OSTIM TECHNICAL UNIVERSITY
ANKARA

Faculty of Engineering

Department of Electrical and Electronics Engineering

EEE 202/ ELECTRIC CIRCUITS II

Experiment Design Report Tamplate

Project Topic No: **PG-21**

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PO	Description	Marking
2.1	Problemin tanımlanma, formüle edilme ve çözülme becerisi;	
2.2	Uygun analiz ve modelleme yöntemlerinin seçimi ve uygulaması	
3.1	Verilen sistemin, belirtilen koşullar altında tasarlanması	
4.1	Problemlerin analiz ve çözümü için gerekli teknik ve araçların kullanımı	
5.1	Verilen konun incelenmesi için deney tasarlanması	
6.1	Etkin takım çalışması	
7.3	Raporun etkinliği, yazımı ve analaşılır olma durumu	
9.1	Etik ilkelerine uygun davranma	

May 2025 – ANKARA

PREFACE

This term Project has been prepared as apart of the course *EEE202 Electric Circuit II* in order to reach the course outcomes. By completing this project we, the project group, have gained the following abilities.

- The ability to define, formulate and solve a problem
- Selection and application of appropriate analysis and modeling methods
- Design of a given system under specified conditions
- Use of techniques and tools required for analysis and solution of the problems
- Design of experiments to examine the given subject
- Effective teamwork
- Effectiveness, writing and comprehensibility of the report
- Acting in accordance with ethical principles

Besides the modelling, analysis and developing experiments for systems, which are covered in lectures, we have also developed skills on system simulation.

Numbers and the names of the students

OSTIM TECHNICAL UNIVERSITY ANKARA
FACULTY OF ENGINEERING
ELECTRICAL & ELECTRONICS ENGINEERING

DECLERATION

Ethical Behavior and Professional Honesty

Fair and accurate assessment are key factors that must be at the core of education. Any act of a student that would cause unfair advantage to himself/herself or another student is considered an academic dishonesty. It is also academic dishonesty to copy someone else's work and make it look like his/her own. This is called **plagiarism**, which means theft.

Allowing someone else to copy your work and make it look like his/her own is also fraud. It is both wrong and unethical to provide all kinds of unfair profits and advantages. It is also wrong to prepare the assignments, projects or laboratory reports of the other students. Doing this is not ethical, neither. Likewise, having his/her own homework, project or laboratory report being prepared and written by someone else is also a complete deception and immorality.

Using another student's answers, homework or reports without his/her knowledge is nothing but stealing that student's labor and this is called **plagiarism** (theft). It is the same thing to pass the course by cheating in exams.

We should not forget that those who cannot learn the truth when they are students continue these mistakes after graduation and become one of the characters we complain about in the society.

We expect our students and alumni to have ethical and humanly behaviors during both their professional business and social lives. For this, we want you to promise us that you will obey the ethical rules by signing this form.

Let us fight with unethical behavior together.

Prof. Dr. İsmail H. ALTAŞ
Department Chair

I believe what is written above is correct within the framework of ethical rules. I promise to behave ethically during and after my education.

Student No	Student Name and Surname	Date	Signature
220202032	Berk Muammer KUZU	16.05.2025	Berk
220202027	Muhammed Bucak	16.05.2025	
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CONTENTS

Black Box Observation and Determination

1. Experiment:

Determining the Elements and Character of the Circuit Inside the Black Box

2. Objective of the experiment:

Determine whether the circuit inside the black box is a parallel RLC circuit and find the values of the components.

3. Equipment and measuring instruments:

The black box as the as the system to be tested, an ammeter, a voltmeter, a two channel oscilloscope, a 1 Ohm resistor, 10K ohm resistor, connection wires, signal generator with step sine, square, and saw tooth signal ports.

4. Preparation questions:

Answer the preparation questions given below.

Q1. How to connect the materials?

Q2. How do you decide that the circuit inside the black box is a parallel RLC circuit?

Q3. How does the impedance behavior of the black box relate to frequency?

5. General description of the experiment:

In this experiment, the signal generator, the black box, will be connected to each other through an ammeter and 1 Ohm resistor in series, and voltmeter connected parallel through A and B terminal. Ammeter and voltmeter to be connected to measure the RMS values of source current and source voltage. The oscilloscope will be used to display the voltage and current signals.

6. Theoretical relations:

6.1 How to connect the materials?

The positive terminal of the signal generator should be connected to a 1**Ω** resistor, and the negative terminal should be connected to the unconnected terminal of the black box. The first channel of the oscilloscope should be connected to the terminals of the 1**Ω** resistor, while the second channel should be connected to the terminals of the black box. 1**Ω** resistor and ammeter should be connected in series to the black box so that the total current through the circuit can be measured. The voltmeter should be connected in parallel to the black box so that the voltage on the black box can be seen. It was decided that we do not need to use a 10k **Ω** resistor.

6.2 How do you decide that the circuit inside the black box is a parallel RLC circuit?

In a parallel RLC circuit, if the frequency of the source is greater than the resonant frequency, the circuit behaves capacitive, and vice versa, the circuit behaves inductively. In the phase angle-frequency graph produced by the NI Multisim program below, it is observed that the phase angle-frequency graph of the black box behaves like a parallel RLC circuit. Because the black box behaves capacitive at frequencies greater than the resonant frequency and inductively at frequencies less than the resonant frequencies.

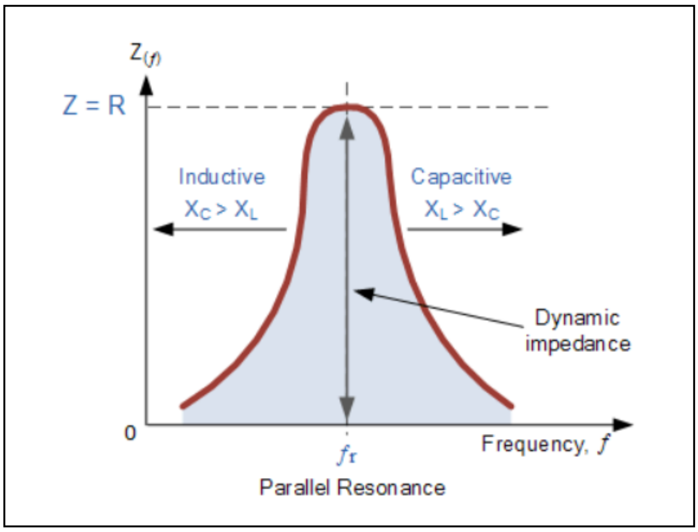

Figure 1: Parallel Resonance Z and f graphic

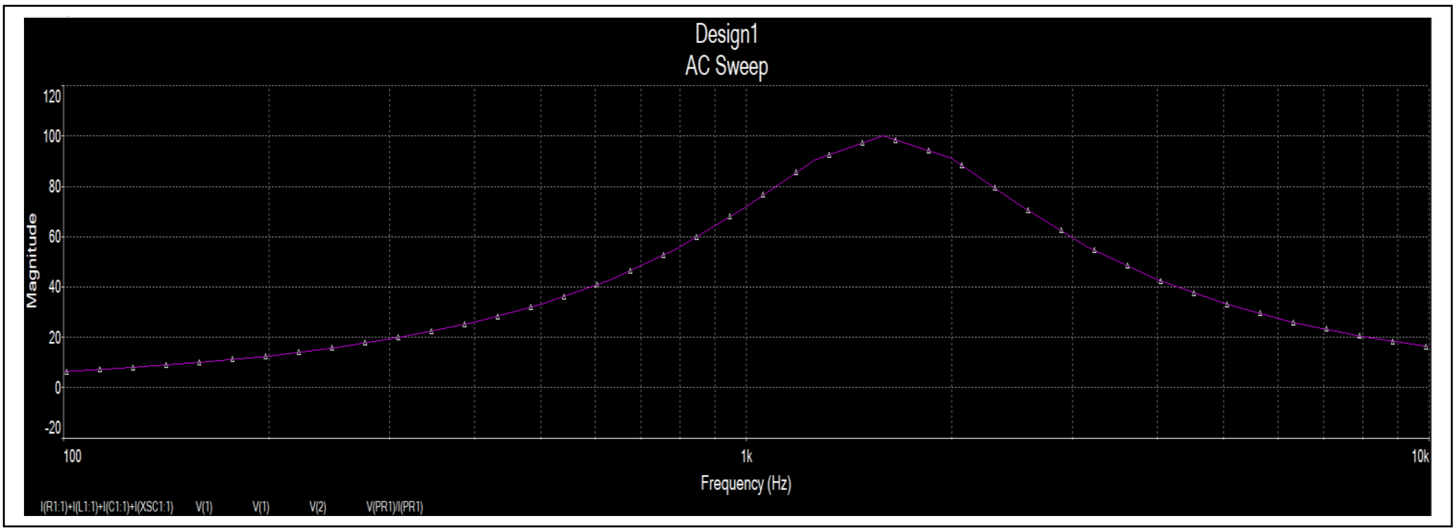

Figure 2: Impedance graph of black box

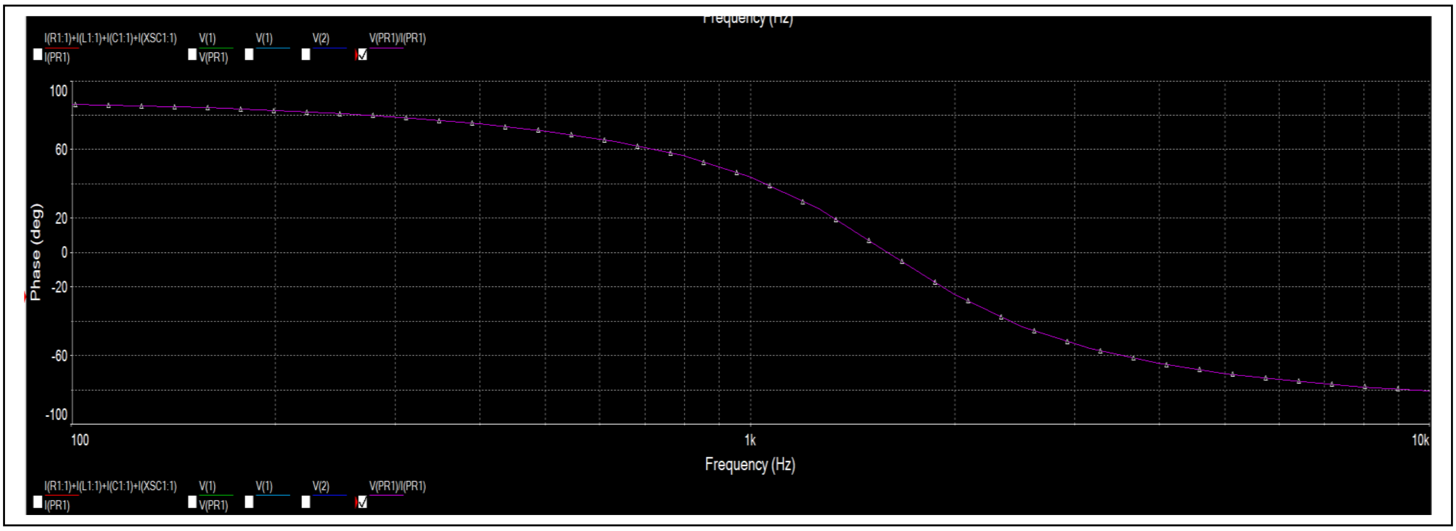

Figure 3: Phase angle-frequency graph of black box

6.3. What is the relationship between phase angle and frequency?

Previous question we determine the black box has parallel R, L, and C.

We don't know exactly values of parallel R, L, and C components but we have oscilloscope and function generator if we adjust frequency we can find the relations between phase angle and frequency.

Let's write the equations and explain the graphics obtained from NI Multisim;

For finding phase angle and frequency between them we can adjust function generator and made the amplitude 1 Volt and set the frequency 100 and increase it up to 10k Hz. After that, we have a values on the output and we obtain the graph of frequency (x-axis) and phase angle(degree)(y-axis). Green voltage between A and B terminal and orange is a 1 ohm resistor voltage shown on oscilloscope

Clearly we can see that at 1.59 KHz our black box is at **resonance**, below the 1.59 KHz our black box is **inductive**. Finally, above the 1.59 KHz up to 10 KHz our black box is **capacitive**. So we can comment that when we increase the frequency, our circuit becomes capacitive. Secondly, we see that our circuit is in resonance within a certain frequency range. Finally, when our frequency is above the resonance frequency, we obtain an inductive circuit.

Let's examine the graphic **Figure 2**, firstly set up to signal generator frequency to 100 Hz to show it's inductive.

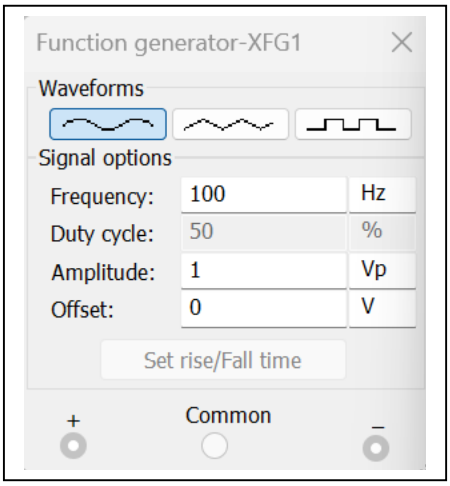

Figure 4

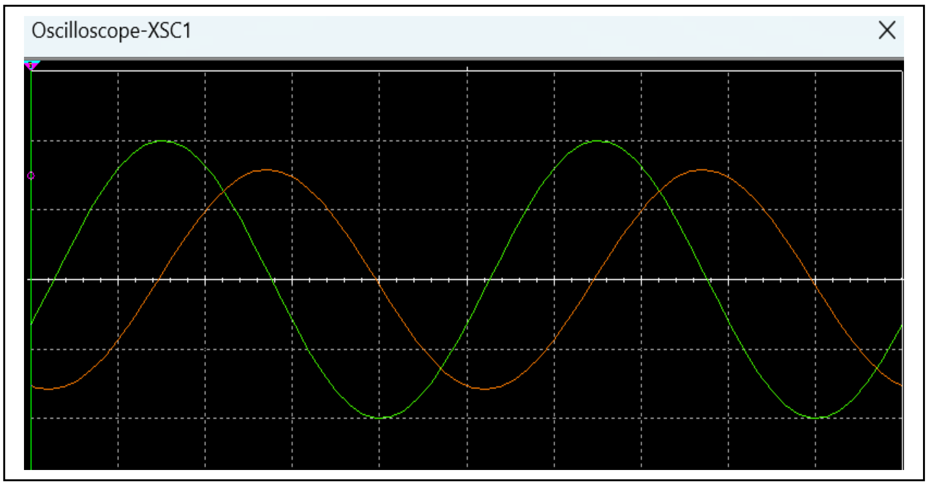

Figure 5

Secondly , set up to signal generator frequency to 1.59 kHz to show it's at resonance.

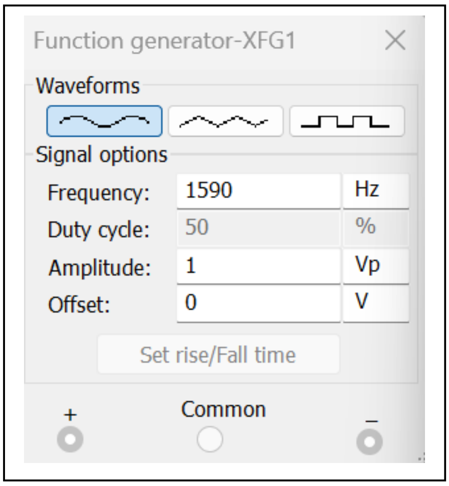

Figure 6

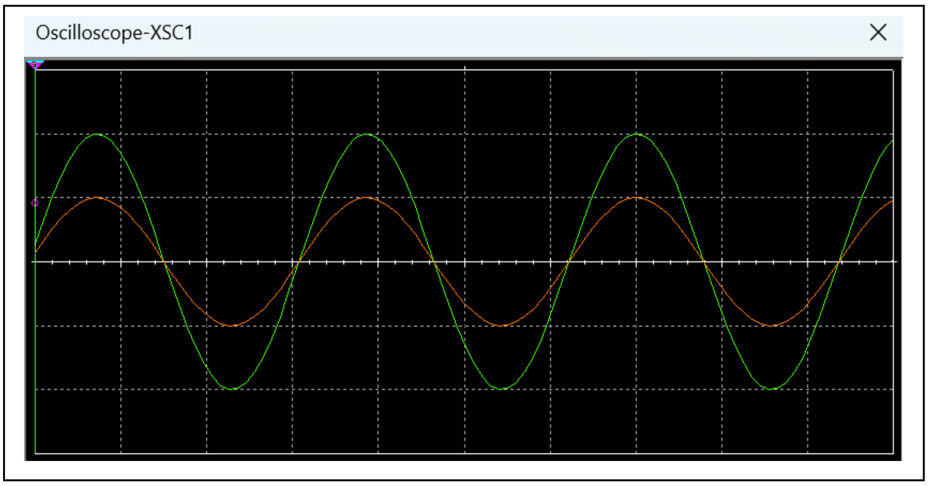

Figure 7

Finally, when we set up the frequency 10 kHz we can clearly see that it's capacitive because phase angle between A and B is lagging.

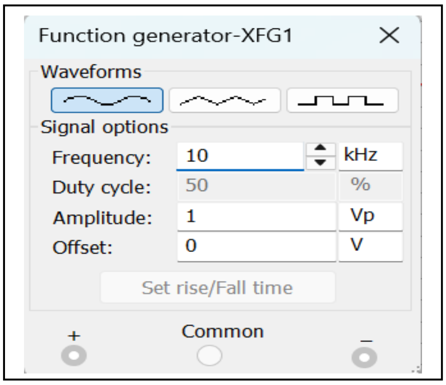

Figure 8

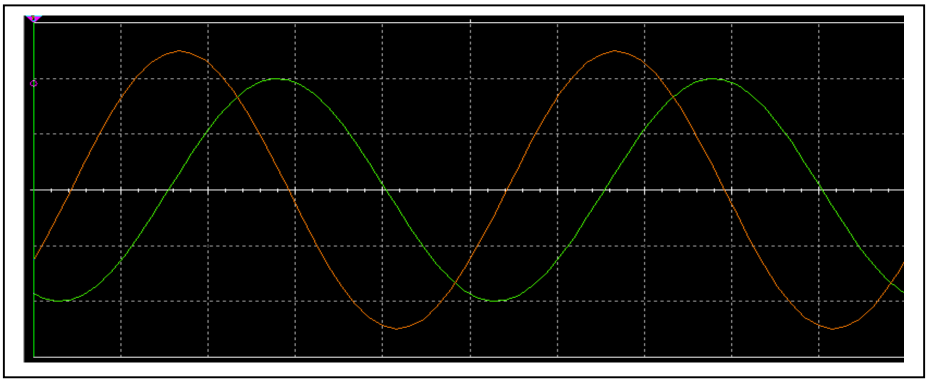

Figure 9

To sum up, we reach our goal and determine the frequency and phase angle.

