Uncovering a Hidden RCL Series Circuit

Purpose

a. To use the equipment and techniques developed in the previous experiment to uncover a hidden series RCL circuit in a box and

b. To measure the values of R, C, and L in that circuit.

Introduction

In this lab exercise, you will be given a hidden series RCL circuit inside a board as in Fig. 1. The three components, R, L, C and inside a box but their terminals can be accessed from the top of the board. The three components are connected in series but they may be in any order that is possibly arranged in RLC, RCL, LRC, LCR, CRL, or CLR. Using the equipment available to you in the lab, you will first have to determine which element is which and how the circuit is laid out underneath the board. It will help to know that all of the components are **oriented in the direction perpendicular to the long side** of the board.

Once you know how they are connected making a series configuration. You will then determine the values of each of the components individually in your particular board. It should be emphasized that any real inductor also has some resistance associated with it such that a real inductor can be considered to be a resistor connected in series with an ideal inductor (which has no resistance). In doing this experiment, you will be encouraged to think things through on your own. Understanding the properties of R, L and C will be very helpful in this lab. You should also discuss with your lab partners how you plan to figure out the circuit and determine the values of the three components. If you really get stuck, of course, your lab instructor will be there to give some hints.

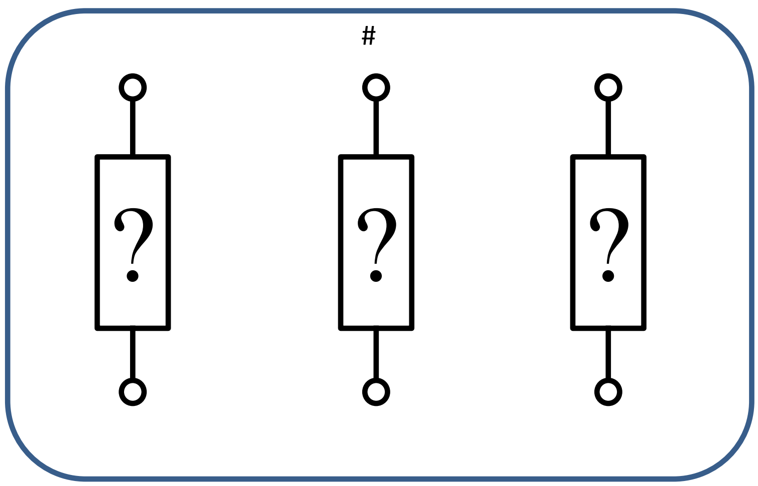


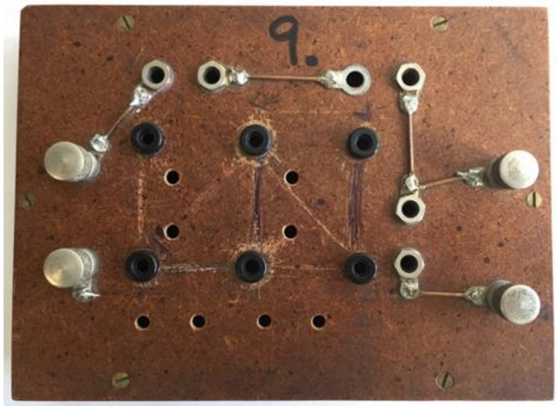
Fig. 1. Orientation of the hidden three components inside the box. They are connected in different ways for different boxes to make series combination.

Apparatus

Circuit board with a hidden series RCL circuit in a wooden box, Vernier LabQuest interface with a differential voltage probe, Decade resistance box, Multimeter, Function generator and connecting wires.

Description of Apparatus

Figure 2 shows the apparatus you will be given in this lab. Fig. 2(a) is the top view of the circuit board (#9) with a hidden series RCL circuit in the reverse side of board, (b) decade resistance box (c) Digital multimeter, (d) Function generator. You will be also provided Vernier voltage probe along with LabQuest and a computer with Vernier Logger Pro software.



a. Circuit board (#9) with a hidden RCL series circuit inside the board

b. Decade resistance box

c. Digital multimeter

d. Function generator

Fig. 2. Apparatus provided for this laboratory.

