

PH102 Lab dc & rc Circuits

Introduction

At this point you should have connected your lab box and started the tutorial software.

In this experiment we will determine how voltages are distributed in resistor circuits according to Ohm's law, and explore series and parallel combinations of resistors.

Resistance is a measure of a device's ability to conduct electric current for a given potential difference. The higher the resistance, the lower the current for a given voltage. Resistors are passive electronic devices which have fixed values. Their relationship between current and voltage follows Ohm's Law: $\Delta V = IR$.

The SI unit of resistance is the ohm, $1 \Omega = 1 \text{ V/A}$. As is the case for capacitors, there are two ways to connect resistors in an electronic circuit—series or parallel connection. In a series connection the components are connected at a single point, end to end as shown below:

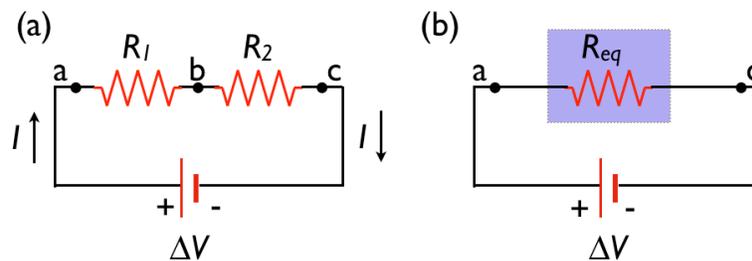


Figure 1: Series Resistors

For a series connection, the current through each resistor will be the same, and the voltage drops will together add up to the source voltage. We can find the equivalent resistance, R_{eq} , from

$$IR_{eq} = \Delta V = V_1 + V_2 = IR_1 + IR_2 \quad (3)$$

Thus

$$R_{eq} = R_1 + R_2 \quad (4)$$

In the parallel connection, the components are connected to each other at both ends as shown below:

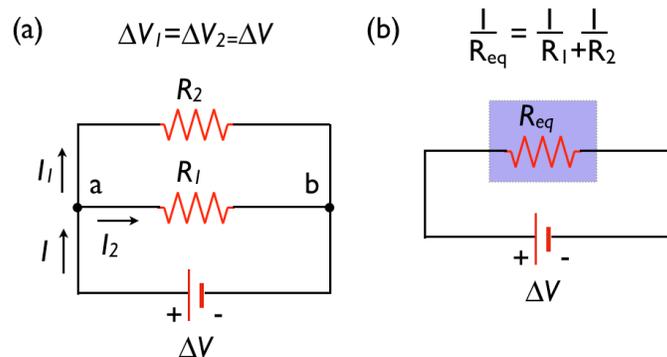


Figure 2: Parallel resistors

PH102 Lab dc & rc Circuits

For a parallel connection, the voltage drops will be the same, but the two currents together will add up to the total current flowing out of the source. Then the equivalent resistance can be calculated by adding the currents:

$$\Delta V/R_{eq} = I = I_1 + I_2 = \Delta V/R_1 + \Delta V/R_2 \quad (5)$$

Thus,

$$1/R_{eq} = 1/R_1 + 1/R_2 \quad (6)$$

Experiment I: Series resistors

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

- Connect two resistors in series by stacking the “banana” plugs.
- Connect one side of one resistor to the “+Iout” terminal on the black “Labjack” box, and the other side of the second resistor to “-Iout”. Do this such that current can go into one resistor, through the second, and back to the source.
- Flip the switch on the side of the box to the “on” position.** No current is flowing yet.
- Connect **one of your resistors only** “+Vin” and “-Vin” terminals. The +Vin connection should be on the same side of the resistor as the +Iout connection. The idea is to measure the voltage drop across only one resistor at a time.
- In the tutorial software, choose “Voltage vs. Current”

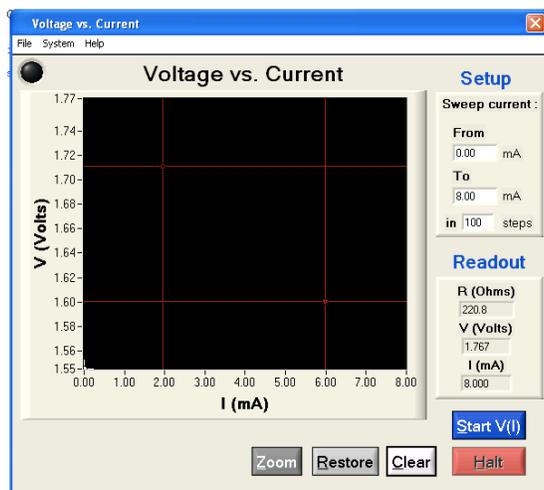


Figure 3: The voltage vs. current panel.

- Sweep the current from zero to a few mA, until you generate a nice straight-line characteristic. From the “File” menu, save your data.
- In Excel, plot the data as “X-Y scatter” and add a (linear) trendline. Have an instructor verify that your graph is OK and **INITIAL HERE** _____ (there is no need to print plots)

PH102 Lab dc & rc Circuits

g) From your trendline, record the slope of your line and the resistance.

Slope = _____ V/A

$R_1 =$ _____ Ω

h) Repeat parts e-g for your second resistor.

Slope = _____ V/A

$R_2 =$ _____ Ω

i) Repeat parts e-g while measuring the voltage across **both resistors at once**

Slope = _____ V/A

$R_{eq} =$ _____ Ω

How well does your data support the rule for combining series resistors?

