Principles of EE I Laboratory

Lab 5 & 6

AC Circuits

Student A	Student B
Full name: …………………………………	Full name: …………………………………
Student number: …………………………………	Student number: …………………………………

I. Objectives

In this laboratory, you will investigate:

1. The impedance of a capacitor and determine the error in a derived result.
2. The impedance of an actual inductor.

II. Procedure

***You must provide all calculations in-details in separate sheets or simulation results as attachments**

LAB 5:

1. RC circuit

Circuit Design and Layout:

Following is a RC circuit, we consider that the input voltage $v(t)$ has form $v(t) = \boldsymbol{V_P} \sin(\omega.\boldsymbol{t} + \boldsymbol{\varphi})$, with $\boldsymbol{\varphi}$ the phase shift between $v(t)$ and $i(t)$.

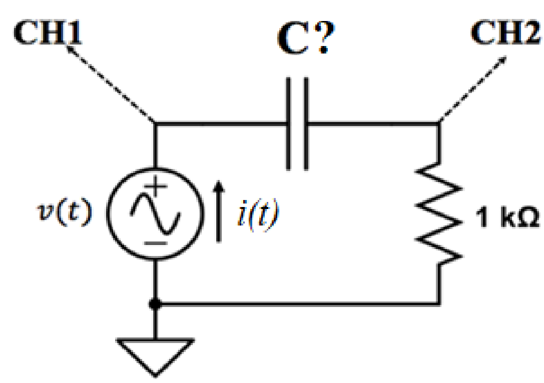

Figure 1. A RC circuit

1.1 Determine value of a capacitor by measuring the phase shift

We would like to measure the phase shift $\boldsymbol{\varphi}$ of $\boldsymbol{v(t)}$ compared to $\boldsymbol{i(t)}$ of RC circuit by using the functions of Oscilloscope. See that $\boldsymbol{i(t)}$ is in phase with $\boldsymbol{v_R(t)}$, it amounts to measuring the phase shift of $\boldsymbol{v(t)}$ and $\boldsymbol{v_R(t)}$, with $\boldsymbol{v_R(t)}$ directly measurable at **R**.

Actually, <u>thereafter $\boldsymbol{v_R(t)}$ will be used for the Voltage Reference</u> (where $\boldsymbol{v_R(t)}$ on **Channel 2 (CH2)** of the Oscilloscope). The sinusoidal voltage $\boldsymbol{v(t)}$ will be issued by the Function Generator.

Experimental work:

→ For this circuit, a random capacitor will be given to each group. The capacitance value is assumed to be unknown.

1.1.1 Generate $\boldsymbol{v(t)}$ as a sine wave with a peak amplitude $V_p = 2$ V and frequency **f = 500 Hz**.

1.1.2 Build the RC circuit of Figure 1, seriously paying your attention to the connections of the Oscilloscope in order to measure the phase shift $\boldsymbol{\varphi}$ of $\boldsymbol{v(t)}$ compared to $\boldsymbol{v_R(t)}$.

1.1.3 Ask your instructor to check your circuit.

1.1.4 For **f = 500 Hz**, measure $\Delta\boldsymbol{t}$ and then calculate/measure the values of the phase shift $\boldsymbol{\varphi}$ (in degree) with the Oscilloscope and complete the first column of the following table.

1.1.5 Redo question 1.1.4 with **f = 750 Hz** and **f = 1000 Hz.**

1.1.6 Then, deduce the value of **C** which is used and complete the rest of table below.

Table 1. Result collection for the circuit in figure 1.

$T = \frac{1}{f}$

$T_2 - T_1$

$\frac{\Delta t}{T} \times 360$

	Simulated	Measured	Simulated	Measured	Simulated	Measured
f (Hz)	500		750		1000	
Period: **T** (s)	2ms	2ms	1.3ms	1.3ms	1	1
Time delay $\Delta\boldsymbol{t}$ (s)	412us	0.4ms	245us	0.52ms	163us	0.18ms
Phase shift $\boldsymbol{\varphi}$ (°)	74.16	72	66.15	69	58.68	64.8
C (μF)	0.0903	0.103	0.094	0.081	0.097	0.075

1.1.7 Considering the values in the table I, what can we conclude:

a. on the evolution of phase shift $\boldsymbol{\varphi}$ in function of frequency? phase shift = time delay * 360 * f

b. on the calculated value for **C** in function of frequency?

c. on different between nominal and measured capacitance value?

$\phi = \tan^{-1}\left(\frac{1}{wRC}\right)$

1.2 Determine value of a capacitor by measuring its impedance

We use the same previous circuit.

Experimental work:

<u>Goal</u>: Use the same circuit in order to measure the amplitudes **Vrms** in the terminals of the capacitor by using multi-meters.

1.2.1 For **f = 1000** Hz

a. Verify at the Oscilloscope that the Peak Amplitude of $\boldsymbol{v(t)}$ stays constant at **2 V**.

b. Complete Table 2 after measuring the voltage **Vrms**, then calculating **Irms,** by using multi-meter in **position** **~V** (measuring effective values - *rms: root-mean-square*). At last, calculate the value $|Z_c|$ and deduce value of the capacitor C.

Table 2

	Simulated	Measured	Simulated	Measured	Simulated	Measured
f (Hz)	1000		250		100	
Vrms (V)	1.4	1.3	1.4	1.4	1.4	1.42
Irms (A)	1.1mA	0.77mA	1.4mA	0.24mA	1.5mA	0.1mA
$\lvert \boldsymbol{Z_c} \rvert = \frac{V_{rms}}{I_{rms}}$ (Ω)	1.27x10^-3	1688	4000	5833	9333	14200
C (μF)	0.125	0.094	0.16	0.11	0.17	0.11

Vr = 0.77 Vr = 0.24V Vr = 0.1V

1.2.5 Compare with the average measured value **C** determined in part 1.1 as well as the nominal value of **C.** Comment your result.

