LRC Circuit
(Power Amplifier, Voltage Sensor)

Object:

Study the resonance conditions in an inductor-resistor-capacitor circuit (LRC circuit) by examining the current through the circuit as a function of the frequency of the applied voltage.

Apparatus:

Science Workshop Interface, Power Amplifier, Voltage Sensor, (2) Patch Cords, CI-6512 RLC circuit board.

Theory:

The amplitude of the AC current (I_0), in a series LRC circuit is dependent on the amplitude of the applied voltage (V_0) and the impedance (Z).

$$I_0 = \frac{V_0}{Z}$$

Since the impedance depends on frequency, the current varies with frequency:

$$Z = \sqrt{(X_L - X_c)^2 + R^2}$$

Where X_L= inductive reactance =ωL, X_C= capacitive reactance =$\frac{1}{\omega C}$, R= resistance, and ω= angular frequency = $2\pi\nu$(v= linear frequency). The current will be at a maximum when the circuit is driven at its resonant frequency:

$$\omega_{res} = \frac{1}{\sqrt{LC}}$$

One can show that, at resonance, $X_L = X_C$ and thus the impedance (Z) is equal to R. At resonance, the impedance is the lowest value possible and the current will be the largest value possible.

Procedure:

In this activity the Power Amplifier produces an alternating current through the LRC circuit. The amplitude of the current depends on the impedance in the circuit, which varies with frequency. The Signal Generator controls the frequency. Since the current is a maximum at the resonant frequency and less than maximum for greater or lesser frequencies, the measured current will peak at the resonant frequency. The current can be determined from the ratio of the resistor voltage to the resistance. The Voltage Sensor measures the voltage drop (potential difference) across the resistor in the circuit.

You will use the Signal Generator to change the frequency of the applied voltage. You will investigate the phase relationship between the applied voltage and the resistor voltage as you vary the frequency. You will also determine the amplitude of the current through the resistor and then plot current vs. frequency. The Science Workshop program collects and displays both the applied voltage and the resistor voltage. You will compare the theoretical resonant frequency to your measured resonant frequency.

Part I: Computer Setup

1. Connect the Science Workshop interface to the computer, turn on the interface, and turn on the computer.

2. Connect the Power Amplifier to Analog Channel A. Plug the power cord into the back of the Power Amplifier and connect the power cord to an appropriate electrical outlet.

3. Connect the Voltage Sensor to Analog Channel B. The voltage measured at Analog Channel B is related to the current through the resistor by $I = \frac{V_R}{R}$.

4. Open the Science Workshop document titled as shown:
   Windows: P45_LRCC.SWS

5. The Sampling Options... for this experiment are: Periodic Samples = Fast at 1000 Hz (set by the Sweep Speed control in the Scope display).

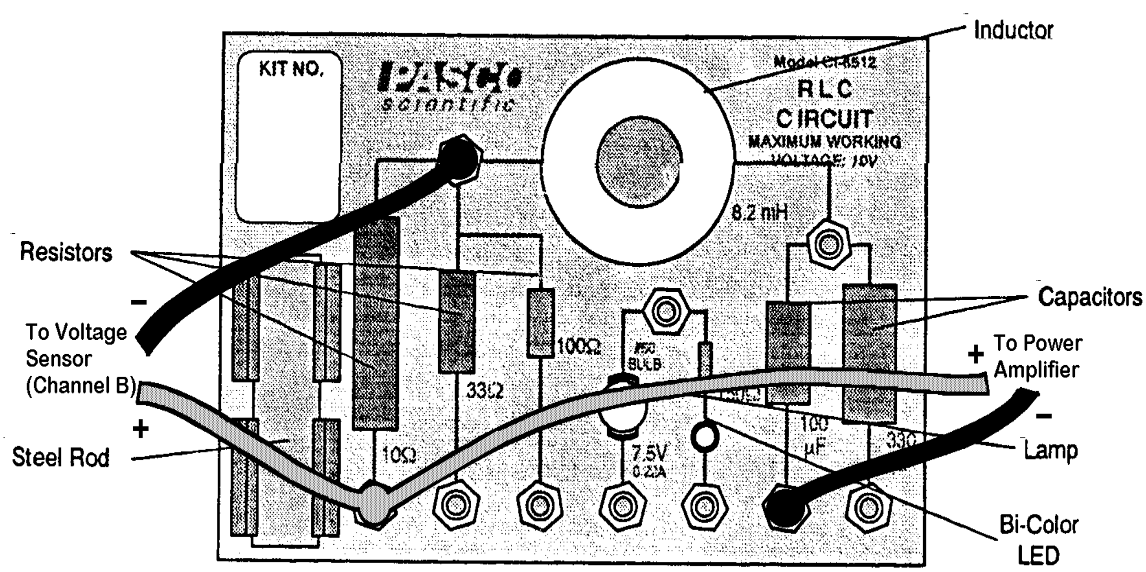
6. The Signal Generator is set to output (applied voltage) a 2.97 V sine wave at 10.00 Hz.

