EET/CPE 1150

1. LAB NUMBER: 2

2. TITLE: Ohm's Law and R, L, C Elements

3. OBJECTIVES:

After completing this lab, the student will be able to:

a) use an oscilloscope to determine the current through an component (R, L, C),
b) study the effect of frequency on Resistance, Capacity Reactance and Inductive Reactance,
c) verify the formulas for calculating Capacity Reactance and Inductive Reactance,
d) verify Ohm's Law for AC circuits.

4. EQUIPMENT:

METEX MS-9150 Generator
Oscilloscope
Experimenter board

5. COMPONENTS:

1 - 10 Ω ½ watt 5% Resistor
1 - 620 Ω ½ watt 5% Resistor
1 - 33 nF Capacitor
1 - 15 mH Inductor

6. TEXT REFERENCE:

Circuit Analysis: Theory and Practice (5^{th} Edition):
A.H. Robbins and W.C. Miller

Chapter 16: R, L, C Elements and the Impedance Concept

Technical Note:

In this Lab, we use a popular technique to measure the current through a component (R, L, C), that is inserting a small resistor (10 Ω) in series with the component under test. By measuring the voltage drop across this "sensing" resistor with an oscilloscope channel, we can deduce the magnitude and phase of the current through the component. Depending on the frequency chosen, this technique may introduce an error less than 5%.

7. PRE-LAB ASSIGMENT:

A – Resistance (R) Study:

a) Resistance (R) is a positive constant. Complete the following Ohm's Law equation for R using its voltage and current phasors:

$$R = \qquad\qquad / $$

b) What is the resistance of a 620 Ω resistor when the AC current flowing through it has a changing frequency?

B – Capacitive Reactance (X_C) Study:

c) X_C is a complex number with a magnitude and a phase angle of -90°. Complete the Ohm's Law equation for X_C using its voltage and current phasors:

$$X_C = \qquad\qquad / $$

d) The magnitude of X_C is frequency dependent. Complete the formula for the calculation of X_C:

$$X_C = \frac{1}{2\pi f \,\_}$$

e) Show a sketch of the curve of X_C as a function of frequency f in the range from 4 kHz to 10 kHz with C = 33 nF.

C – Inductive Reactance (X_L) Study:

f) X_L is a complex number with a magnitude and a phase angle of +90°. Complete the Ohm's Law equation for X_L using its voltage and current phasors:

$$X_L = \qquad\qquad / $$

g) The magnitude of X_L is frequency dependent. Complete the formula for the calculation of X_L

$$X_L = 2\pi f \,\_$$

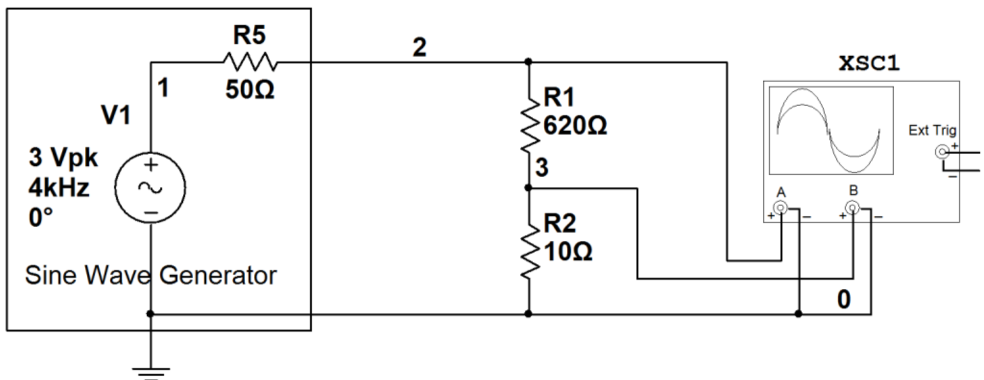
h) Show a sketch of the curve of X_L as a function of frequency f in the range from 3 kHz to 9 kHz with L = 15 mH.

