Department Of electrical and computer Engineering

ENEE2103 CIRCUITS AND ELECTRONICS LABORATORY

Experiment No.4 report

Instructor: Dr. Alhareth Zyoud

Made By: Islam Jihad

ID: 1191375

TA: MR. Ismail Abualia

Date: 5/12/2021

Partners: Yousef Hamad and Wejdan Aljamal

Abstract:

In this experiment we intend to investigate the sinusoidal steady state circuits, combined with understanding some elementary concepts in distinct sort of circuits (resistive, capacitive and inductive) then measure them using specific equipment, like oscilloscope, DMM and Wattmeter.

Each of the instruments will be utilized in separate stages of the experiment, to determine elements impedance, voltage, current phasors and power.

Table of Contents

1. Theory:

The primary purpose of studying this experiment is to notice the altering of impedances due to various frequencies in sinusoidal steady state circuits and observe the phase shift \sand power of circuit's components.

1.1 Impedance:

- What is electrical impedance? Electrical impedance is a measure of the entire opposition that a circuit or a component of a circuit exhibits to electric current.
- The magnitude of the impedance Z of a circuit is equal to circuit's elements' voltage phasor, divided by circuit's elements' current phasor, or simply Z = V/I. The unit of impedance, like that of resistance, is the ohm.
- Thus, the impedance of a resistor is R, the inductor is jwl and the capacitor is 1/jwc. In the frequency domain it's the quantity of similar to resistance, inductance and capacitance
- Depending on the nature of the reactance component of the impedance (whether inductive or capacitive), the alternating current either lags or leads the voltage.

1.2 Capacitive and inductive behavior:

The RLC circuit below has a single loop with the instantaneous current flowing through the loop which is the same for each circuit element and since the reactance of inductor and capacitor is a function of frequency, the sinusoidal response will vary with the frequency and the voltage drop across each element will be out of phase. The formulae for the circuit reactance and impedance are provided below:

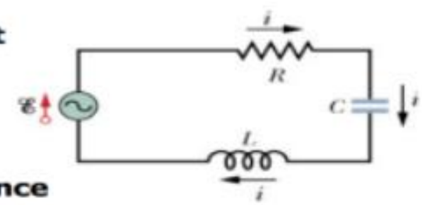
$I_m = \frac{\varepsilon_m}{Z}$ **Maximum current**

$\tan\phi = \frac{X_L - X_C}{R}$ **Phase angle**

$X_L = \omega L \quad (\omega = 2\pi f)$ **Inductive reactance**

$X_C = 1/\omega C$ **Capacitive reactance**

$Z = \sqrt{R^2 + (X_L - X_C)^2}$ **Total impedance**



The impedance and phase shift of the circuit are summarized as below:

➔RLC circuit has a minimum of impedance Z=R at the resonant frequency, and the phase angle is equal to zero at resonance as Therefore, VL and VC are 180^{o} "out-of-phase" and in antagonism to one other.

➔ The circuit is inductive when wL > 1 / wC , and it is capacitive when 1 / wC > wL.

➔ The instantaneous voltage across a pure resistor, VR is "in-phase" with the current.

➔ The instantaneous voltage over a pure inductor, VL "leads" the current by 90o.

➔ The instantaneous voltage across a pure capacitor, VC “lags” the current by 90o

➔ Therefore, VL and VC are 180º “out-of-phase” and in antagonism to each other.

1.3 Sinusoidal steady state power:

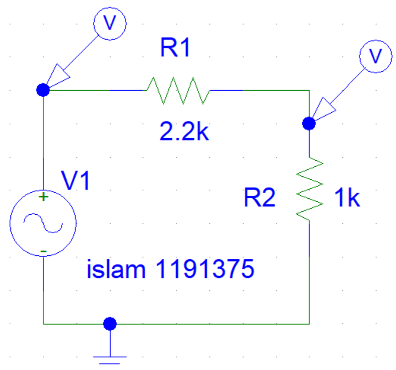
There are numerous sorts of power such as:

- Instantaneous power: in watt which is the product of the instantaneous terminal voltage and current. $p(t)=v(t)I(t)$
- Average power: For many uses, an average value of the power over time is more useful than instantaneous power and is referred to as real power. Its units are likewise watts. It is expressed as $(P_{avg}) = V_m * I_m/2 \cos(\varnothing_v - \varnothing_i)$
- Reactive power: Reactive power is the electric power transferred between an inductor (or a capacitor) and the source that drives it. Reactive power is never transformed to nonelectric power. Its units are (volt amp reactive, or VAR), and is stated as $(Q) = V_m * I_m/2 \sin(\varnothing_v - \varnothing_i)$.
- The power factor is the cosine of the phase angle between the voltage and the current $(P_f) = \cos(\varnothing_v - \varnothing_i)$

Procedure and data calculations:

1. Impedance:
   The purpose of this portion is to discover the impedance of various circuit's components – resistors, capacitors and inductors- and the phase shift of the current and voltage with different frequencies provided.

- Resistive circuit:
  The initial resistive circuit was set up as shown in the diagram below:

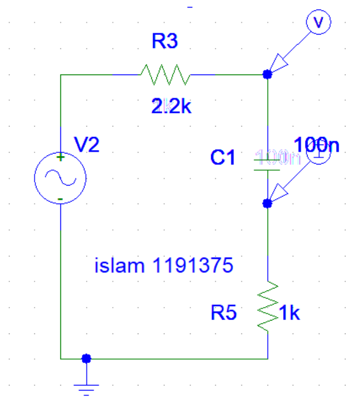


The generator was then tuned to emit a sinusoidal wave with an amplitude of 5 volts, or 10 peak to peak voltages, and the generator's initial frequency was likewise set to 1 KHz.

The voltage and frequency should be set after the circuit has been configured. Using pspice simulation cursors, the total voltage and current were monitored to derive the impedance, as well as the phase shift between the signals.

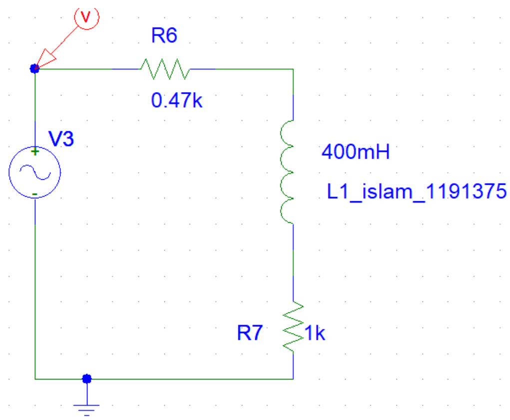
The processes above were repeated with frequencies of 500 HZ and 1.5 KHz, and the results were entered into table 1 at the conclusion.