1.2.6 Conclusion/Comment/Interpretation the result compared to the theory.

END OF LAB 5

$$Z_c = \frac{1}{j\omega C} = \frac{1}{j2\pi f C}$$

LAB 6:

2. RL Circuit

We start with the following laboratory circuit to which you should also add your signal generator input as in part 1.1.

Build this RL circuit in the same manner as the previous RC in Figure 1. The nominal value of the resistor should be 1 kΩ as in Figure 2.

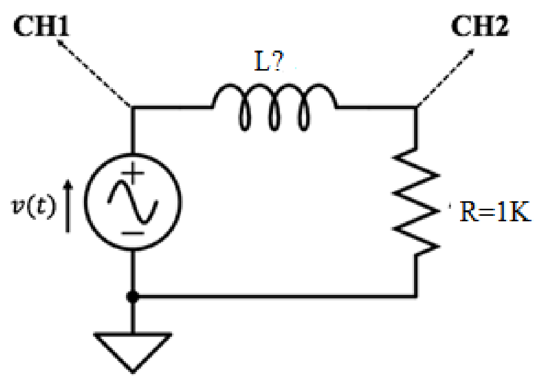

Figure 2. A RL circuit

In Figure 2 is a *RL* circuit, we consider that the input voltage $v(t)$ has form $\boldsymbol{v(t)} = \boldsymbol{V_P} \sin(\omega.\boldsymbol{t} + \boldsymbol{\varphi})$, with $\boldsymbol{\varphi}$ the phase shift between $\boldsymbol{v(t)}$ **and** $\boldsymbol{i(t)}$.

2.1 Determine value of an inductor by measuring the phase shift.

We would like to measure the phase shift $\boldsymbol{\varphi}$ of $\boldsymbol{v(t)}$ compared to $\boldsymbol{i(t)}$ of *RL* circuit by using the functions of Oscilloscope. See that $\boldsymbol{i(t)}$ is in phase with $\boldsymbol{v_R(t)}$, it amounts to measuring the phase shift of $\boldsymbol{v(t)}$ and $\boldsymbol{v_R(t)}$, with $\boldsymbol{v_R(t)}$ directly measurable at **R**.

Actually, thereafter $\boldsymbol{v_R(t)}$ will be used for the Voltage Reference (where $\boldsymbol{v_R(t)}$ on **CH2** of the Oscilloscope). The sinusoidal voltage $\boldsymbol{v(t)}$ will be issued by the Function Generator.

Experimental work:

→ For this circuit, an inductor will be given to you. The inductance is assumed to be unknown.

2.1.1 Generate $\boldsymbol{v(t)}$ as a sine wave with a peak amplitude $\boldsymbol{V_p} = \mathbf{2}$ **V** and frequency **f = 1 kHz**.

2.1.2 Build the RC circuit of Figure 2, seriously paying your attention to the connections of Oscilloscope in order to measure the phase shift $\boldsymbol{\varphi}$ of $\boldsymbol{v(t)}$ compared to $\boldsymbol{v_R(t)}$ with the Oscilloscope.

2.1.3 Ask your instructor to check your circuit.

2.1.4 For **f = 1 kHz**, measure $\Delta \boldsymbol{t}$ and **T** then measure/calculate the values of $\boldsymbol{\varphi}$ (in degree and in radian) of $\boldsymbol{v}(\boldsymbol{t})$ compared to $\boldsymbol{v_R}(\boldsymbol{t})$ with the Oscilloscope and complete the first column of the following table.

2.1.5 Redo question 1.1.4 with **f = 2 kHz** and **f = 4 kHz.**

2.1.6 Then, deduce the value of **L** which is used and complete the rest of table 3.

2.1.7 Upon completing your table, what can we conclude:

a. on the evolution of phase shift $\boldsymbol{\varphi}$ in function of frequency?

b. on the measured value for **L** in function of frequency?

c. on different between nominal and measured inductance value?

$T = \frac{1}{f}$

$T_2 - T_1$

Table 3

	Simulated	Measured	Simulated	Measured	Simulated	Measured
f (Hz)	1000		2000		4000	
Period: **T** (s)	1	1				
Time delay $\Delta \boldsymbol{t}$ (s)		0.04ms				
Phase shift $\boldsymbol{\varphi}$ (°)						
L (m)						

2.2 Determine value of an inductor by measuring its impedance

We use the same previous circuit.

$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

Experimental work:

2.2.1 Use the same circuit in order to measure the amplitudes **Vrms** in the terminals of inductor by using multi-meters.

2.2.2 For **f = 1** kHz

a. Verify at the Oscilloscope that the Peak Amplitude of $\boldsymbol{v}(\boldsymbol{t})$ stays constant at **2 V**.

b. Complete Table 4 after measuring the voltage **Vrms**, then calculating **Irms**, by using multi-meter in position ~V (measuring effective values - rms: root-mean-square). At last, calculate the value $|Z_L|$ and deduce value of the inductance L.

Table 4

	Simulated	Measured	Simulated	Measured	Simulated	Measured
f (Hz)	1000		2000		4000	
Vrms (V)						
Irms (A)						
$\lvert \boldsymbol{Z_c} \rvert = \frac{\boldsymbol{V_{rms}}}{\boldsymbol{I_{rms}}}$ (Ω)						
L(mH)						

1.2.5 Compare with the average measured value **L** determined in part 2.1 as well as the nominal value of **L.** Comment your result.

1.2.6 Conclusion/Comment/Interpretation the result compared to the theory.

END OF LAB 6