8. MEASUREMENTS:

A – Resistance (R) Study:

a) Build the circuit of Fig. 1. CH1 of the oscilloscope measures the output of the Sine wave Generator; CH2 measures the voltage across the sense resistor R2. This resistor is much smaller in value than the resistance under test R1. So CH1 can be considered as measuring the voltage across R1 (with an error of less than 2%), that is we accept that Vr1+Vr2 ~ Vr1.

Figure 1:



b) Since R1 and R2 are in series, the current through R2 is also the current through R1, this current is I1 = Vr2/R2.

So, according to Ohm's Law R1 = Vr1/I1 =Vr1 x R2/Vr2

c) Set the Generator to 3V peak and change its frequency to values in Table 1 then measure Vr1 (CH1) and Vr2 (CH2) and complete Table 1:
(Note: since we take the ratio of voltages, Peak values are suitable).

Table 1:

Frequency (kHz)	Vr1 (V)	Vr2 (mV)	R1 = Vr1 x R2/Vr2 (Ω)
4	3		
6			
8			
10			

d) Do the results show that the calculated value of R1 is independent of frequency?

e) Is there a phase shift between Vr1 and Vr2?

B – Capacitive Reactance (X_C) Study:

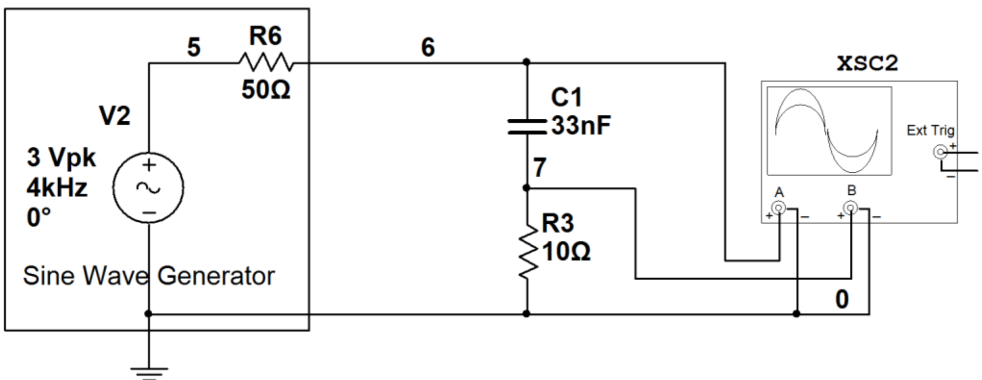
f) Build the circuit of Fig. 2. CH1 (A) of the oscilloscope measures the total voltage of C1 and R3 in series; however, as R3 is very small, we can accept that this voltage is the capacitor voltage Vc1 (with a small error). CH2 measures the voltage across the sensing resistor R3 which gives us the current Ic through the capacitor: Ic = Vr3 / R3

g) The magnitude of the Capacity Reactance X_C is given by:

$$X_C = Vc1 / Ic = Vc1 \times R3 / Vr3$$

h) Since Ic and Vr3 have the same phase angle (from part A observation), the angle of X_C is given by the phase shift between Vc1 and Vr3.

Figure 2:



i) Set the Generator to 3V peak and change its frequency to values in Table 2 then measure Vc1 (CH1) and Vr3 (CH2) and complete Table 2:

Table 2:

Frequency (kHz)	Vc1 (V)	Vr3 (mV)	Xc = Vc1 x R3/Vr3 (Ω)
4	3		
5			
6			
7			
8			
9			
10			

j) Which waveform is <u>lagging</u>, Vc1 or Vr3 (Ic)?
k) What is the approximate value of the shift angle (>, = or < -90°)?
l) Plot a graph showing Xc as a function of f using the points of Table 2.

