AC Circuits Laboratory **Lab # 3**

R-L Series Circuit Analysis and Practical Inductors

Lab Objectives

1. To predict the response of an R-L series circuit to a sinusoidal forcing function.
2. To compare the predicted response to the simulated response of an AC circuit in the time domain.
3. To take measurement data showing the response of an AC circuit in the time domain using the oscilloscope.
4. To compare measured data to simulated and calculated results in order to better understand AC circuit operation.
5. Design and build a simple speaker from an everyday object, a magnet and magnet wire.

Pre-Laboratory Preparation:

Prior to your scheduled laboratory meeting time the following items need to be completed. The prelab quiz will be based on this preparation.

Research/Review

1) Review the text sections and your lecture notes on reactance, phasors and impedance.

Circuit Analysis

2) **Calculations - Study the circuit in Figure 1**. On green engineering or quadrille lined graphing paper:
   a) Calculate the impedance of each component (at the signal frequency).
   b) Draw the impedance diagram of the network as seen by the source. Label each impedance (magnitude and angle), including $\mathbf{Z_T}$.
   c) Use Ohm's Law to determine **I_in**, **VL** and **VR1**
   d) Using your results from part 2-c, determine the equations for i_in(t), VL(t) and VR1(t)

3) **Simulation – Simulate the circuit in Figure 1**. Using Multisim transient analysis, simulate the circuit shown:
   a) Set the initial inductor current to 0A.
   b) Simulate from t=2msec to 3msec with a maximum time step of 10e-6 or smaller. This will give the circuit time to reach a steady-state solution and also for at least 100 data points.
   c) Show the source voltage (Vs), the voltage across R1 (VR1) and the voltage across the inductor (VL1).
   d) Using your simulated results from part 3-c, determine the equations for i_in(t), VL(t) and VR1(t)

4) **Comparison – For the circuit in Figure 1**. Using Excel, compare your calculated and simulated peak values and angles for i_in(t), VL(t) and VR1(t):
   a) Leave room for measured data from lab
   b) Calculate the % error between your simulated and calculated results, using your calculated results as the basis.

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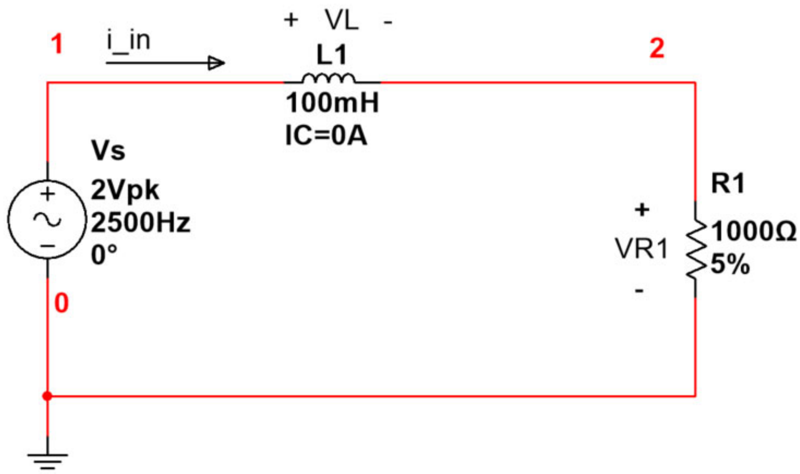

Figure 1 - RL Series Circuit

AC Circuits Lab Procedure: Work with your lab partners and make sure you know your assigned roles

Part 1: R-L Series Circuit Measurements

1) BEFORE building the circuit shown, measure and record L1 (using the LCR meter at 1kHz) and the DC Resistance (DCR) of L1 and R1 using the lab DMM. Record your results below and on the schematic.
   DCR=____________
   L1 = ____________@ 1kHz
   R1 = ____________
2) Build the circuit shown in Figure 1. Make sure you dial in the appropriate signal level and frequency. Check these values in-circuit with the oscilloscope BEFORE proceeding. *** Use the 10Meg-Ohm probe and setting ***
3) Display 1 to 3 cycles of the applied voltage (Vs) on channel 1 (AC Coupling), and the voltage across the 1kΩ resistor (V_{R1}) on channel 2. Note that V_{R1} divided by 1kΩ is the current through the resistor, and therefore, the current through the inductor (since this is a series circuit).
4) As you are displaying these voltages simultaneously, make sure each waveform takes up at least half of the vertical screen and each channel is AC coupled. Use the center major gridline for the ground reference for each channel.
5) Set the oscilloscope measurements to display the peak value of each voltage and the phase difference between the waveforms.
6) Capture the image on the oscilloscope, and embed it on page one of a WORD document titled **AC Circuits Lab 3 [your team name]**.
7) In WORD, show your work below the image, determine the equation for $V_{R1}(t)$ and i_in(t).
8) Repeat steps 3, 4 and 5, this time showing Vs(t) and $V_L(t)$. Use the MATH function to display CH1 - CH2 = V_L. Embed your image and write the equation for VL(t) by hand, below the image on page two of the same Word document.
9) <u>**Comparison – For the circuit in Figure 1**</u>. Using Excel, compare your calculated and measured peak values and angles for i_in(t), VL(t) and VR1(t):
   a) Use the same data table you created in the prelab.
   b) Calculate the % error between your measured and calculated results, using your calculated results as the basis.
   c) Point out any significant discrepancies below your data table on the same page.
10) **Have your instructor sign off on your prints**. Make sure you title and label them properly.