- capacitive circuit:



The circuit below was wired up as shown in the diagram. The resistive circuit was adjusted by adding a 100 nF capacitor, and the generator was set to 10 Vp-p and 1 KHz frequency. The signal was monitored, and the voltage, current, and phase shift were calculated using pspice simulation. Table 2 was filled by repeating the processes with various frequencies of 0.5KHz and 1.5KHz.

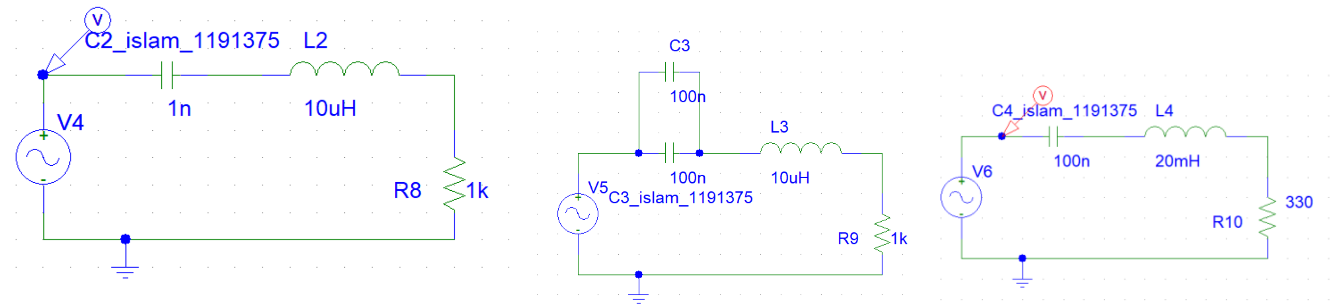
- Inductive circuit:



This circuit is linked as shown in the diagram, with the exception that a 400mH inductor has been added and the value of Rx has been changed to 0.47k. The generator was adjusted to the necessary voltage and frequency as shown in the diagram, and the pspice was used to monitor the total voltage, current, and phase shift.

Capacitive and inductive behavior:

The circuit was connected as in the figure below



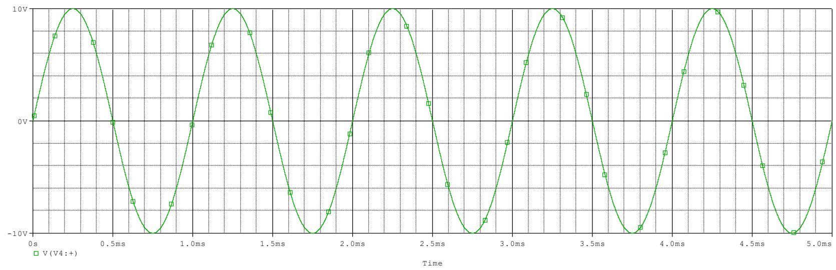
The generator was then adjusted to produce a sinusoidal wave with a 10 Vp-p and a frequency of 1 kHz.

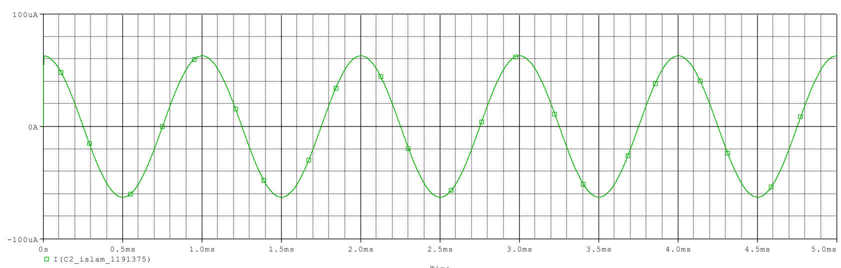
The pspice simulation was then used to determine the phase shift and time between the current and the voltage. The stages were then repeated with the frequency increased to 2,3,4,5,6, and 8 KHz.

The resonance frequency was then established and determined by varying the frequency value until the two waves were in phase and the shift between them was equal to zero. Following the discovery of the resonance frequency, a second 100nF capacitor was connected in parallel with C1 in the circuit, and the outcome was seen. Finally, the additional capacitor was unplugged, and L1's value was increased by a factor of two.

F_o= 5k

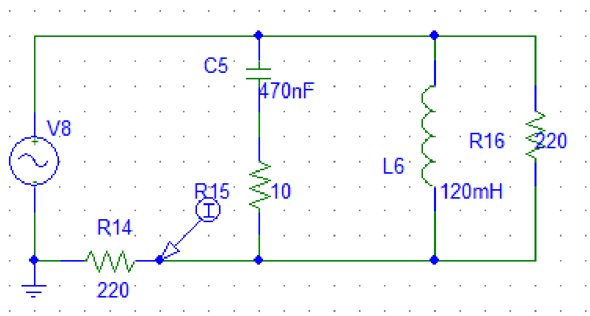
1/2pisqrt(LC)





Sinusoidal steady state power:

The PSpice simulation tool connected this circuit as shown in the diagram below, and the simulation detected the RMS voltage and current, as well as the phase shift and power.

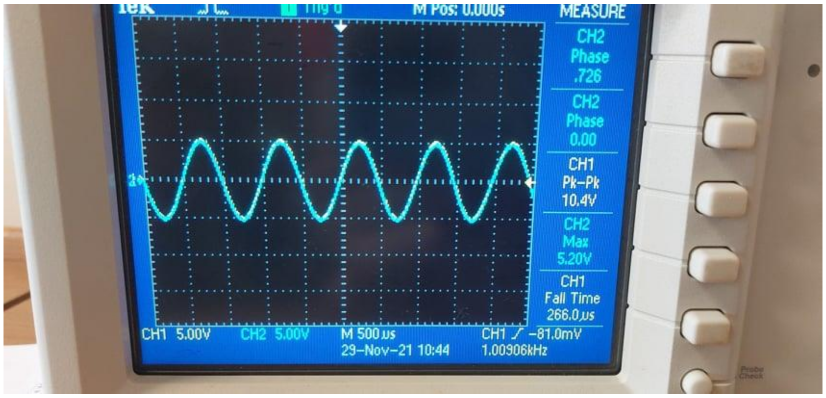


Data calculation, and analysis of results:

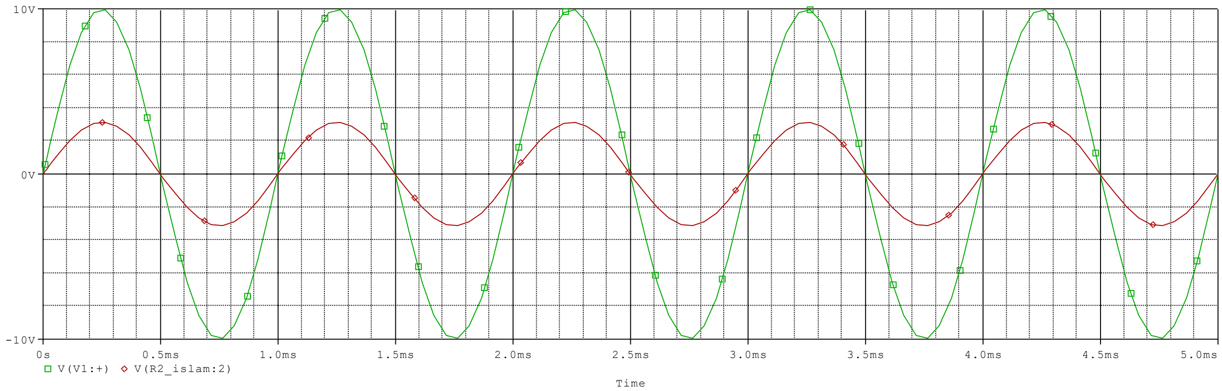
Impedance:

- Resistive circuit:

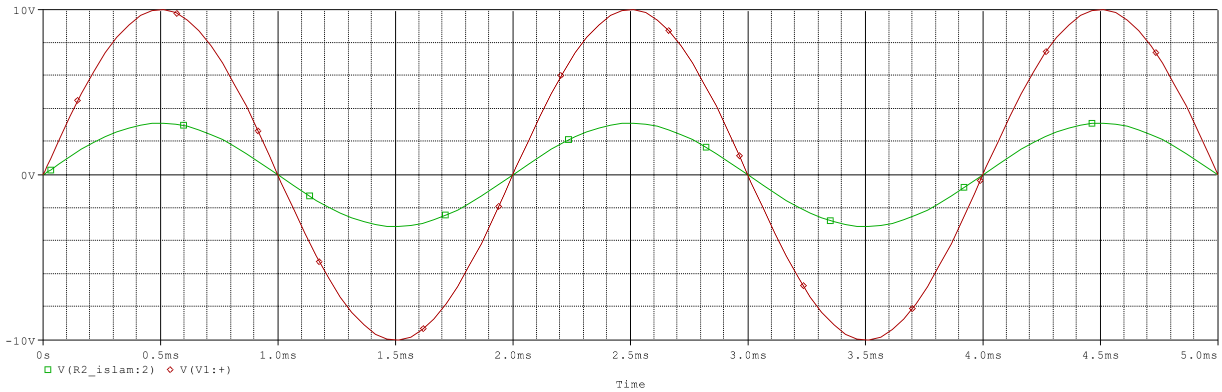
f [Hz]	Vrms	Irms	Δt	Phase shift
1K ~~500~~	3.5 V	1.07mA	0	0
500 ~~1k~~	3.5	1.0	0	0
1.5k	3.44	1.1	0	0



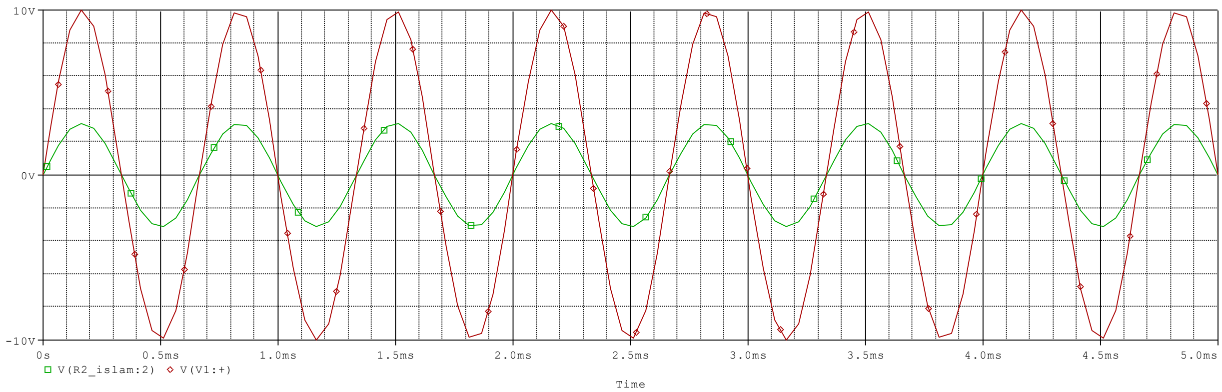
Zero change in phase and time



1KHz



500 Hz



1500 Hz

The theoretical values for all frequencies are:

➔ Impedance: Zin = R1 + R2 = 3.2 KΩ

➔ Total voltage: Vp = 5V

➔ Total current: Ip =Vp/Zin= 1.562 mA

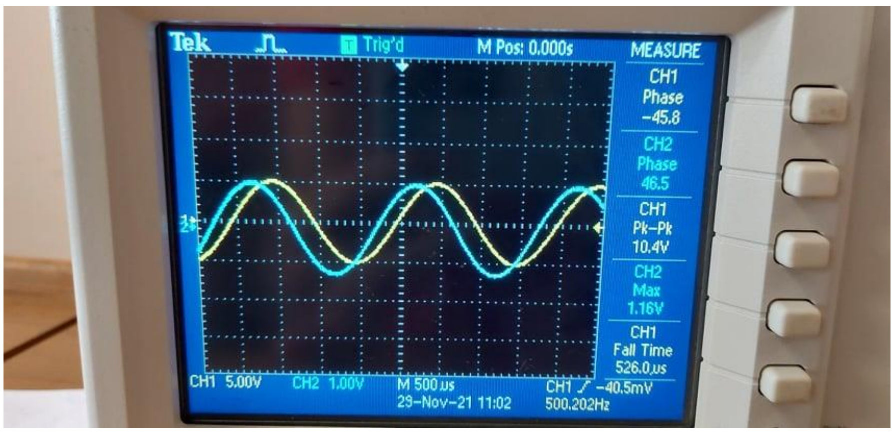
Phase shift:$\Delta\theta = \tan^{-1}$(Im/Re)= ° 0. Since the imaginary part is zero

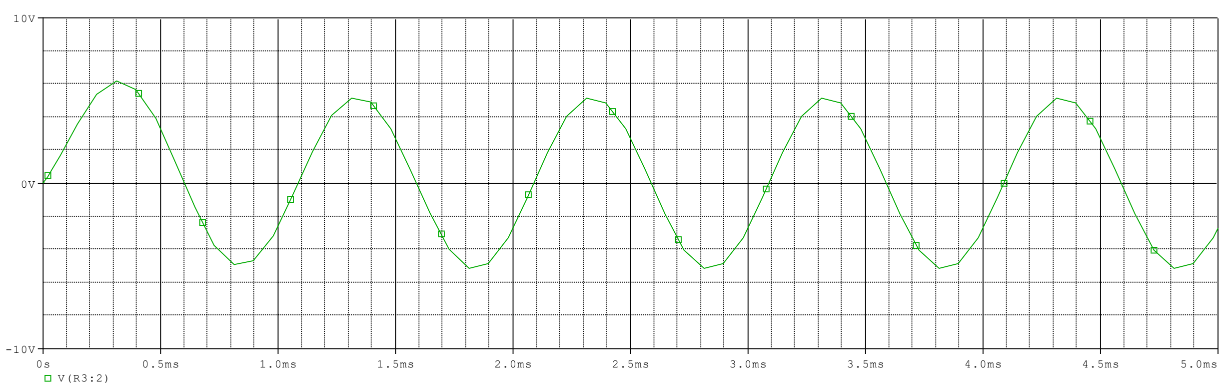
The impedance in the resistive circuit does not rely on the frequency and does not change value, although the voltage and current had the same values for all frequencies, indicating that the circuit is in phase and has no shift, and so the result is acceptable. Furthermore, the values obtained in practice are near to or equivalent to those obtained theoretically, indicating that the findings are accurate. As seen the voltage and current did not changed because there isn’t any piece like capacitor or inductor

