Faculty of Engineering & Technology Electrical & Computer Engineering Department

ENEE2103

CIRCUITS AND ELECTRONICS LABORATORY

Report I :Experiment 4
Sinusoidal Steady State Circuit Analysis

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Abstract

This experiment helps us understand the concept of impedance and phase shift by studying it on different types of circuits, such as resistive, RC, RL, and RLC circuits. We'll learn how the total impedance affects the phase shift of voltage and current at different frequencies. It's also important to know the resonant frequency, which is when the current and voltage are in phase. We'll also learn how to calculate power in a steady state. Finally, we'll learn how to connect circuits and use various equipment like an oscilloscope and DMM.
All circuits were assembled on a board using wires, and DC values such as voltage and current were measured using a Digital Multimeter device (DMM). We utilized a function waveform generator to generate a sinusoidal AC signal with a specific amplitude value, and the oscilloscope was employed to display graphical representations of varying signal voltages.

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1.Theory

1.1 Impedance

Impedance is a measure of the opposition to the flow of electrical current in a circuit. It is made up of reactance and resistance, which both limit the flow of electrons. Impedance affects the circuit's ability to produce current. The unit of impedance is the ohm (Ω), and it is represented by the letter Z. It is typically used to describe the behavior of circuits that contain capacitors, inductors, or both, such as AC power systems, audio circuits, and radio frequency (RF) circuits. We can measure impedance (Z) by dividing the maximum voltage (V) by the maximum current (I), or Z = V/I.

1.1.1 Resistor Impedance

Resistors in AC circuits work just like they do in DC circuits. The impedance of a resistor only has a real part, which equals the resistor's resistance. So, the impedance can be expressed using the equation shown,

$$\boxed{Z = R}$$

where Z is the impedance and R is the resistance. Since a resistor has no reactance, it cannot store any energy. When voltage is applied to a resistor, the current that flows through the resistor is in sync with the voltage, as illustrated in the figure.

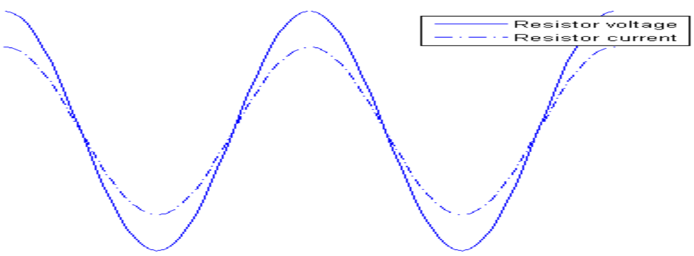

Figure 1. Resistor AC Response

1.1.2. Inductor Impedance

Inductors are parts that add inductance to a circuit. They can store electricity for a little while in a magnetic field. Inductors make the current in a circuit slower than the voltage by 90 degrees, which can be seen on a graph.

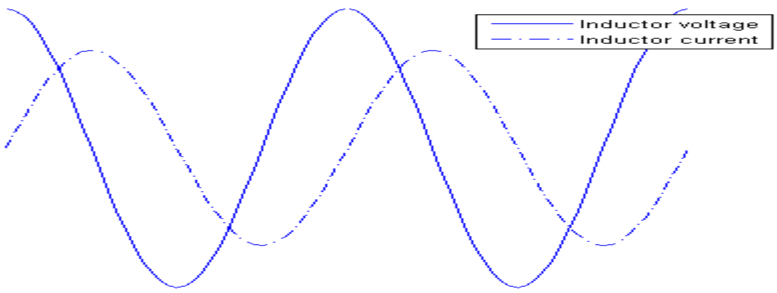

Figure 2. Inductor AC Response

The voltage in an inductor is faster than the current in a capacitor by 90 degrees. We use an equation with frequency and inductance values to calculate the impedance of an inductor. From this equation,

$$\boxed{Z = jwl}$$

While the phase shift is determined by the formula:

$$\boxed{\varphi = \tan n - 1\ (\omega L/R)}$$

We can see that the resistance of an ideal inductor is zero, and its impedance is always positive(absolute value). The impedance of an inductor changes with frequency and always gets bigger with increasing frequency.

1.1.3. Capacitor Impedance

Capacitors are components which introduce a certain capacitance into a circuit.They can store electricity for a little while in an electric field. They make voltage in a circuit slower than the current by 90 degrees, which is easier to see on a Figure 3.

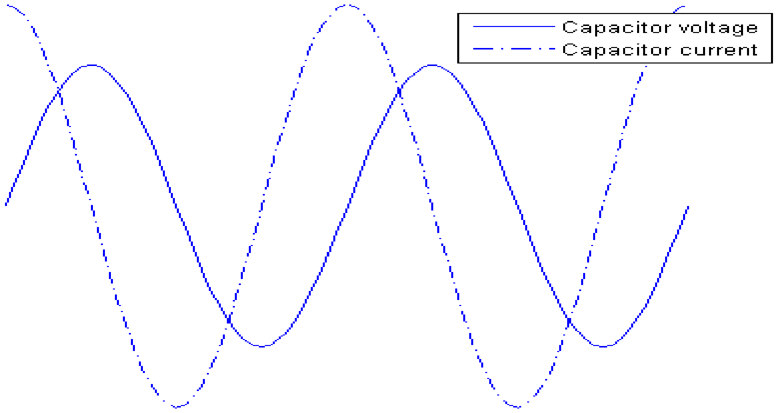

Figure 3. Capacitor AC Response

When you look at a graph, you can see that the voltage in a capacitor is slower than the current by 90 degrees. Or, you can say that the current is faster than the voltage by 90 degrees. To represent this fact using complex numbers, we use an equation that depends on the frequency and capacitance of the capacitor.

$$\boxed{Z= 1/ (j\,\omega C)}$$

The impedance of a capacitor depends on the frequency, and it gets smaller as the frequency increases.

While the phase shift is determined by the formula:

$$\boxed{\varphi=\tan^{-1} (1/(\omega RC))}$$

1.2 Capacitive and Inductive behavior:

An RLC circuit consists of a resistor, inductor, and capacitor. The term RLC refers to the schematic symbol of the respective components, notably:R - Resistor,L - Inductor and C - Capacitor.

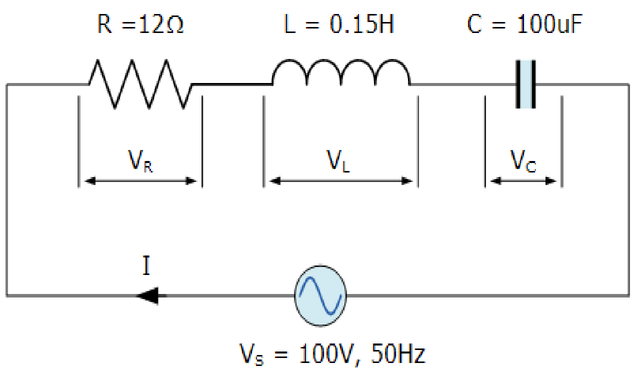

Figure 4. RLC circuit

Inductors and capacitors have different impedances at different signal frequencies, but resistors are only affected by DC current. The impedance of each component in an RLC circuit affects the total impedance of the circuit. The equation for the impedance of the circuit is:

$$Zt= \sqrt{R2 + (\omega l - \frac{1}{wc})^2}$$

While the phase shift is determined by the formula:

$$\varphi=\tan^{-1}((ZL-Zc)/R)$$

The way the circuit behaves depends on whether the source voltage leads or follows the circuit current. There are 3 cases:

- If ZL>ZC, the circuit is capacitive and the current leads.
- If ZL<ZC, the circuit is inductive and the voltage leads.
- If ZL=ZC, the circuit behaves resistively and is in-phase.

When the frequency is at the resonant frequency (fo), which is calculated as $fo=(1/(2\pi\sqrt{LC}))$, the circuit behaves resistively.

1.2.1 Resonant frequency

The frequency at which a circuit is in resonance is referred to as the resonant frequency. An LC circuit, also called a tank circuit, is used to achieve resonance and consists of an inductor and capacitor connected in parallel. Resonant circuits are employed to generate or isolate a specific frequency from a complex circuit. The equation for calculating resonant frequency is:

$$Fo = 1 / (2 * \pi * \sqrt{(lc)})$$

1.3 Sinusoidal steady state power:

AC electrical circuits require two types of power, reactive power (Q) and active power (P), and their amounts depend on the circuit elements like resistance (R), inductance (L), and capacitance (C).