Now let's write the theoretical part:

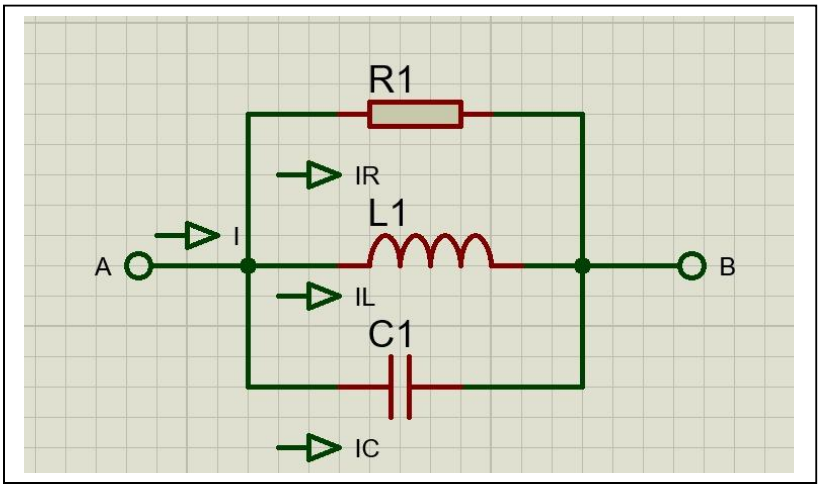

Figure 10: Black box representation, Parallel

$$-I + I_R + I_L + I_C = 0 \Rightarrow I = I_R + I_C + I_L$$

$$I = \frac{V}{R} + \frac{V}{jX_L} + \frac{V}{-jX_C} \Rightarrow I = V\left[\frac{1}{R} + j\left(\frac{1}{X_C} - \frac{1}{X_L}\right)\right]$$

Let's use admittance for easy calculation. **I = VY**, therefore:

$$Y = \frac{1}{R} + j\left(\frac{1}{Xc} - \frac{1}{X_L}\right) \Rightarrow \frac{1}{X_C} = \frac{1}{X_L} \Rightarrow Xc = X_L$$

$$\omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC}$$

$$\omega_P = \frac{1}{\sqrt{LC}}, \text{ for } \frac{L}{C} \geq 100R_{coil}$$

$$f_p = \frac{1}{2\pi\sqrt{LC}}$$

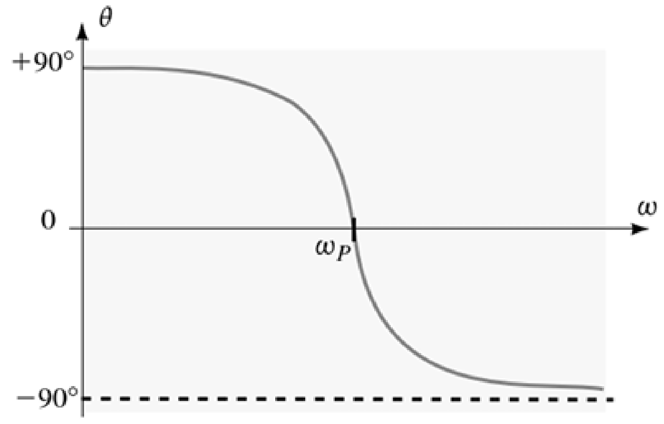

Figure 11

$$Q_p = \frac{REACTIVE\ POWER}{ACTIVE\ POWER} = \frac{V^2/X_L}{V^2/R}$$

$$I_R = \frac{V}{R} = I\ ,\ I_L = \frac{V}{X_L\angle -90^\circ} = \frac{V}{\left(\frac{R}{Q_P}\right)\angle 90^\circ} = Q_P I < 90^\circ\ ,$$

$$I_C = \frac{V}{X_c} = \frac{V}{\left(\frac{R}{Q_P}\right)\angle 90^\circ} = Q_P I < 90^\circ$$

HALF POWER FREQUENCIES

$$\omega_1 = \frac{-1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} \quad (\frac{rad}{s})$$

$$\omega_2 = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} \quad (\frac{rad}{s})$$

$$BAND\ WIDTH = \omega_1 - \omega_2 = \frac{1}{RC} \quad (\frac{rad}{s})$$

$$BAND\ WIDTH = \frac{\omega_P}{Q_P} \quad (\frac{rad}{s})$$

7. Connection diagram

The connection shown in the figure () is a parallel RLC circuit. In this circuit we used a signal generator for the source. The resistor, inductor and capacitor in the figure are the loads inside the black box and are connected in parallel to each other. We use the 1-ohm resistor connected in series(R1) to the black box to measure the total current circulating in the whole circuit, so we connected an ammeter in series to the resistor (U1). We also connected a parallel voltmeter to these loads to measure the total voltage of the loads (XMM1). We connected part A of the oscilloscope to the 1-ohm resistor and got the signal there. We connected part B to our loads connected in parallel and got the signal of the loads.

