ΠΑΝΕΠΙΣΤΗΜΙΟ ΔΥΤΙΚΗΣ ΑΤΤΙΚΗΣ
UNIVERSITY OF WEST ATTICA

DEPARTMENT OF COMPUTER AND INFORMATION TECHNOLOGY AND COMPUTER ENGINEERING

PROJECT 4
COORDINATION

STUDENT DETAILS :

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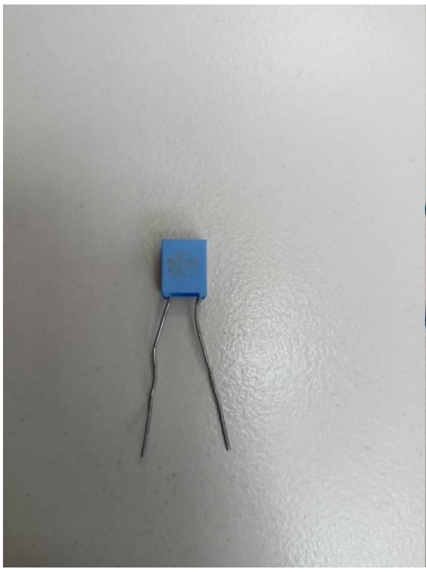
STUDENT ID: 19390005
STUDENT SEMESTER : 6th
STUDENT STATUS : UNDERGRADUATE
PROGRAMME OF STUDY : UNIWA
LABORATORY SECTION : THC 05 11:00-13:00
LABORATORY PROFESSORS : CHRISTOS KAMPOURIS-GEORGIOS ANTONIOU

ADDITIONAL INFORMATION :

DATE OF EXERCISE : 25/5/2022
DATE OF DELIVERY OF EXERCISE : 23/6/2022

PHOTOS OF EQUIPMENT USED IN THE LABORATORY

Analog Multimeter
Capacitor
Cables
Resistor



Digital Multimeter	Breadboard	Oscilloscope	Inductor

CONTENTS

1.1 : Tuning in an RLC circuit in series

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. The table below presents a summary for the selection of the appropriate coil value used in the circuits presented in the chapters "Simulated Solution" and "Experimental Solution".

Table 1

Implementation	C	L Theoretical	L Typical	Deviation from f_R
In Series	47nF	0.64 mH	6200 μH	681 Hz
In parallel	27nF			

Theoretical Solving

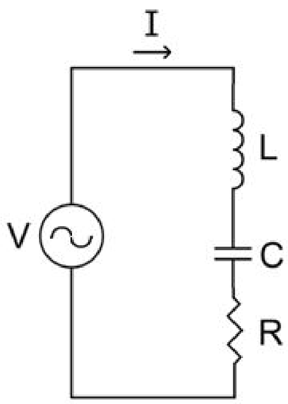


Figure 1

The circuit in Figure 1 achieves the resonance effect in an RLC circuit, where the inductor (L) and capacitor (C) are connected in series. The effect will be observed at a frequency where the inductive response (X_L) and the capacitive response (X_C) cancel each other out, ie, they are equal. The impedance of the circuit is : $Z = \sqrt{R^2 + (X_L - X_c)^2}$ and therefore, during the resonance effect the impedance will be equal to the ohmic resistance (R). Also, during the effect the maximum current flowing through the circuit is observed, since from Ohm's law and Kirchhoff's law of voltages we have :

$V = V_L + V_C + V_R \Rightarrow V = IX_L + IX_C + IR \Rightarrow V = IX_C + IX_C + IR \Rightarrow V = I\,(2X_C + R)$

(From the resonance effect, where $X_C = X_L$)

$I = V / Z \Rightarrow I = [I\,(2X_C + R)\,] / [\sqrt{R^2 + (X_L - X_c)^2}] \Rightarrow I = [I\,(2X_C + R)\,] / R$

The third observation is that the sinusoidal signal emitted by the input of the circuit (capacitor) and the corresponding signal emitted by the output of the circuit (coil, which is observed using the oscilloscope) are in phase, ie, they have the same phase (cof = 1). Since, the voltages V_C and V_L are equal it means that the total voltage of the circuit can take large voltage values, ie, in the RLC circuit in series during the resonance effect, overvoltages are observed.