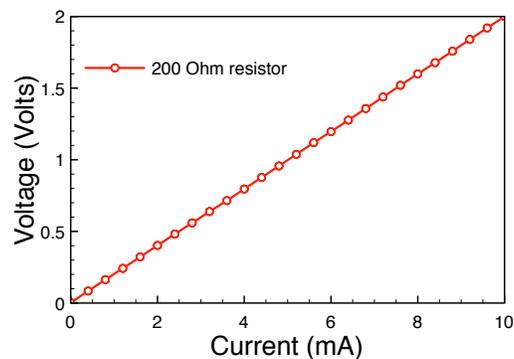


Figure 4: Example Voltage-Current plot.

Experiment II: Parallel Resistors

a) Using the same two resistors from Experiment I, now connect them in parallel.

b) repeat parts e-g above while measuring the voltage across both resistors.

Slope = _____ V/A

$R_{eq} =$ _____ Ω

Plot OK: instructor's **INITIAL HERE** _____

Given the values of R_1 and R_2 from Experiment I, how well does your data support the rule for combining parallel resistors?

PH102 Lab dc & rc Circuits

Experiment III: “RC” circuits

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.

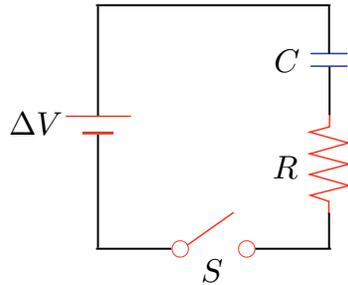


Figure 1: A basic “RC” circuit

In the lab, the switch S is controlled in software, as is the source voltage ΔV . If the capacitor C is initially 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, as it provides the time scale over which the capacitor takes to charge to certain fraction of its full charge. 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 charge and discharge the capacitor while simultaneously measuring the voltage, giving us our $\Delta V_C(t)$ curve directly.

Part I: Charging & discharging the capacitor

- 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.

PH102 Lab dc & rc Circuits

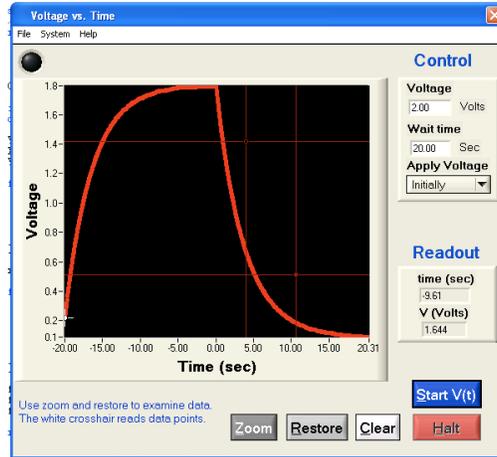


Figure 2: The voltage vs. time panel.

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.)

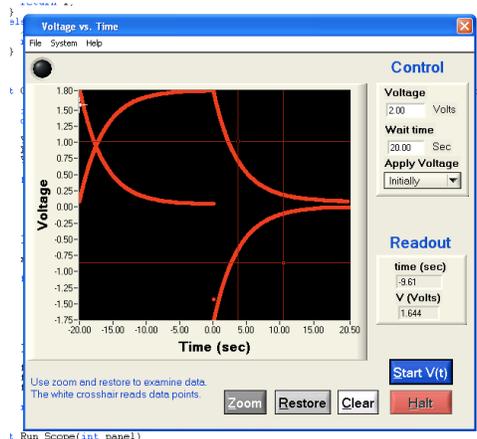
Now the program will immediately apply a voltage (of your choosing) once you press “Start V(t).” It will leave the voltage on for the time you specify, and then turn it off. Time “t=0” is defined as the point when the voltage is turned off.

f) Adjust the delay time until you see a curve like the one above, such that the curve rises and is nearly flat before the voltage is turned off at t=0.

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

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:



PH102 Lab dc & rc Circuits

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 5 different times that the $V_C + V_R$ is a constant. *At times less than zero, there is a voltage applied. For times greater than zero, the source voltage is zero.*

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?

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").

PH102 Lab dc & rc Circuits

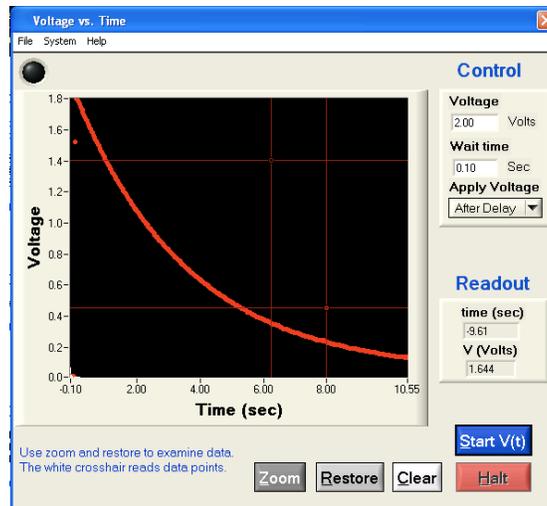


Figure 4: Discharging of a capacitor

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 the switch on the side of the box to "off."
- Put away your components and wires
- Turn in a hard copy of your report with all group members names