C – Inductive Reactance (X_L) Study:

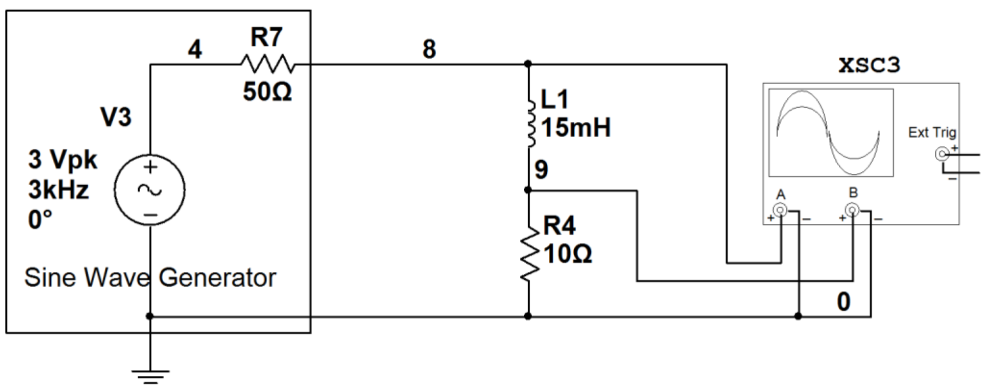
m) Build the circuit of Fig. 3. CH1 (A) of the oscilloscope measures the total voltage of L1 and R4 in series; however, as R4 is very small, we can accept that this voltage is the inductor voltage VL1 (with a small error). CH2 measures the voltage across the sensing resistor R4 which gives us the current IL through the inductor: IL = Vr4 / R4

n) The magnitude of the Inductive Reactance X_L is given by:

$$X_L = VL1 / IL = VL1 \times R4 / Vr4$$

o) Since IL and Vr4 have the same phase angle (from part A observation), the angle of X_L is given by the phase shift between VL1 and Vr4.

Figure 3:



p) Set the Generator to 3V peak and change its frequency to values in Table 3 then measure VL1 (CH1) and Vr4 (CH2) and complete Table 3:

Table 3:

Frequency (kHz)	VL1 (V)	Vr4 (mV)	X_L = VL1 x R4/Vr4 (Ω)
3	3		
4			
5			
6			
7			
8			
9			

q) Which waveform is leading, VL1 or Vr4 (IL)?

r) What is the approximate value of the shift angle (>, = or < +90°)?

s) Plot a graph showing X_L as a function of f using the points of Table 3.

9. LAB REPORT REQUIREMENT:

Your team's Lab Report should contain the followings:

A Cover Page with Lab Number, Lab Title, Team members' Names and Date.
An Introductory Page with list of Equipment and Components used.

Result Pages with:

A – Resistance (R) Study:

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 1.

Discussions:

1) Answer 8(d).
2) Answer 8(e).
   What conclusion can you make about the nature of R?
3) What is the percentage of error in calculating R1 comparing to the theoretical value of 620 Ω?

B – Capacitive Reactance (X_C) Study:

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 2.

Discussions:

1) Answer 8(j).
2) Answer 8(k).
   From these two answers, what can you conclude about the phase of X_C?
3) Attach the graph of 8(l). Compare it to 7(e) (Pre-Lab).

C – Inductive Reactance (X_L) Study:

Procedure:

(Summarize the main activities that your team did (past tense) in this section).

Results:

Show a copy of Table 3.

Discussions:

1) Answer 8(q).
2) Answer 8(r).
   From these two answers, what can you conclude about the phase of X_L?
3) Attach the graph of 8(s). Compare it to 7(g) (Pre-Lab).

D – Conclusions:

1) How are the results of 8A compared to the theory of Resistance (R)?

2) How are the results of 8B compared to the theory of Capacity Reactance X_C?

3) How are the results of 8C compared to the theory of Inductive Reactance X_L?

4) Are all the Lab objectives met? Explain if some are not.

Appendix:

Attach all Pre-Lab calculations.