CIRCUIT THEORY

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UNIVERSITY OF WEST ATTICA

DEPARTMENT OF INFORMATION AND COMPUTER ENGINEERING

PROJECT 3
RLC COMPONENT CONNECTIONS TO AC POWER SUPPLY

CIRCUIT THEORY

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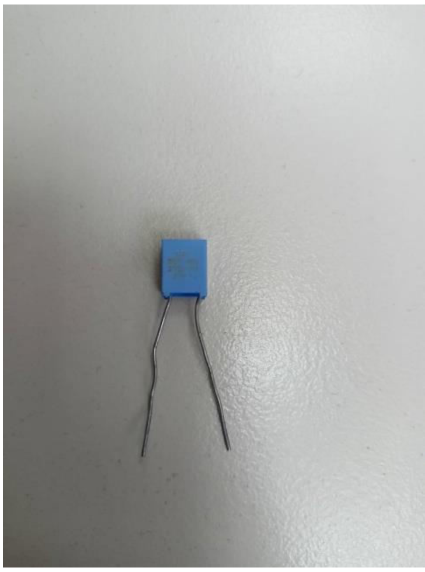
ADDITIONAL INFORMATION :

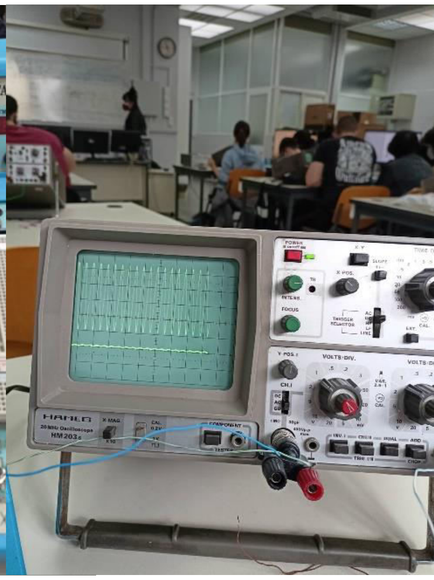
DATE OF EXERCISE : 4/5/2022
DATE OF DELIVERY OF THE EXERCISE : 23/6/2022

PHOTOS OF EQUIPMENT THAT IS USED IN THE LABORATORY

Analog
Capacitor
Cables
Resistor
Multimeter



Digital
Breadboard
Oscilloscope
Multimeter



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1. 2.1 : RC component in series at AC voltage

General

In the chapters "Simulated Solution" and "Experimental Solution" the components used and the observations made during the experiment are presented in detail with snapshots from the " Multisim " software and photos of the experiment from the laboratory environment respectively, while in the chapter " Theoretical Solution" the behavior of the circuit is analyzed in general.

Theoretical Solving

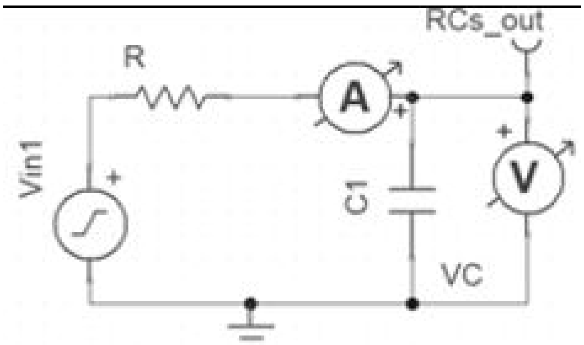


Figure 1

The circuit in Figure 1 accomplishes capacitor charging and discharging in series to an AC voltage source. From the formula of the capacitor's active resistance $X_C = -j * (1 / 2\pi fC)$, from the results recorded in Table 1 in the chapter "Simulated Solution" and from Ohm 's law (I = V / R), it is observed that as the frequency of the sine wave voltage increases, the voltage at the ends of the capacitor and therefore its active resistance decreases. From Ohm's law, it is found that as the resistance decreases, the current increases. The behavior of the sine wave voltage is recorded with the help of the oscilloscope and is discussed in the chapters "Simulated Solution" and "Experimental Solution".