Simulative Resolution

Table 2

F (Hz)	Z (Ω)	X (Ω)	X_L (Ω)	X_C (Ω)	I_{rms} (A)	V_{Lrms} (V)	V_{Crms} (V)
1	3333333333.3	0.0040003	0.004	$3 * 10^{-6}$	$296{,}788 * 10^{-9}$	$12 * 10^{-10}$	$9 * 10^{-14}$
10	333333333.33	0.040003	0.04	$3 * 10^{-5}$	$2.968 * 10^{-6}$	$12 * 10^{-8}$	$9 * 10^{-11}$
100	33333333.333	0.40003	0.4	$3 * 10^{-4}$	$29.625 * 10^{-6}$	10^{-5}	$9 * 10^{-9}$
500							
1000	3333333.3333	4.0003	4	$3 * 10^{-3}$	$295.179 * 10^{-6}$	10^{-3}	$9 * 10^{-7}$
1500							
2500							
5000							
10k							
30k	333	40,003	40	$3 * 10^{-2}$	$2.24 * 10^{-3}$	$9 * 10^{-2}$	$7 * 10^{-5}$
50k							
100k	33.3	400,003	400	$3 * 10$-1	$2.01 * 10^{-3}$	0.804	$6 * 10^{-4}$
200k							

500 k							
1M							
10M							

F (Hz)	**Vi(V) Kan. A Measurement**	**Vo(V) Kan. B Measurement.**	**20log10(Vo/Vi) (db) Calculated**	**I $_{rms}$ (A) Measurement**
1	1,410	7.165 * 10 $^{-6}$		296,788 * 10 $^{-9}$
10	61.647 * 10 $^{-3}$	65.028 * 10 $^{-6}$		2.968 * 10 $^{-6}$
100	412.207 * 10 $^{-3}$	7.562 * 10 $^{-3}$		29.625 * 10 $^{-6}$
500	5.417 * 10 $^{-3}$	1.361 * 10 $^{-3}$		147,994 * 10 $^{-6}$
1000	2.260 * 10 $^{-3}$	3.302 * 10 $^{-3}$		295.179 * 10 $^{-6}$
1500	6.370 * 10 $^{-3}$	4.998 * 10 $^{-3}$		440.775 * 10 $^{-6}$
2500	4.487 * 10 $^{-3}$	5,500 * 10 $^{-3}$		724.203 * 10 $^{-6}$
5000	1.118 * 10 $^{-3}$	11.328 * 10 $^{-3}$		1.361 * 10 $^{-3}$
10k	3.094 * 10 $^{-3}$	15.304 * 10 $^{-3}$		2.24 * 10 $^{-3}$
30k	25.755 * 10 $^{-3}$	25.755 * 10 $^{-3}$		3.002 * 10 $^{-3}$
50k	1.577 * 10 $^{-3}$	7.799 * 10 $^{-3}$		2.785 * 10 $^{-3}$
100k	1.691 * 10 $^{-3}$	2.459 * 10 $^{-3}$		2.01 * 10 $^{-3}$

200k	$19.784 * 10^{-3}$	$3.891 * 10^{-3}$		$1.166 * 10^{-3}$
500k				
1M				
10M				

Table 3

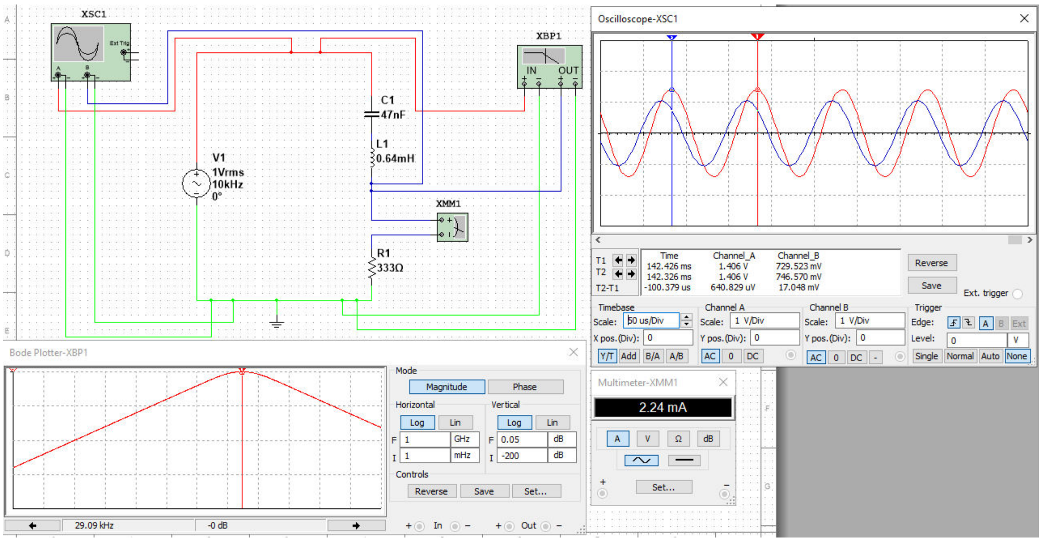
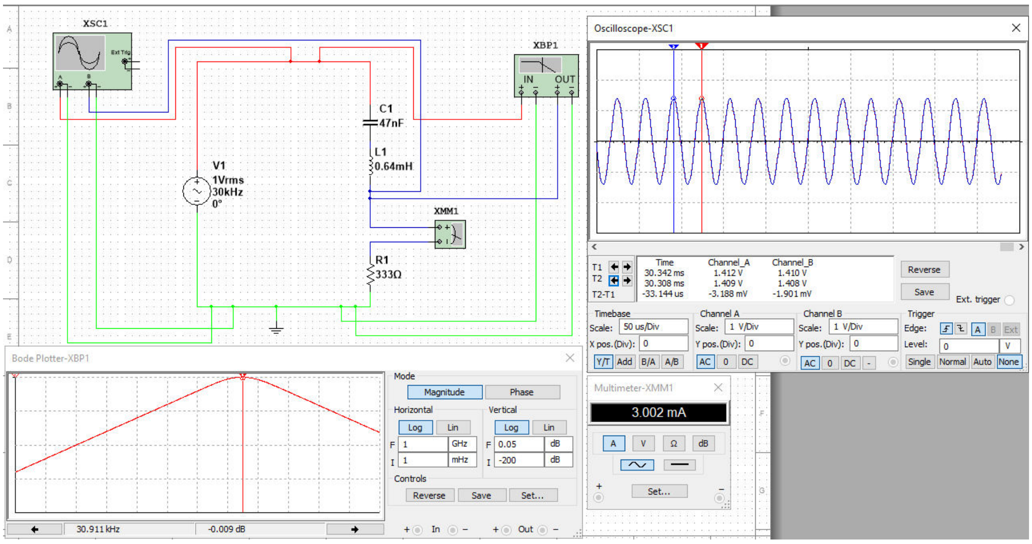


Figure 2



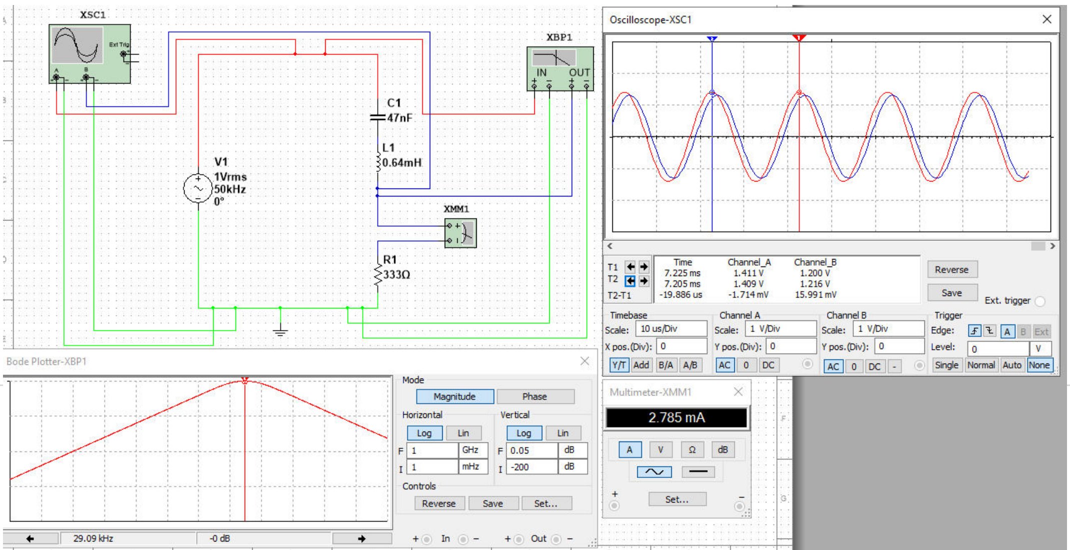


Figure 3

Figure 4

From the simulated solution in the "Multisim" software (Figures 2, 3, 4) and from the measurements recorded in Tables 2 and 3, the resonance effect in an RLC circuit, where the inductor and capacitor are connected in series, is clearly illustrated .

First, the theoretical value of the coil noted in the 2nd line of Table 1 in the "General" section was calculated from the resonance frequency formula, which is : $f_r = \frac{1}{2\pi\sqrt{LC}}$, where "L" is the inductance of the coil, "C" is the capacitance of the capacitor and " f_r" is the resonant frequency. In detail, in Table 2, the values were calculated using the following formulas:

Complex resistance $Z = (R^2 + X)^{21/2}$ (in Ω)

Active resistance $X = X_L - X_C$ (in Ω)

Inductive reactance X_L 2πfL (in Ω)

Capacitive reaction X_C 1 / 2πfC (in Ω)

$I_{rms} = V_{rms} Z$ (in A)

$V_{Lrms} = I_{rms} * X_L$ (in V)

$V_{Crms} = I_{rms} * X_C$ (in V)

In Table 3, the values were noted from the measurements made in "Multisim". From Tables 2 and 3 and Figures 2, 3 and 4, it is observed, and even in bright red (Figure 3), that the resonant frequency is 30 kHz. This is justified by the following three observations:

1. The sinusoidal signal emitted by the capacitor (input of the circuit) has the same phase as the corresponding signal emitted by the output of the circuit (coil) and this can be observed with the help of the oscilloscope in Figure 3.
2. The resistance of the circuit "Z" from the count in Table 2, is observed to be equal to the ohmic resistance "R" (333 Ω). This is justified by the impedance formula "Z", which is: $Z = \sqrt{R^2 + (X_L - X_c)^2}$and during resonance, the inductive reaction "X_L" cancels each other out with the capacitive reaction "X_C", ie, they are equal. Therefore, Z = R^2✇ Z = R.
3. The current flowing in the circuit at the resonant frequency (Figure 3) is the maximum, as, at frequencies above the resonant frequency (Figure 4), the current decreases.