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Part 2: Homemade Speaker.

1) Build a speaker/inductor.

a) Without using a ruler, cut about 12 feet of red 30 AWG magnetic wire. 12 feet is 2 fathoms. A fathom is about the distance between a grown man's outstretched arms, tip to tip.

b) Leaving a foot of wire on each end, wrap the wire tightly ~30 times around a plastic tube. Keep the coil tight against the cylinder in a clean orderly wrap.

c) Carefully slide the wire coil off the cylinder. Use 3 small drops of hot melt glue to keep the newly made voice coil from falling apart. Fasten the voice coil to the selected speaker body with hot melt glue. Keep the glue use to a minimum to make the voice coil as light as possible.

d) Cut a playing card into a circle (or square) just larger than the bottom of the speaker body. The card separates the voice coil and diaphragm from the magnet. Using black tape, tape the card over the voice coil, and a magnet to the other side of the card.

Note: The magnet will remain stationary. The coil, when current flows, will change its magnetic field. The two fields will react with one another and the coil will move (along with the flexible diaphragm). This makes a transducer that changes electrical energy to mechanical energy (sound waves).

e) Scrape the insulation off the ends of the wire and plug them into the stereo. The stereo will take 2 speakers, so you can test two at a time. You should be able to hear the music played through your speaker. **Demonstrate your working speaker, and have the instructor sign off on this step**.

f) Using the function generator set to sine wave, with the peak voltage at 10V, connect your speaker and determine the lowest frequency that can be heard, and the highest frequency that is audible. Record the frequency response (lowest frequency – highest frequency) on the lab cover sheet. NOTE: The human ear (especially younger people of college age) can typically hear sound frequencies from about 30Hz to about 18,000Hz.

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Post Lab Requirements:

1. After lab, **during a time specified by your instructor**, take the Post Lab Quiz on myCourses. You may use your prelab work, lab data and calculations as reference material.
2. Turn in your completed documentation at the beginning of next week's lab before you take that week's prelab quiz. Your submission package will be graded and returned with comments. Submit only the following (in order) at the start of lab NEXT week:

   a. The following cover page (completely filled in by all of your team members) with sign-offs and your speaker frequency response numbers included, one per team.

   b. 2 pages of lab data in WORD, including oscilloscope data, calculations and annotations, one per team.

   c. Your EXCEL data table from the prelab and lab, showing your calculated, simulated and measured results as well as % Error values as specified.

   d. The circuit schematic from Figure 1, the impedance diagram from the prelab AND a new impedance diagram based on your measured data, all on a single page, properly labeled. Directly below this information, explain the differences between the two impedance diagrams and how these differences may have led to the discrepancies you noticed between your calculated and measured data, one per team.

Lab Note 1: Speaker Design

A speaker is a transducer that takes electrical energy and changes it into mechanical (sound) energy. A speaker uses 2 magnetic fields to do this. One is fixed (the speaker magnet) and the other is an inductor attached to a diaphragm that has current flowing through it. Remember that any wire that is carrying current has a magnetic field around it (Lentz's law, right hand rule) and when the wire is wrapped in a toroid (cylinder shape) it can focus the magnetic field inside the turns. A toroid shaped coil used in a speaker is called a voice coil. Recalling physics, every magnet has a North and South pole, different poles attract, and same poles repel. When the current through the voice coil changes direction, its poles reverse. The attraction or repulsion seen at the voice coil when in the fixed magnetic field of the speaker magnet is proportional to the current in the coil. To get a loud sound, merely increase the current.

Designing a speaker is a challenge; the engineer has to balance low frequency power capacity (large and heavy voice coil) with high frequency response (needing a small light voice coil). This is why stereo speakers come in systems with a woofer (low frequency high power) a mid-range speaker (lighter voice coil with a smaller and lighter diaphragm) and a tweeter (very small very light voice coil and diaphragm). Your speaker can be designed as you see fit. Feel free to use a different cup or bowl in your design, and note the effect on the frequency response when more turns are used, or a larger diaphragm is used. Get together with the other students and compare notes.

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Team Name and Lab Section:...

Team Members Present (printed)

First Name, Last Name	Role This Lab	RIT Program

TEAM LABORATORY RESULTS GRADE

(all work done neatly, legible and properly organized, all signoffs in place, oscilloscope plots and annotations included, EXCEL data table, schematic and impedance diagrams and explanations correct, no missing information and no extraneous information)

Instructor Signature, RL Series Circuit ________	/10
Oscilloscope plots, Annotations and Calculations	/10
Instructor Signature, Working Speaker ________	/10
EXCEL Data Table (including % error calcs, point out discrepancies)	/15
Schematic, Impedance Diagrams and Explanation	/15
Final Team Grade	**/60**

Estimated Speaker Frequency Response: _________ Hz to _________ Hz

Instructor comments: