PHYS245 Lab: Phase relations in capacitor and inductor

Purpose:

• Use the Dual-channel feature of the Oscilloscope.
• Measure the phase difference using the Oscilloscope
• Understand the current – voltage phase relations in capacitor and inductor.

Equipments: ELVIS II, 4.7 nF capacitor, 10 mH inductor, 330 Ω and 10 Ω resistor, two coaxial cables, two banana-to-minigrabber cables, and jump wires.

For a resistive load, the current through the load and the voltage across the load is always in phase. But the current and voltage are not in phase for capacitive or inductive load. For a capacitor, the current leads the voltage by a phase difference of $\pi/2$. For a inductor, the current lags behind the voltage by a phase difference of $\pi/2$. The phase relations between current and voltage can be displayed on the dual-channel Scope of the ELVIS II.

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Pre-Lab exercises

Practice the circuit construction using the prototyping board picture on the next page.

Answer the following questions:

• For a 10 mH inductor, what is its impedance at 5 kHz?

• For a 4.7 nF capacitor, what is its impedance at 10 kHz?

• If a sine wave voltage is applied across an inductor, sketch the wave forms of the voltage across the inductor and the current through the inductor. Pay attention to the phase relations between the two signals.

• If a sine wave voltage is applied across a capacitor, sketch the wave forms of the voltage across the capacitor and the current through the capacitor. Pay attention to the phase relations between the two signals.

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Pre-Lab exercises
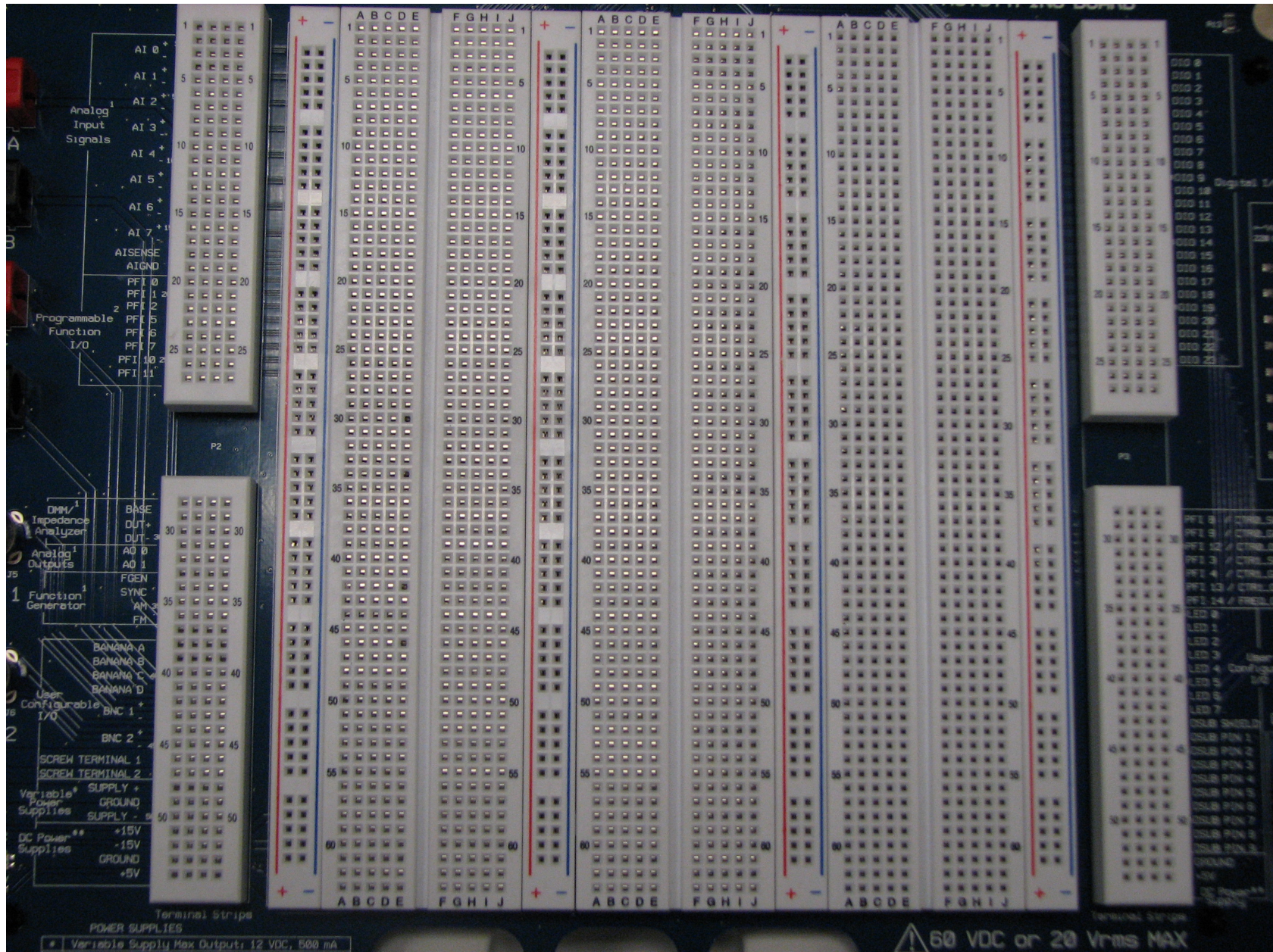
Experiment I: Current and voltage phase relation of a inductor