Finally, during resonance it is observed from Tables 2 and 3 that the values of the capacitor V_C and the inductor V_L voltage are quite high, proving the formulation in "Theoretical Solution" for the overvoltage phenomena that occur in an RLC circuit, where capacitor and inductor are connected in series, during resonance.

Table 4

Resistance (Ω)	$Q_{ser} = \frac{1}{R}\sqrt{\frac{L}{C}}$	IR (mA)
1k	0.117	999,952 * 10 -3
500	0.233	2
220	0.53	4,542
100	1.17	9,964
10	11.7	76,144
1	117	116.66

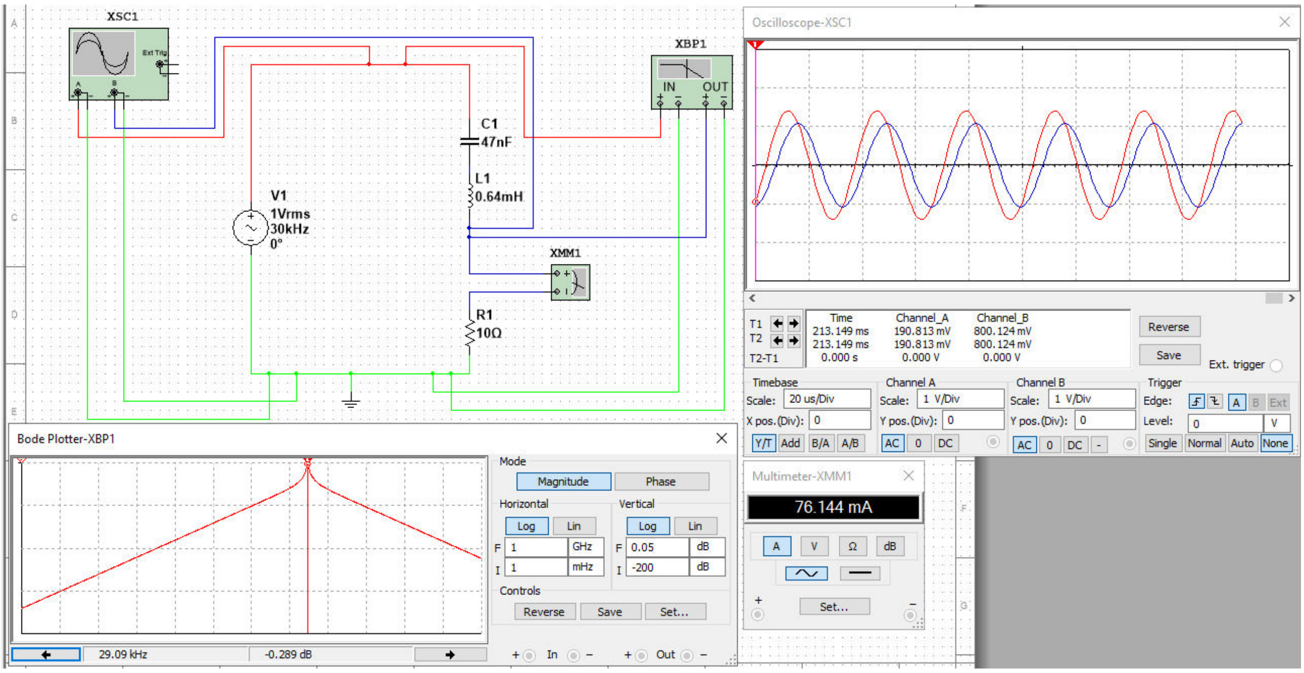


Figure 5

According to the measurements recorded in Table 4, as the ohmic resistance "R" of the circuit decreases, the current flowing through the circuit increases. This is justified by Ohm's law (I = V/R), where the resistance (R) and the current intensity (I) are inversely proportional quantities. Also, as the resistance decreases, the efficiency of the circuit Q increases, from the formula $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$. Finally, it is worth noting from Figure 5 that the resonant frequency of the circuit is not the frequency of 30 kHz, as long as the value of the ohmic resistance is 10 Ω. This is observed from the input and output signals presented in the oscilloscope . The two signals are not in phase and in fact the inductive reaction signal "X $_L$ " is preceded by the inductive reaction signal.

