

## Class #5: Experiment Electromagnetic Oscillations LC Circuits

**Purpose:** In this experiment you will examine voltage oscillations of a simple  $LC$  circuit. This should ideally be done as a team of two students.

Background: Before doing this experiment, students should be able to

- Determine the values of series and parallel combinations of resistors
- Identify the value of standard, low wattage resistors from the color and pattern of their stripes
- Identify a specific inductor and capacitor from a given set of components (from the parts kit)
- Set up the Analog Discovery scope and Function Generator to characterize the relationship between the input and output of a simple circuit. Set up the Function Generator to produce a specified, time-varying voltage signal. Set up the Scope to display a few cycles of a periodic signal and using most of the screen area to achieve maximum measurement resolution.
- Annotate plots to highlight key information

Learning Outcomes: Students will be able to

- Calculate the ideal resonant frequency of a parallel LC circuit
- Experimentally determine the oscillating frequency of an LC circuit
- Describe the function of a diode
- Trigger the scope to provide maximum information in the scope display
- Identify a decaying sinusoid signal and qualitatively describe the origins of the two main features of a realistic LC circuit voltage.
- Export Analog Discovery scope data as a csv file, useful for Excel and Matlab
- Observe the self-resonance frequency of an inductor and use it to determine its parasitic capacitance

Equipment Required

- 1 inductor, inductance  $L = 1$  mH
- 1 capacitor  $C = 1$   $\mu$ F
- 1 resistor 1 k $\Omega$
- Analog Discovery function generator and oscilloscope
- 1 diode (1N914)
- A protoboard

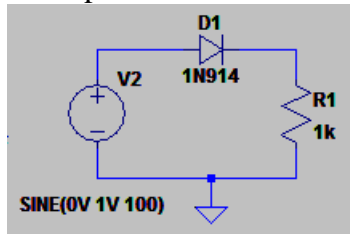
### Pre-Lab

*Required Reading and Viewing:* Before beginning the lab, at least one team member must read over and be generally acquainted with this document and the other **required reading and viewing** materials listed on the course website.

*Hand-Drawn Circuit Diagrams:* Before beginning the lab, hand-drawn circuit diagrams must be prepared for all circuits either to be analyzed using SPICE or physically built and characterized using your Analog Discovery board.

## Instructions:

- Set up the Function Generator 1 (W1) to create a sine wave of about 100 Hz and peak to peak amplitude of 4V (amplitude = 2V).
- Set up the Oscilloscope to view two full cycles of the W1 on Channel 1 (1+) and so that the signal looks as large as possible without going off the screen. (Adjust the horizontal time base and vertical scale. Trigger on Channel 1.)
- Set up the circuit below, with Channel 2 connected across R1:

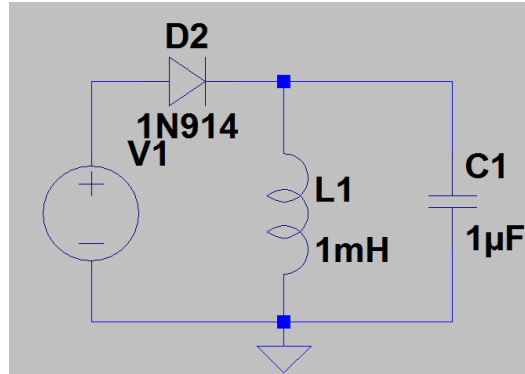


- Click Run on both the function generator and the scope. (You will usually not be given this direction. It is assumed that you will know you have to do this in each case.)
- On your hand-draw the circuit diagram, carefully label the connections from Analog Discovery for W1, GND, 1+, 1-, 2+, 2-.
- Use the Add Channel feature on the scope and add a channel that displays the difference between channel 1 and channel 2. For this experiment, make sure the vertical scales are the same for all three signals you are plotting.

Observe what happens to the sine wave. Describe the waveform in a sentence. Capture the waveform and copy and paste it into your report doc. Label the input (voltage produced by the function generator) and the output (voltage across the resistor). Also show the magnitude of each signal at key points (do not assume that the reader can easily figure it out from the scales on the plot.