Active power is the power that actually does useful work. In DC circuits, active power is simply calculated by multiplying the voltage and current because they are in phase, which means they start and end at the same time. There is no power factor in DC circuits.
Whereas in AC circuits, there is a phase angle between voltage and current expressed with the added component of

$$P= V *I \text{ for DC circuit}$$

In a single-phase AC circuit active power is:

$$P= V *I *\cos\theta$$

Reactive power happens when voltage and current are not in sync in AC circuits. It's measured in VAR (voltage ampere reactive). In real-world, loads can be a mix of resistive, inductive, and capacitive elements, making it hard to figure out their nature. There are two kinds of reactance, capacitive and inductive, which can have positive or negative power depending on the direction of power flow. Reactive power is only defined for AC circuits and is shown with the letter Q.

$$Q = V * I * \sin\theta$$

Apparent power is the sum of these two powers as show in figure 5:

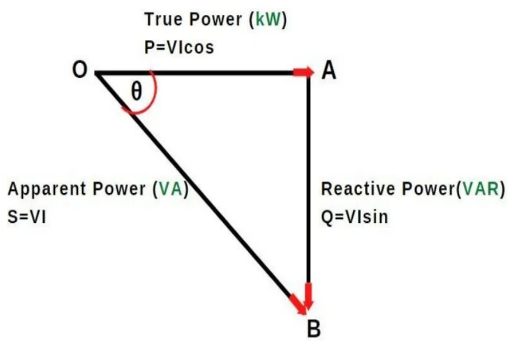

Figure 5. Apparent power

2. Procedure

2.1. Impedance

In this part of the experiment, we connected three circuits: resistive, capacitive, and inductive circuits. We measured the impedance and phase shift by taking voltage and current measurements.

2.1.1.Resistor Impedance

A signal generator produced a 1 kHz sinusoidal waveform with 5 V amplitude. A circuit was built by connecting two resistors, R1 (1 kΩ) and Rx (2.2 kΩ), to the circuit shown in figure 6.

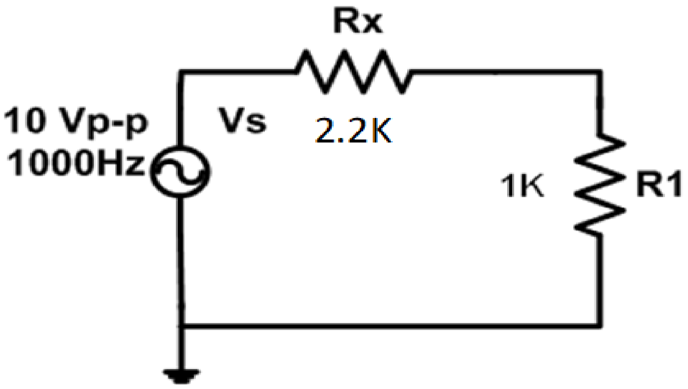

Figure 6. Resistive Circuit used in part A

Once the circuit was connected, the total voltage and current were measured using a DMM, while the phase shift between the total voltage and the voltage across resistor Rx was evaluated using an oscilloscope.

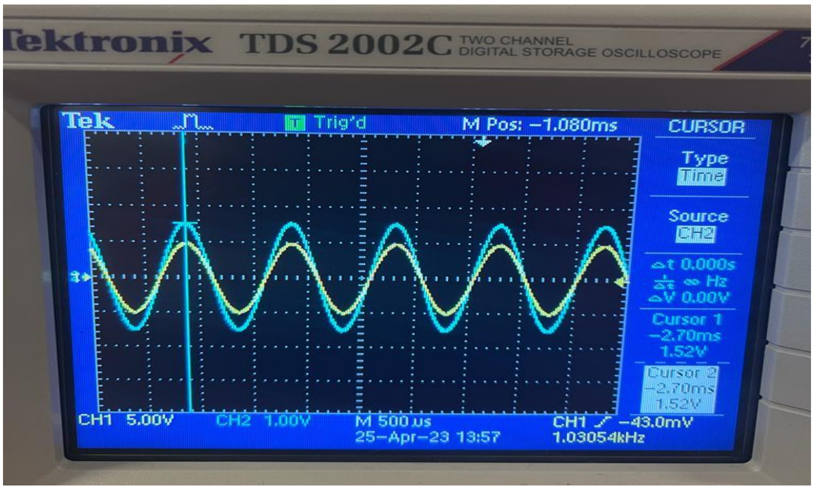

Figure 7. Delta t with when f =1 kHz

The same procedure was done again at 500 Hz and 1.5KHz, and the outcomes are displayed in figures 8 and 9.

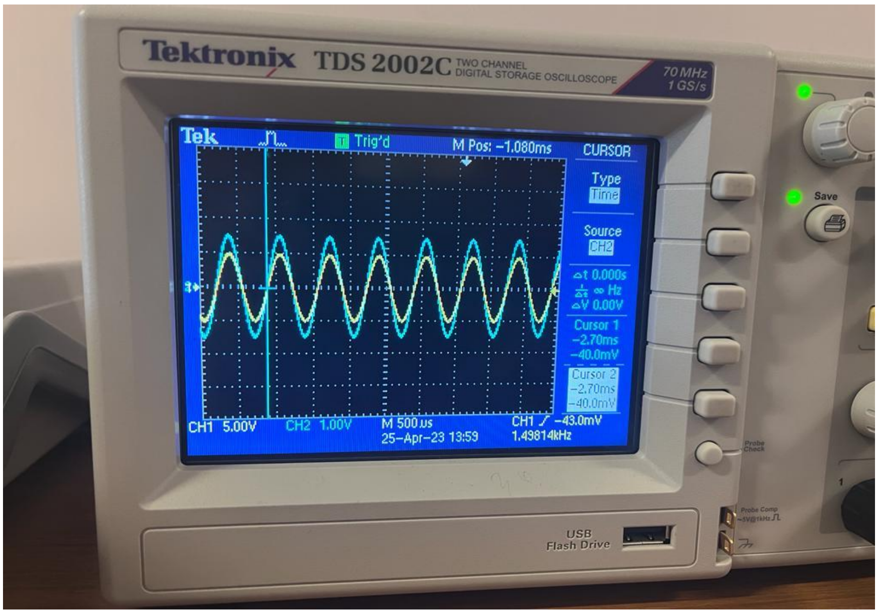

Figure 8. Delta t with f =1500 kHz

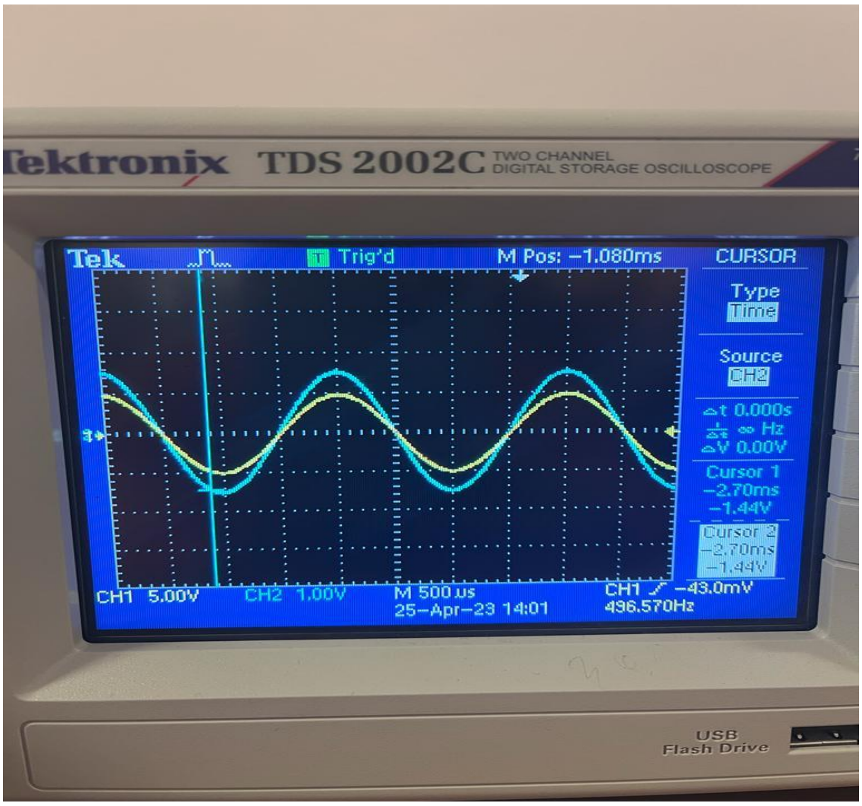

Figure 9. Delta t with f =500 kHz

Calculation:

- Experimentally

The ***experimentally*** measured results are shown in Table 1 and Table 2:

F [Hz]	Vrms	Irms	Δt	Phase shift
500	3.3	1.03	0	0°
1K	3.3	1.03	0	0°
1.5K	3.3	1.03	0	0°

Table 1. Results Experimentally for Resistive Circuit

impedance = v/I (Experimentally)

F [Hz]	Impedance(z)	Phase shift
500	3.204	0°
1K	3.204	0°
1.5K	3.204	0°

Table 2. Results Experimentally of impedance of Resistive Circuit

- Theoretically

-impedance= Rx + R1 =2.2 kΩ + 1 kΩ =3.2 kΩ

-Phase shift = tan-1$\left(\frac{Imaginary\ part}{real\ part}\right)$ = tan-1$\frac{0}{3.2K}$ = 0

★ **The experimental and theoretical results are very similar, with no difference in the phase and almost the same impedance value.**

2.1.2.Capacitive Impedance

The circuit illustrated in figure 10 was connected with two resistors, namely R8 with a value of 1 kΩ and Rx with a value of 2.2 kΩ, and a capacitor (C4) of 100 nF. The signal generator was configured to produce a sinusoidal waveform with a frequency of 1 kHz and an amplitude of 5 V.