   * The Signal Generator is set to “Auto” so it will start automatically when you click “MON” or “REC” and stop automatically when you click “STOP” or “PAUSE”.

7. Arrange the Scope display and the Signal Generator window so you can see both of them simultaneously.

Part II: Equipment Setup

1. Choose the 10 Ω resistor and the 100 μF capacitor, and make the LRC circuit shown below.

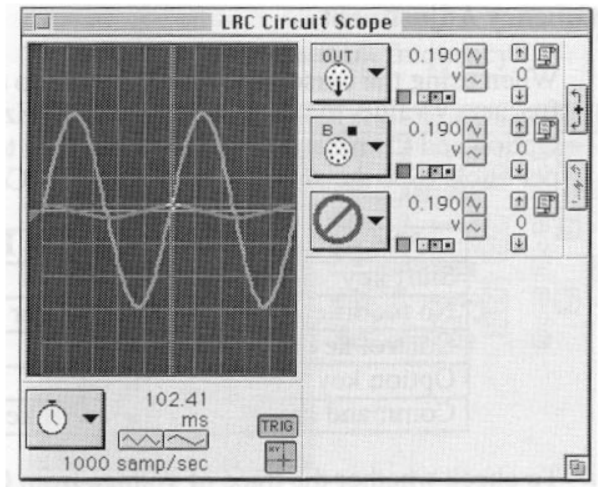


Part III: Data Recording

1. Turn on the power switch on the back of the Power Amplifier.

2. Click the "MON" button to begin monitoring data. The Signal Generator will start automatically.

3. In the Scope display, click the "Smart Cursor" button. The cursor changes to a cross-hair. Move the cursor/ cross-hair to a peak of the voltage across the resistor, V_R(red trace). Record the voltage that is displayed next to the input Menu button for Channel B (for example, 0.190 V in this figure). Find 10 Hz in the Data Table. Record the voltage in the Data Table.



4. In the Signal Generator window, click on the "Up" arrow to increase the frequency by 10 Hz. Find the new frequency (20 Hz) in the Data Table. Repeat the process of using the "Smart Cursor" to find the new value for the resistor voltage V_R(red trace). .

5. Repeat the process until 50 Hz is reached. At this frequency, click the Scope to make it active. Adjust the Sweep Speed in the Scope display from 1000 samples/sec to 5000 samples/sec using the "Increase Speed" button as needed.

6. Click the Signal Generator window to make it active. Increase the frequency to 60 Hz. Repeat the process of using the Smart Cursor to find the new value for the resistor voltage, V_R (red trace), at 60 Hz.

   * Increase the frequency by 10 Hz increments and repeat the process until 150 Hz.

7. Look at the Data Table and determine approximately the resonant frequency (where voltage across the resistor reaches a maximum and the output voltage and resistor voltage are in phase).

8. Click on the frequency in the Signal Generator window to highlight it. Type in the approximate resonant frequency, then press <enter> or <return> on the keyboard to record your change.

9. Make fine adjustments to the frequency until the red trace of resistor voltage from Channel B is in phase with the green trace of the applied Voltage.