1. Based on this observation, what is the function of a diode?

- Switch the function generator to square wave output and make sure the oscilloscope shows a few cycles of the periodic signal. Save this waveform and include it in your report. Again, fully annotate your plot.
- Reconnect the instruments with the diode, inductor and capacitor as shown in the diagram below. As above, connect Channel 1 of the scope across the function generator and channel 2 across the capacitor and inductor. Be sure that you carefully identify the components. There are only two inductors in the parts kit, but many capacitors. You will find the pictures shown in the Digilent parts kit documentation to be helpful.  
(<https://www.digilentinc.com/Products/Detail.cfm?NavPath=2,842,845&Prod=APK>)



2. Calculate the frequency at which the circuit should oscillate. The information necessary to answer this question is found in the required reading and viewing materials.
  - Now you will use the oscilloscope to measure the frequency at which the circuit actually oscillates. When you apply the 100 Hz square wave, the *LC* circuit will oscillate immediately after either the rising or falling edge. Change your trigger to place the oscillations at the left of your screen (so you can see as much of the oscillation as possible).
  - Change your Horizontal Time/Div in order to easily observe and measure the period of oscillation. Capture the waveform and include in your report (fully annotated).
  - What is your time/div setting? Use the cursors to measure the period of oscillation. (Activate the cursors by clicking on the X in the lower left hand corner of the window.)
  - Record how you set up the scope trigger. If you are unsure of how triggering works, explore the various features that allow you to change the trigger and observe what happens to the display as a result.
3. From the period, determine the frequency at which the circuit oscillates. The frequency should be close to the calculated frequency. If it is not, check your circuit and calculation. Note whether the frequency you measure is a little smaller or a little larger than the one given by the formula.

(Do you see why a diode was used? A diode passes current in one direction only. During half of the square wave, the diode conducts, and energizes the *LC* circuit. For the other half of the square wave the diode does not conduct, so the *LC* circuit is effectively isolated from the function generator and free to oscillate.)

Show your working experiment to a TA or instructor, along with your annotated plots and your two calculations of frequency. Explain why your results make sense. Obtain a signature that you have completed this task. \_\_\_\_\_

4. Is the waveform purely sinusoidal, or does it grow or decay? Describe the waveform in words and discuss why it differs from simple theory. Look up the spec sheet for the inductor and see if you can find the characteristic that causes the growth or decay. (Here is where reading the entire write-up will help you.)

- Now adjust the square wave so that its maximum positive amplitude is 1V and negative amplitude is -2V. You will need to adjust both the amplitude and offset to make this happen.
  - Repeat the measurements you just made, again saving and annotating the data plots.
5. What is different about the voltages measured? (Compare with previous plot.)
- Before moving to the last part of this experiment, export the data in your plot, saving it as a comma-separated-value (csv) file called DiodeLC.csv. Be sure you remember where you put it because we will be analyzing this data using Excel in a future activity. Click the export button at the upper left of your scope screen (depending on the Waveforms version you are using, you may find it in the drop down File menu). At the bottom of the window that comes up, give the name you want to save the file as and the location.

All inductors possess an inherent capacitance, called a “parasitic” capacitance. The inductor acts as if it has a capacitance connected in parallel.

- Disconnect the capacitor and measure the frequency at which the inductor oscillates.
6. Calculate the value of the parasitic capacitance from the frequency you have measured.

Inductors also have sufficient resistance that we cannot ignore it when they are modeled.

- Measure the resistance of your inductor using your Ohmmeter. If the resistance is small (less than a few Ohms), you must also measure the resistance of your probe wires and subtract it from the value read. To do this, short the two meter probes together and you will see their resistance.
  - Also look up the resistance of your inductor to see what the manufacturer claims it is. To check the specs of any of the devices in your parts kit, go to the Digilent website. On the page with information on the parts kit, find the inductor (the name and picture are shown), click on Link at the right and you will find the spec sheet.  
(<https://www.digilentinc.com/Products/Detail.cfm?NavPath=2,842,845&Prod=APK>)
7. Compare the resistance value you measured with the one found on the spec sheet. What aspect of the oscillating signal you measured for the LC circuit is caused by the resistance?

Report: List all 7 questions/tasks. Provide the annotated data for each one along with the answers to any questions. Collect any additional information asked for and include in your report.

8. (Extra Credit) Your answer to question 6 is likely to be incorrect if you have not taken the input capacitance of the scope into account. Correct your result using this additional information. *Hint: Redraw the circuit including both the parasitic and input capacitors.*