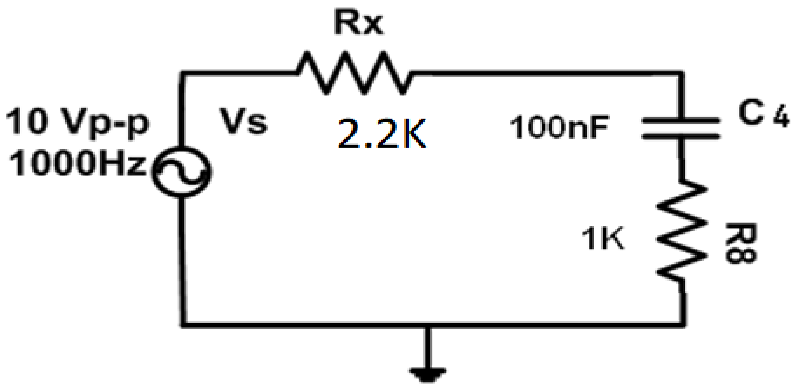

Figure 10. Capacitive Circuit used in part A

Once the circuit was connected, the total voltage and current were measured using a DMM. Additionally, the oscilloscope was utilized to assess the phase difference between the total voltage and the voltage across the Rx resistor, as depicted in Figure 11

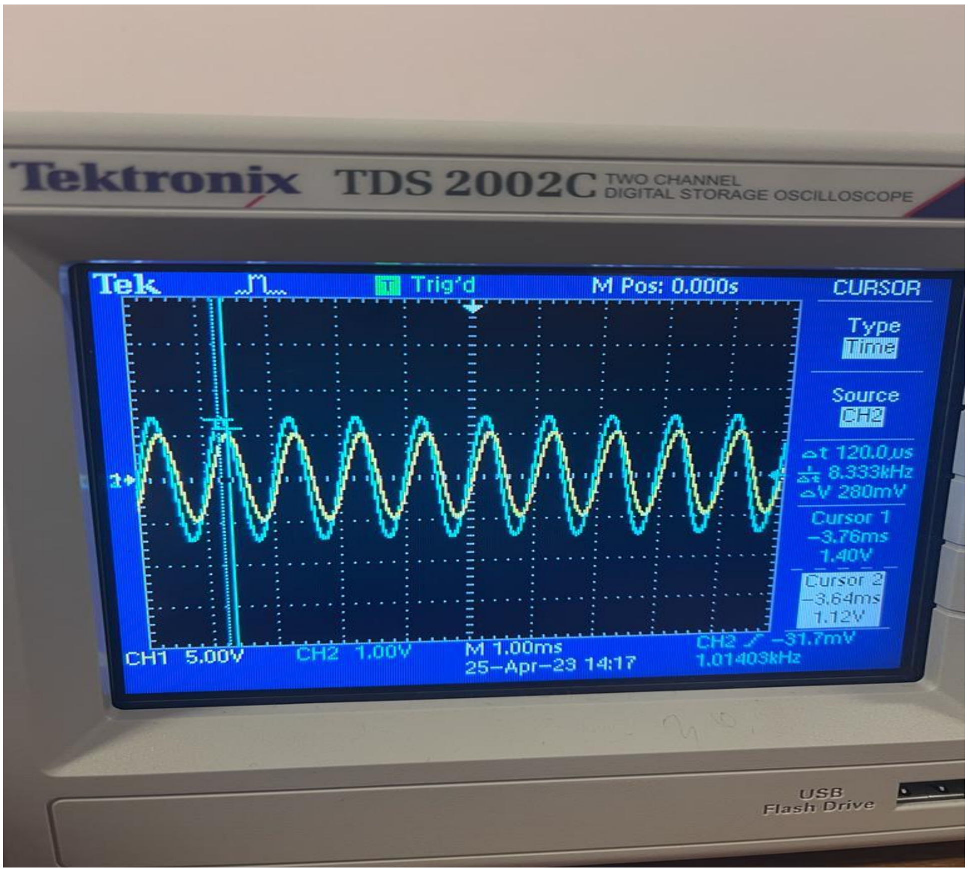

Figure 11. Delta t with f =1 kHz

There are two methods to determine the Phase shift: auto measure and by calculating $\Delta\tau$ as depicted in Figure 12. Once we have obtained $\Delta\tau$, we can then calculate the Phase shift using the formula $360\Delta\tau F$.

Figures 12 and 13 display the outcomes of performing the previous stage twice, first at 500 Hz and then at 1.5KHz.

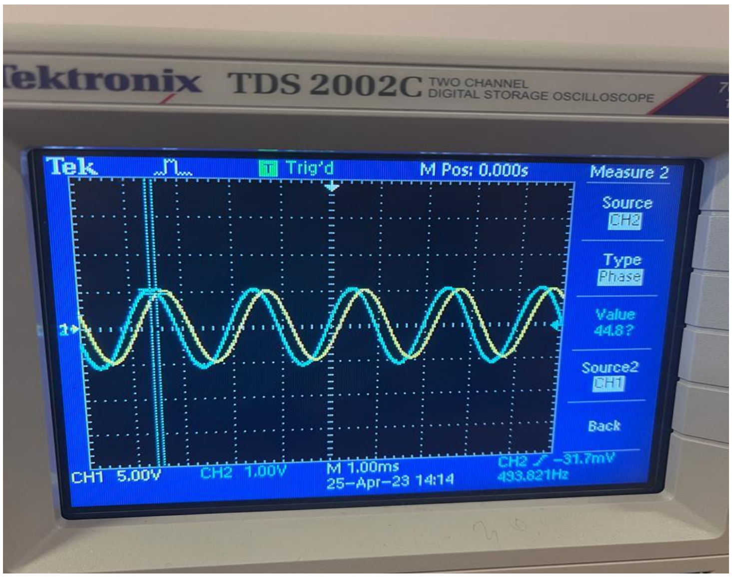

Figure 12. Phase Shift when f =500Hz

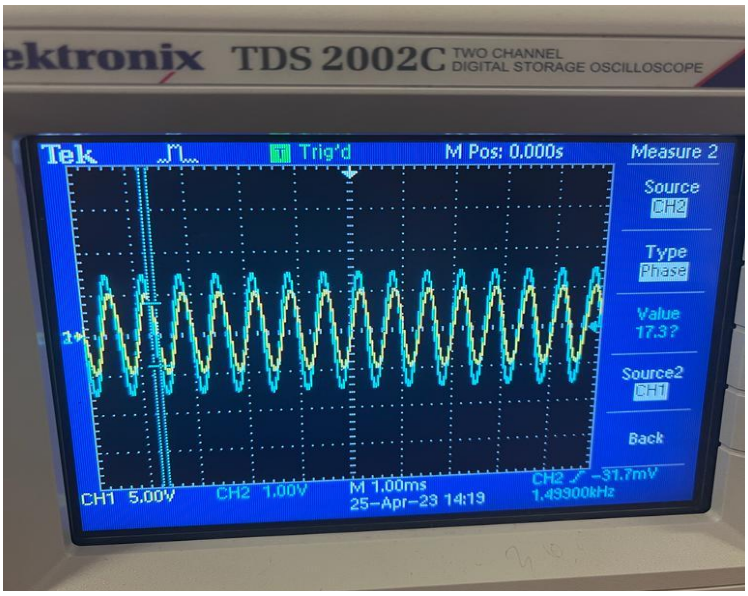

Figure 13. Phase Shift when f =1500Hz

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Calculation:

- Experimentally

The ***experimentally*** measured results are shown in Table 3:

F [Hz]	Vrms	Irms	Δt	Phase shift
500	1.61	0.745	—	-44.8
1K	2.04	0.950	120Ms	-26.3
1.5K	2.17	1.024	—	-17.3

Table 3. Results Experimentally for Capacitive Circuit

impedance = *v*/*I* (Experimentally)

F [Hz]	Impedance(z)
500	2.161
1K	2.147
1.5K	2.112

Table 4. Results of Impedance for Capacitive Circuit

- Theoretically

impedance = $Rx + R8 + \frac{1}{jwc}$ =2.2 kΩ + 1 kΩ + -j/(Ꞷc) (Theoretically)

$|Z|= \sqrt{R\ total} + (1/wc)\ 2\sqrt{\ }$

Phase shift = $\tan\text{-}1(\frac{Imaginary\ part}{real\ part})$

F=500Hz:

- ❖ Impedance = Rx + R8 + j(ꞶL) = 1.47 K + j*2π*0.5 K* 400mH
  =1.47 + j 1.256, |Z|= 1.934 K.
- ❖ Phase shift = tan-1 ($\frac{1.256}{1.47}$) = 40.5

F=1KHz:

- ❖ Impedance = Rx + R8 + j(ꞶL) = 1.47 K + j*2π*1 K* 400mH
  =1.47 + j 2.513, |Z|= 2.911 K.
- ❖ Phase shift = tan-1 ($\frac{2.513}{1.47}$) = 59.67.

F=1.5KHz:

- ❖ Impedance = Rx + R8 + j(ωL) = 1.47 K + j*2π*1.5 K* 400mH
  =1.47 + j 3.77, |Z|= 4.046 K.
- ❖ Phase shift = tan-1 ($\frac{3.77}{1.47}$) = 59.67.

F [Hz]	Impedance(z)	Phase shift
500	1.924 K	40.5°
1K	2.911 K	59.67°
1.5K	4.046 K	59.67°

Table 5. Theoretical Results for Capacitive Circuit

★ The experimental and theoretical results are similar, with the difference in the phase and impedance for 1.5K

2.1.3.Inductive Impedance

To set up the circuit depicted in Figure 14, a sinusoidal waveform with a frequency of 1 kHz and an amplitude of 5 V was produced by the signal generator. Two resistors were connected to the circuit: the first resistor (R8) had a value of 1 k, and the second resistor (Rx) had a value of 0.47 k. Additionally, a 400 mH inductor was included.

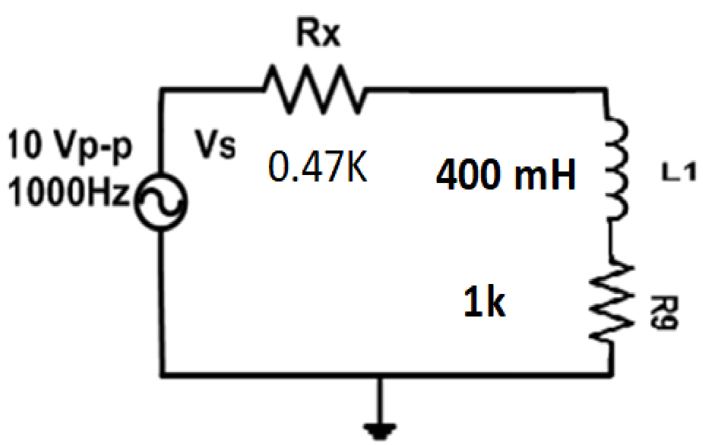

Figure 14. Inductive Circuit used in part A

Once the circuit was connected, the total voltage and current were measured using a DMM, and the phase shift between the total voltage and the voltage across resistor Rx was assessed using an oscilloscope, as illustrated in Figure [15-17].

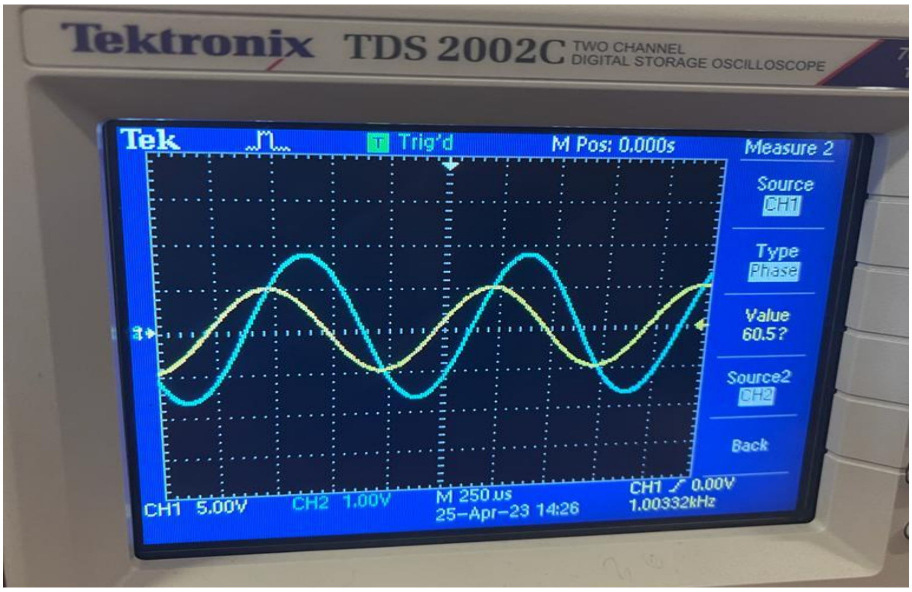

Figure 15. Phase Shift when f =1 kHz

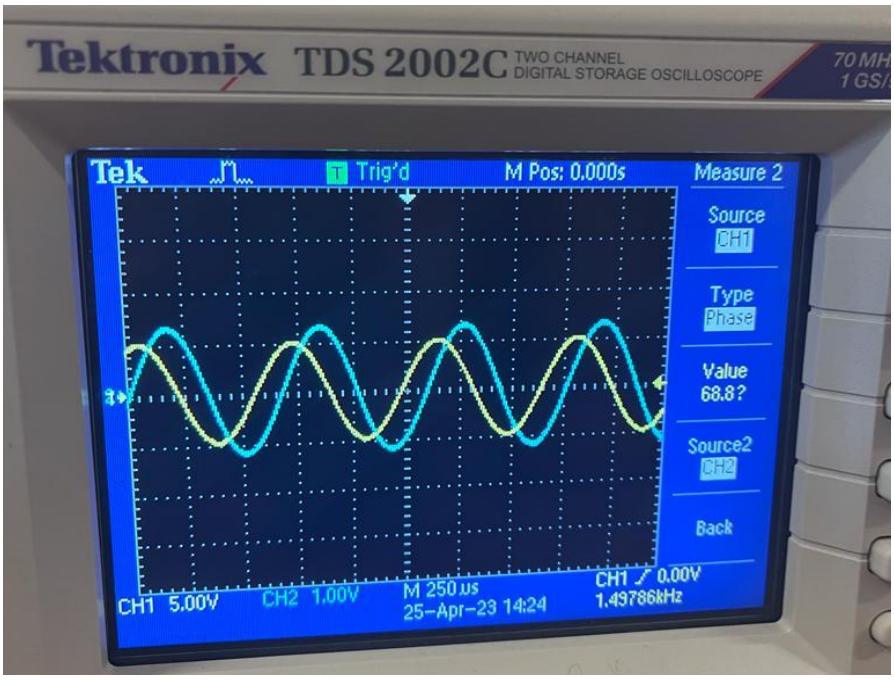

Figure 16. TPhase Shift when f =1500 kHz

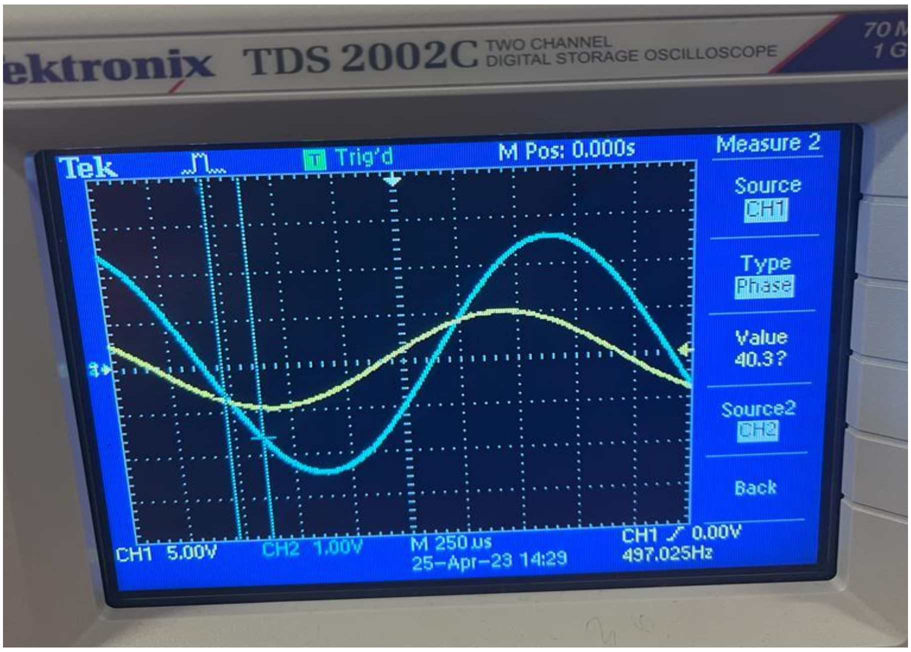

Figure 17. Phase Shift when f =500 kHz

Calculation:

- Experimentally

The experimentally measured results are shown in Table 6:

F [Hz]	Vrms	Irms	Δt	Phase shift
500	3.76	1.735		40.3
1K	3.49	1.162	1.Ms	60.5
1.5K	3.34	.829		68.8

Table 6. Experimental Results for Inductive Circuit

impedance = *v*/*I* (Experimentally)

F [Hz]	Impedance(z)
500	2.197
1K	3.003
1.5K	4.029

Table 7. Impedance Results for Inductive Circuit

- Theoretically

impedance = $Rx + R8 + \frac{1}{jwc}$ =2.2 kΩ + 1 kΩ + -j/(Ѿc) (Theoretically)

|Z|= $\sqrt{R\ total}$ + (1/wc) 2$\sqrt{\ }$

Phase shift = tan-1($\frac{Imaginary\ part}{real\ part}$)

F=500Hz:

- ❖ Impedance = Rx + R8 + j(ѾL) = 1.47 K + j*2π*0.5 K* 400mH =1.47 + j 1.256, |Z|= 1.934 K.
- ❖ Phase shift = tan-1($\frac{1.256}{1.47}$) = 40.5

F=1KHz:

- ❖ Impedance = Rx + R8 + j(ѾL) = 1.47 K + j*2π*1 K* 400mH =1.47 + j 2.513, |Z|= 2.911 K.