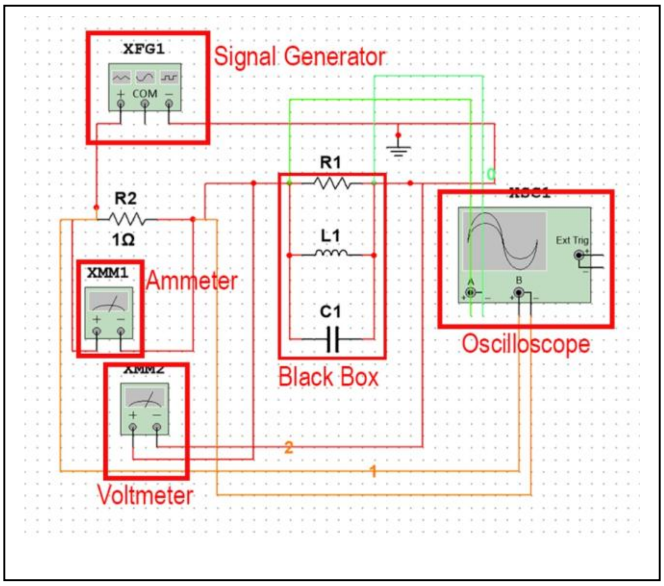

Figure 12: Connection Wire Diagram

8. Measurements

Voltage (V)	Current (A)	Time & Phase Difference	Leading Variable
1 VOLT	0.087 A	Frequency=10kHz ≈87.1°	I is leading V
2 VOLT	0.174 A	Frequency=10kHz same result (87.1°)	I is leading V
2 VOLT	0.028 A	Frequency = 1.59 kHz → resonance → no phase difference	There is no phase angle difference between I and V

1 VOLT	**0.042 A**	**Frequency = 500 Hz ≈-72.5°**	**V is leading I**
2 VOLT	**0.085 A**	**Frequency = 500Hz -72.5°**	**V is leading I**

Table 1:

In the table above, there are measurements of a parallel RLC circuit under different conditions. When the voltage across the shunt resistor changes, the measured current value across this resistor also changes; in the circuit, this provides a direct measurement of the main current using the equation V = I·R, since the resistance value is 1 Ω. Thus, the only factor that affects the change in the phase difference is the change in frequency. The measured results show that resonance occurs at 1.59 kHz. Other than frequency, no other factor alters the phase difference. Note: **The values are approximate.**

$\varphi(\text{rad}) = \omega.\Delta t = 2\pi.f.\Delta t = 2\pi.T.\Delta t$

$\Delta\varphi = T.\Delta t \times 360°$

$T_2–T_1$ = 124.194 µs; φ = (124.194/100)·360 = 447.1°; φ_mod = 447.1° – 360° = 87.1°

$T_2–T_1$ = 1.597 ms; φ = (1.597/2)·360 = 287.5°; φ_mod = 287.5° – 360° = –72.5°

9. Calculations

After proving that the inside of the black box is parallel RLC, we proceeded to find the values of the components. Although the value of the components was determined by us, the values were pretended to be unknown, and we tried to determine the value of the components. We already knew the resonant frequency from phase angle-frequency graph. Then we found the value of the resistance in the parallel RLC circuit from the peak of the impedance graph which is 100**Ω**. To calculate the L and C values, we needed to find the quality factor. In parallel RLC circuits, the quality factor is found by dividing the resonant frequency by the bandwidth. We obtained the bandwidth by dividing the peak value of the impedance graph by the root 2 and then calculating the difference between the obtained values. After finding the quality factor, L and C values are found.

$Q_p = \frac{f}{BW}$ $L = \frac{R}{Qp\ w}$ $C = \frac{1}{L\ w\hat{}2}$ w is 1590 x 2π = 9990,265 rad/s

