LRC Resonance

EQUIPMENT

	INCLUDED:	
1	RLC Circuit Board	CI-6512
1	GLX Power Amplifier	PS-2006
1 set	Patch Cords	SE-7123
	NOT INCLUDED, BUT REQUIRED:	
1	Xplorer GLX	PS-2002
1	DataStudio Software	CI-6870

INTRODUCTION

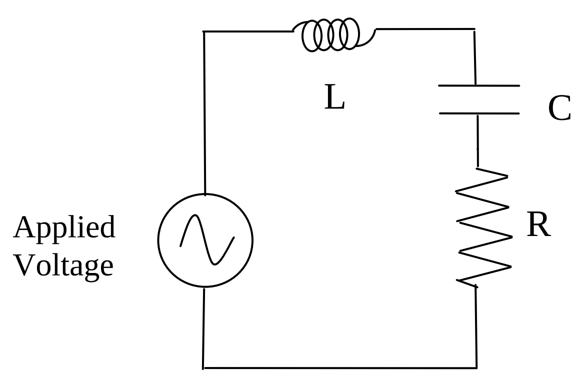
The current through a series LRC circuit is examined as a function of applied frequency and the effects of changing the values of the resistance, inductance, and capacitance are observed.

The phase difference between the applied voltage and the current is measured below resonance, at resonance, and above resonance.

THEORY

If the applied voltage is $\mathcal{E} = \mathcal{E}_{max}\sin(\omega t)$, then the current in the series LRC circuit is

$$I = I_{max}\sin(\omega t + \varphi)$$



where

$$I_{max} = \frac{\mathcal{E}_{max}}{Z} \quad \text{and} \quad \tan\phi = \frac{X_C - X_L}{R}$$

The impedance Z is given by

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

where the capacitive reactance is $X_C = \frac{1}{\omega C}$ and the inductive reactance is $X_L = \omega L$.

At resonance, the current is maximum and thus the impedance is at its minimum. The minimum impedance is equal to R. This occurs when $X_L = X_C$. This yields the resonant frequency:

$$\omega_{res} L = \frac{1}{\omega_{res} C}$$

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

SETUP

1. Connect the GLX Power Amplifier to the GLX by plugging the two cables into the side of the GLX. One cable into the GLX on-board voltage sensor port, the other into the external speaker output port. You can identify each cable by the size of the digital plug.

Figure 1.

2. Connect the GLX Power Amplifier to its power supply (the green LED should light).

3. Open the GLX file called **lrc.glx**.

4. Construct the circuit shown below, **without** the **iron core** in the coil, the 100 μF capacitor, and the 10 Ω resistor in series with the applied voltage.

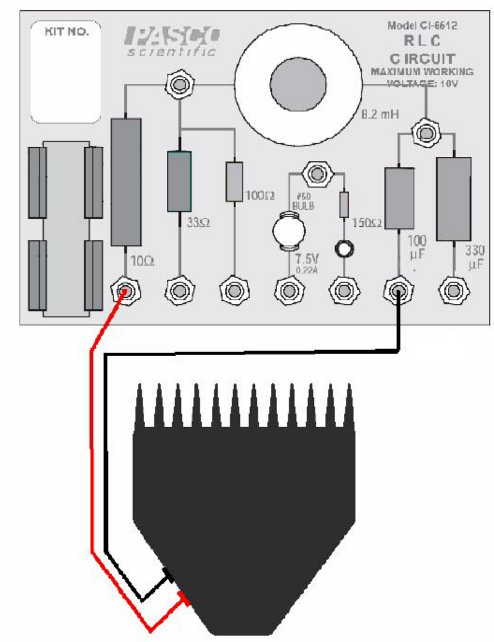
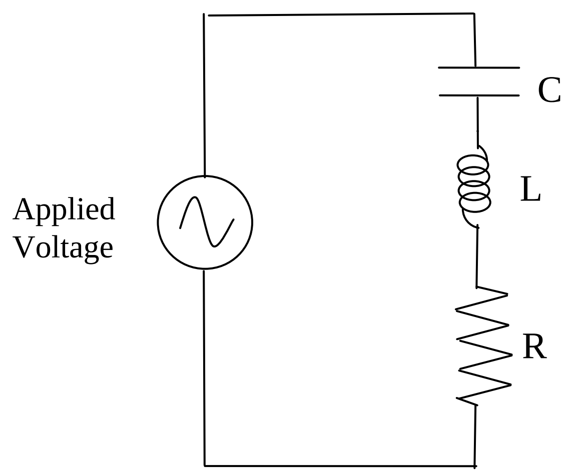


Figure 3.