Experimental Solution

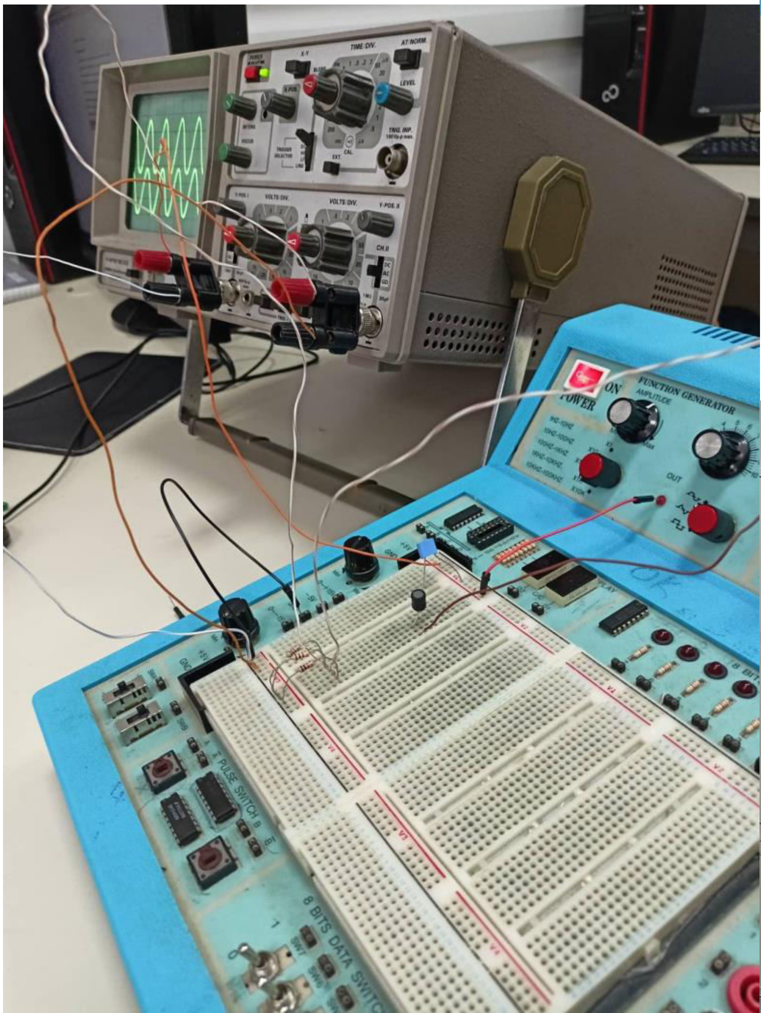
CIRCUIT THEORY

For the experimental solution carried out in the laboratory environment, the "breadboard", the oscilloscope, an analog multimeter set to calculate current intensity (ammeter), cables, three 1 kΩ resistors, a 470 nF capacitor and a 1 mH inductance coil were used .

To start, we connected with a cable, the AC voltage source to a shorted line on the "breadboard" and the ground with another cable to another shorted line as well. We then took the three 1 kΩ resistors, and connected them in parallel to form, indirectly, the 333 Ω isodynamic resistor that we used in the "Simulated Solution". Immediately afterwards, we connected the capacitor and the inductor in series with the three resistors and started the experiment by connecting the measuring instruments as well. More specifically, in series with one end of the equivalent resistor and one end of the inductor (as shown in Figure 6), we connected the analog multimeter set to be an ammeter to measure the current flowing through the circuit. Also, we connected one channel of the oscilloscope to the source (input of the Vin circuit) and the other to the coil (output of the Vout circuit) to observe the waveforms emitted by the capacitor and the coil. As we observe in Figure 6, the phases of the two sinusoidal signals are equal (in-phase) at 5 kHz, which means that we are at the resonant frequency. Figure 7 shows the ammeter reading at a frequency greater than 5 kHz (which is the resonant frequency) at 2 mA. At the resonance frequency the current reached 9 mA, where it was at its maximum, as, as we increased the input frequency from the source, the current gradually decreased. Figure 8 shows the resistance-frequency plot, which depicts the value of the inductive response (X_L) and the value of the capacitive response (X_C for various values of input frequency from the source. As, of course, observed the two values are equal at some frequency and the value of the circuit impedance is constant, ie, the ohmic resistance, signaling that it is the resonant frequency.

In summary, both experiments are found to correctly verify the formulations recorded in "Theoretical Solution".

Figure 7



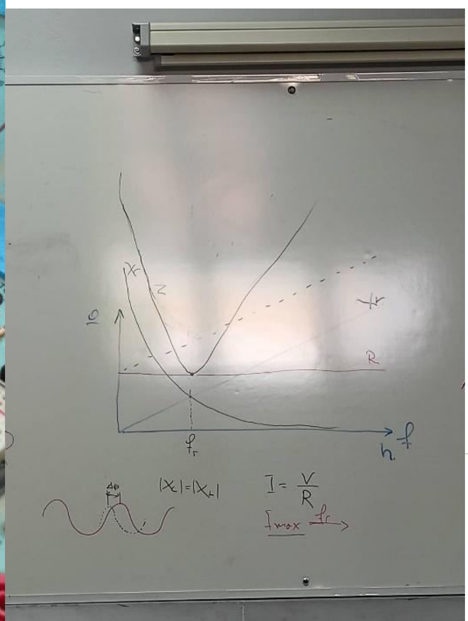


Figure 6

Figure 8

1.2 : Tuning in an RLC circuit in parallel

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. The table below presents a summary for the selection of the appropriate coil value used in the circuit presented in the "Simulated Solution" chapter.