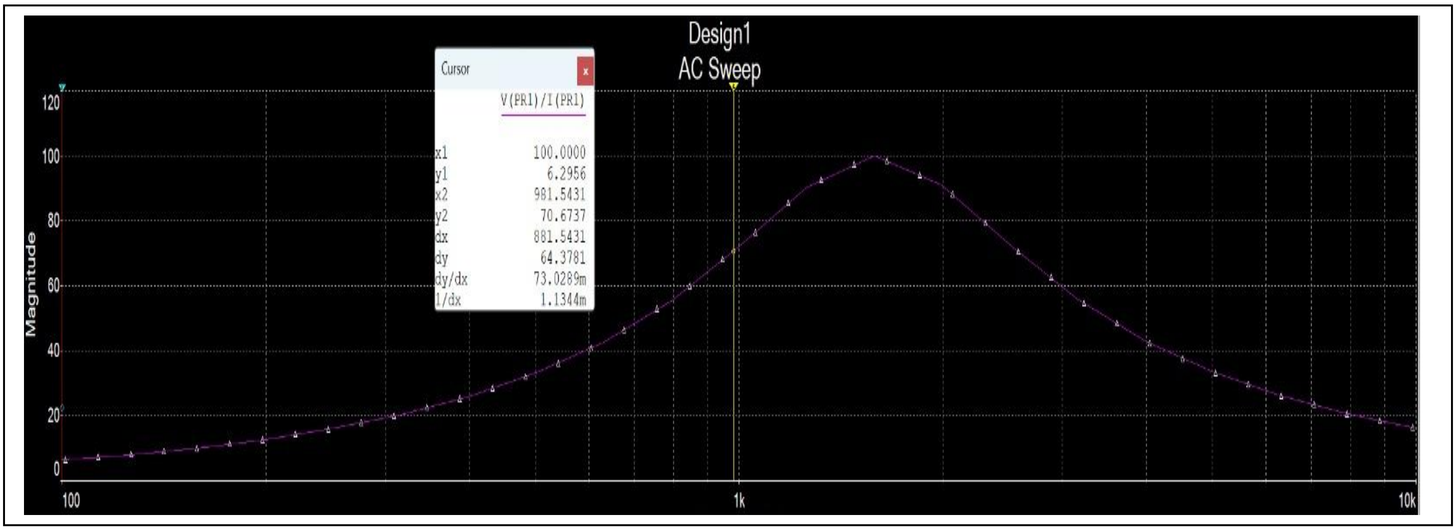

Figure 13: First value (Peak value divided by root 2)

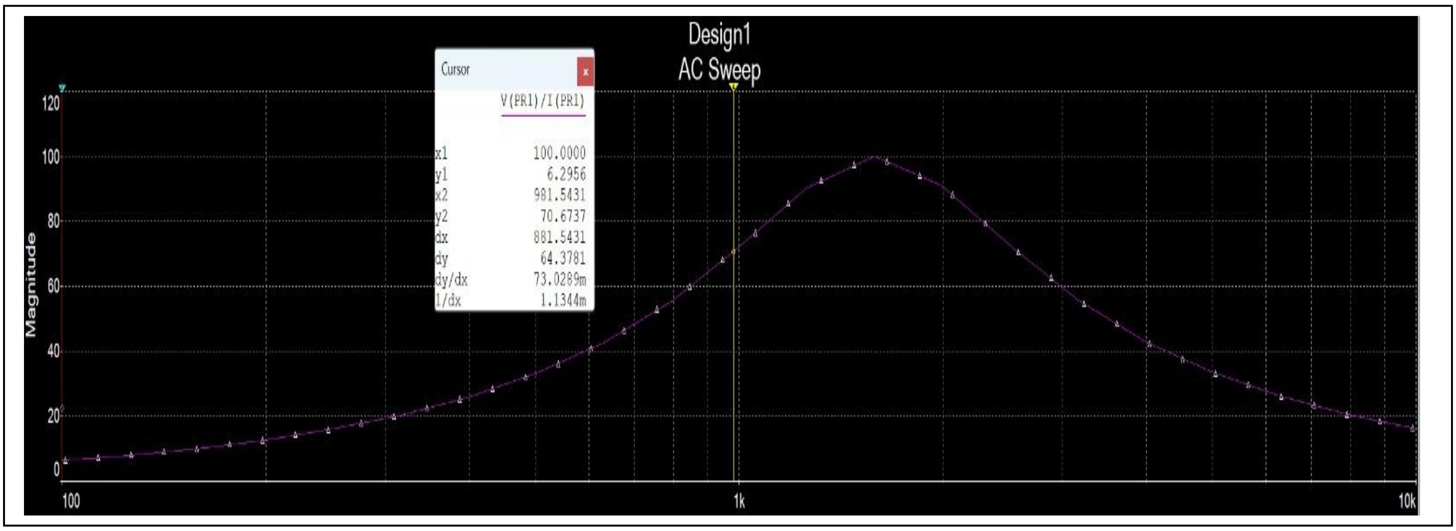

Figure 14: Second value (Peak value divided by root 2 again)

2581,1 – 981,54 = 1599,56 Hz (Bandwidth)

Q_p = 1590/1599,56 = 0.9940

L = $\frac{R}{Qp\ w}$ = 100/(0.9940 x 1599,56 x 2π) = 0,01H which is equal to 10mH

C = $\frac{1}{L\ w\hat{}2}$ = 1/(0,01 x (1599,56 x 2π)^2) = 10 x 10^{-7} = 10^{-6} C which is equal to 1uF

