ECE 214 - Lab #6 — Inductors and the RLC Circuit

22 March 2016

Introduction: The basic functions of the oscilloscope, function generator and power supply, first used in Labs 1 - 5, are reviewed. The inductor is introduced. An RLC circuit is analyzed, simulated in MicroCap, and measured. MATLAB® is used to compare simulated and theoretical results.

Pre-Lab:

Review the step response of a series RLC circuit from your notes in ECE 210. Make sure you can distinguish between a critically damped, underdamped and overdamped circuit and derive the equations for the voltage across the circuit elements as a function of time.

Laboratory:

1. Review of oscilloscope and function generator. Record all results in your notebook.
   (a) Turn on the Agilent E3630A DC power supply and use the ±20 V knob to adjust this display to show 12.00 volts.
   (b) Connect Ch#1 on the scope to the power supply by connecting the black lead to the COM of the power supply and the red lead to the +20 terminal. Use the single trace and trigger controls to capture the power supply's output voltage when it is turned on. Measure the time constant of this signal.
   (c) Capture the supply's output voltage when it is turned off. Measure the time constant of this signal. Note: wait at least 10 seconds after turning the power supply on or off to make sure the supply has reached its final value.
   (d) Set the function generator to produce a 1 Vpeak sine wave with a 2 Vdc offset at a frequency of 1 kHz. Verify the signal is correct using the oscilloscope. Record the signal in your notebook.
   (e) Set the function generator's output to produce a burst of one cycle every time you press the *trig* button. The signal should be a sine wave at 1 kHz, with an amplitude of 1 Vpeak, and a DC offset of 2 volts. Capture this signal and have it fill the screen of the oscilloscope. The ground symbol on the scope display should be in the middle of the screen for this display. You will need to use AC coupling for this.
2. Each team will be supplied with an inductor. The inductor is to be used in Lab #6 and Labs #8 – #10.
   (a) Measure the inductance and quality factor Q for the inductor using the LCR meter at frequencies of 1kHz and 10kHz.
   (b) Calculate the equivalent series resistance of the inductor from the measured value of Q.
   (c) Measure the DC resistance of the inductor using a DVM. Explain the difference in the DC resistance compared to the value obtained in step 2b?

(d) Use two experimental techniques to approximate the number of turns of wire on the inductor. Provide a convincing argument as to the number of turns of wire on one inductor with an estimate of the error. Explain any discrepancy between the two measurement techniques.