The function generator can output sine, square, triangle signals with a frequency range of 0.001 Hz to 150 kHz in addition to DC signal. The output signal can be set up to ±10 Volts at 1 A current maximum. The signal type, frequency, voltage and current are displayed on the LCD display. To change waveform press waveform button and select by rotating the 'voltage' adjust knob.

Procedure

Part I. Determination of RCL arrangement

1. Make note of the number on your circuit board. You will be using this same board again next week!
2. Using your multimeter and perhaps the voltage probe as well, identify each of the components in your circuit. Also figure out how the components are connected. Remember their orientation in the box and they are connected in a series circuit. You will thereby also identify which are the two ends of the series RCL circuit.

   [Hint: a short metallic wire connection between two points will have zero, or very close to zero, resistance.]
3. Draw your circuit diagram in your notebook for your box with all three components and how they are connected.
4. Measure the resistance of each of the components in your circuit. Also include the value of the component if you have already measured. Can you identify the components based on the value of resistance?

Part II. Determination of the value of C

You can proceed to this part only if you have identified capacitor in your circuit board.

1. Construct a RC series circuit using the identified capacitor on the board (**making sure the capacitor only**) and a variable resistor set from the decade box as shown in Fig. 3. Choose a resistance in the decade box, $R_{D,}$ in table 1.

2. Set the function generator to the square wave output at a frequency of about 100 Hz and voltage, V_p ~ 5 V.

3. Set up software: Open Logger Pro in the computer. Connect the terminals of the voltage probe together and zero the sensor by clicking at  (or short keys, *Ctrl+0*).
Set up the sampling rate to 5000 samples/sec {*Experiment →Data collection→ Sampling Rate = 5000 and Duration =1 sec→ Done*}.
Set the x-axis scale from 0 to 0.020 sec.
Now, connect the voltage probe to the source output (pay attention to the polarity) on the function generator and collect the data to check/confirm the source signal on the computer. (The time scale should have a period of about 10 ms).

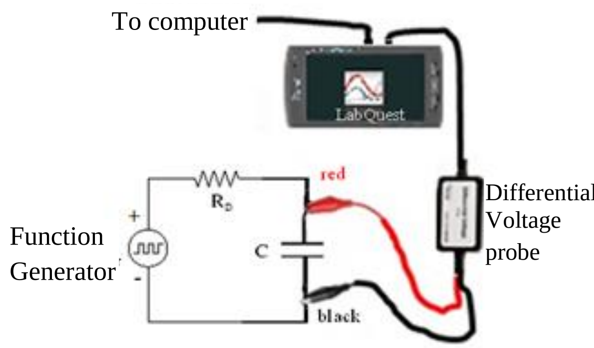


Fig. 3. RC series circuit for determining C.

4. Connect the source output to the RC series circuit and connect the voltage probe across the capacitor with the proper polarity (i.e. to measure the positive voltage on the capacitor) to record the V_C (t) (see Fig. 3).

5. Click ***Collect*** on menu bar to measure V_C (t). You should observe the charging and discharging graphs with exponential transient profile on the screen. You should take repeated scans until you have one that shows the full exponential decay for charging and discharging graphs. That is the one you want to analyze.

6. Fit separately for the charging and discharging portion of the graph and determine the time constant (τ = RC) of the circuit. Note that $R = R_s + R_D$ in this case, where R_s is the source internal resistance, which is equal to 50 ohm, and the R_D is the resistance in decade box.

