The Series RLC Circuit and Resonance

Purpose: To use the equipment and techniques developed in the previous experiments to measure the values of the L and C using the impedance method and to study the behavior of a series RLC circuit.

Apparatus: Circuit Board with hidden series RLC circuit, Vernier LabPro Interface, Dual Voltage Probes, Decade Resistance Box, Voltmeter, Function Generator.

References: Refer to your text for a discussion of the series RLC circuit.

Introduction: In this lab exercise, you will be given the same hidden RLC circuit that you worked with last week. You have already measured the values of R and R_L (the resistance of the inductor itself) but you may want to check those measurements again using the multimeter in resistance mode. You have also measured the values of L and C by measuring the time constants. Today you will measure L and C again by a different technique, using measurements of current and voltage to determine the impedance. You will then study the behavior of the series RLC circuit as a function of frequency and measure the resonance curve. The peak of the resonance curve occurs at a frequency given by the relationship

$$\omega_o^2 = 1 / LC \quad \text{where} \quad \omega_o = 2\pi f_o$$

Also, at resonance the current and voltage in the circuit are in phase with each other.

Procedure:

Make sure that you have the same (numbered) circuit board that you worked with last week.
Refer to the circuit diagram that you made in the previous lab.

I. Measurement of C

1. The computer and interface should already be turned on. Double-click on the Logger Pro icon labeled "Voltage - 2 Probes" to open the software for this part of the experiment.

2. Connect the decade resistance box in series with the capacitor in your circuit (and nothing else!) and connect the function generator output across the combination of R and C.

3. Set the decade resistance box to a resistance $R_D = 200\ \Omega$. Set the function generator to a sine wave output at a frequency of about 300 Hz. Note that at this frequency you will see approximately 3 complete cycles on the computer screen with a time scale going from 0 to 0.01 sec. The exact frequency is not crucial - you will measure whatever it is.

4. Connect voltage probe #1 across the capacitor and voltage probe #2 across the decade resistance box. Maintain the same polarity for both connections, i.e. measure the voltage from high to low (red to black) in the same direction for both.

5. Click on "collect" and observe the two wave forms. The voltage across the capacitor is shown in red and the voltage across the decade resistor is shown in blue. Click on "stop" to stop the data collection. Observe the phase relationship between the two signals and comment on its significance in your lab report.

6. Use the "automatic curve fitting" feature to fit both of the signals, sequentially, with a sine wave. Make sure you know which one you are fitting and make sure that the fit is a good one! The fitting program will return the values of the voltage amplitude (parameter A) and the angular frequency ω (parameter B). Record both of these, keeping four significant figures. The values of B, of course, should be very nearly the same (ideally, identical) for both of the signals but the amplitudes will be different.

7. Calculate the capacitance from the equation:

$$\mathbf{C = (\Delta V_R / \Delta V_C)} \times \mathbf{(1/\omega R_D)} \qquad \mathbf{(1)}$$

where ΔV_R is the amplitude of the voltage across the decade resistor, ΔV_C is the amplitude of the voltage across the capacitor, ω is the angular frequency, and R_D is the resistance of the decade resistance box.

8. Repeat the above measurements for a frequency of approximately 500 Hz.

II. Measurement of L

Follow the same procedure described above (steps 1 through 6) but now with the decade resistance box connected in series with the inductor. Calculate the inductance from the equation:

$$\mathbf{(\omega L)^2 = (R_D} \times \mathbf{\Delta V_L / \Delta V_R)^2 - R_L{}^2} \qquad \mathbf{(2)}$$

where ΔV_R is the amplitude of the voltage across the decade resistor, ΔV_L is the amplitude of the voltage across the inductor, ω is the angular frequency, R_L is the resistance of the inductor, and R_D is the resistance of the decade resistance box.

Again, repeat the measurements for a frequency of approximately 500 Hz.

 Experiment # 8

III. Measurement of the RLC resonance curve

1. Connect the function generator across your RLC series circuit such that all three elements are in the circuit. Do not connect the decade resistance box - leave it out of the circuit.

2. Connect voltage probe #1 across the entire circuit, i. e. across the output of the function generator. This is ΔV for the whole series circuit. Connect voltage probe #2 across the resistor in your circuit. Note that voltage probe #2 is indirectly measuring the current in the circuit, since $I = \Delta V_R / R$ Maintain the same polarity for both connections.

3. Measure the voltage amplitudes for both signals as a function of frequency, for the following approximate frequencies:

f = 100 Hz, 200 Hz, 250 Hz, 300 Hz, 350 Hz, 400 Hz, 500 Hz, 600 Hz, 800 Hz

As before, use the automatic fitting program to determine the amplitudes (parameter A), the angular frequencies (parameter B), and the phases (parameter C) for each of the probes. Record your data in the table provided on the back of this page.

In your report:

1. Derive equations (1) and (2).

2. Compare all the measurements of C obtained in this experiment as well as last week. Which of these do you think are most reliable? Do they agree within experimental errors? Calculate what you think is the best estimate for C, based on all your measurements. Comment on the significance of the phase observed in step 5 of part I.

3. Compare all the measurements of L obtained in this experiment as well as last week. Which of these do you think are most reliable? Do they agree within experimental errors? Calculate what you think is the best estimate for L, based on all your measurements. Comment on the significance of the phase observed in step 5 of part II.

4. Make a graph of the ratio $\Delta V_R / \Delta V$ vs frequency, f, as measured in part III. What is the significance of this graph? Determine the resonance angular frequency, $\omega_o = 2\pi f_o$. How well does it agree with the value calculated from your best values for C and L?

5. What happens to the phase relationship between ΔV and ΔV_R as the frequency passes through resonance? Why?

Experiment # 8

Data Table for RLC Resonance

	Probe	**#1**		**Probe**	**#2**				
Fit Coeff.	A	B	C	A	B	C			
Approx freq.	ΔV	ω	ϕ_V	ΔV_R	ω	ϕ_R	$f_{measured}$	$\Delta V_R/\Delta V$	$\phi_V - \phi_R$
~ 100									
~ 200									
~ 250									
~ 300									
~ 350									
~ 400									
~ 500									
~ 600									
~ 800									