- ❖ Phase shift = tan-1 ($\frac{2.513}{1.47}$) = 59.67.

F=1.5KHz:

- ❖ Impedance = Rx + R8 + j(ѾL) = 1.47 K + j*2π*1.5 K* 400mH =1.47 + j 3.77, |Z|= 4.046 K
- ❖ Phase shift = tan-1 ($\frac{3.77}{1.47}$) = 68.96.

F [Hz]	Impedance(z)	Phase shift
500	1.934 K	40.5°
1K	2.911 K	59.67°
1.5K	4.046 K	68.96°

Table 8 : Theoretical Results for Inductive Circuit

★ The experimental and theoretical results are very similar, with no difference in the phase and almost the same impedance value.

2.2. Capacitive and Inductive behavior:

A sinusoidal waveform with a frequency of 1 kHz and an amplitude of 5 V was generated by the signal generator. The circuit in Figure 19 was then established with one resistor (R13) having a value of 330 ohm, a capacitor (C4) with a capacitance of 100nF, and an inductor (L3) with a value of 10mH.

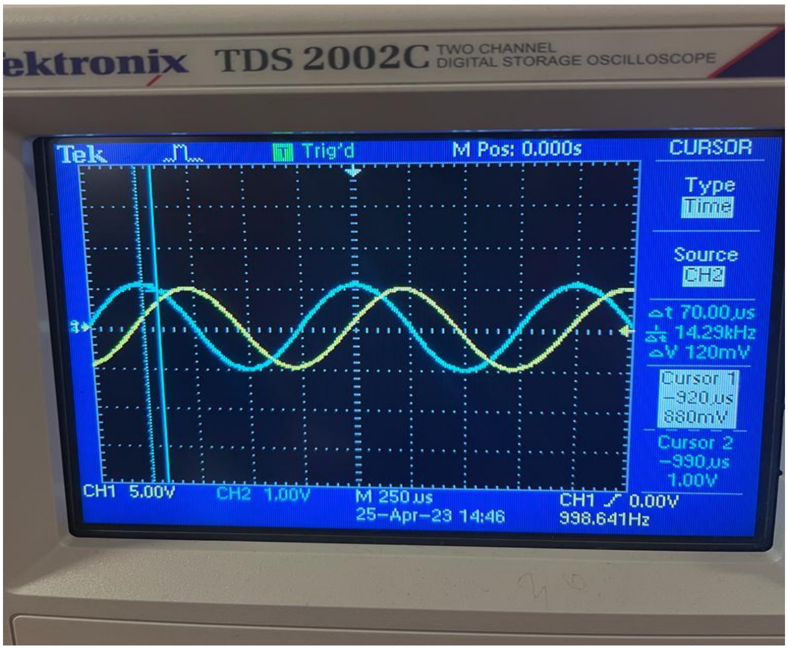

Figure 18. phase shift between total current and the voltage when f= 1 KHz

In order to evaluate the circuit's response to frequency changes, the frequency was altered to several different values (2KHz, 4KHz, 6KHz, and 8KHz), and the results were recorded in Figures 19-22.