Table 5

Implementation	C	L Theoretical	L Typical	Deviation from f_R
In Series	47nF	0.64 mH	6200 μH	681 Hz
In parallel	27nF	3.3mH	3300 μH	

Theoretical Solving

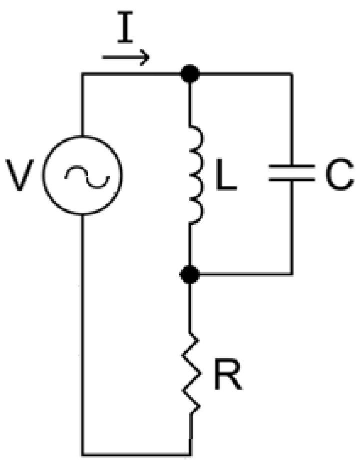


Figure 8

The circuit in Figure 8 achieves the resonance effect in an RLC circuit, where the inductor (L) and capacitor (C) are connected in parallel. The effect will be observed at a frequency where the inductive response (X_L) and the capacitive response (X_C) cancel each other out, ie, they are equal. The impedance of the circuit is : $Z = \sqrt{R^2 + (X_L - X_c)^2}$and therefore, during the resonance effect the impedance will be equal to the ohmic resistance (R). Also, during the effect the maximum current flowing through the circuit is observed, since from Ohm's law and Kirchhoff's law of voltages we have :

$V = V_L + V_C + V_R$ ✇ $V = IX_L + IX_C + IR$ ✇ $V = IX_C + IX_C + IR$ ✇ $V = I(2X_C + R)$

(From the resonance effect, where $X_C = X_L$)

$I = V / Z \Rightarrow I = [I(2X_C + R)] / [\sqrt{R^2 + (X_L - X_c)^2}] \Rightarrow I = [I(2X_C + R)] / R$

The third observation is that the sinusoidal signal emitted by the input of the circuit (capacitor) and the corresponding signal emitted by the output of the circuit (coil, which is observed using the oscilloscope) are in phase, ie, they have the same phase (cof = 1). In contrast to the RLC circuit, where the capacitor and coil are connected in series and the voltages V_C and V_L are equal which means that the total voltage of the circuit can take large voltage values, ie, in the circuit during the resonance effect , overvoltages are observed, in the corresponding circuit with parallel connection, large current intensities are observed during the resonance effect, ie, overvoltages are present in the circuit.

Simulative Resolution

F (Hz)	**Z (Ω)**	**X (Ω)**	**X_L (Ω)**	**X_C (Ω)**	**I_{rms} (A)**	**V_{Lrms} (V)**	**V_{Crms} (V)**
1	0.02	218430.25	0.02	218430.27	$3.003 * 10^{-3}$	0.00006	6559.5
10	0.2	21842.827	0.2	21843.027	$3.003 * 10^{-3}$	0.0006	655.95
100	2	2182.3027	2	2184.3027	$3.003 * 10^{-3}$	0.006	65.59
500	0.33	426.86	10	436.86	$3.003 * 10^{-3}$	0.03	1.31
1000	0.33	198.43	20	218.43	$2.997 * 10^{-3}$	0.06	0.6
1500	0.33	114.92	30	144.92	$2.99 * 10^{-3}$	0.09	0.4
2500	0.33	38.9	50	88.9	$2.965 * 10^{-3}$	0.1	0.3
5000	0.33	56.5	100	44.5	$2.841 * 10^{-3}$	0.3	0.12
10k	0.33	178.2	200	21.8	$2.159 * 10^{-3}$	0.4	0.05
30k	0.33	592.6	600	7.4	$2.28 * 10^{-3}$	1.3	0.02
50k	0.33	995.5	1000	4.5	$2.79 * 10^{-3}$	2.8	0.01
100k	0.33	1997.9	2000	2.1	$2.955 * 10^{-3}$	5.9	0.006

200 k	0.33	3999	4000	1	$2.991 * 10^{-3}$	12	0.003
500 k	0.33	9999.5	10000	0.5	$3.001 * 10^{-3}$	30	0.002
1M	0.33	1999.5	20000	0.2	$3.003 * 10^{-3}$	60	0.0006
10M	0.33	19999.98	200000	0.02	$3.003 * 10^{-3}$	600	0.00006

