PRINCIPLES OF EE1 LAB

Lab 3

Frequency and Phase Shift Measurement

Full name: ………………………………………………

Student number: …………………………………….

Class: ………………………………………………....

Date: …………………………………………………….

I. Objectives

After completing this experiment you should be able to:

- Graphically represent complex number (phasor diagram).
- Use an oscilloscope to measure the frequency and phase shift of periodic waveforms.
- Calculate equivalent impedance a circuit using the oscilloscope.
- Verify theoretical relations among frequency, impedance, voltage, and current in an AC network.

II. Introduction

This laboratory will explore the effects of an AC source on electric circuits. With AC circuits, capacitors and inductors will prove to be more challenging than they might be in DC circuits. These capacitors and inductors are energy storage elements that behave differently depending on the frequency of the source. Therefore, an AC circuit designed for 60 Hz cannot be used in radio frequency (RF goes from 90 kHz to 110 MHz), or microwave circuits (up to 300 GHz). This concept must be clear understood in order to successfully design electronic circuits.

In AC circuits, the value of the circuit impedance can change depending on the frequency of the source. The impedance of an inductor is $j\omega L$ Ω, and the impedance of a capacitor becomes $(j\omega C)^{-1}$ Ω. These values will change with ω, which is the frequency of the AC source. Thus, a circuit could go from a small impedance to a large impedance or vice versa just by changing the frequency of the input signal.

When the AC circuit has capacitors and inductors, not only the magnitude of the impedance changes but also its phase. Therefore, the impedance of an AC circuit can change from being inductive to capacitive or vice versa depending on the frequency of the source.

This laboratory will analyze the impedance change of simple AC circuits when the frequency of the power source is changed.

III. Pre-Laboratory

Part A: RC Circuit and Transient Analysis

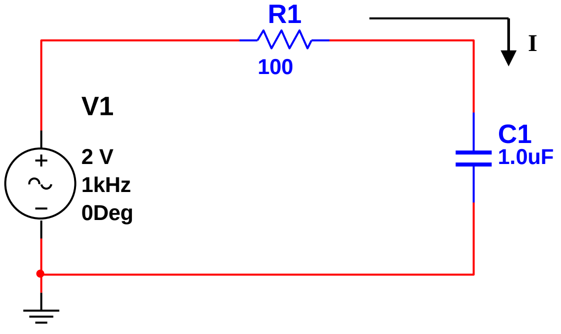

Figure 1 – RC circuit

1. Using any circuit analysis technique, find the voltage drop across the resistor $\mathbf{R_1}$, the voltage drop across the capacitor $\mathbf{C_1}$ and the mesh current **I** for the circuit shown in Figure 1. Complete Table 1 (see Laboratory Data Section). <u>*Note:*</u> All these values are complex number; so you must calculate amplitude and phase. Assume $\mathbf{R_1} = 100\ \Omega$, $\mathbf{C_1} = 1\ \mu F$, $\boldsymbol{f} = 1$ KHz and $\mathbf{V_1} = 2$ V.
2. Draw a phasor diagram <u>to scale</u> showing the source voltage $\mathbf{V_1}$, the voltage drop across the resistor $\mathbf{R_1}$, the voltage drop across the capacitor $\mathbf{C_1}$ and the mesh current calculated **I** of the circuit shown in Figure 1. Use the source voltage (also called input voltage) $\mathbf{V_1}$ as your reference. <u>State module and phase of each phasor</u>.
3. **(Optional)** Using Orcad Pspice, run a *transient* analysis of the circuit presented in Figure 1.
   a. <u>Plot in the same graph</u> the input voltage $\mathbf{V_1}$, the voltage drop across the resistor $\mathbf{R_1}$, the voltage drop across the $\mathbf{C_1}$, and the mesh current **I**. <u>*Note:*</u> use a different y-axe for the mesh current **I**.
   b. <u>Calculate</u> the phase shift between the input voltage $\mathbf{V_1}$ and the voltage drop across the resistor $\mathbf{R_1}$. Calculate the phase shift between the input voltage $\mathbf{V_1}$ and the voltage drop across the capacitor $\mathbf{C_1}$.
   c. <u>Calculate</u> the phase shift between the voltage drop across the resistor $\mathbf{R_1}$ and the mesh current **I**. Calculate the phase shift between the voltage drop across the capacitor $\mathbf{C_1}$ and the mesh current **I**. Make sure that these values match, within reasonable error, to those ones calculated in 1?
   d. Use the results obtained in a. and b. to complete Table 1 (see Laboratory Data Section). Make sure that these values match, within reasonable error, to those ones calculated in 1?