Scope Ch0

$L = 10$ mH

Scope Ch1

FGEN

5 kHz sine wave ($V_{pp} = 2$ V)

$R = 10\ \Omega$
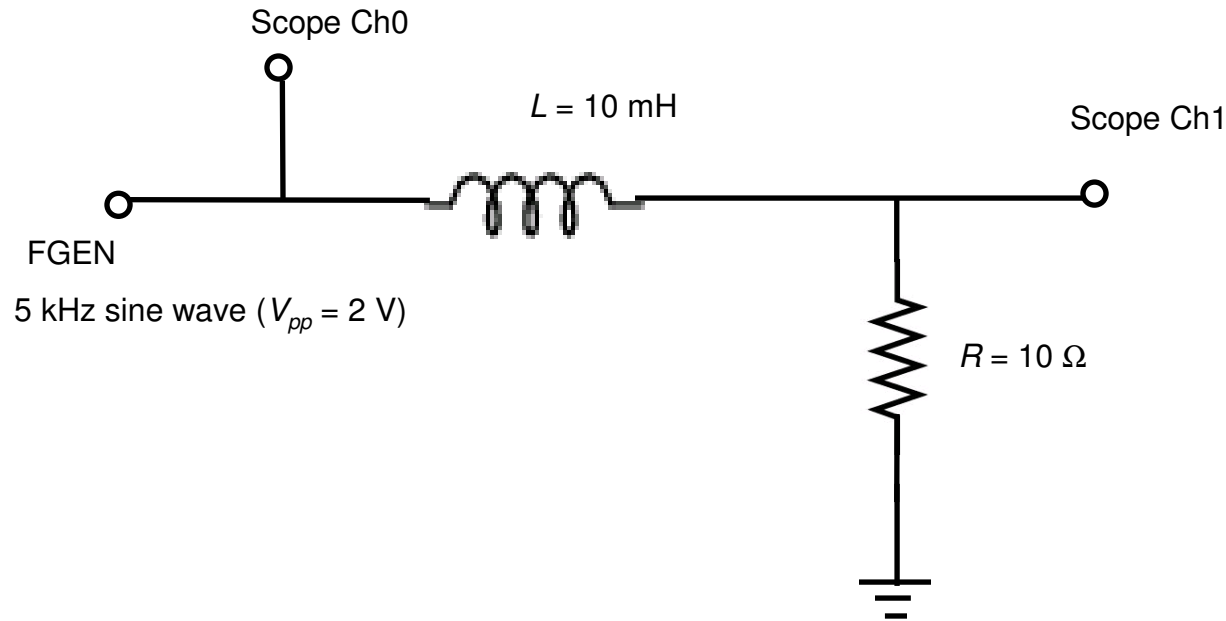
Construct the above circuit on the prototyping board. Note that the circuit is greatly simplified by using a common ground. The ground connection is available on the distribution stripe. The metal shields of the BNC connectors for FGEN, Scope Ch0 and Scope Ch1 are also internally grounded.

The Scope Ch0 will display the input signal from FGEN, and the Scope Ch1 will display the signal across resistor R. To a very good approximation, Ch0 represents the voltage across inductor L, and Ch1 represents the current through inductor L.

For a resistor, the current and voltage are always in phase. Therefore the voltage across R is a good representation of the current through R. Since the resistor R and inductor L are in series, the current through L is the same as current through R. Thus voltage signal of Ch1 represents the current through the inductor L.

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Also bear in mind that the oscilloscope can only directly measure an *a.c.* voltage, not an *a.c.* current. It is a common practice to display the voltage on a resistor and use it to represent the current in that branch of the circuit.

As for the signal of Ch0, you may notice that it is actually the total voltage of the inductor *L* and the resistor *R*. However, at 5 k Hz, the impedance of inductor Z_L is much larger than resistance *R*. Verify this using the calculations in the Pre-Lab. Since Z_L >> R, the total voltage supplied by the FGEN predominantly drops on the inductor, according to the voltage divider rule. So the signal of Ch0 is a good representation of the inductor voltage.
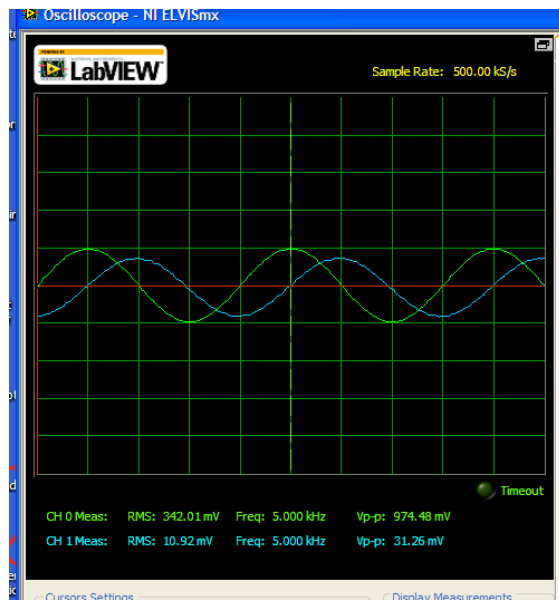

Activate the FGEN and Scope to display the waveforms. Enable both channels (Ch0 and Ch1) to display two waveforms at the same screen. Adjust the timebase and the sensitivity (Volts/Div) accordingly to achieve a clear display of the waveform. Use different sensitivity for Ch0 and Ch1, because the amplitudes of signals for two channels are quite different.

The snapshot on the left is an example of displayed waveforms. Obtain stable waveforms on your Scope by using "Edge" trigger. Refer to annotation at the bottom the screen to identify which waveform is for which channel. Determined the phase difference between the current and the voltage of the inductor.

Verify that the voltage leads the current by $\pi/2$.

It is also a good exercise to verify the voltage divider rule in this *a.c.* circuit. For components in series, the voltage across a component should be proportional to its impedance. The inductor and resistor are in series. Verify that the ratios of the two voltages equal to the ratios of the two impedances.

Experiment II: Current and voltage phase relation of a capacitor

Scope Ch0

$C = 4.7$ nF

Scope Ch1

FGEN

10 kHz sine wave ($V_{pp} = 2$ V)

$R = 330\ \Omega$
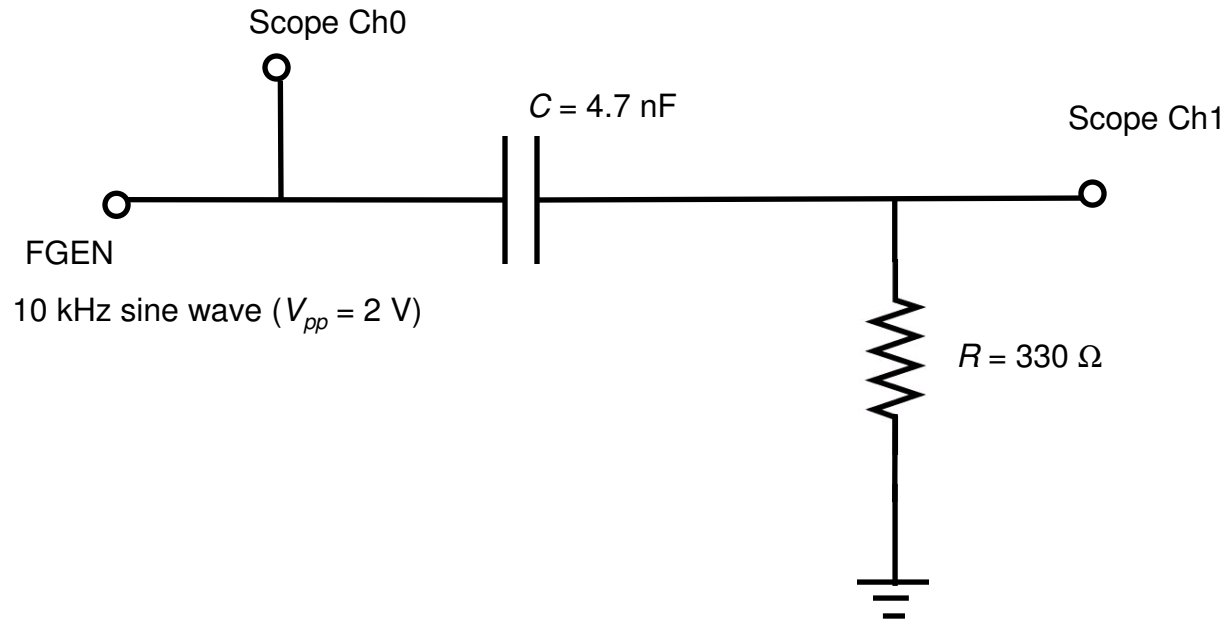
Construct the circuit on the prototyping board according to the diagram on the left.

Make an argument that you can use Ch0 as a representation of the voltage on the capacitor and use Ch1 as a representation of the current through the capacitor. Include your reasoning in the Lab report.

Display the waveforms on the Scope and verify that the current leads the voltage by $\pi/2$.

Verify the voltage divider rule in this circuit.

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