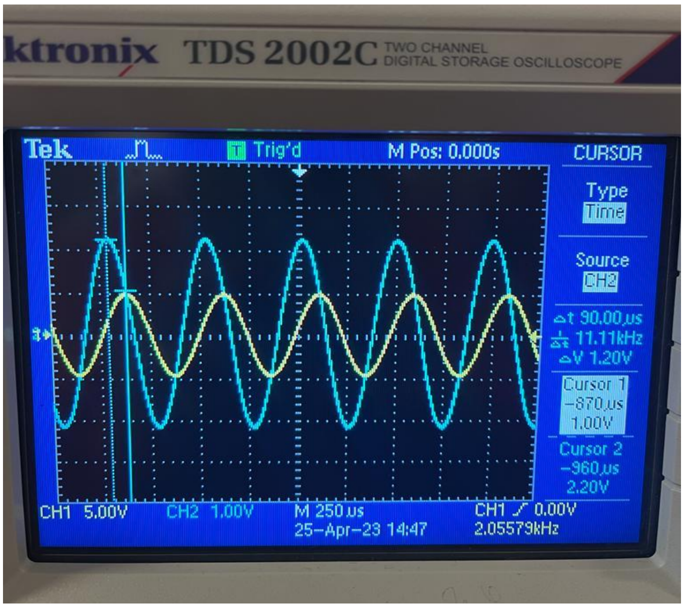

Figure 19. phase shift between total current and the voltage when f= 2 KHz

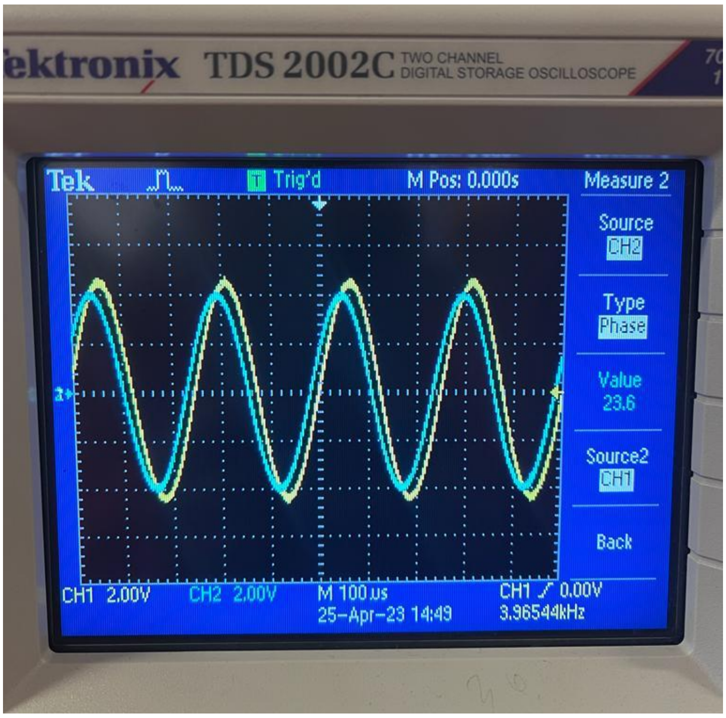

Figure 20. phase shift between total current and the voltage when f= 4 KHz

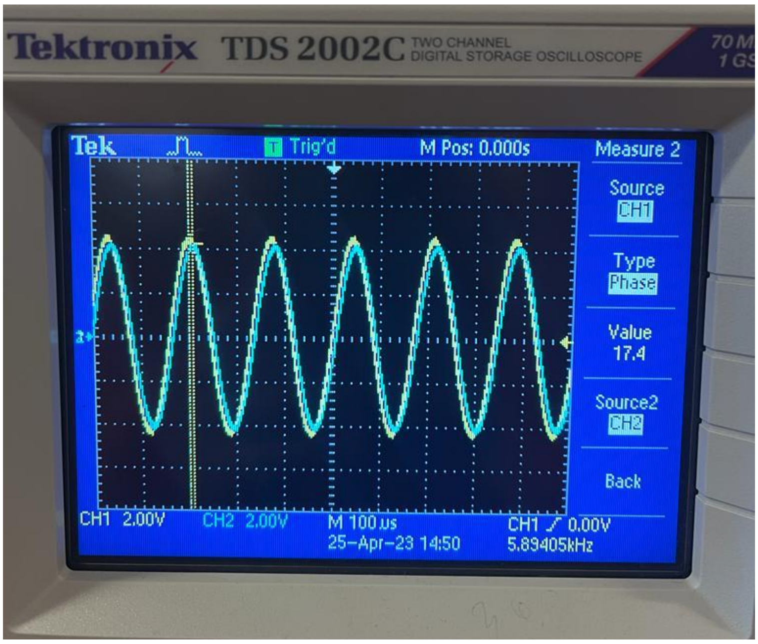

Figure 21. phase shift between total current and the voltage when f= 6 KHz

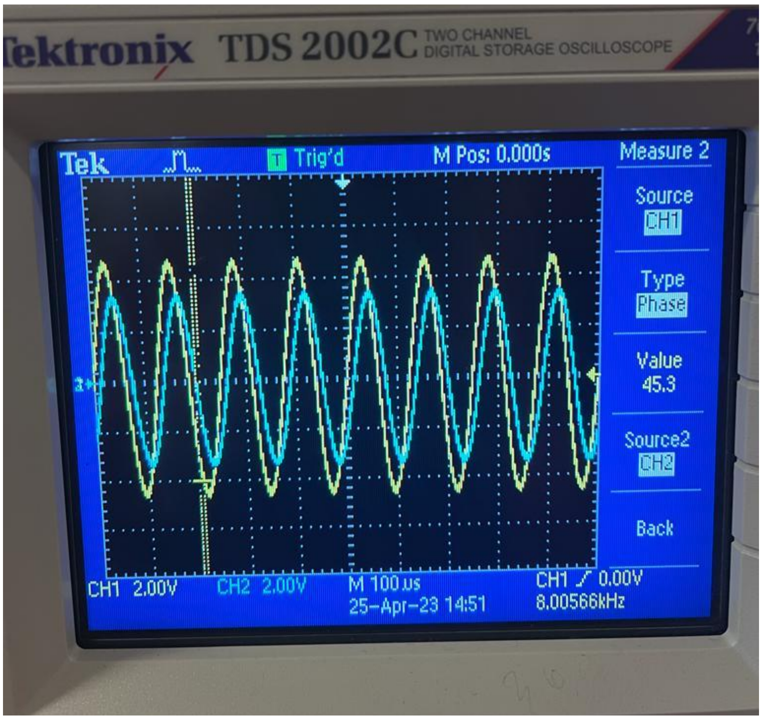

Figure 22. phase shift between total current and the voltage when f= 8 KHz

Calculation:

- Experimentally

The *experimentally* results are shown in Table 9:

F in Hz	1 K	2 K	4 K	6 K	8 K	Fo
Δτ	80Ms	90Ms	16Ms	8Ms	15Ms	4.9Ms
$\theta vs - \theta Is$	77.8	62.1	24	17	44.2	0

Table 9. Experimental results for the phase shift of capacitive and inductive behavior.

- Theoretically

impedance = $R13 + jwl + \frac{1}{jwc}$

Phase shift = tan-1 ($\frac{(x)Imaginary\ part}{(y)real\ part}$)

F=1KHz:

- Impedance =R13+ $jwl + \frac{1}{jwc}$ =330+ $j2\pi * 1K * 10\ Ms + \frac{1}{j2\pi*1kHz*100\ n}$
  = 330+ j -1529.5 K
- Phase shift = tan-1 ($\frac{-1529.5}{330}$) = -77.82.

F=2KHz:

- Impedance =R13+ $jwl + \frac{1}{jwc}$ =330+ $j2\pi * 2K * 10\ Ms + \frac{1}{j2\pi*2kHz*100\ n}$
  = 330 j -670.5 K
- Phase shift = tan-1 ($\frac{-670.5}{330}$) = -63.7.

F=4KHz:

- Impedance =R13+ $jwl + \frac{1}{jwc}$ =330+ $j2\pi * 4K * 10\ Ms + \frac{1}{j2\pi*4kHz*100\ n}$
  = 330+ j -146.8 K
- Phase shift = tan-1 ($\frac{-146.8\ K}{330}$) = -23.9.

F=6KHz:

- Impedance =R13+ $jwl + 1\ jwc$ =330+ $j2\pi * 6K * 10\ Ms + \frac{1}{j2\pi*6kHz*100\ n}$ = 330+j 111.5 K
- Phase shift = tan-1 ($\frac{111.5}{330}$) = 18.6.

F=8KHz:

- Impedance =R13+ $jwl + \frac{1}{jwc}$ =330+ $j2\pi * 8K * 10\ Ms + \frac{1}{j2\pi*8kHz*100\ n}$

$= 330+ j\ 303.4$ K

❖ Phase shift = tan-1 ($\frac{303.4}{330}$) = = 42.5

F= fo: fo = $1\ 2\pi\sqrt{LC} = 1\ 2\pi\sqrt{10Ms+100n} = 5.033$ K.

❖ Impedance = R13+ $jwl + 1\ jwc = 330 + j\ 2\pi * 5.033\ K * 10Ms + \frac{1}{j2\pi*5.033KHz*100\ n} = 0$

❖ Phase shift = tan-1 ($\frac{0}{330}$) = 0

F in Hz	1 K	2 K	4 K	6 K	8 K	Fo at 5.033 K
Phase Shift	-77.82	63.7	-23.9	18.6	42.5	0

Table 10. Theoretical results for the phase shift of capacitive and inductive behavior.

★ The experimental and theoretical results are very similar.

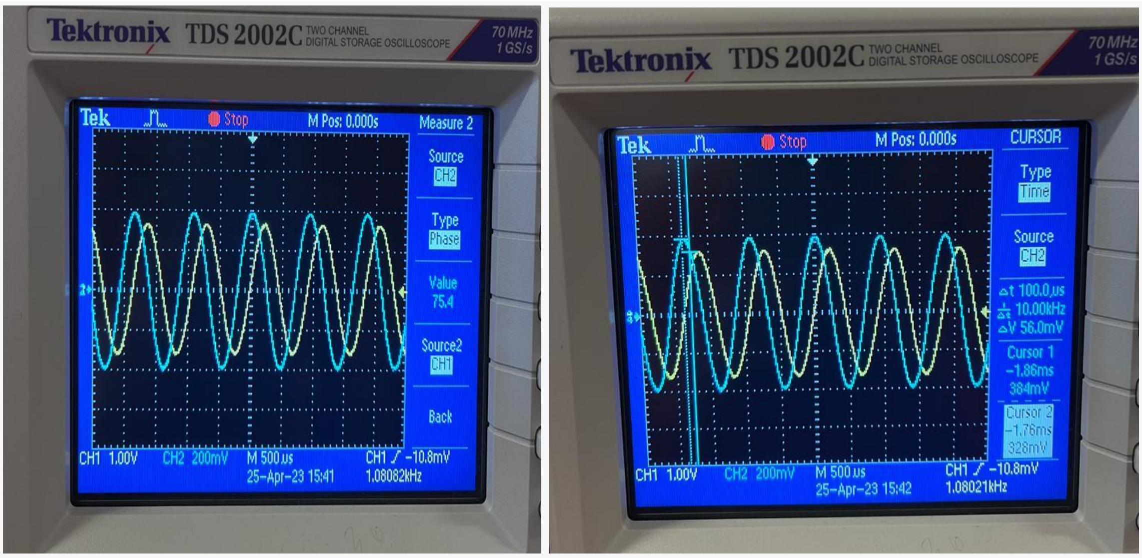

Figure 24. Connecting another 100nF in parallel to C2

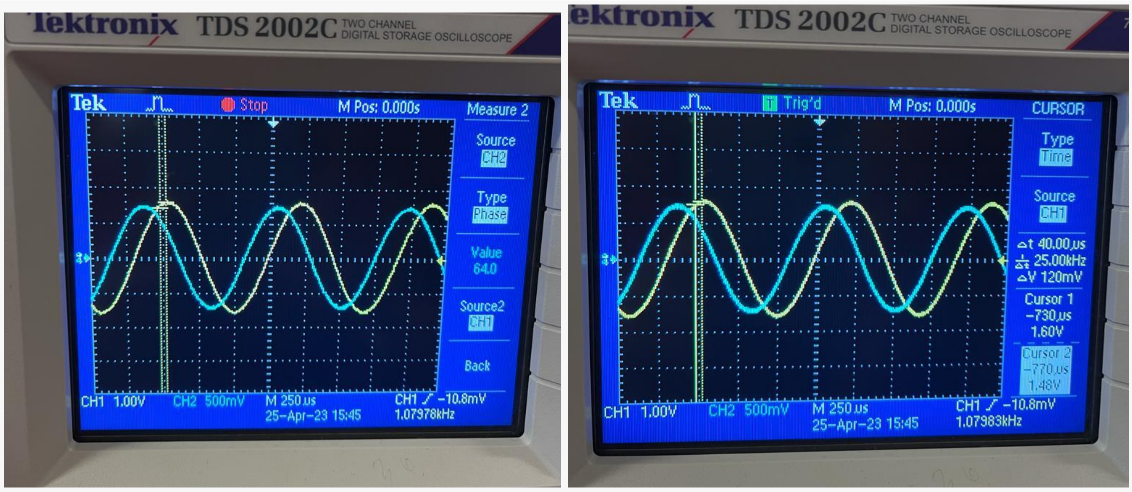

Figure 26. Disconnecting Extra Capacitor and Double the value of L3

2.3. Sinusoidal steady state power:

To establish the circuit in Figure 27, a sinusoidal waveform with a frequency of 2 kHz and an amplitude of 2.5 V was generated using the signal generator. The circuit consisted of three resistors; R1 and R2 had a value of 220 ohms, and R3 had a value of 10 ohms. Additionally, a capacitor (C4) with a capacitance of 470 nF and an inductor (L1) with a value of 120 mH were also included.

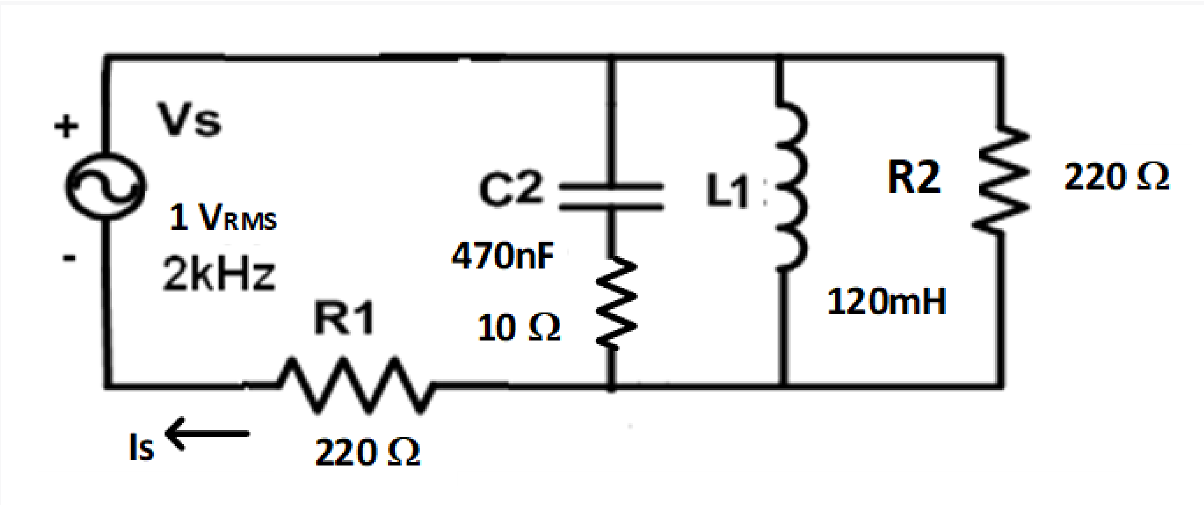

Figure 27. Using RCL to determine power.

To obtain the data presented in Table 11, we performed the following steps: First, we measured the RMS voltage and current across R2, L1, C2, and R1 in the circuit. Next, we measured the phase difference between the total voltage

(Vs) and current (Is) as shown in Figure 26. We then connected an Rx (10-ohm) in series with the voltage (Vc) and current (Ic) to assess the phase shift between the two, as illustrated in Figure 27. We also recorded the voltages of Rx and C2+Rx on the capacitor. Finally, we calculated the power for each element in the circuit.

The experimentally results are shown in Table 11:

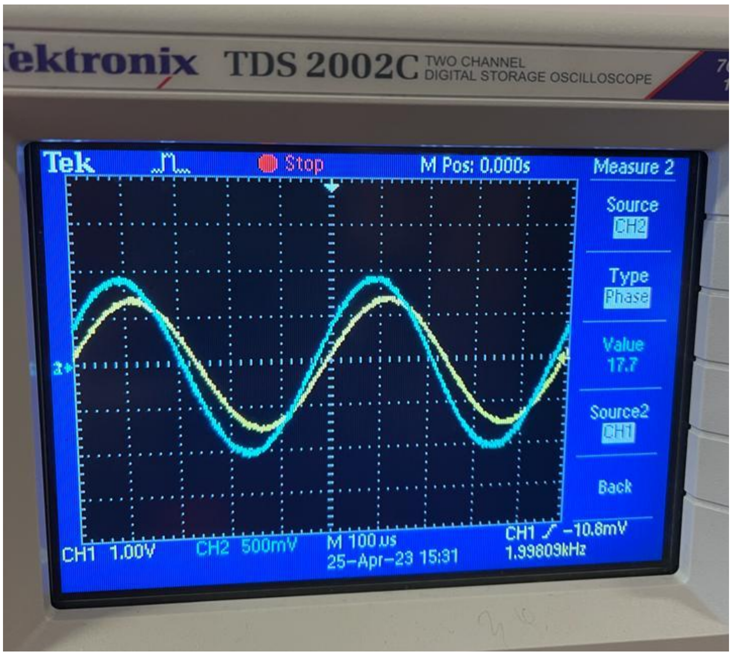

Figure 28. ∅Vs- ∅Is

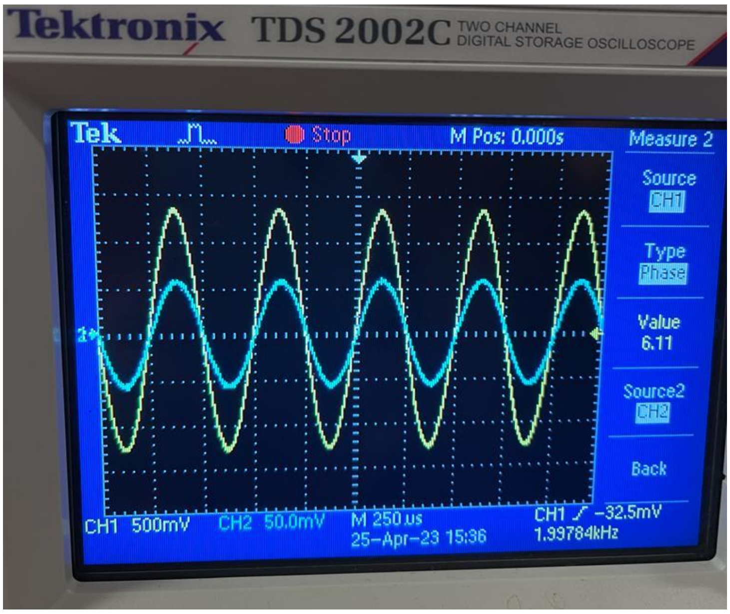

Figure 29. ∅Vs- ∅Is

Calculation:

- Experimentally

V R1	V L	I L	I R2	Vs	Is	$\varnothing Vs - \varnothing Is$	Vc	Ic	$\varnothing Vc - \varnothing Ic$
0.7379	0.4075	0.312	1.815	0.9872	3.315	17.7	0.4068	2.442	6.11

Table 11. Experimental results for power in sinusoidal steady state.

- Theoretically

reactive power = Vrms Irms sin(θ).
active power = Vrms Irms cos(θ).
P factor = cos(θ).

❖ reactive power: Pc = 0.410 * 2.550 * sin (18.6) = 0.3334 mWatt,
Pl = 0.415 * 0.270 * sin (18.6) = 0.0357 mWatt .
Pvs= 3.17*1.10*sin (18.6) =1.1122 mWatt

❖ active power: R1 = 0.687 V * 3.17 mA * cos (18.6) = 2.06 mWatt.
R2 = 0.415V * 1.85mA * cos (18.6) = 0.6276 mWatt .
Pvs= 3.17*1.10*cos (18.6) =3.9917 mWatt
Pc=0.410 * 2.550 * cos (86.9) =0.0565 mWatt

❖ power factor: Vs→Cos (16.7) = 0.95.
R1, R2, R3→Cos (0) =1
C2→ Cos (0) =0 , experimentally equal from true power/apparent power 0.167.
L→= Cos (90) = 0 experimentally equal from true power/apparent power 0.925.

Element		R1=220ohm	R2=220ohm	R3=10 ohm	C2	L1
reactive power	1.1122 mWatt	0	0	0	0.3334 mWatt	0.0357 mWatt
active power	3.3048 mWatt	2.06 mWatt	0.6276 mWatt	0.0535 mWatt	0.0565 mWatt	0.087 mWatt
P factor	0.95	1	1	1	0.167	0.925

Table 12. Theoretical results for power in sinusoidal steady state.

3. Conclusion

The primary objective of this experiment was to gain insights into how frequency affects the circuit's response and how the presence of elements such as capacitors and inductors influences it. When the circuit solely consists of resistors, the frequency has no impact on the voltage and current, and there is no phase shift between them. However, if a capacitor or inductor or both are present, a phase shift between the current and voltage is observed.

We were able to determine the active power, reactive power, factor power, and check the conversation of the power law.

4. References

[1] https://eepower.com/capacitor-guide/fundamentals/impedance-and-reactance/

[2]https://resources.pcb.cadence.com/blog/2022-advanced-pcb-design-blog-what-is-the-impedance-of-an-rlc-circuit

[3]https://control.com/technical-articles/active-power-reactive-power-apparent-power-and-the-role-of-power-factor/

5. Appendix

Circuits & Electronics Lab ENEE2103

Experiment#4 ENEE2103

Sinusoidal Steady State Circuit Analysis

AC → مكبس

Objectives:

1. To use the Oscilloscope, the DMM, the Wattmeter for AC electric quantities measurement..
2. To measure the circuit elements impedances and voltage and current phasors.
3. To verify the validity of the Circuit theorems in the sinusoidal steady state.
4. To measure the power in sinusoidal steady state circuits.

Equipment :

1. Digital Multimeter.
2. Oscilloscope (TDS-2002B).
3. Power supply.
4. Function generator.

Pre-lab:

1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
2. Verify if Simulation Results match the expected results

Procedure:

A. *Impedance:*

1. Connect the circuit of Fig (4.1)
2. Value of R_x =2.2 kΩ
3. Set the signal generator to generate a sinusoidal waveform with amplitude 5 → $5 \times 2 = V_{pp}$ volts and frequency 1 kHz.
4. Measure the total impedance of the circuit using DMM by measuring the total voltage and current. Find the phase shift between total voltage and current using the oscilloscope cursor menu. — $\frac{\text{الفولتية الكلي}}{\text{التيار الكلي}}$

   $rms = \frac{5}{\sqrt{2}}$
5. Repeat the step (4) with the signal frequencies: 500 Hz , 1500 Hz. Fill in the results in table 4.1
6. Write your conclusions about the variation of the impedance of the resistor with the frequency.
7. Connect the circuit of Fig (4.2).
8. Repeat the steps (2-5) with the signal frequencies: 500Hz , 1500 Hz. Fill in the results in table 4.2
9. Write your conclusions about the variation of the impedance of capacitor with the frequency.
10. Connect the circuit of Fig (4.3)
11. Repeat the steps (2-5) with the signal frequencies: 500Hz , 1500 Hz. Fill in the results in table 4.3
12. Write your conclusions about the variation of the impedance of the inductor with the frequency.

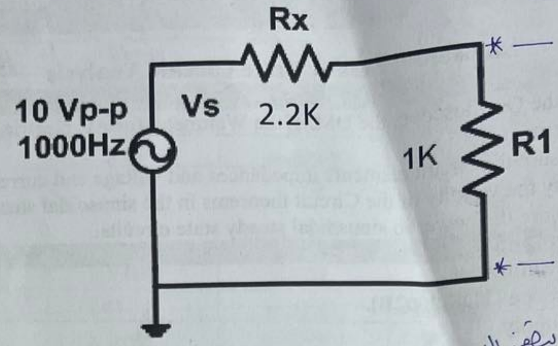

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Fig (4.1)

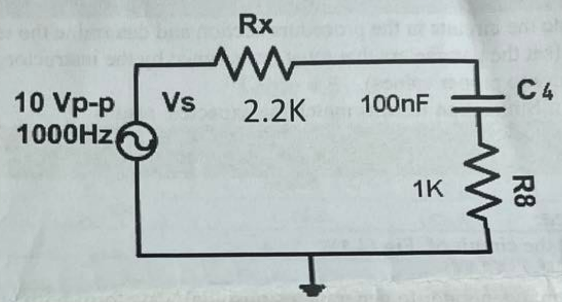

Fig (4.2)

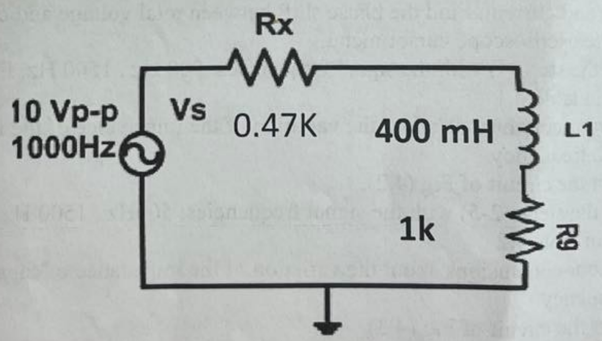

Fig (4.3)

B. Capacitive and inductive behvior:

1. Connect the circuit in Fig (4.4) (note : use table 4.5 to fill in the results)
2. Set the generator to generate a sinusoidal waveform with amplitude 5 volts and frequency 1 kHz.
3. Measure the phase shift between the total current and the voltage.
4. Repeat the step (3) incrementing the frequency 2 kHz, 4 kHz,6 kHz,8 kHz .
5. Determine the resonance frequency fo experimentally ***(note that at fo, both voltage and current will be in phase)***

6. Write your conclusions about the circuit behavior in relation to the capacitive and inductive and the resistive behavior.
7. Set the generator frequency to the resonance frequency found in 5.
8. Connect another 100nF capacitor in parallel to C2 and explain the behavior of the circuit according to the circuit response.
9. Disconnect the extra capacitor and double the value of L3 and Explain the behavior of the circuit according to the circuit response.

1K Δt=40μ Ph=64

1K Ph.=75.4 Δt=100μ $f_o = \frac{1}{2\pi\sqrt{LC}}$

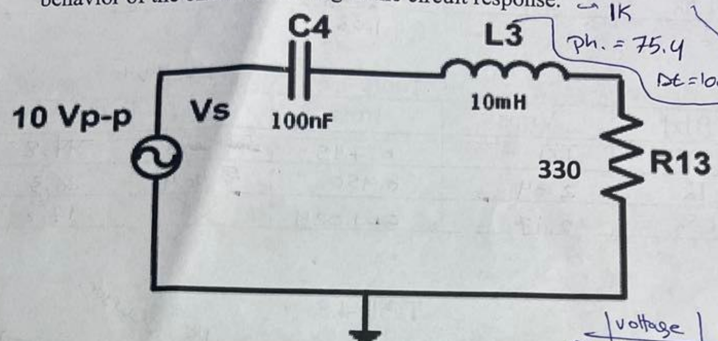

Fig (4.4)

	voltage	current	phase s
R2	9.74		

C. Sinosoidal steady state power:

1. Set the voltage source to amplitude ~~2.5~~V and frequency 2 kHz
2. **Connect** the circuit in Fig (4.5)
3. **Measure** the rms voltage and the rms current across R2, L1 , C2 and R1
4. **Measure** the phase shift between Vs and Is; Vc and Ic and fill table 4.5.

Notice that in order to measure phase shift between Vc, Ic , you need to add
a 10 Ω resistor in series with C2. Find the phase shift between voltage of C2+ Rx and the voltage of Rx.

5. **Compute** the active power (average power), the reactive power and the power factor in each element.
6. **Verify** the validity of the conversation of energy law (∑input Power=∑Output Power)

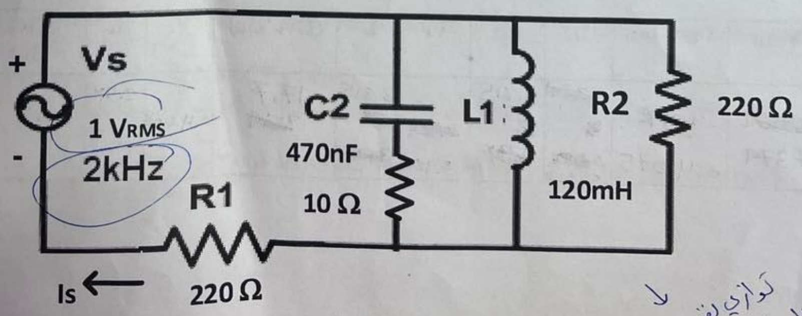

Fig (4.5)

$V_{rms} = 3.36$

$I_{rms} =$

Table 4.1

f [Hz]	Vrms	Irms	Δt	Phase shift
500	3.3	1.03	0	0
1k	3.3	1.03	0	0
1.5k	3.3	1.03	0	0

1k

Δt × 360 / Period

freq. [illegible]

Table 4.2

f [Hz]	Vrms	Irms	Δt	Phase shift
500	1.61	0.745	120µs	−44.8
1k	2.04	0.950	120µs	26.3
1.5k	2.17	1.024	X	17.2

Period = 2.020

Fc = 988 µ

Table 4.3

1k cursor

measure → [illegible]

f [Hz]	Vrms	Irms	Δt	Phase shift
500	3.76	1.735	X	40.1
1k	3.49	1.162	150µs	60.5
1.5k	3.34	0.829	X	69.1

Table 4.4

f	1k	2k	4k	6k	8k	fo
Δt	80µs	90µs	16µs	8µs	15µs	4.95kH
$(\Theta_{Vs} - \Theta_{Is})$	77.8	62.1	24	17	44.2	zero

phase shift

phase = 0

← zero

Table 4.5

$V_{(R1)}$	$V_L = V_{(R2)}$	I_L	I_{R2}	V_s	I_s	$(\Theta_{Vs} - \Theta_{Is})$	V_c	I_c	$(\Theta_{Vc} - \Theta_{Ic})$
0.7379	0.4075	0.312	1.815	0.9872	3.315	17.7	0.4068	2.442	6.11

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