Part B: RL Circuit and Transient Analysis

Replace capacitor C1 by inductor L1 = 47mH. Repeat Part A

Part C: RLC Circuit and AC Sweep Analysis

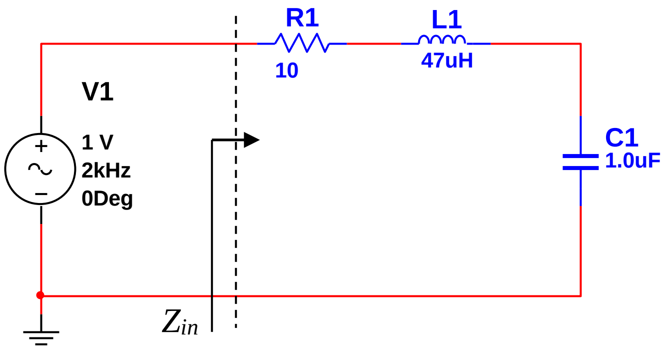

Figure 2 – RLC circuit

4. For the circuit shown in Figure 2, do the following:
   a. Find the input impedance $\boldsymbol{Z_{in}}$ and determine at which frequency, ω in rad/s, $|\mathbf{X_L}| = |\mathbf{X_C}|\ \mathbf{\Omega}$. Do this symbolically. Do not use any specific value.

b. For this value of ω, what is the phase shift between the applied voltage $\mathbf{V_1}$ and the loop current $\mathbf{I_1}$? What does this imply?

c. Using the equation obtained in part a, calculate the frequency in Hertz at which $|\mathbf{X_L}| = |\mathbf{X_C}|$ **Ω**, assuming $\mathbf{R_1} = 10\ \Omega$, $\mathbf{C_1} = 1\ \mu F$, $\mathbf{L_1} = 47\ \mu H$.

5. **(Optional)** Using Pspice run an AC *Sweep* simulation (from 2 KHz to 30 KHz) of the circuit presented in Figure 2 to verify the calculation in 4. Note: you need to plot the input impedance (Z_{in}) seen by the input voltage source V_1. Remember, impedance is a complex value you must plot magnitude and phase.

   a. Plot the input impedance Z_{in} (magnitude and phase) as a function of frequency.

   b. According to your simulation, at which frequency does $|\mathbf{X_L}| = |\mathbf{X_C}|$ **Ω**? Does this frequency match with the one calculated in part 4c?

   c. Using the input impedance equation obtained in 4a, and the results of the AC Sweep simulation performed in 5a, complete Table 2 of Laboratory Data Section.

6. Run a *transient* simulation of the circuit shown in Figure 2 using the frequency calculated in part 5b. as the frequency of the voltage source V1. Plot on the same graph the voltage across V_1 and the mesh current I_1. Are these two waveforms in phase (i.e. zero phase shift). Why or why not?

IV. Laboratory

Required equipment:

- Dual-trace oscilloscope, voltage probe.
- Sinusoidal waveform generator.
- Resistors, capacitor, inductor.
- Breadboard and connecting wires.

Part A, B: RC, RL Circuit and Transient Analysis

The purpose of this section is the determination of the magnitude and the phase shift of several waveforms and how they relate to the results obtained during the Pre-Laboratory.

1. Construct the circuit shown in Figure 1.

2. Connect the voltage probe in Channel 1, and the voltage probe in Channel 2.

3. Stimulate the circuit using a sinusoidal waveform generator set to an amplitude of 2 V peak and a frequency of 1 KHz. Connect the voltage probe (i.e., oscilloscope channel 1) at the input voltage source to make sure that the sinusoidal waveform generator is generating the desire amplitude and frequency. Next, connect the voltage probe (i.e., oscilloscope channel 2) at the capacitor C_1.

   a. Using the oscilloscope measuring features (i.e., measure menu) measure the peak-to-peak amplitude of both waveforms as well as the frequency of the input voltage V_1 (i.e., channel 1).

      i. Base on the measured values, calculate the proper amplitudes taking into account any probe gain. Compare these results to the ones obtained in the Pre-Lab to make sure that they are in agreement within a reasonable error.

ii. Show your instructor the waveforms, and then draw it in scale on your paper.

b. Using the oscilloscope measure the time delay (or time difference) between the input voltage V_1 (i.e., channel 1) and the voltage drop across the capacitor C_1 (i.e., channel 1). Change the horizontal scale if necessary to improve the accuracy of your measurement.

i. Base on the measured values calculate the proper phase shift. Compare these results to the ones obtained in the Pre-Lab to make sure that they are in agreement within a reasonable error. Is it leading or lagging?

ii. Using these values and the values obtained in 4a, determine the complex number (magnitude and phase) the represents the input voltage V_1 and the voltage drop across the capacitor C_1 and complete Table 1 (see Laboratory Data Section).

iii. Show your instructor the waveforms, and then draw it on your paper.

