Name: Lab section:

Total score for lab: _______ /10

Lab 3: AC Phasors

INTRODUCTION:

In this lab, you will apply your knowledge on phasor techniques to analyze some basic circuits comprising resistors and reactive components (i.e. **inductors**). The objective here is to relate a theoretical understanding of impedance and phase to what can be observed using an oscilloscope. In the process, you will learn how to use a signal generator to output a sinusoid signal and an oscilloscope to measure them.

Learning outcomes

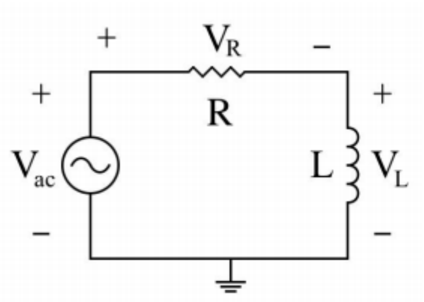
- ☐ Demonstrate use of a signal generator to output AC signals and an oscilloscope to measure them
- ☐ Explain from observation the dependence of impedance on the AC signal frequency
- ☐ Observe the superposition of multiple frequency sources in a basic circuit with reactive components
- ☐ Appreciate that coaxial cables have **inductances** and explain their effects on AC signals

REQUIRED MATERIALS:

Hardware:
1) Digital multimeter (DMM)
2) Cathode ray oscilloscope (CRO)
3) Signal generator

Components:
1) Set of resistors
2) Capacitor and inductor
3) Breadboard

Lab Task 1: Applying phasor techniques using single source



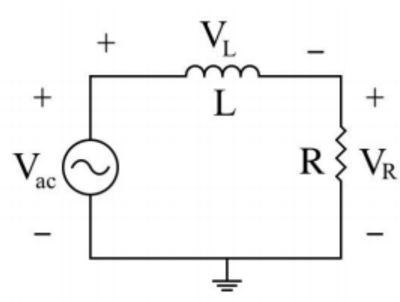


Fig 1a (left) & Fig 1b (right): Schematic of an **RL** circuit

1.1 Assemble the circuit of Fig. 1 on a breadboard, given $V_S = 5\cos(2\pi f\,t)$ V, R = 1 kΩ, L = 10 mH. Use the signal generator to apply the AC signal (V_{ac}), setting the frequency to 2.5kHz. Tune the amplitude of the sine wave until it reaches 5V.

1.2 Using the oscilloscope, measure V_L (using Fig 1a) and V_R (using Fig 1b) at 10kHz. To measure phase, the wave form of Vs should also be monitored on the oscilloscope when you measure V_L and V_R.

1.3 Then set the frequency of the signal generator to 20kHz and measure V_L and V_R again.

Table 2: Measured values for Task 1

	Measured V_L (Fig 1a)		**Measured V_R (Fig 1b)**		**I (Calculate using V_R)**	
	Amplitude	**Phase**	**Amplitude**	**Phase**	**Amplitude**	**Phase**
@ 10kHz						
@ 20kHz						

What is the closest phase of the capacitor voltage relative to the current used in your circuit at 2.5kHz and 5kHz?

For 10 kHz: ☐0° ☐-45° ☐45° ☐-90° ☐90°

For 20 kHz: ☐0° ☐-45° ☐45° ☐-90° ☐90° _______ / **4**

Make sure you are graded for Lab Task 1 before moving on to Lab Task 2

Lab Task 2: Dual source

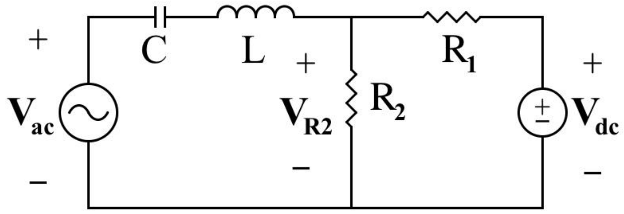


Fig 2: Schematic of circuit with two input sources with different frequencies

2.1 Assemble the circuit you have analyzed in Fig. 2 on a breadboard, giving R_1 = 1.5 kΩ, R_2 = 1 kΩ, L = 10 mH, C = 68 nF, $V_{ac} = 5\cos(2\pi ft)$ V, and V_{dc} = 3V. This should only require a small modification of the circuit. Use the power supply to apply a DC voltage of V_{dc} = 3V.

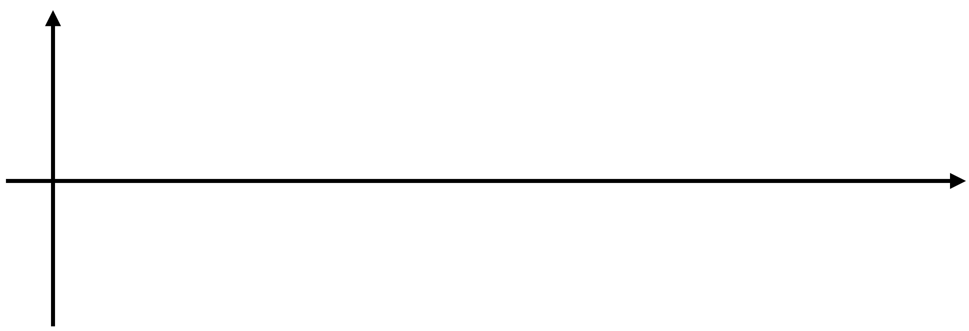
2.2 Keep the amplitude of the AC signal at 5V (same as Lab Task 1) and set the frequency to 10 kHz.

2.3 Measure V_{R2}. Observe the waveform of V_{R2} in both AC mode and DC mode. You should notice two frequency components on the oscillator. The DC component is more distinguishable when you change the oscilloscope setting from AC mode to DC mode. Ask a lab staff to show you how to switch between AC and DC mode on the oscilloscope if you are unsure.

2.4 Draw the two waveforms of V_{ac} and V_{R2} (in DC mode) in the space provided below. Identify the various frequency components on your graph. Note down the amplitude of the AC wave from V_{R2} and its phase relative to V_{ac}.

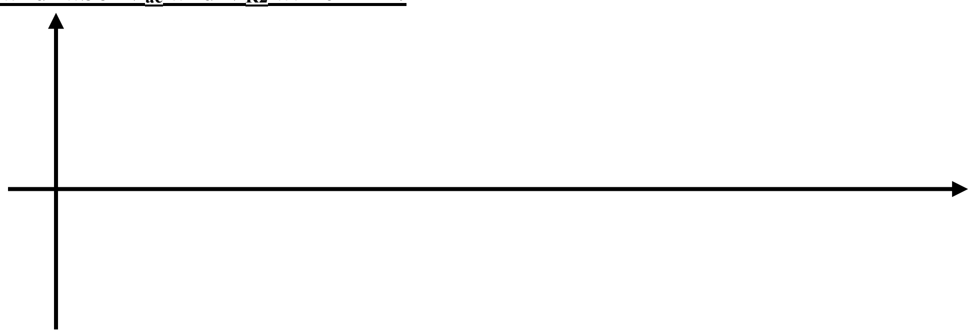
2.5 Then adjust the signal generator frequency to 20 kHz and measure V_{R2} again.

Draw and label V_{ac} and V_{R2} at 5 kHz:



At 5 kHz, V_{R2} = __________ (DC component) + _______________ (AC component)

Draw and label V_{ac} and V_{R2} at 20 kHz:



At 20 kHz, V_{R2} = __________ (DC component) + _______________ (AC component)

2.6 What is the difference between your results from Lab Task 2 and Lab Task 1?

☐ No difference ☐ positive DC offset ☐ negative DC offset _______/ **3**

Make sure you are graded for Lab Task 2 before moving on to the final lab task.

Lab Task 3: Co-axial cable capacitance

3.1 Write down the capacitance (C_L) and resistance (R_L) seen at the input terminals of the CRO. These values can be found around the input socket that connects to the coaxial cable.

C_L = _____ pF, R_L = _____ MΩ

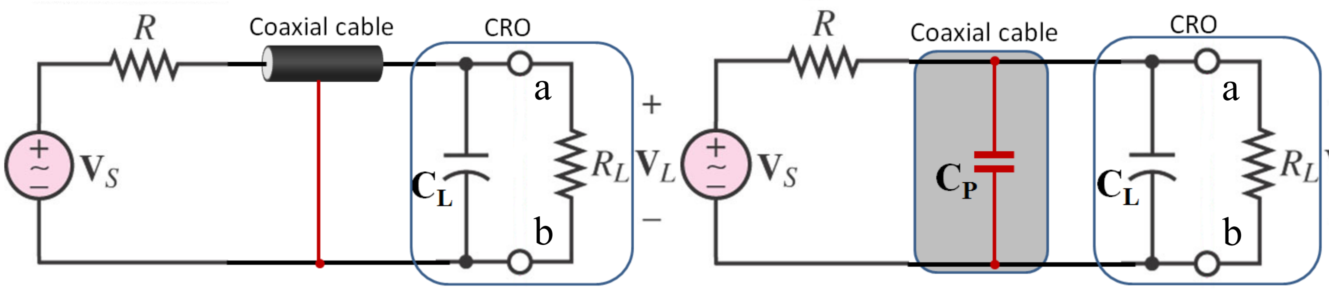


Fig 3a Fig 3b

Assemble a circuit according to Fig 3a where R = 1MΩ. We can represent the coaxial cable by a capacitor C_P as shown in Fig 3b. C_P is the total capacitance of the cable, which depends on the length of the cable and its specified capacitance per unit length (pre-lab 3). By estimating the length of the cable, provide an estimate of C_P.

3.2 **Estimate** the length and thus the total capacitance of your coaxial cable (C_P) using the value found in **Pre-lab 3**.

Estimated C_P = ☐25 ☐50 ☐100 ☐200 pF

Estimated total capacitance across terminals a-b: ☐50 ☐75 ☐125 ☐225 pF

3.3 With V_S set to 5V peak, answer the following questions.

(a) Measure V_L when V_S is set to 100Hz

At 100Hz, V_L = _____ V

(b) Measure V_L when V_S is set to 100kHz

At 100kHz, V_L = _____ V

_________/ **1**

3.4 With V_S set to 5V peak, answer the following questions.

(a) At 50 Hz, the impedance across terminals a-b is determined by ☐R_L ☐$(C_L + C_P)$,
and a reasonable estimate of this impedance is
(Hint: Compare the impedances of $(C_L + C_P)$ and R_L at 50 Hz. Current prefers a less resistive path.)

☐0Ω

☐100kΩ

☐1MΩ

☐10MΩ

(b) Based on the above estimate of impedance across a-b at 50 Hz, a reasonable estimate of V_L is
(Hint: Express V_L in terms of R, R_L, $(C_L + C_P)$ and V_S. Find V_L at 50 Hz)

☐0V

☐0.5V

☐2.5V

☐5V

(c) At 200 kHz, the impedance across terminals a-b is determined by ☐R_L ☐$(C_L + C_P)$,
and a reasonable estimate of this impedance is
(Hint: Compare the impedances of $(C_L + C_P)$ and R_L at 200 kHz. Current prefers a less resistive path.)

☐0Ω

☐6kΩ

☐60kΩ

☐1MΩ

(d) Based on the above estimate of impedance across a-b at 200 kHz, a reasonable estimate of V_L is
(Hint: Express V_L in terms of R, R_L, $(C_L + C_P)$ and V_S. Find V_L at 200 kHz)

☐0V

☐0.03V

☐0.1V

☐0.5V

_________ **/ 2**