Simulated solution

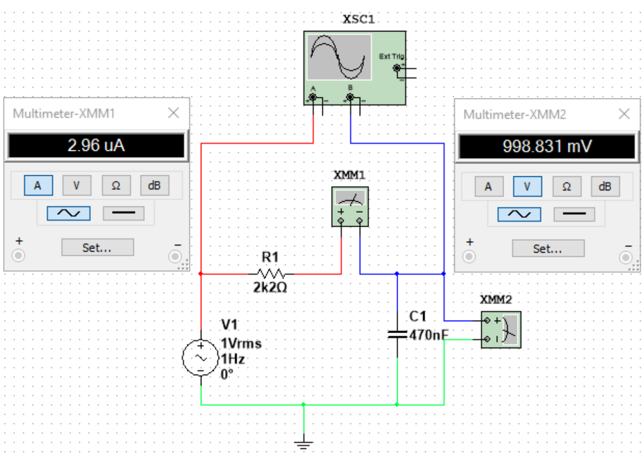


Figure 2

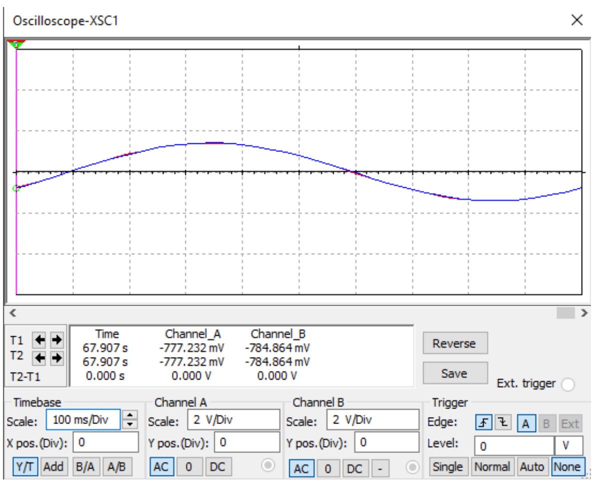
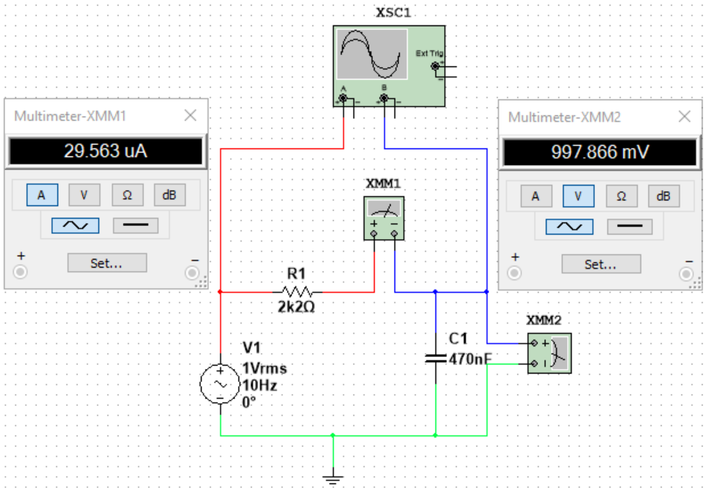


Figure 3



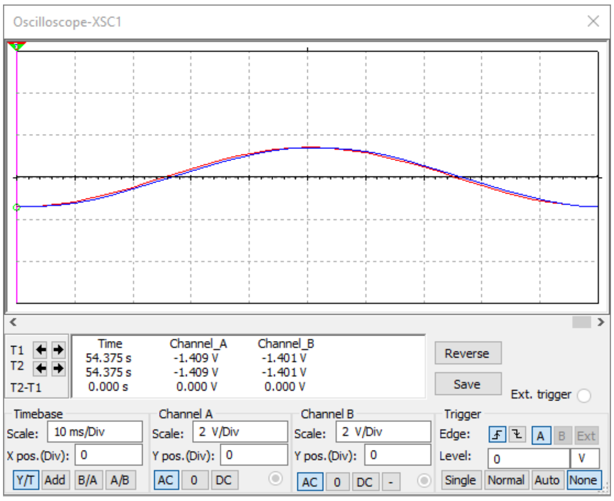
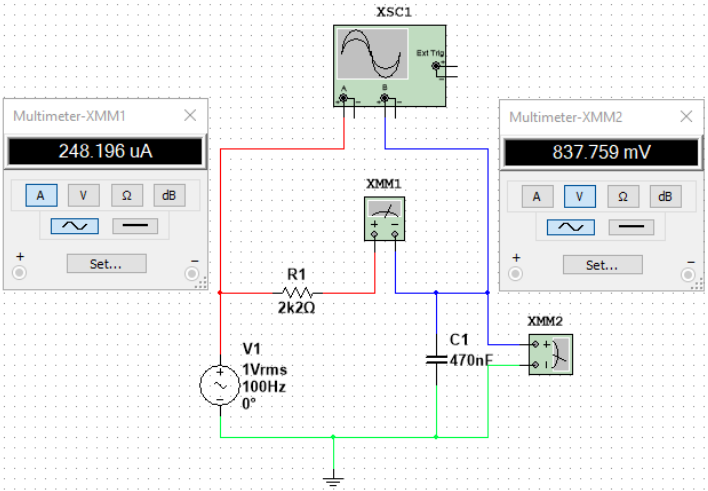


Figure *4*



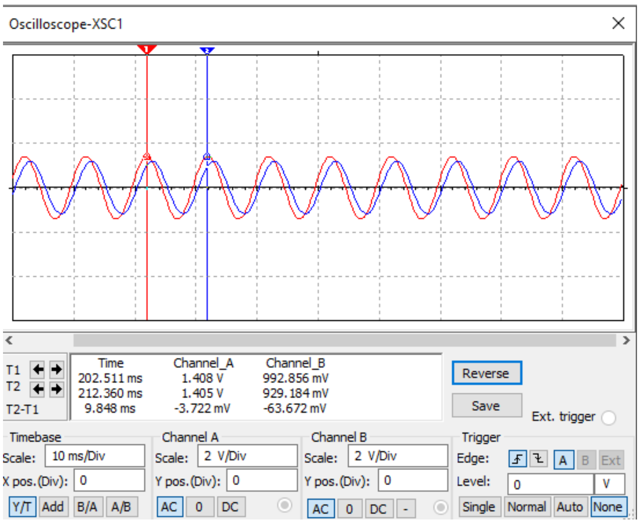
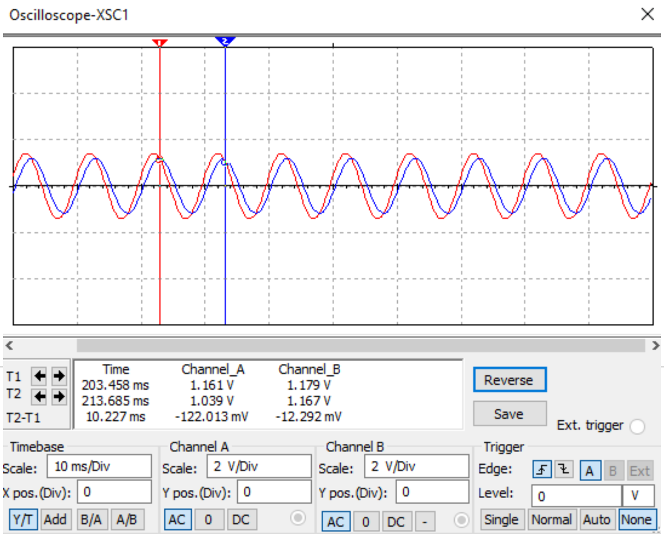