- Capacitive circuit:

Table 4.2

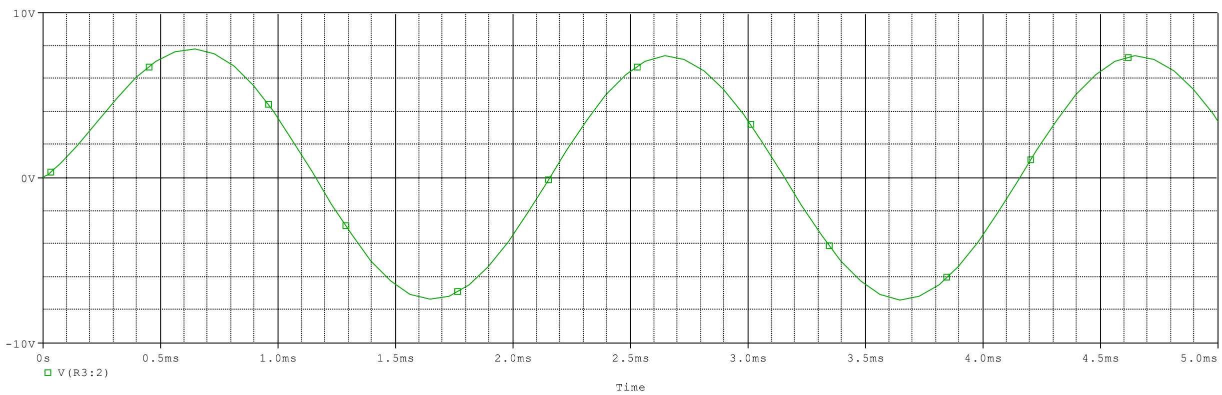
f [Hz]	Vrms	Irms	Δt	Phase shift
500	3.5	.804	280 µs	44.7
1k	3.5	1	70 µs	26.3
1.5k	3.49	1.06	40 µs	18.5



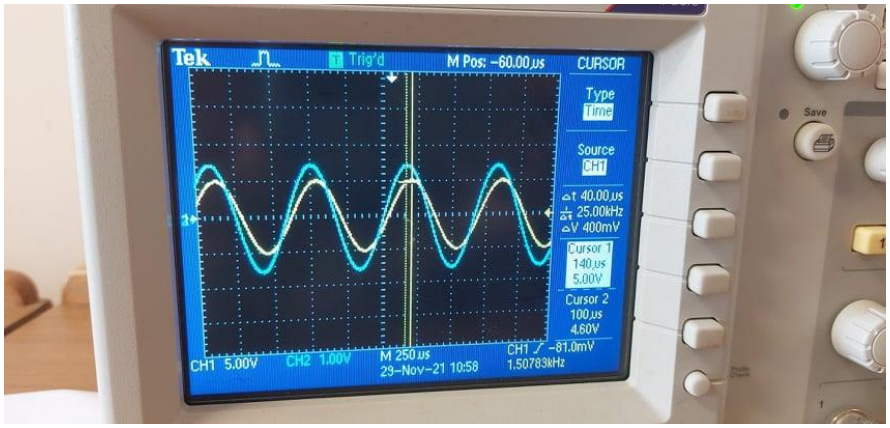


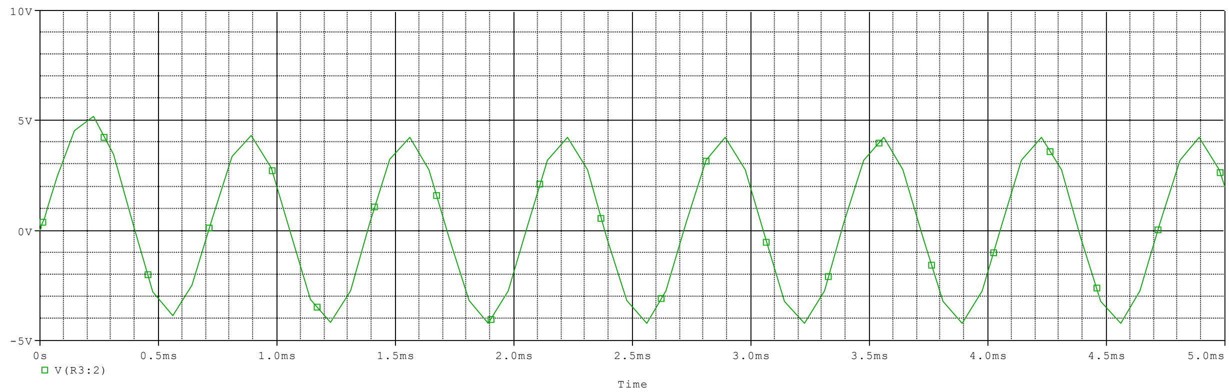
Phase = 46.5°

1KHz



500Hz





Delta t= 40uS

1.5KHz

The theoretical values for all frequencies are:

➔ Impedance: Zin = R3 + R4 + Zc , while Zc =1/jωc

➔ Total voltage: Vp = 5V

➔ Total current: Ip =Vp/Zin

Phase shift: $\Delta\theta = \tan^{-1}(Im/Re)$

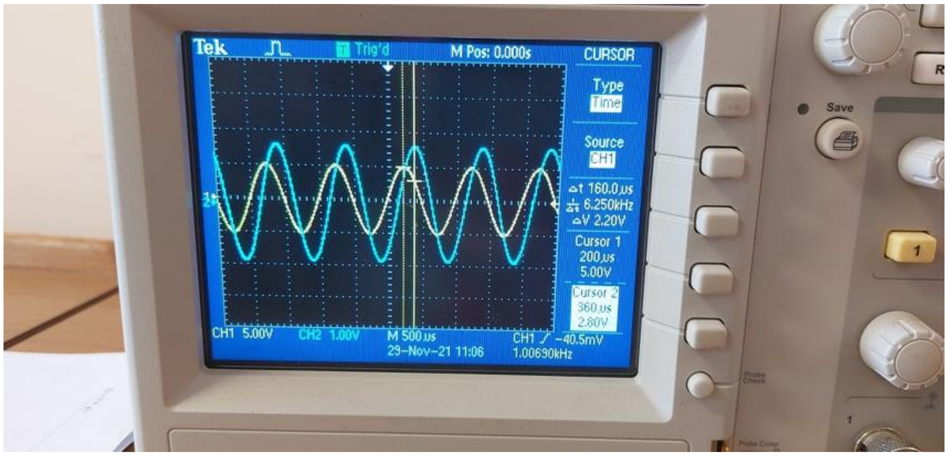
As seen here the delta t and the phase shift changed