4. Using the same procedure describe in 4 measured the voltage drop across the resistor R_1. *Note:* Make sure of follow the entire procedure describe above including the saving of all waveforms and the completion of Table 1 in Laboratory Data Section.

5. The mesh current is measured indirectly by measuring the voltage across the resistor R_1 since it can be estimated by dividing this voltage drop by the resistor value (i.e., $I = V_{R1}/R_1$). In addition, since the impedance presented by the resistor R_1 has no phase (i.e., the imaginary part is equal to zero), the phase of the mesh current I is equal to the mesh of the voltage drop across the resistor R1. Using the measured resistor voltage drop and the above mentioned technique calculate the mesh current and complete Table 1 in Laboratory Data Section.

Part C: RLC Circuit and AC Sweep Analysis

The purpose of this section is the determination of the input impedance Z_{in}, how it changes with respect to frequency and how it relates to the results obtained during the Pre-Lab. The input impedance Z_{in} is measured indirectly by measuring the input voltage V_1 and the mesh current I. Next, the input impedance Z_{in} is calculated using Ohms law.

6. Construct the circuit shown in Figure 2. Stimulate the circuit using a sinusoidal waveform generator set to an amplitude of 1 V peak and a frequency of 2 KHz. Connect the voltage probe (i.e., oscilloscope channel 1) at the input voltage source to make sure that the sinusoidal waveform generator is generating the desire amplitude and frequency.

a. Connect the voltage probe (i.e., oscilloscope channel 2) at the resistor R_1 (after swap positions of R1 and C1) and measure the voltage drop across this resistor using the measuring feature of the oscilloscope. Draw this waveform on your paper.

b. Calculate the mesh current I by dividing the voltage drop across R_1 by the resistor value.

c. Measured the time delay between the input voltage V_1 (i.e., channel 1) and the voltage drop across the resistor R_1 (i.e., channel 2). Change the horizontal scale, if necessary, to improve the accuracy of your measurement. Draw this waveform on your paper.

d. Using this value calculate the mesh current phase shift and determine the complex number (magnitude and phase) the represents the mesh current. Complete Table 2 of the Laboratory Data Section.

7. Repeat the entire process above for the different frequencies give in Table 2 (i.e., 2, 10, 15, 20, 25, 30 KHz). *Note:* Make sure of follow the entire procedure describe above including the saving of all waveforms.
8. Measure the frequency in Hertz at which $|X_L| = |X_C|$ Ω by adjusting the frequency of the sinusoidal waveform generator until the input voltage V_1 and the voltage drop across the resistor R_1 are in phase. Write these values, and draw this waveform on your paper.

V. Post-Laboratory

The lab report is a written document where you compare your calculation with the measurements taken during the Laboratory section. This document must contain your theoretical calculations, and your measurements.

Part A, B: RC, RL Circuit and Transient Analysis

Compare the measurements obtained during the lab for the RC circuit with the theoretical analysis. Make sure of explaining any possible differences and what might be their causes.

Part C: RLC Circuit and AC Sweep Analysis

Compare the measurements obtained during the lab for the LRC circuit with the theoretical analysis. Make sure of explaining the following points:

1. Did the input impedance Z_{in} change in any way from the lower frequency to the higher frequency (i.e., magnitude and phase)? How could this impedance be viewed at 2 KHz and 30 KHz?
2. Is there a point where $|X_L| = |X_C|$? If so, at which frequency? Compare this frequency with the one obtained analytically and using simulation. Explain any possible differences and what might be their cause.
3. Compare the calculated, and measured input impedance. Explain any possible differences and what might be their cause.

Finally, draw a general laboratory conclusion based in your theoretical analysis, and comparison of calculated, and measured values.

Laboratory Data Section

Table 1: RC Circuit and Transient Analysis

Circuit	Variable	Calculations		Measurements	
		Magnitude	Phase	Magnitude	Phase
RC	V_1				
	V_{C1}				
	V_{R1}				
	I				
RL	V_1				
	V_{L1}				
	V_{R1}				
	I				

Table 2: RLC Circuit and AC Sweep Analysis

Frequency [KHz]	Calculations		Measurements	
	Magnitude	Phase	Magnitude	Phase
2				
5				
10				
15				
20				
25				
30				