Figure 5

Figure 6

Figure 7

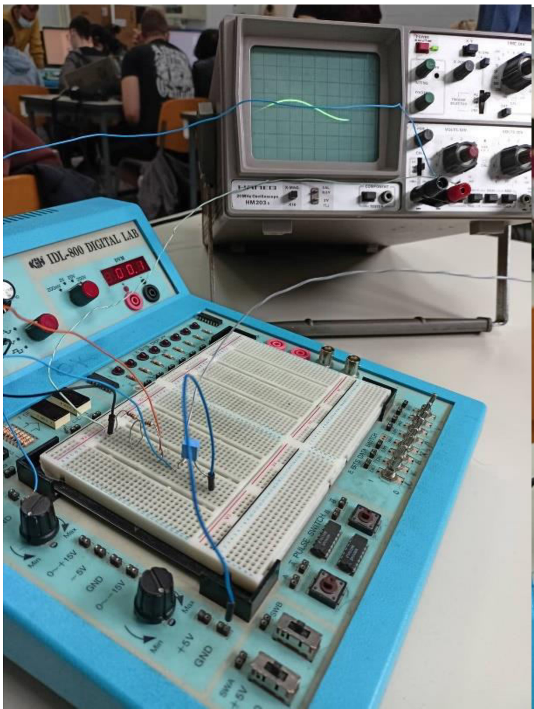


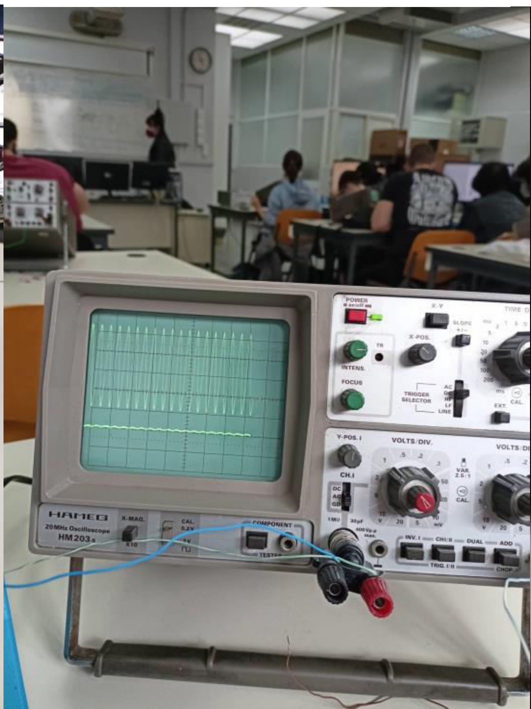
F(Hz)	X_c theoretical (Ω)	I_C (A)	V_C (V)	X_c Calculated (Ω)
1	338799.3	0.0000003	0.9999	3333000
10	33879.93	0.0000296	0.9979	33712.84
100	3387.993	0.0002482	0.8378	3375.504
1k	338.7993	0.0004493	0.1516	337.4137
10k	33.87993	0.0004545	0.0153	33.66337
100k	3.387993	0.0004545	0.0015	3.300330

Figure 8

Table 1

From the simulated solution in the " Multisim " software (Figures 2, 3, 4, 5, 6, 7, 8) the voltage drop Vc at the ends of the capacitor C_1 of 470 nF capacity is clearly illustrated. From the measurements recorded in Table 1, it is clarified that the formula $X_C = -j * (1 / 2\pi fC)$ was used to calculate X_C (theoretical), the readings of I_C and V_C are from the readings of the XMM_1 ammeter and the XMM_2 voltmeter and for the calculation of X_C (calculated) the Ohm 's law was used ($I_C = V_C / X_C$). The measurements prove the claims made in the "Theoretical Solution" chapter.






Using both channels of the oscilloscope, where channel A is connected to the source V_1 and channel B is connected to the capacitor C_1, a phase difference is observed in the sine wave voltage signal of the source with that of the capacitor in Figure 8 , where the frequency is 100 Hz. In particular, the difference in the periods of the two signals is 10 ms and this is justified by the fact that the capacitor, when fully charged, will not entirely take the voltage of the source.

Experimental Solution

Figure 9 ***Figure 10*** ***Figure 11***

For the experimental solution carried out in the laboratory environment, the interface board " breadboard ", an AC voltage source set at 1 V_{en} and a frequency of 1 to 100k Hz , a grounding, two resistors of resistance 1 kOhm were used , a 470 nF capacitor, cables, a digital multimeter set to calculate AC voltage (voltmeter), an analogue multimeter set to calculate sine wave current (ammeter), an oscilloscope.

Initially, a cable was used to connect the AC voltage source to the " breadboard ". Due to the absence of a resistor with a resistance of 2.2 kOhm , two resistors with a resistance of 1 kOhm connected in series were used. Then, the capacitor is also connected in series with the resistors and a cable is used to connect the grounding to the rest of the circuit.
The measurements start with the analog multimeter in the role of an ammeter connected in series between the resistor and the capacitor to calculate the current. The digital multimeter in the role of a voltmeter is connected in parallel with the capacitor to calculate the voltage drop at its ends and finally, the oscilloscope with the help of both channels with one connected to the source and the other to the capacitor. The experimental solution verifies the measurements recorded in Table 1 in the "Simulated Solution" section.

