at times $t > 0$, where you observe the smoothly decreasing voltage on the resistor.

e) Have an instructor verify that your graph is OK and **INITIAL HERE** _____

Q4: What is the time constant for your circuit, in seconds?

Q5: What does the constant “A” from your trendline mean physically?

Q6: Find the value of R for your resistor. You can use the “multimeter” panel in the software to source a current and measure a voltage, for example. Using this and your time constant, what is the value of C for your capacitor?

When you are finished turn in a hard copy of your report