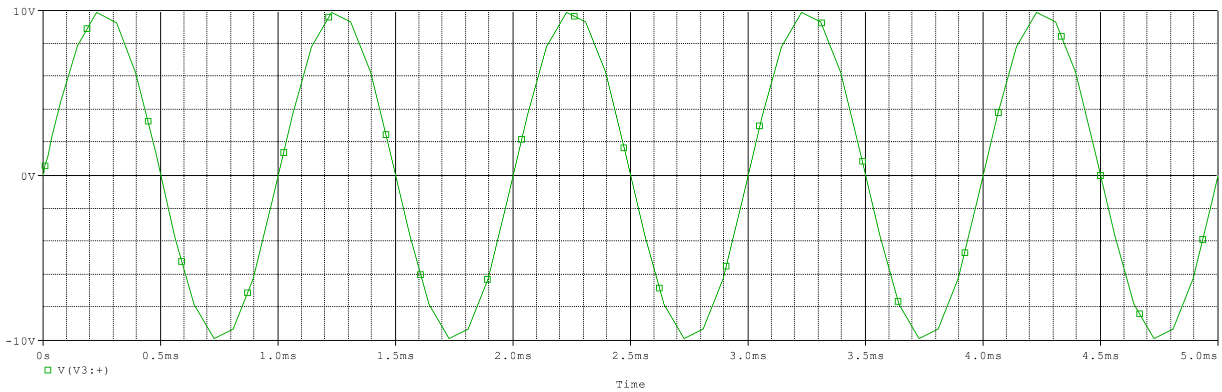
The impedance here is frequency dependent; it lowers as the frequency rises and changes value in the capacitive circuit together with the voltage and current, resulting in a circuit that is not in phase and has a shift between the voltage and current, with the voltage lagging the current.

- Inductive circuit:

Table 4.3

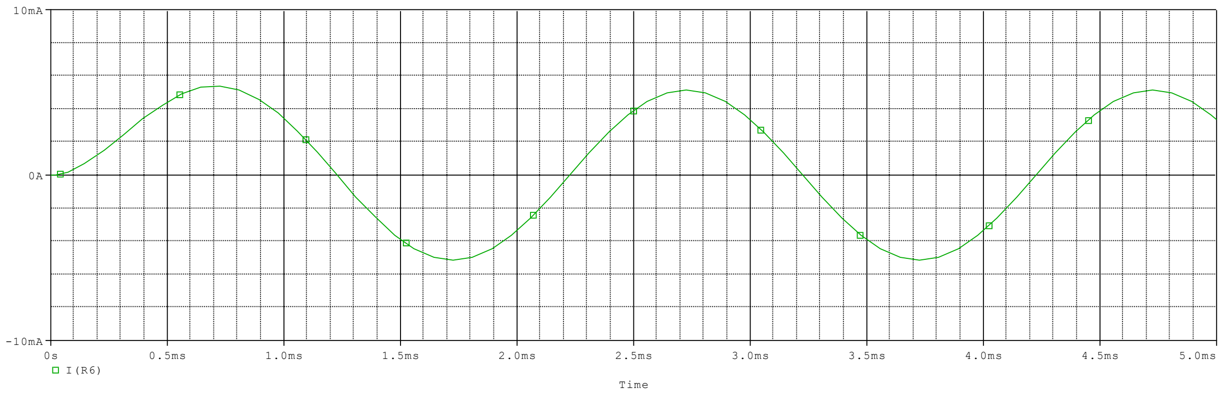
f [Hz]	Vrms	Irms	Δt	Phase shift
500	3.48	1.[illegible]79	240µs	-40.7
1k	3.52	1.195	160µs	-60.2
1.5k	3.5	1.850	140µs	-69.3

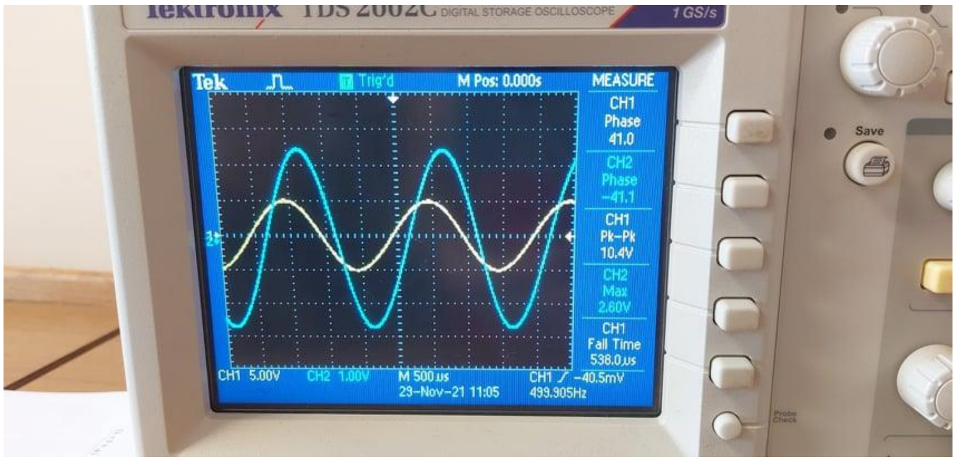




Delta t= 160 uS

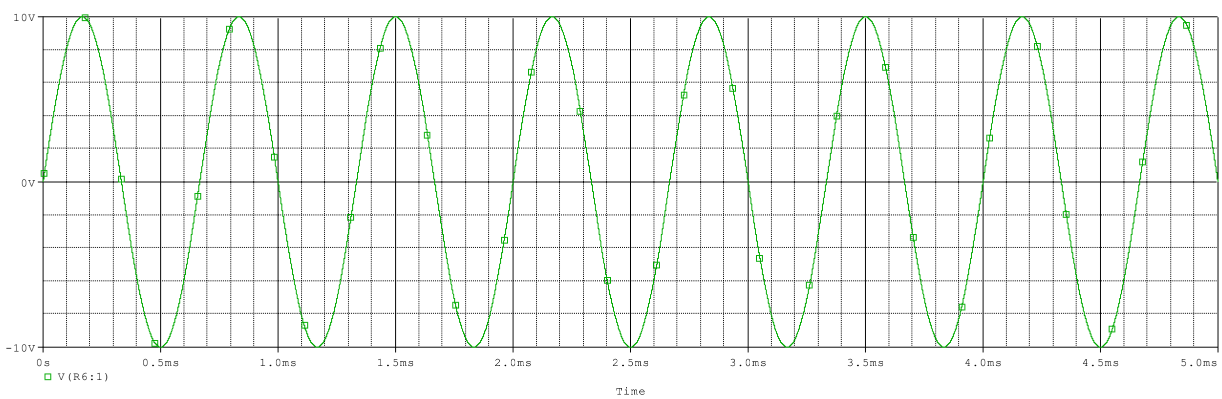
1KHz





Phase= 41°

500Hz



1.5KHz

The theoretical values for all frequencies are:

➔ Impedance: Zin = R5 + R6 + ZL, while ZL = jωL

➔ Total voltage: Vp = 5V

➔ Total current: Ip =Vp/Zin

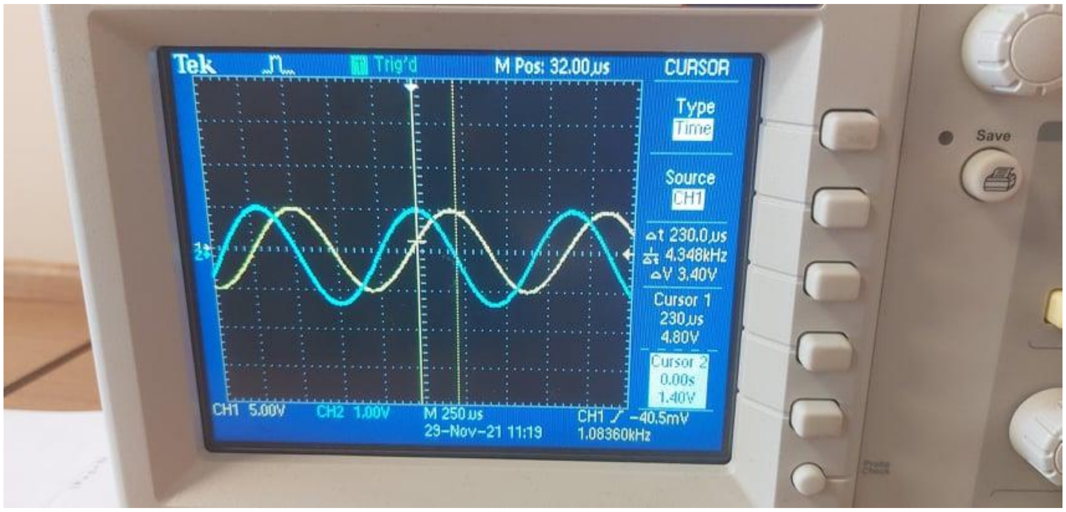
Phase shift:$\Delta\theta = \tan^{-1}(Im/Re)$

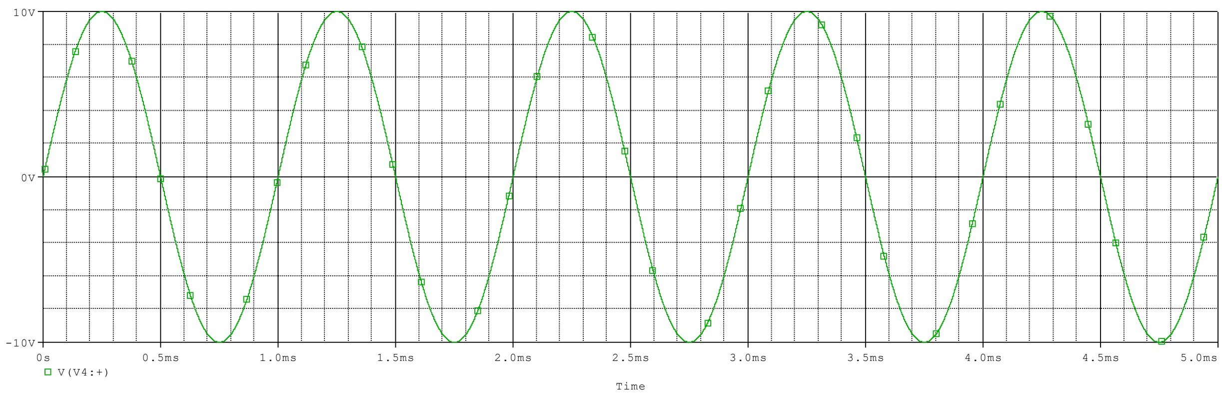
Change in phase shift and delta t and current

It's worth noting that the impedance in this circuit is frequency dependent; it rises as the frequency rises and changes value in an inductive circuit alongside the voltage and current, indicating that the circuit isn't in phase; the voltage and current are out of phase, and the current lags the voltage.

Capacitive and inductive behavior:

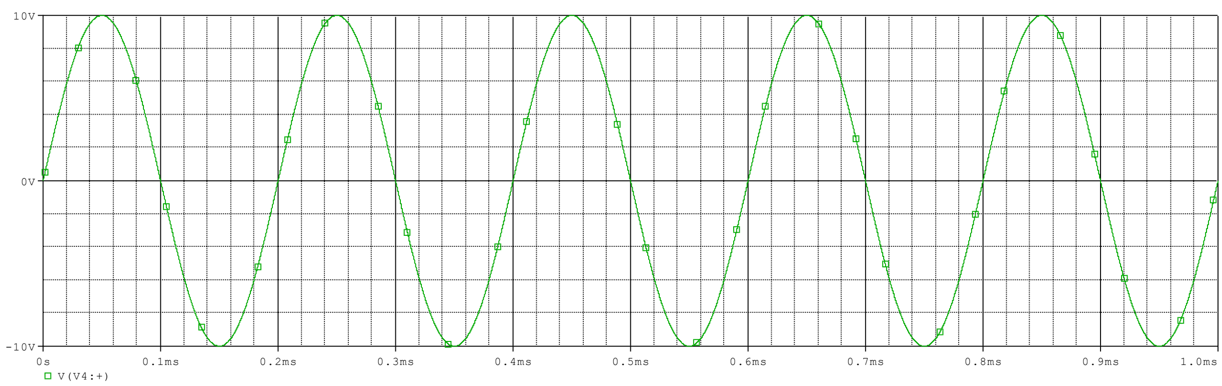
f	1k	2k	4k	6k	8k	fo
Δt	230µs	100µs	69.4µs	46.29µs	34.72µs	0
$(\Theta_{Vs} - \Theta_{Is})$	-76.7	-60.5	-20.2	24.6	48.4	0





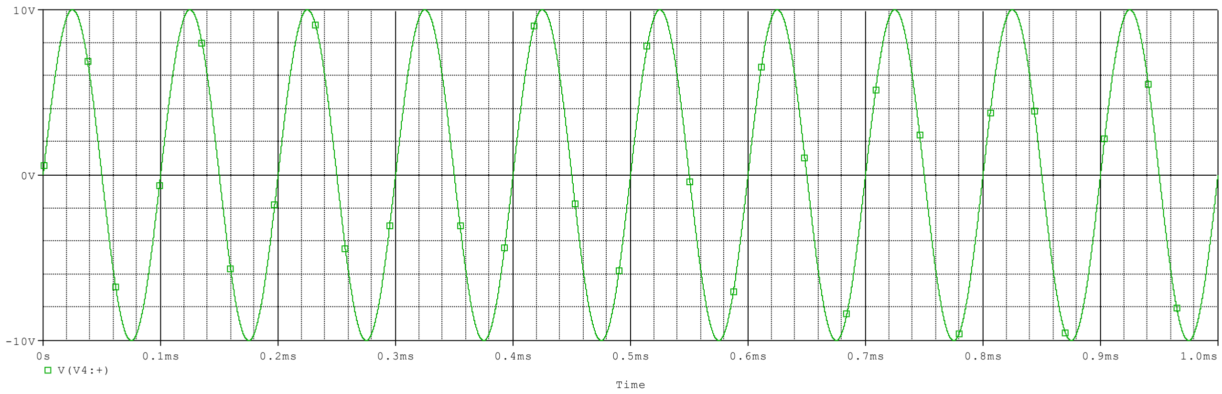
F=1KHZ

Delta t= 230 uS



F = Fo (Resonance Frequency):

5033



F = 2Fo

Theoretical formulas for finding the values of phase shift of different frequencies are as below:

ZT = R1 + ZC + ZL

Zc =−j/ωc

ZL = jωL

➔ To determine circuit behavior for each frequency value:

f = 1 KHz :

Zc = −j 3.183 kΩ   ZL = 125.6j Ω

Zc > ZL => Capacitive

F =5K (Fo = 5033)

Zc = −j 636.6 Ω ZL = 628.3j Ω

Zc > ZL => Capacitive

resonance

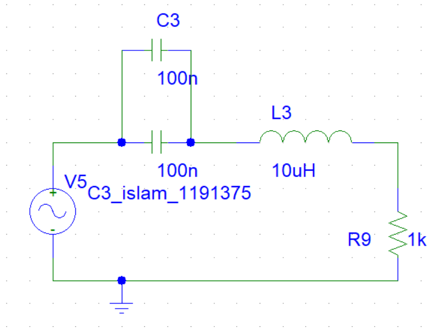
F =8K (2Fo)

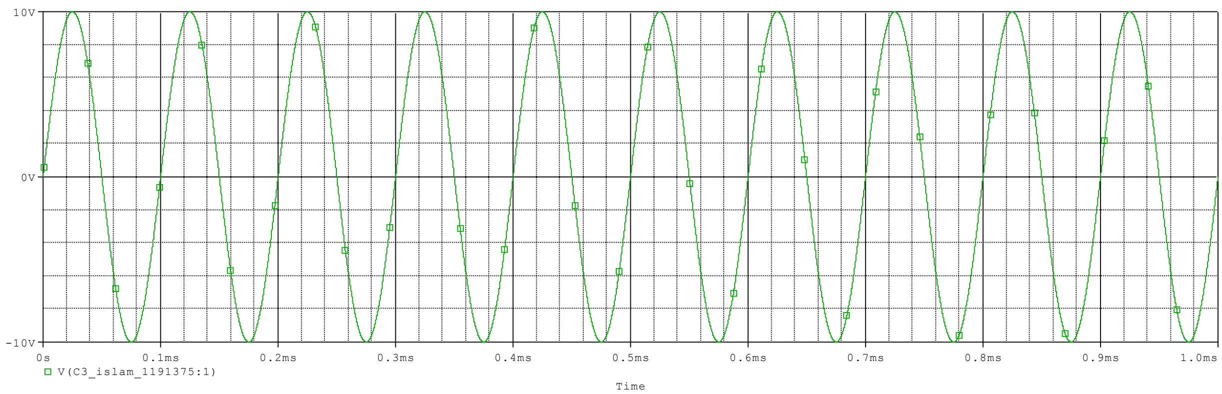
Zc = −j 397.8 Ω ZL = 1.005j KΩ

Zc < ZL => Inductive

Adding 100 nF to the circuit:

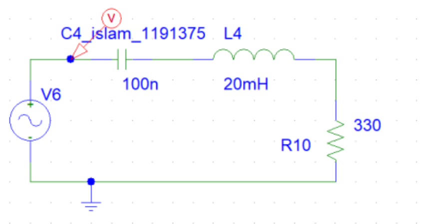
We simply need to raise the value of the original capacitor in the circuit by 100 nF to do this additional job, and we can do so since the extra capacitor is connected in parallel. As a consequence, the following will happen:

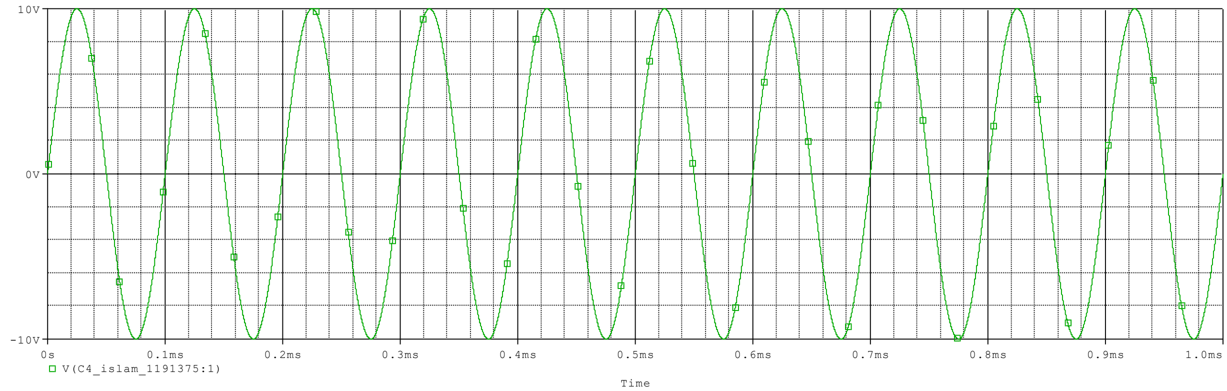




It was discovered that raising the capacitance at resonance frequency made the circuit inductive, as ZC ZL again, and a new resonance frequency for the new circuit was found.