1.2.2 : RL component in series at AC voltage

General

In the chapter "Simulation Solution" the components used and the observations made during the experiment are presented in detail with snapshots from the " Multisim " software, while in the chapter "Theoretical Solution" the behavior of the circuit is analyzed in general.

Theoretical Solving

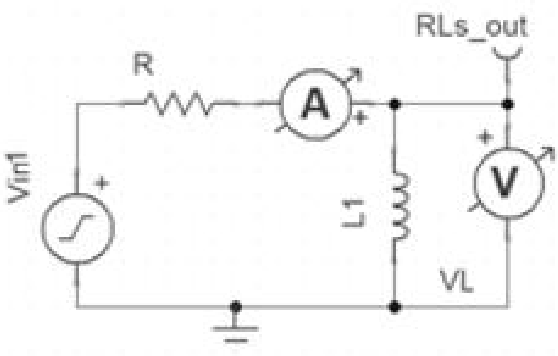


Figure 12

The circuit in Figure 12 achieves the series coil connection to an AC voltage source. From the coil active resistance formula $X_L = j2\pi fL$, from the results recorded in Table 2 in the "Simulated Solution" section, and from Ohm 's law ($I = V/R$), it is observed that as the frequency of the sine wave voltage increases, the current intensity remains approximately the same, while the voltage at the ends of the coil fluctuates. The behavior of the sine wave voltage is recorded with the help of the oscilloscope and is discussed in the "Simulated Solution" chapter.

Simulative Resolution

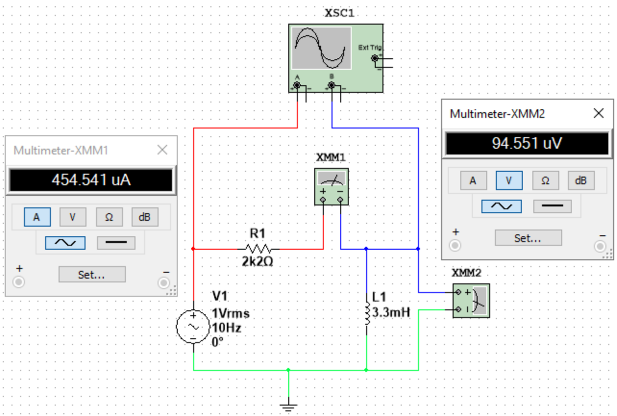


Figure 13

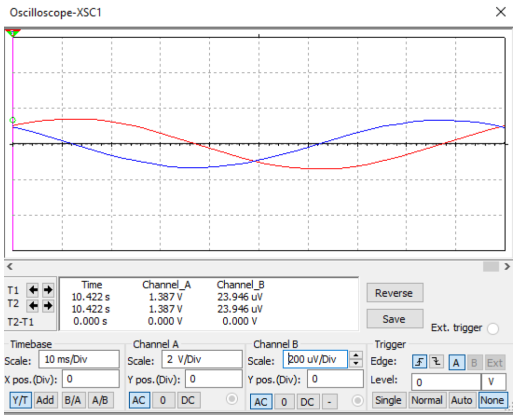


Figure 14

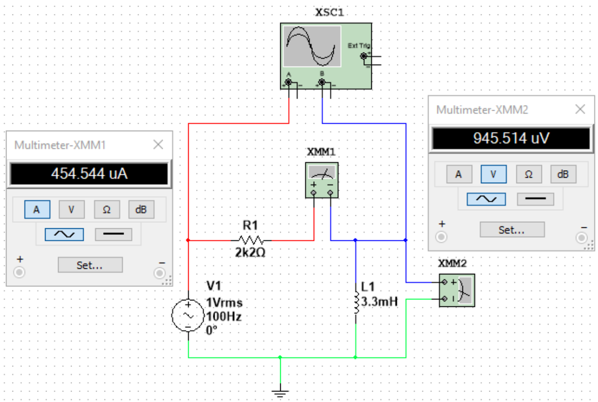


Figure 15

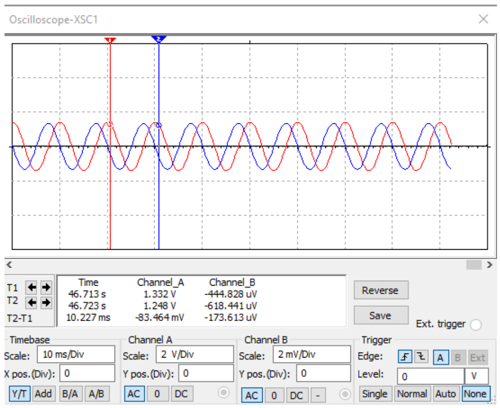
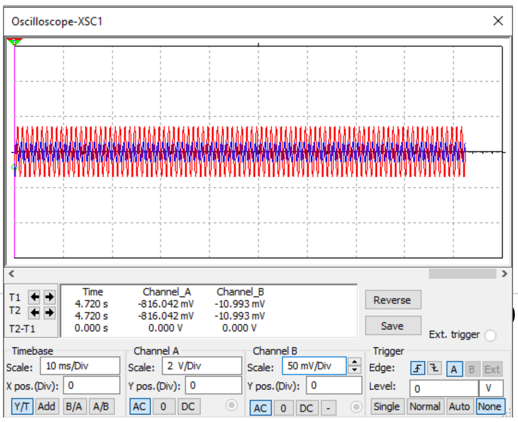