> ***Curve Fitting:*** *select a region of a graph in charging or discharging portion from voltage versus time graph. Click on "Analyze" and select "Curve Fit", and then choose the function "Inverse Exponent" or "Natural Exponent" depending upon charging of discharging region of the curve. Then click on "Try Fit" and finally on "OK" to show the fitting parameters in a box on the graph. You will also see bracket symbols ([ ]) in the graph covering the data used to make fitting. Move those brackets to modify the portion of the graph. Note that τ is the reciprocal of the fitting constant C (this C is not the capacitance!). After fitting for both charging and discharging regions, if the two values of C are in good agreement and if the "Root MSE" for each is less than ~ 0.01, record the average values of τ in table 1. Otherwise repeat the analysis or entire measurement.*

7. To enhance the accuracy in determining the value of C, you will measure τ with at least three more different values of $R_{D.}$ Repeat the previous step by setting different resistance on the decade box and record the values of τ in table 1. Note: you may adjust the source frequency so that you can observe the complete charging or discharging curve on the graph.

III. Determination of the value of L

If you are still confused if the component is resistor or inductor. This step might give you clear distinction between a resistor and inductor. Similar to part II, you will construct an RL series circuit and measure the charging and discharging time constant, $\tau = L/R$, where $R = R_D + R_L + R_s$ (Ω), is the total resistance in the RL series circuit. Remember that the inductor has its own resistance, R_L, which cannot be physically separated from the inductor.

1. **Confirming R or L:** Move those connecting wires and the probe from the capacitor to the identified inductor (!). Collect the data. What kind of wave form did you observe? Does it make sense? If the component were resistor, how should the waveform look like?

   Move the wires and the probe from the inductor (!) to the resistor in the box and collect the data. What kind of wave form did you observe? Does it make sense?

2. At this moment you must have identified all the components without confusion. Construct an RL series circuit from the identified inductor in the board and a variable resistor set from the decade box and then apply a periodic square-wave source signal to the circuit. This case, connect the **Differential Voltage Probe across the resistor R_D.** Why not across the inductor?

3. Click ***Collect*** on menu bar to measure $V_{RD}(t)$. You should observe the charging or discharging graphs with exponential transient profile on the screen. What if the graph is not exponential? Think about the possibilities.

   The transient voltage across the resistor R_D, $V_{RD}(t) = I(t) R_D$, where $I(t)$ is the current in the series circuit. By fitting the curve, determine the time constant, τ, by following the same procedure as in part II. Note that τ is the reciprocal of the fitting constant C. Record the value in table 2.

4. To enhance the accuracy in determining the value of L, measure τ with at least three more different values of R_D on the decade box and record the results in table 2.

Computation

You need to include a neat circuit diagram of your RCL series circuit with the values of R, C, and L clearly labeled. In addition, the value of R_L should also be indicated.

Plot the graph of τ vs. R from the data in Table 1. Fit the data point with a straight line and the slope. Determine the value of capacitance, C from the slope.

Similarly, plot the graph of τ vs. 1/R from the data in Table 2. Fit the data point with a straight line and the slope. Determine the value of capacitance, C from the slope.

Questions

1. Why is it L/R not LR for the charging and discharging a series RL circuit?
2. In the determination of C in Part II, what will you observe if the voltage probe is connected across R_D? Can you determine capacitance from this?
3. In the determination of L in Part III, what will you observe if the voltage probe is connected across the terminals of the inductor? Can you determine inductance from this?
4. If a sinusoidal signal is used instead of square wave in the function generator, what kind of graphs do you expect in the RC and RL circuit?

Data Sheet

Date experiment performed:

Name of the group members:

Box number:

Table 1. Measured data for determining the capacitor value

R_D (Ω)	R_s (Ω)	$R = R_s + R_D$ (Ω)	τ (s)
100			
200			
300			
400			
500			

Slope of the τ vs. R graph =

Value of capacitance, C =

Table 2. Measured data for determining the inductor value

R_D (Ω)	R_s (Ω)	R_L (Ω)	$R = R_D + R_s + R_L$ (Ω)	1/R (Ω^{-1})	τ (s)
100					
200					
300					
400					
500					

Slope of the τ vs. 1/R graph =

Value of inductance, L =