Table 6

Table 7

F (Hz)	Vi(V) Kan. A Measurement	Vo(V) Kan. B Measurement.	20log10(Vo/Vi) (db) proportional	I_{rms} (A) Measurement
1	$1.518 * 10^{-3}$	$166.442 * 10^{-3}$		$3.003 * 10^{-3}$
10	$829.431 * 10^{-3}$	1,433		$3.003 * 10^{-3}$
100	$75.065 * 10^{-3}$	$1.505 * 10^{-3}$		$3.003 * 10^{-3}$
500	$14.992 * 10^{-3}$	$8.228 * 10^{-3}$		$3.003 * 10^{-3}$
1000	$8.852 * 10^{-3}$	$3.734 * 10^{-3}$		$2.997 * 10^{-3}$
1500	$29.343 * 10^{-3}$	$36.154 * 10^{-3}$		$2.99 * 10^{-3}$
2500	$6.786 * 10^{-3}$	$1.161 * 10^{-3}$		$2.965 * 10^{-3}$
5000	$13.188 * 10^{-3}$	$1.021 * 10^{-3}$		$2.841 * 10^{-3}$
10k	$2.469 * 10^{-3}$	$18.884 * 10^{-3}$		$2.159 * 10^{-3}$
30k	$4.351 * 10^{-3}$	$3.521 * 10^{-3}$		$2.28 * 10^{-3}$
50k	$1.201 * 10^{-3}$	$7.637 * 10^{-3}$		$2.79 * 10^{-3}$
100k	$1.025 * 10^{-3}$	$11.740 * 10^{-3}$		$2.955 * 10^{-3}$
200k	$87.475 * 10^{-3}$	$61.391 * 10^{-3}$		$2.991 * 10^{-3}$