PROCEDURE: RESONANCE SCAN

1. Turn the GLX Power Amplifier *On* by navigating to the **Output** screen on the GLX and pressing **F1**. You will see that the **F1** button is labeled above it as "On." The relay inside the Power Amplifier should click and the green light inside the case will indicate that the unit has been switched on.

2. Now navigate back to the **Graph** screen and press the **Start/Stop** button on the GLX. The frequency scan will begin. After the current has reached its maximum and has returned to its starting value, press the **Start/Stop** button on the GLX to stop recording.

3. Press the **Auto Scale (F1)** button.

ANALYSIS OF RESONANCE SCAN

1. Use the Smart Cursor to find the resonant frequency where the Peak Current is a maximum.

2. Compare the measured resonant frequency with the theoretical value. If an LRC meter is available, measure the inductance and the capacitance.

FURTHER INVESTIGATION

1. In the graph window, select **Tools** and **Power Amp Config.** This brings up the Power Amplifier settings below the graph. Press the **Esc** button to toggle between the graph and the Power Amplifier settings. Set the frequency of the Power Amplifier back to 20 Hz in preparation for a new run.

2. Decrease the resistance in the circuit by adding the 33Ω resistor in parallel with the 10Ω resistor.

3. Press the **Start/Stop** button on the GLX and scan the frequencies again. Find the resonant frequency.

4. To display both runs, choose **Graphs (F4)** in the Graph screen and choose **Two Runs (5)**.

5. Next change the inductance by inserting the iron core into the coil. This increases the inductance from approximately 8 mH to 20 mH. Set the starting frequency to 20 Hz and do another scan. Find the new resonant frequency. Note: when adding the iron core, there will be some parasitic capacitance between the coils and the iron that may affect the resonance frequency somewhat.

6. Now remove the iron core to return to the original value of the inductance and change the capacitor from 100 μF to 330 μF. Do another scan and find the new resonant frequency.

PROCEDURE: PHASE DIFFERENCE

In this part of the experiment, the phase difference between the applied voltage and the current is examined for different frequencies.

1. Return to the original circuit with 10 Ω, 100 μF, and no iron core in the coil.

2. Open a the file called **lrc part 2**.

3. In the graph window, select **Tools** and **Power Amp Config.** This brings up the Power Amplifier settings below the graph. Press the **Esc** button to toggle between the graph and the Power Amplifier settings. Turn the Power Amplifier on by selecting **Output: On**.

4. Press the **Start/Stop** button on the GLX. After acquiring enough data to fill the screen, press the **Start/Stop** button again and choose the **Delta Tool (2)** from the **Tools (F3)** menu. Use the delta tool to determine the difference in time (Δt) between the peaks of the current and voltage. Does the current lead or lag the voltage?

5. Using the difference in time, calculate the phase difference using

   $\phi = \frac{\Delta t}{T} \times 2\pi$ where T is the period.

6. Compare this phase difference with the theoretical value:

   $\tan\phi = \frac{X_C - X_L}{R}$ where $X_C = \frac{1}{\omega C}$ and $X_L = \omega L$

7. Repeat Steps 4 through 6 for the resonant frequency and for 300 Hz. Note whether the current leads or lags the voltage.

8. Set the frequency at resonance. Press the **Start/Stop** button and insert the iron core into the coil. Observe the changes.