Figure 16



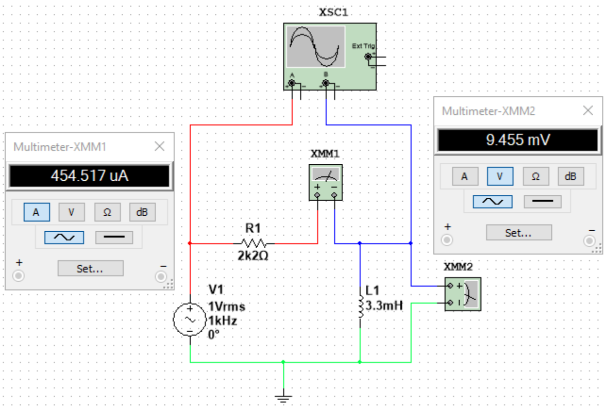


Figure 17

Figure 18

Table 2

F(Hz)	X_L theoretical (Ω)	I_L (A)	V_L (V)	X_L Calculated (Ω)
1	0.020724	0.00045453	0.000009455	0.020801707
10	0.20724	0.00045454	0.000094551	0.208014696
100	2.0724	0.00045454	0.000945514	2.080155762
1k	20,724	0.00045452	0.000009455	0.020802165
10k	207.24	0.00045253	0.000094132	0.208012728
100k	2072.4	0.00033028	0.000687034	2.080156231

From the simulated solution in the " Multisim " software (Figures 13, 14, 15, 16, 17, 18) the voltage drop V_L at the ends of the 3.3 mH inductor L_1 is clearly illustrated. From the measurements recorded in Table 2, it is clarified that the formula $X_L = j2\pi fL$ was used to calculate X_L (theoretical) , the readings of I_L and V_L are from the readings of the ammeter XMM_1 and the voltmeter XMM_2 , and Ohm 's law ($I_L = V_L / X_L$) was used to calculate X_L (calculated). The measurements prove the claims made in the "Theoretical Solution" section.
Using both channels of the oscilloscope, where channel A is connected to the source V_1 and channel B is connected to the coil L_1 , a phase difference is observed in the sine wave voltage signal of the source with the corresponding coil in Figure 16, where the frequency is 100 Hz . In particular, the difference in the periods of the two signals is 10 ms and this is justified by the fact that the current in the coil will reach its maximum intensity at the mediation of some time interval $\tau = k * (L/R)$.

1.2.3 : RC component in parallel to AC voltage

General

CIRCUIT THEORY

In the chapter "Simulation Solution" the components used and the observations made during the experiment are presented in detail with snapshots from the " Multisim " software, while in the chapter "Theoretical Solution" the behavior of the circuit is analyzed in general.

Theoretical Solving

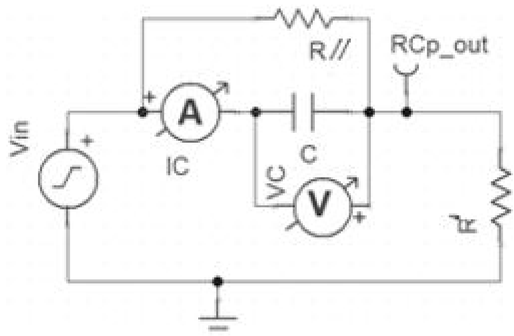
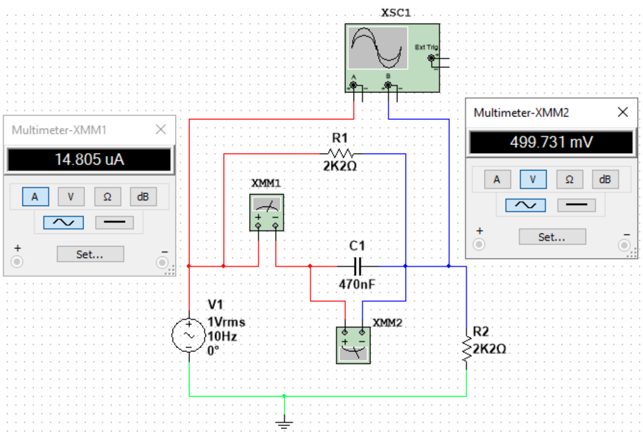


Figure 19

The circuit in Figure 19 achieves capacitor charging and discharging in parallel with a resistor in an AC voltage source. From the formula for the capacitor's active resistance $X_C = -j * (1 / 2\pi fC)$, from the results recorded in Table 3 in the "Simulated Solution" section, and from Ohm 's law (I = V / R), it is observed that as the frequency of the sine wave voltage increases, the voltage at the ends of the capacitor and hence its active resistance decreases. From Ohm's law, it is found that as the resistance decreases, the current increases. The behavior of the sine wave voltage is recorded with the help of the oscilloscope and is discussed in the "Simulated Solution" chapter.