500k				$3.001 * 10^{-3}$
1M				$3.003 * 10^{-3}$
10M				$3.003 * 10^{-3}$

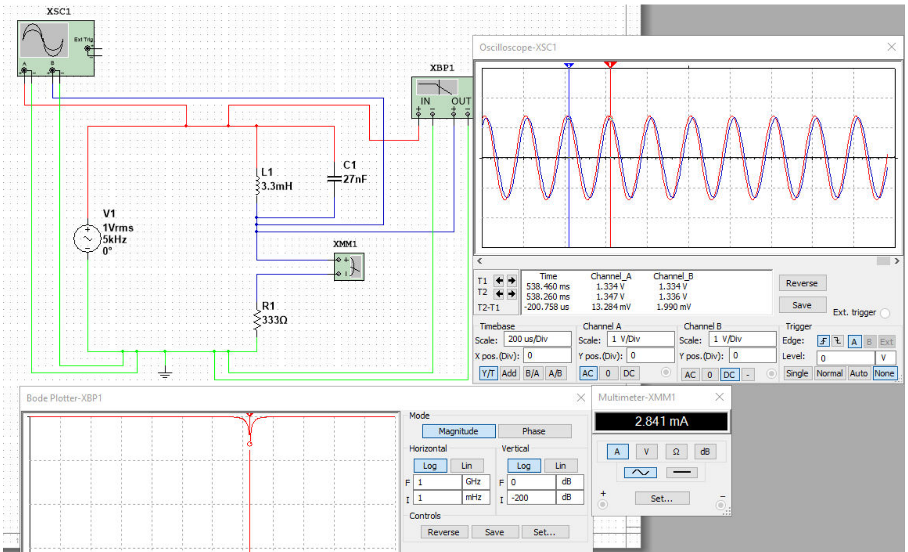


Figure 9

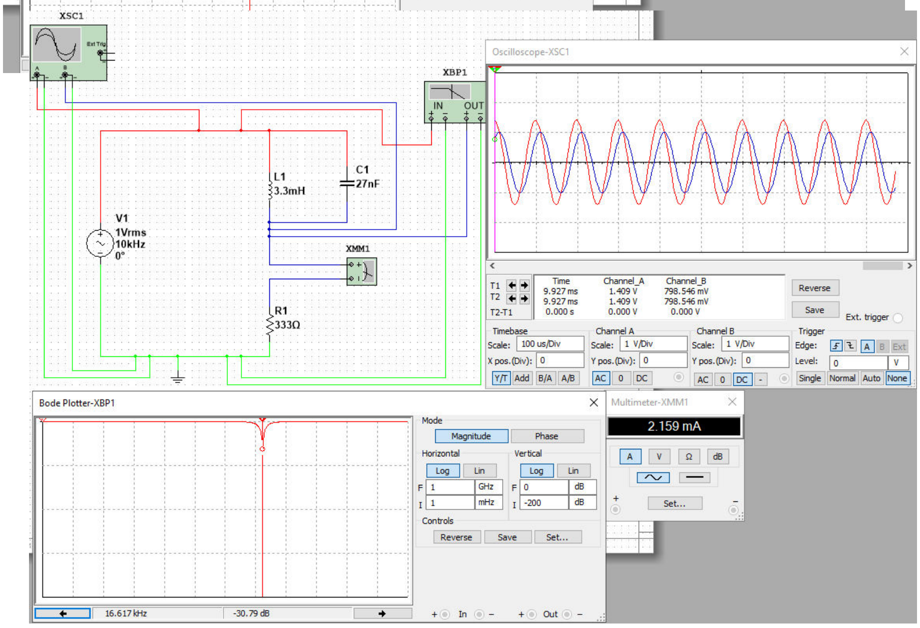


Figure 10

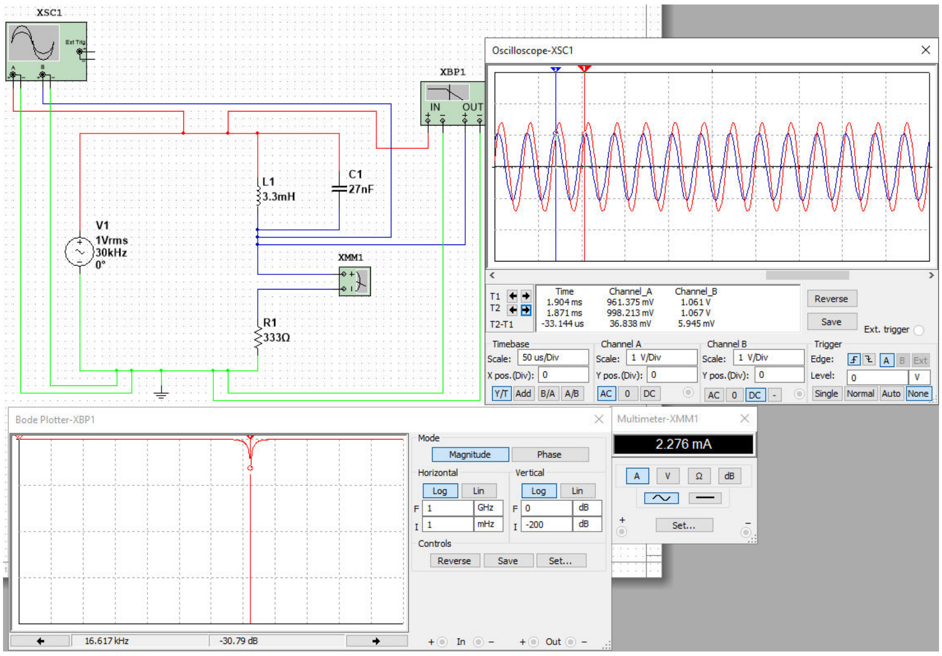


Figure 11

From the simulated solution in the "Multisim" software (Figures 9, 10, 11) and from the measurements recorded in Tables 6 and 7, the resonance effect in an RLC circuit, where the inductor and capacitor are connected in parallel, is clearly illustrated .

First, the theoretical value of the inductor noted in the 3rd $^{\text{line}}$ of Table 4 in the "General" section was calculated from the resonance frequency formula, which is : $f_r = \frac{1}{2\pi\sqrt{LC}}$, where "L" is the inductance of the coil, "C" is the capacitance of the capacitor and " f_r" is the resonant frequency. In detail, in Table 6, the values were calculated using the following formulas:

Impedance $Z = 1 / (1/ R^2 + 1 / X)^{21/2}$ (in Ω)

Active resistance $X = X_L - X_C$ (in Ω)

Inductive reactance $X_L\ 2\pi fL$ (in Ω)

Capacitive reaction $X_C\ 1 / 2\pi fC$ (in Ω)

$I_{rms} = V_{rms} Z$ (in A)

$V_{Lrms} = I_{rms} * X_L$ (in V)

$V_{Crms} = I_{rms} * X_C$ (in V)

In Table 7, the values were noted from the measurements made in "Multisim". From Tables 6 and 7 and Figures 9, 10 and 11, it can be observed, and even in bright red (Figure 10), that the resonant frequency is 10 kHz. This is justified by the following three observations:

4. The sinusoidal signal emitted by the capacitor (input of the circuit) has the same phase as the corresponding signal emitted by the output of the circuit (coil) and this can be observed with the help of the oscilloscope in Figure 10.
5. The resistance of the circuit "Z" from the count in Table 6, is observed to be equal to the ohmic resistance "R" (333 Ω). This is justified by the impedance formula "Z", which is: $Z = \frac{1}{\sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}}$ and during resonance, the inductive reaction "X_L" cancels each other out with the capacitive reaction "X_C", ie, they are equal. Therefore, Z = R^2□□Z = R.
6. The current flowing in the circuit at the resonant frequency (Figure 10) is the minimum, as, at frequencies exceeding the resonant frequency (Figures 9, 11), the current fluctuates.

Finally, during resonance it is observed from Tables 6 and 7 that the Irms voltage values are quite high proving the formulation in "Theoretical Solution" for the overcurrent phenomena that occur in an RLC circuit, where capacitor and inductor are connected in parallel, during resonance .