

## EXPERIMENT 18

### THE LRC SERIES AC CIRCUIT

#### I. THEORY

In this experiment we will study an LRC series circuit driven by a sinusoidal voltage source. The inductance of the circuit will be provided by a coil. The coil will also provide a portion of the overall resistance of the circuit. The circuit will also contain a resistor and a capacitor. We will observe the phase relationship between the current in the circuit and the source voltage for frequencies above, below and at the resonant frequency. We will also observe the phase relationships for the voltages across the coil, resistor and capacitor individually.

We will experimentally determine the resonant frequency of the circuit and use that to calculate the inductance of the coil. We will also determine the resistance of the coil.

#### II. LABORATORY PROCEDURE

The equipment you will be using in this experiment includes the following

- a PASCO RLC circuit board (Model CI-6512) containing various resistors, capacitors, and a coil (there are also an LED and a light bulb that we will not be using)
- a Laptop Computer with DataStudio software
- a ScienceWorkshop interface
- three voltage probes
- two banana to banana plug leads

1. Plug in and turn on the laptop. Connect the ScienceWorkshop (SW) to one of the USB ports on the laptop. Plug in and turn on the SW.
2. Use the two banana to banana plug leads to connect the output of the SW to the plugs on the base of the circuit board under the 100- $\mu$ F capacitor and the 33- $\Omega$  resistor. These are nominal values; you will be calculating experimental values as part of this lab. The capacitor and resistor will then be connected in series with the source, each other, and the coil.
3. Connect a voltage probe across the capacitor, paying attention to polarity, and plug that probe into port “A” of the SW. Connect a second voltage probe across the inductor, paying attention to polarity, and plug that probe into port “B”. Finally, connect the third voltage probe across the resistor and plug it into port “C”. Of course, you will observe the polarity here also. Have your instructor check your wiring.
4. Open the folder on the desktop of the computer labeled “Physics”. In the folder open the file “LRC\_Lab.ds”. After the program starts, you should see three windows labeled “Signal Generator”, “Source Voltage and Current”, and “Resistor, Inductor and Capacitor Voltage”.

In the “Signal Generator” window at the top, you can control the amplitude and frequency of the voltage output of the SW. For this lab, we will keep the amplitude at

2.00 V and vary the frequency. The frequency can be varied with the +/- and arrow buttons below the field where the frequency is displayed.

The “Source Voltage and Current” oscilloscope window will display traces of the source voltage and the current and the voltage across the resistor. Note the legend in the upper right of the window which indicates the color and scale for each. The scale for each can be changed with the arrows. At the bottom of the window the scale for the horizontal time axis is displayed and can be changed with the arrow buttons.

The “Resistor, Inductor, and Capacitor Voltage” oscilloscope window will display traces of the voltage across each component in the circuit. As with the other oscilloscope window, there is a legend and time scale.

5. Set the output voltage, in the “Signal Generator” window, to 2.00 V at 50.0 Hz. The source voltage and resistor voltage scales should be set to 1V/div in the “Source Voltage and Current” oscilloscope window. Set the current scale to 0.02A/div. The time axes in both oscilloscope windows should be set at 2ms/div. Press the “Start” button. You should see sinusoidal functions displayed in both oscilloscope windows. The sinusoidal functions will drift and it will be difficult to take any measurements. Press the “Stop” button. You should be left with a snap shot of the sinusoidal functions.
6. Verify that the period of each sinusoidal function is 20 ms. This indicates a frequency of 50 Hz, as it should.
7. Note the phase relationships between the voltages across the coil, resistor and capacitor. The voltages across the coil and the capacitor should be approximately 180° out of phase. They are not actually 180°, because the coil is both an inductor and a resistor in the circuit. The voltage across the resistor should be 90° out of phase with the capacitor and less than 90° out of phase with the coil. The voltage across the resistor should lag the voltage across the coil and lead the voltage across the capacitor. This means the voltage across the coil should reach a maximum before the voltage across the resistor reaches a maximum and the voltage across the capacitor should reach a maximum last. These phase relationships should remain the same throughout the experiment.
8. On the other oscilloscope, note that the voltage across the resistor is in phase with the current. If this is not the case or any of the relationships in the previous step were not correct, check your wiring and consult your instructor.
9. Note that the current leads the source voltage, meaning that the current has its maximum at an earlier time than the source voltage. This means the phase angle  $\phi$  will be negative.
10. Determine and record the time between when the current becomes zero and when the source voltage becomes zero. Adjust the scale on the time axis so that you can record two significant figures. Adjust the scale on the time axis back to 2 ms/div.
11. Record the amplitude and frequency of the source voltage, the amplitude of the current in the circuit, and the amplitude of the voltage across each component in a table with six columns. Adjust the scales if necessary to obtain two significant figures.

12. Adjust the frequency of the output voltage to 500 Hz. Adjust the scale on both time axes to 0.5ms/div. Press “Start” then “Stop” again. Verify that the period of each sinusoidal function is  $2 \text{ ms} = 1/(500 \text{ Hz})$ . Note that the source voltage now leads the current. This means that the phase angle will be positive. Note also that in the “Resistor, Inductor, and Capacitor Voltages” oscilloscope window the coil and capacitor are more nearly  $180^\circ$  out of phase than when the frequency was 50.0 Hz.
13. Determine and record the time between when the source voltage becomes zero and when the current becomes zero. Adjust the scale on the time axis so that you can record two significant figures. Adjust the scale on the time axis back to 0.5 ms/div.
14. Record the amplitude and frequency of the source voltage, the amplitude of the current in the circuit, and the amplitude of the voltage across each component in your table. Adjust the scales if necessary to obtain two significant figures.
15. Through trial and error, determine the frequency at which the source voltage and current in the circuit are in phase. This is the resonant frequency. Because of noise in the current, you can probably only determine the resonant frequency to the nearest 1 Hz. At resonance why is voltage across the resistor less than the voltage of the source?
16. Repeat step 14.
17. Insert the steel core into the coil. Through trial and error, determine the new resonant frequency. Because of noise in the current, you can probably only determine the resonant frequency to the nearest 1 Hz.
18. Turn off the SW. Exit the program. Close any open folders and shut down the computer. Disassemble your circuit.

### III. CALCULATIONS

1. Use the frequency, voltage amplitudes, and current amplitudes from steps 11, 14, and 16 to calculate three values of the resistance of the resistor and the capacitance of the capacitor. Find the percent difference between the average of the three values obtained here and the nominal values listed on the RLC circuit board.
2. Use the average values of the resistance and capacitance obtained in step 1 and the data collected for the resonant frequency of the coil without the steel core to determine the inductance and resistance of the coil.
3. Make a table containing columns labeled: frequency, inductive reactance, capacitive reactance, total resistance, theoretical phase angle, experimental phase angle, and percent difference. Calculate these quantities for the frequencies of 50 Hz and 500 Hz, using the values calculated in steps 1 and 2.

Lab Partners: \_\_\_\_\_  
\_\_\_\_\_

Name: \_\_\_\_\_

## THE LRC SERIES AC CIRCUIT

Circuit Board Letter: \_\_\_\_\_

Frequency (Hz)	Time between Voltage and Current Maximum (ms)	Current Amplitude (mA)	Voltage Amplitudes			
			Source (V)	Resistor (V)	Capacitor (V)	Coil (V)