Simulated solution



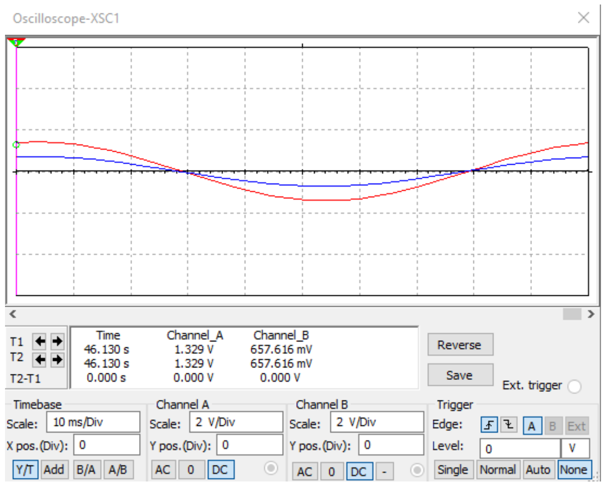


Figure 20 ***Figure 21***

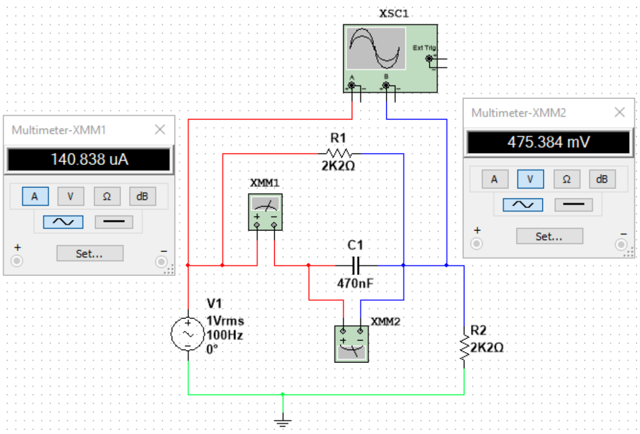


Figure 22

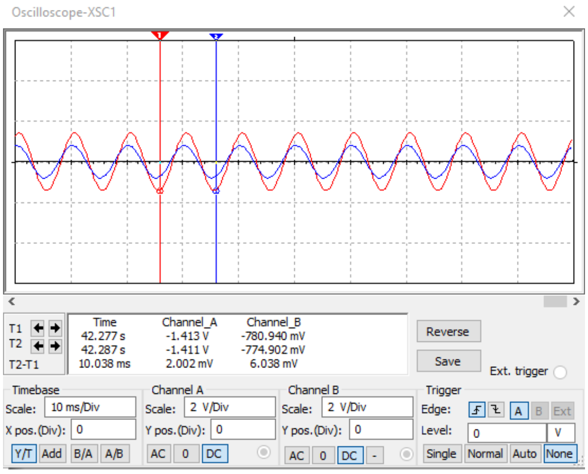
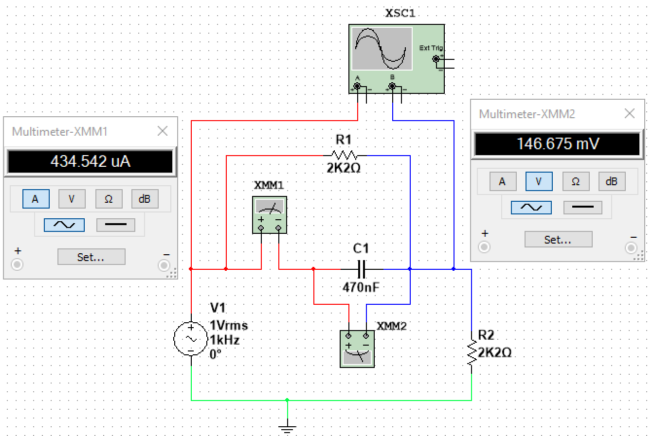


Figure 23

F(Hz)	X_c Theoretical (Ω)	I_C (A)	V_C (V)	X_c Calculated (Ω)



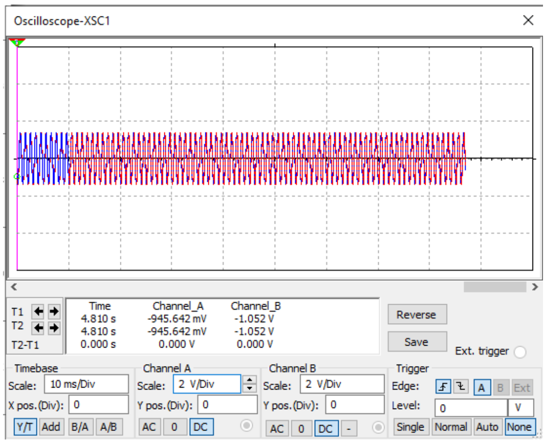


Figure 24

Figure 25

1	338799.3	0.000001481	0.499981	337596.893
10	33879.93	0.000014805	0.499733	33754.340
100	3387.993	0.000140839	0.475386	3375.3860
1k	338.7993	0.000434542	0.146675	337.5393
10k	33.87993	0.000454331	0.015335	33.75292
100k	3.387993	0.000454542	0.001534	3.374826

Table 3

From the simulated solution in the " Multisim " software (Figures 20, 21, 22, 23, 24, 25) the voltage drop Vc at the ends of the capacitor C_1 of 470 nF capacity is clearly illustrated. From the measurements recorded in Table 3, it is clarified that the formula $X_C = -j * (1 / 2\pi fC)$ was used to calculate X_C (theoretical), the readings of I_C and V_C are from the readings of the XMM_1 ammeter and the XMM_2 voltmeter and for the calculation of X_C (calculated) the Ohm 's law was used ($I_C = V_C / X_C$). The measurements prove the claims made in the "Theoretical Solution" chapter.
Using both channels of the oscilloscope, where channel A is connected to the source V_1 and channel B is connected to the capacitor C_1 , a phase difference is observed in the sine wave voltage signal of the source with that of the capacitor in Figure 23 , where the frequency is 100 Hz. In particular, the difference in the periods of the two signals is 10 ms and this is justified by the fact that the capacitor, when fully charged, will not entirely take the voltage of the source.