Double the value on Inductor:





Finally, when the inductance is doubled and the input frequency is adjusted to resonance frequency,

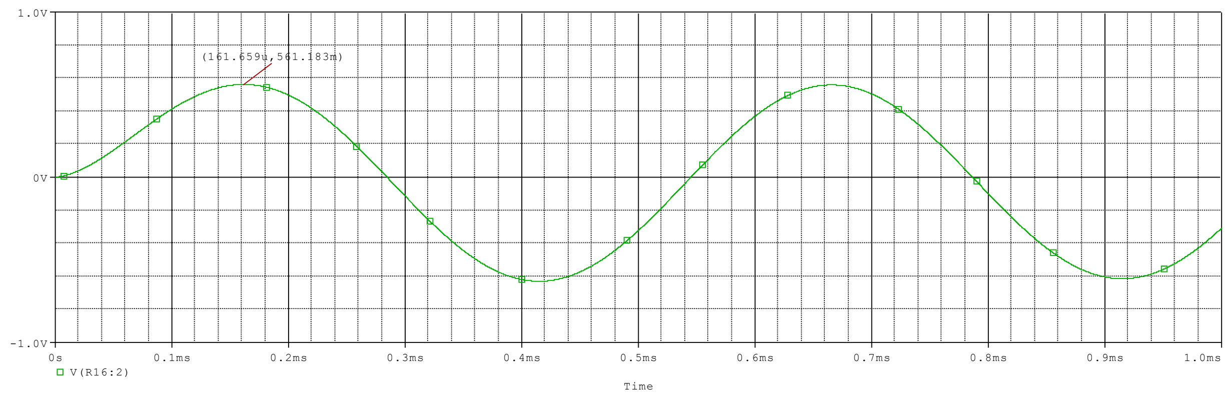
Since ZC ZL, and a new resonance frequency was obtained for the new circuit, it was discovered that raising the inductance at resonance frequency made the circuit inductive.

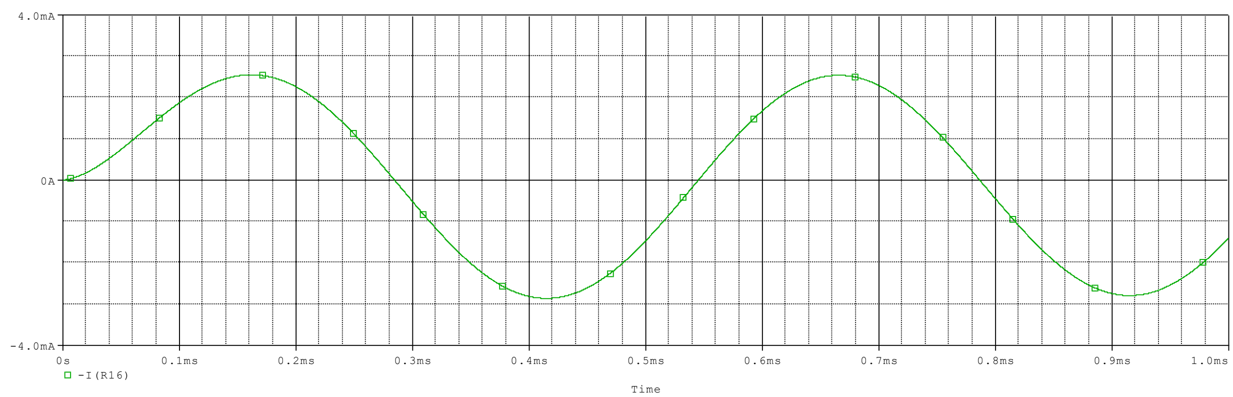
Sinusoidal steady state power:

Table 4.5

$V_{(R1)}$	$V_L=V_{(R6)}$	I_L	I_{R6}	V_s	I_s	$(\Theta_{Vs}-\Theta_{Is})$	V_c	I_c	$(\Theta_{Vc}-\Theta_{Ic})$
0.6	0.365	0.267	1.89	1.5	3.146	-70.2	0.422		85

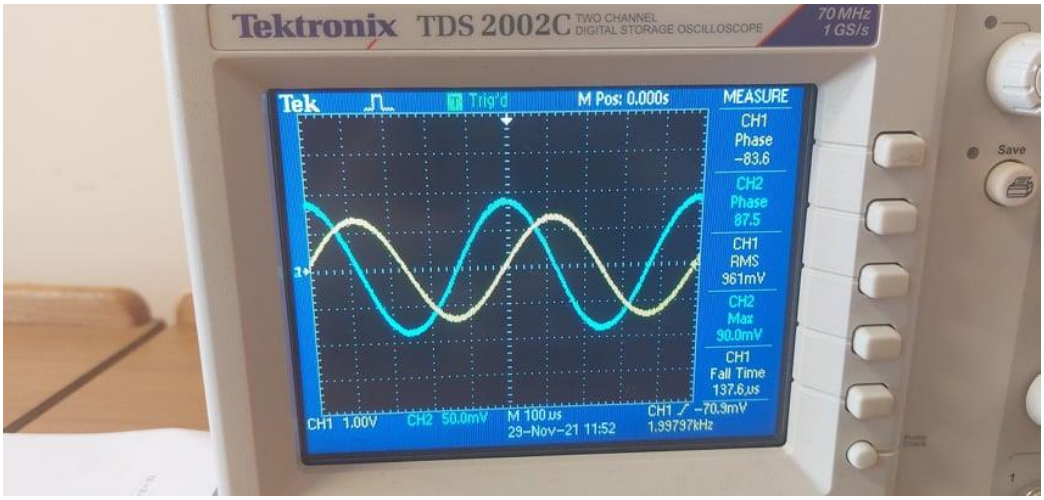
2.68





- Its clear from the above figures that current and voltage of the resistor are in phase

- we can notice that Voltage lags current so this circuit is capacitive circuit



- Its clear from the above figure that current and voltage of the capacitor have phase shift almost 100ms with phase 85 must be 90
- From the data and pictures we didn't take a screenshot by mistake we notice that for inductor there is phase shift between current and voltage

The average and reactive power alongside with the power factor were also measured:

power (R2) = I^2 R =$(1.89)^2$*220 = 7.858 m watt

Conclusion:

Impedances of various circuit components, such as resistors, capacitors, and inductors, were measured and investigated to wrap up this experiment's work. The phasor domain, which simplifies the sinusoidal steady state, was also studied, as well as the behavior of the voltage and current of different components of the sinusoidal source, as well as the phase shift between them, and the results were summarized as follows: the resistance does not change in the time domain, and the circuit is then called resistive; however, if there is any inductance or capacitance, the impedance will be expressed in complex numbers, with the resistance as the reagent; and the In addition, the influence of frequency on the impedance above and below the resonance in RLC circuits when Zc=Zl was explored, as well as the principle of resonance frequency identified in RLC circuits when Zc=Zl. Finally, the sinusoidal steady state power was understood and measured, and the conservation of energy law's validity was confirmed.

References:

- lab manual
- Dr. Nasser slides
- electrical impedance | physics | Britannica