QUESTIONS

1. ~~Why isn't the Peak Current versus Frequency curve symmetrical about the resonant frequency?~~

2. ~~How did changing the resistance, capacitance, and inductance change the resonant frequency?~~

3. ~~What is the phase difference between the applied voltage and the current at resonance?~~

4. Does the current lead or lag behind the applied voltage below the resonant frequency?

5. Which is larger above the resonant frequency: the capacitive reactance or the inductive reactance?

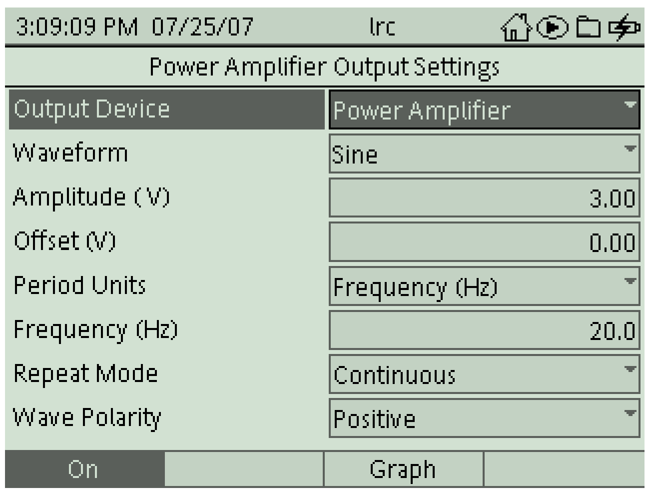
APPENDIX: XPLORER GLX CONFIGURATIONS

Resonance Scan

1. Plug the GLX Power Amplifier into the GLX.

2. Activate the GLX Power Amplifier: From the home screen, go to the **Output** screen and change the **Output Device** from **Internal Speaker** to **Power Amplifier**. The GLX will then quickly calibrate the Power Amplifier.

3. Set the waveform to a **Sine** wave with amplitude equal to 3.00V, frequency equal to 20.0 Hz, and a 0.00V offset.



4. Go to the Calculator and make the following calculation:

   freq = outputfreq(1,20+10*[Time(s)])

   This causes the Power Amplifier scan through the frequencies in steps of 10 Hz each second, starting at 20 Hz.

5. From the main menu, select **Graph (F1)** and make a graph of **Peak Current** vs. **Output Freq**. Select **Graphs (F4)** and select **Two Runs (5)**.

6. Open the Data Files window on the main menu and name the file "lrc" and save it. Return to the Graph window. The GLX is now ready to record data.

Phase Difference

1. Plug the GLX Power Amplifier into the GLX.

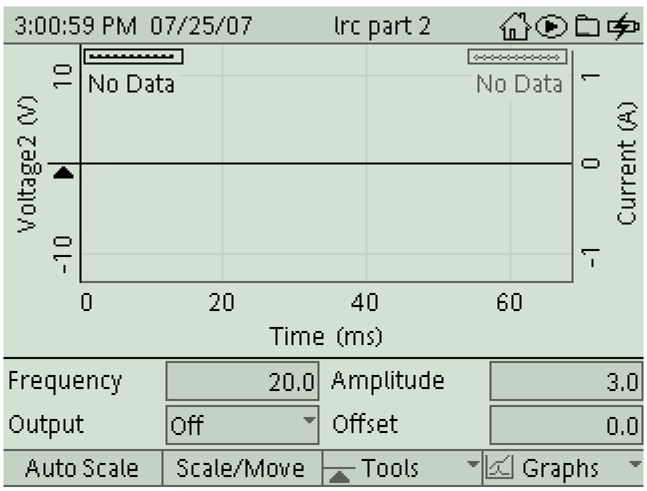
2. Activate the GLX Power Amplifier: From the home screen, go to the **Output** screen and change the **Output Device** from **Internal Speaker** to **Power Amplifier**. The GLX will then quickly calibrate the Power Amplifier.

3. On the graph screen, choose **Graph (F4)** and choose **Two Measurements (4)**. Choose Current and Power Amplifier Voltage for the two axes. Note that there are two Voltage measurements listed. One is for the GLX Voltage Sensor and the other is for the Power Amplifier.

4. On the graph screen, choose **Graph (F4)** and choose **Scope Mode (3)**. Press the **Scale/Move (F2)** button and the left/right arrows to rescale the time axis to 80 ms.

5. In the graph window, select **Tools** and **Trigger Settings**. Enable the Trigger for Rising and Level 0.00 V.

6. In the graph window, select **Tools** and **Power Amp Config.** This brings up the Power Amplifier settings below the graph. Press the **Esc** button to toggle between the graph and the Power Amplifier settings. Set the Power Amplifier frequency to 20 Hz and the amplitude to 3.0 V.



7. Open the Data Files window on the main menu and name the file "lrc part 2" and save it. Return to the Graph window. The GLX is now ready to record data.