6.4.1: Inductor Voltage-current Relations

Overview:

In this assignment, we will measure the relationship between the voltage difference across a capacitor and the current passing through it. We will apply several types of time-varying signals to a series combination of a resistor and a capacitor. The voltage difference across the resistor, in conjunction with Ohm's law, will provide an estimate of the current through the capacitor. This current can be related to the voltage difference across the capacitor.

The results of our voltage-current measurements will be compared to analytical expectations.

Before beginning this lab, you should be able to:

- State voltage-current relationships for inductors in both differential and integral form
- Apply the inductor voltage-current relations to calculate a inductor's voltage from its current and vice-versa
- Use the Analog Discovery's arbitrary waveform generator and oscilloscope to apply and measure time-varying waveforms (Lab 6.2.1)

After completing this lab, you should be able to:

- Use the Analog Discovery oscilloscope's math function to calculate the current through a known resistor from the measured voltage difference.
- Export data acquired by the Analog Discovery to files for post-processing by other programs
- Verify a inductor's voltage-current relations using measured data

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit

Symbol Key:

DEMO Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.

ANALYSIS Analysis; include principle results of analysis in laboratory report.

SIM Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.

DATA Record data in your lab notebook.

General Discussion:

We will use the circuit of Figure 1 in this lab assignment. Both the voltage difference across the inductor and the resistor ($v_L(t)$ and $v_R(t)$) will be measured. From this data, we can readily compare the voltage across the inductor with the current through the inductor. Since the voltage across the resistor is measured, we can readily infer the current through the resistor via Ohm's law:

$$i_R(t) = \frac{v_R(t)}{R} \tag{1}$$

The resistor and inductor are in series, so the current through the inductor is the same as the current through the resistor, so:

$$i_L(t) = \frac{v_R(t)}{R} \tag{2}$$

Since we are also measuring the voltage difference across the inductor, $v_L(t)$, we can readily compare these parameters with our expectations based on our mathematical models of the capacitor voltage-current relationships.

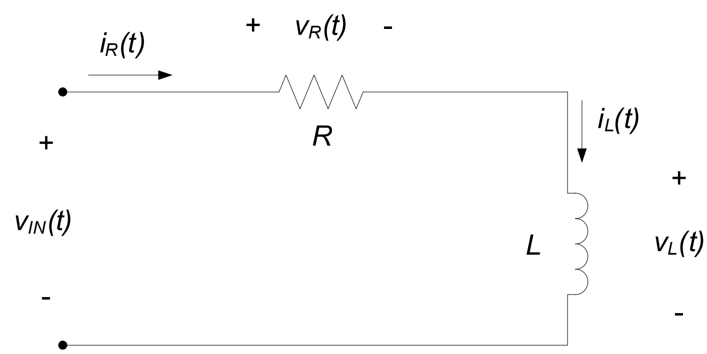


Figure 1. Series RL circuit.

Pre-lab:

In this lab, we will apply sinusoidal signals to the inductor of Figure 1. Mathematically, the form of the inductor current will be:

$$i_L(t) = A\cos(2\pi ft) \tag{3}$$

ANALYSIS

where A is the amplitude of the sinusoid (in volts) and f is the frequency (in Hz). The waveform is shown graphically in Figure 2. For the circuit of Figure 1, use the inductor voltage-current relations to calculate the inductor voltage resulting from application of the voltage of equation (3). Your results may be dependent up on the parameters A, f, and L.

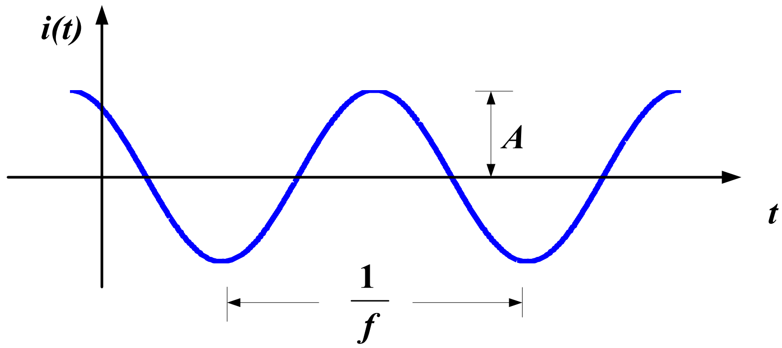


Figure 2. Basic waveform used in this lab.

Lab Procedures:

Construct the circuit of Figure 1 with L = 1mH and R = 100Ω. Use channel 1 of your oscilloscope to measure the resistor voltage difference, and channel 2 of your oscilloscope to measure the inductor voltage difference. Use channel 1 of your waveform generator (W1) to apply the voltage $v_{in}(t)$ in Figure 1. Set up a math channel to calculate the current through the inductor per equation (2) in the pre-lab[1]. Set the oscilloscope measurements to provide at least the amplitude of each of the three displayed waveforms.