3. Build the RLC circuit shown in Figure 1.

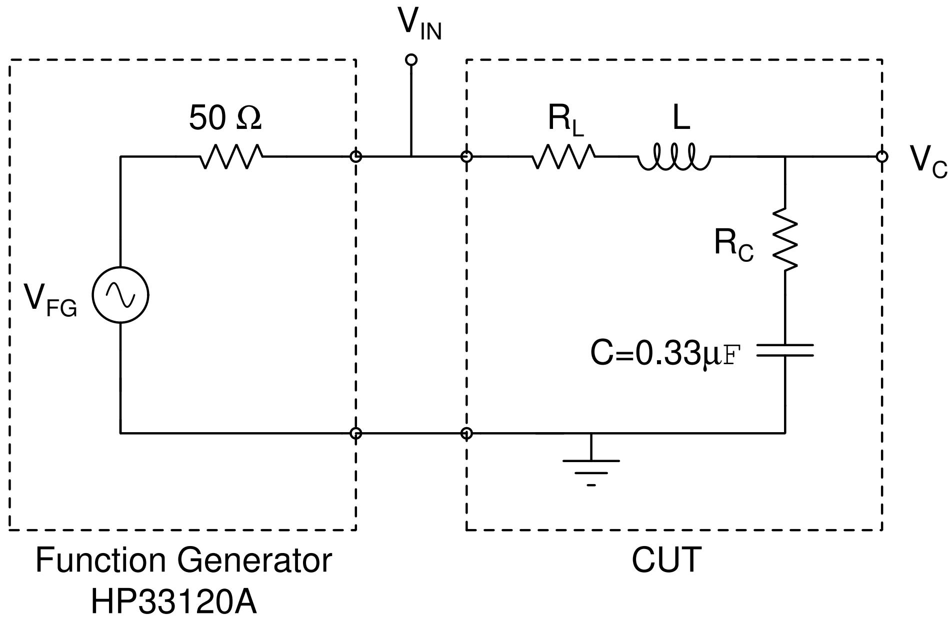

Figure 1: RLC circuit to be analyzed and measured in Lab #6.

(a) Set the function generator to produce a sinusoidal signal with a peak–to–peak voltage of 2 V and a DC offset of 1 V. Verify on the oscilloscope that the function generator is producing the correct waveform. Use the oscilloscope to measure the voltages V_C and V_{IN}.

(b) Use the XY mode of the scope and Lissajous figures to determine the frequency that produces a phase shift across the capacitor of 45° with respect to the input signal. Does the voltage across the capacitor lead or lag the input voltage at this frequency? How do the measured results compare to the simulated results?

(c) Determine the frequency or frequencies that produce a phase shift across the capacitor of 90° with respect to V_{IN}? Does the voltage across the capacitor lead or lag the input voltage at these frequencies?

(d) Measure the voltage across the capacitor V_C at frequencies of 1kHz, 10kHz, 50kHz, 100kHz and 300kHz. Note any problems you encounter. Use averaging to reduce the random noise if necessary.

(e) Connect the "sync" output from the function generator to the external trigger input of the scope. Set the scope to external triggering. Measure the voltage across the capacitor V_C at frequencies of 1kHz, 10kHz, 50kHz, 100kHz and 300kHz. Use averaging to reduce the random noise if necessary. How does this result compare with the measurement in the previous step?

(f) Adjust the function generator to output a single pulse of 2 V peak-to-peak and a pulse width of 50 ms. Make the generator produce only a single pulse when you press the *trig* button. Adjust the offset to make the generator's output 0 volts when the pulse is not present.

(g) Now use the single trace and trigger controls on the scope to capture a single event. Capture the signals that appear at V_{IN} and V_C when a single pulse is generated. Sketch these signals in your notebook. Use the Math key (+/-) on the scope to look at the voltage across the inductor (the difference between channel #1 and #2).

Post-Lab:

Analyze the RLC circuit shown in Figure 1 using actual values of the capacitor and inductor.

1. Is the circuit under-damped, over-damped, or critically-damped?
2. Derive an equation describing the voltage across the capacitor, V_C, and the inductor, V_{IN}–V_C, when the input is a 2 Volt peak–to–peak sine wave at a frequency of 10kHz.
3. Use AC simulation to examine the response of this circuit in the frequency domain from 1 kHz to 1 MHz. Plot the node voltages V_{IN} and V_{C} on one graph and plot the voltage across the inductor, V_{IN}–V_C, on a separate graph. Do the values of V_{C} and V_{IN}–V_C agree with your calculation at 10kHz? Explain and differences in your notebook.
4. Derive an equation describing the voltage across the capacitor, V_C, and the inductor, V_{IN}–V_C, when the input is a 2 Volt step function.
5. Simulate the *expected* voltages when the input signal is a 2 Volt step function. Use transient simulation to examine the response of this circuit in the time domain. Plot the three voltages V_{FG}, V_{IN} and V_{C} on one graph and plot the voltage across the inductor, V_{IN}–V_C, on a separate graph. Save your results so they can be imported into MATLAB® .
6. Use MATLAB® to compare the theoretical voltage across the inductor obtained in step 4 with the simulated result obtained in setp 5. Do these signals look like the signal you measured in step 3g of the lab procedure? Make an entry to the graph in your table of contents. Discuss this result and note any discrepancies in your notebook.
7. How do these simulated and theoretical results compare with the measured results?