<u>1.2.4 : RL component in parallel to AC voltage</u>

<u>General</u>

In the chapter "Simulation Solution" the components used and the observations made during the experiment are presented in detail with snapshots from the " Multisim " software , while in the chapter "Theoretical Solution" the behavior of the circuit is analyzed in general.

<u>Theoretical Solving</u>

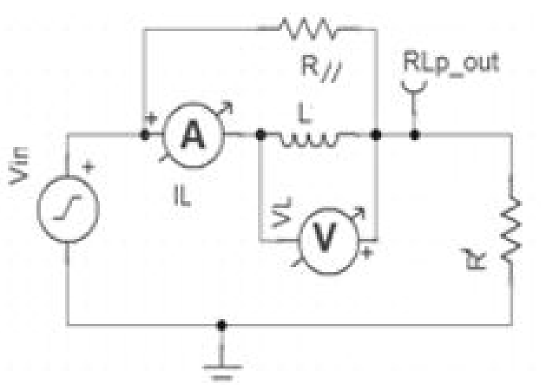


Figure 26

The circuit in Figure 26 achieves the coil connection in parallel with a resistor to an AC voltage source. From the coil active resistance formula $X_L = j2\pi fL$, from the results recorded in Table 4 in the "Simulated Solution" section, and from Ohm 's law (I = V/R), it is observed that as the frequency of the sine wave voltage increases, the current intensity remains approximately the same, while the voltage at the ends of the coil fluctuates. The behavior of the sine wave voltage is recorded with the help of the oscilloscope and is discussed in the "Simulated Solution" chapter.