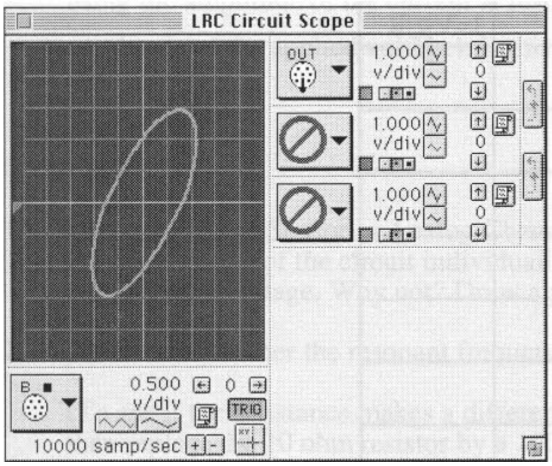
10. To check whether the trace of voltage from Channel B is in phase with the trace of the applied Voltage, create an X-Y mode Scope:

    a. Click the "STOP" button. Click the graph button, on the Vertical Axis Input, select Analog channel B from the Vertical Axis Input menu.

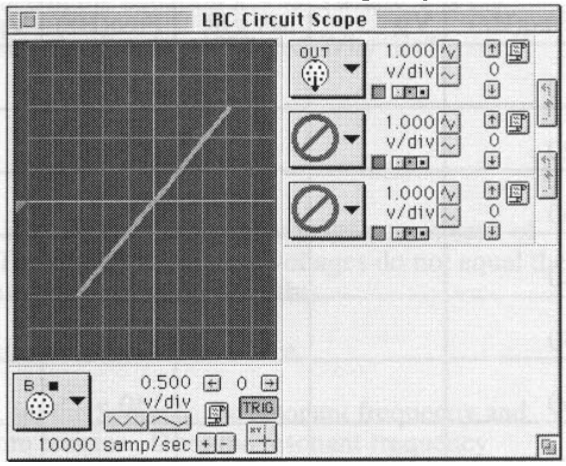
b. Click on the Horizontal Axis Input Menu button along the bottom edge of the Scope. Select on Input from the Channel A from Input menu. Or using the mouse place the cursor over the Channel A signal generator(the applied voltage) and click and drag to the horizontal axis of your graph.

* When the two inputs are in phase, the Scope display in X-Y mode will show a diagonal line. Any phase difference will cause an oval trace. Record the new resonant frequency in the Data Table.

*** X-Y mode at 40 Hz**



*** X-Y mode at resonant frequency**



11. Click the "STOP" button. Turn off the switch on the back of the Power Amplifier.

<u>Analyzing the Data</u>:

1. Calculate the current through the resistor and record the values in the Data Table. Graph the current versus the linear frequency. You can use a graphing program or separate graph paper. (NOTE: The frequency displayed in the Signal Generator window is the linear frequency.)

2. Using the resonant frequency found from the Scope display, calculate the resonant angular frequency and record the value in the Data Table:

$$\omega_{res} = 2\pi\nu_{res}$$

3. Calculate the theoretical resonant angular frequency using the value of the inductance and capacitance:

$$\omega_{res} = \frac{1}{\sqrt{LC}}$$

<u>DATA TABLE</u>:

Freq (Hz)	V_R	$I = V_R / R$	Freq (Hz)	V_R	$I = V_R / R$
10			90		
20			100		
30			110		
40			120		
50			130		
60			140		
70			150		
80					

Item	**Value**
Inductance	mH
Resistance	Ω
Capacitance	μF
Resonant frequency (linear)	Hz
Resonant angular frequency	Hz
Theoretical resonant angular frequency	Hz

<u>Questions</u>:

1. How does your measured value for resonant angular frequency compare to the theoretical value for resonant angular frequency?

   Remember, **Percent discrepancy =** $\left|\frac{|theoretical - actual|}{theoretical}\right| \times 100\%$

2. Is the plot of current versus frequency symmetrical about the resonant frequency? Explain.

3. At resonance, the reactance of the inductor and the capacitor cancel each other so that the impedance (Z) is equal to just the resistance (R). Calculate the resistance of the circuit by using the amplitude of the current at resonance in the equation $R = \frac{V}{I}$ (where V is the amplitude of the applied voltage, 2.97 Volts). Is this resistance equal to 10 ohms? Why not?