1. Apply a sinusoidal input voltage with frequency = 1kHz, amplitude = 2V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to C1, C2, and M1; measurement window displaying amplitudes of C1, C2, and M1). Export the data in the oscilloscope time window to a .csv file for later processing. **DATA**
2. Apply a sinusoidal input voltage with frequency = 2 kHz, amplitude = 2V, and offset = 0V to the circuit of Figure 1. Use your oscilloscope to display the data listed above (waveforms corresponding to C1, C2, and M1; measurement window displaying amplitudes of C1, C2, and M1). Export the data in the oscilloscope time window to a .csv file for later processing. **DATA**
3. **DEMO** Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.

Post-lab Exercises:

ANALYSIS **ANALYSIS**

Import the data acquired in the lab procedures into your favorite numerical analysis software (e.g. Excel, Matlab, Octave, etc.) Use the software and the results of your pre-lab analysis to calculate the expected inductor voltage waveforms corresponding to the inductor current waveforms you measured in the lab procedures. Use the software to overlay plots of the expected and measured inductor voltages for each of the cases tested in the lab procedures. Comment briefly on the agreement between the measured and expected inductor voltages for each of the cases. In your comments, be sure to include a quantitative comparison (including percent difference) between the expected and measured amplitudes of the inductor voltages.

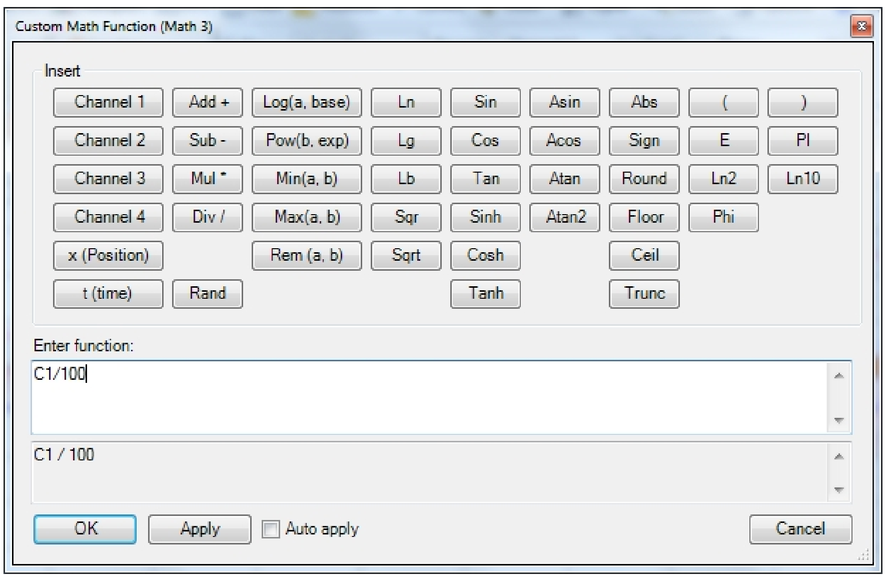
[1] Detailed instructions for doing this are provided in Appendix A.

Appendix A – Math channel to calculate current from resistor's voltage

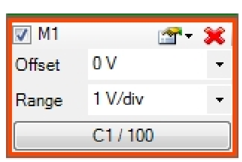
The analog discovery provides capabilities for performing mathematical operations on the displayed waveforms and displaying the result. Essentially, there are two basic "types" of mathematical operations which can be performed: "Simple" and "Custom". The simple math operations consist of addition, subtraction, or multiplication of the two channels. The custom operations are much more wide-ranging. In order to determine the resistor current, we want to divide the resistor voltage by a constant (the resistance value), so we will create a custom math channel. To do this, follow the steps below:

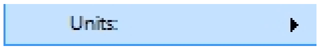
1. Click on Add Channel. Select Add Mathematic Channel from the resulting drop-down menu and choose Custom.

2. A custom math function window will open, as shown below. Type the desired math function (typically a function of the scope channels, C1 and C2) in the text box in this window or use the buttons in the window to create the function. We are using channel 1 (C1) to measure the resistor voltage. The current through the resistor is simply the resistor voltage divided by the resistance value (100Ω), so our function is: C1/100, also shown in the Figure below. Click OK to display the function in the main window.



3. The properties of the math channel display can be adjusted using the channel's control box, just as any with any other channel displayed by the scope. A typical control box is shown below:



4. The units of our math channel are amperes. It is nice to have the displayed units agree with the actual units of the measurement. To change the units, click on the  icon on the control box and select  from the resulting drop-down menu. Volts, will typically be the default unit; it you want the vertical axis in amps, click the icon and select **A** from the resulting menu[2].

[2] Choices of units are volts (V), amps (A), and watts (W).