Simulative Resolution

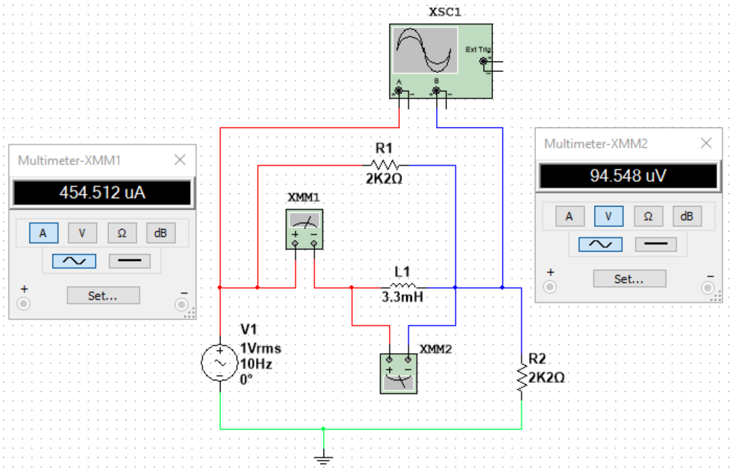


Figure 27

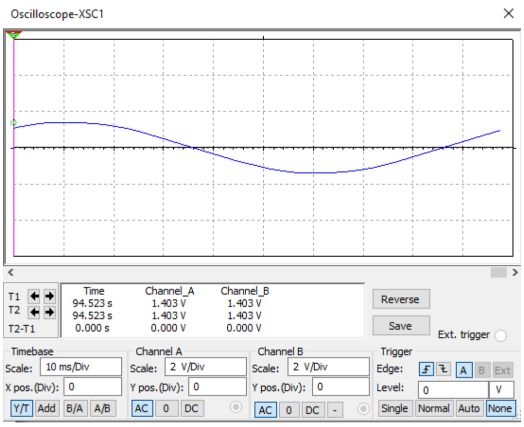


Figure 28

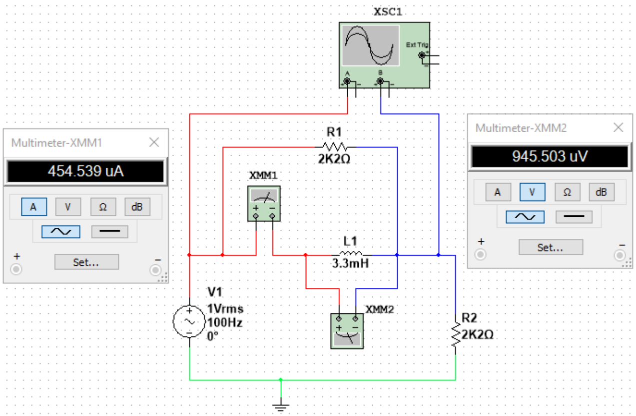


Figure 29

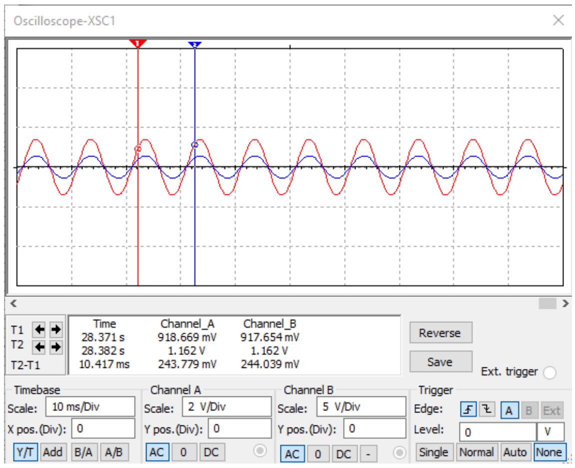


Figure 30

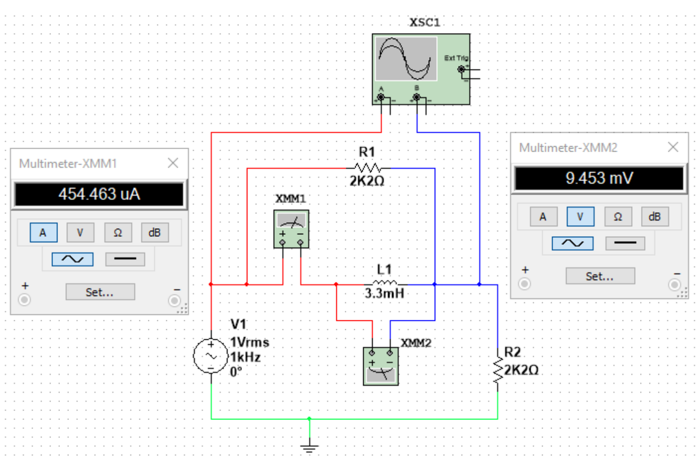


Figure 31

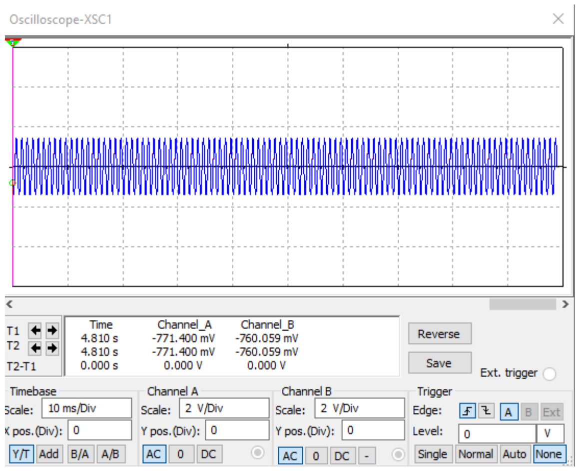


Figure 32

Table 4

From the simulated solution in the " Multisim " software (Figures 27, 28, 29, 30, 31, 32) the voltage drop V_L at the ends of the 3.3 mH inductor L_1 is clearly illustrated. From the measurements recorded in Table 4, it is

F(Hz)	X_L theoretical (Ω)	I_L (A)	V_L (V)	X_L Rated (Ω)
1	0.020724	0.0004545	0.000009454	0.0208008800
10	0.20724	0.00045454	0.000094551	0.2080146961
100	2.0724	0.00045454	0.000945503	2.0801315161
1k	20,724	0.00045463	0.009453	20.792732555
10k	207.24	0.00044662	0.092905	208.01800189
100k	2072.4	0.00021249	0.441998	2080.0884748

clarified that the formula $X_L = j2\pi fL$ was used to calculate X_L (theoretical) , the readings of I_L and V_L are

from the readings of the ammeter XMM $_1$ and the voltmeter XMM $_2$, and Ohm 's law ($I_L = V_L / X_L$) was used to calculate X_L (calculated). The measurements prove the claims made in the "Theoretical Solution" section.
Using both channels of the oscilloscope, where channel A is connected to the source V_1 and channel B is connected to the coil L_1, a phase difference is observed in the sine wave voltage signal of the source and the coil in Figure 30, where the frequency is 100 Hz . In particular, the difference in the periods of the two signals is 10 ms and this is justified by the fact that the current in the coil will reach its maximum intensity at the mediation of some time interval $\tau = k * (L/R)$.

1.3 : Questions

Question 1

Does the impedance of a capacitor to an alternating current increase or decrease as the frequency of that current increases? Justify .

The impedance of a capacitor to alternating current decreases as the frequency of that current increases.

$Z_C = 1 / C\omega$
$Z_C' = 1 / C\omega'$
oh' > oh

$Z_C / Z_C' = 1 / C\omega / 1 / C\omega' \rightarrow Z_C / Z_C' = C\omega' / C\omega \rightarrow Z_C / Z_C' = \omega' / \omega \rightarrow Z_C \omega = Z_C' \omega' \rightarrow Z_C' = Z_C (\omega / \omega')$
Since $\omega' > \omega$ then $\omega / \omega' < 1$, therefore, $Z_C (\omega / \omega') < 1 \rightarrow Z_C' < 1$

Question 2

At what frequency does a capacitor with a capacitance of 47 μF have an impedance of 50 Ω? Analyze your calculations.

$Z_C = 1 / C\omega \rightarrow Z_C = 1 / C2\pi f \rightarrow 50 = 1 / 47 * 10 * ^{-6} 2 * 3.14 * f \rightarrow f = 1 / 0.14758 \rightarrow f = 6.7$ Hz

Where Z_C, the capacitive impedance of the capacitor capacitance (C) $47 * 10^{-6}$ and with angular frequency ω ($2\pi f$).

Question 3

How much inductance would a coil have to have to provide an impedance of 540 Ω at a frequency of 400 Hz? Write your calculations in detail.

$Z_L = L\omega \rightarrow L = Z_L / \omega \rightarrow L = Z_L / 2\pi f \rightarrow L = 540 / 2 * 3.14 * 400 \rightarrow L = 0.2$ H

Where Z_L, the capacitive impedance of the inductance coil L and with angular frequency ω ($2\pi f$).

Question 4

Consider a transformer with a primary to secondary ratio of 100:200000. Apply an input signal of 4.2V $_{pp}$. calculate the voltage that will appear across the secondary winding of the transformer. Can we consider the transformer as a unit of amplification?

VP / VS = NP / NS ➔VS = (VP * NS) / NP ➔VS = (2.4 * 200000) / 100 ➔VS = 4200 Volts

Vp-p = 2Vp ➔4.2 = 2Vp ➔Vp = 2.4 volts

We cannot consider the transformer as an amplification unit, as the power is approximately the same both at the input and at the output, depending on the performance of the transformer.