We find the RLC unknown values using this equation and graphic information,

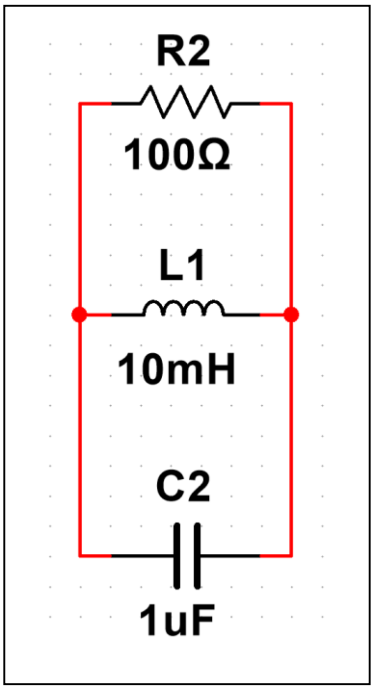

Figure 15: Black box values

10. Resultant graphs:

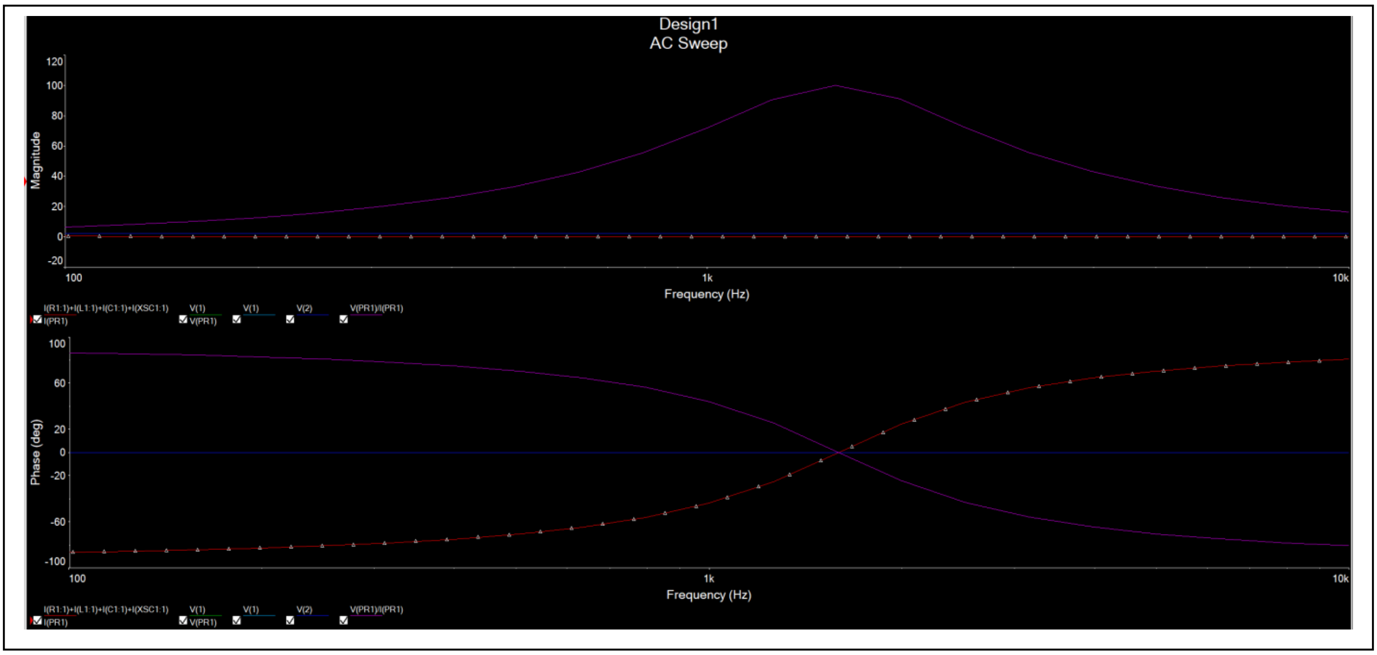

Figure 16

11. Conclusion

In this experiment, AC analysis information is used to characterize a circuit whose content is unknown and cannot be changed. The company's need for a parallel RLC circuit has been fulfilled and the company can now use this circuit for various tasks including signal processing, electrical filters, and communication systems according to natural response of the circuit. Overdamped circuits are essential for smooth voltage transitions without oscillations, making them useful in power supply circuits. Underdamped circuits, which exhibit oscillations, are widely applied in resonant circuits, radio frequency (RF) communication, and tuning applications. Critically damped circuits strike a balance between speed and stability, often used in control systems and transient response optimization.[3]

12. References

[1]. Allan H. Robbins and Wilhelm C Miller, "Circuit Analysis: Theory and Practice", 5th Ed., 984 page, Cengage Learning, 2012.

[2]. James W. Nisson, ‘Electric Circuits’, 2nd Ed. Addison-Wesley Publishing Company, 1987.

[3]. https://electricalacademia.com/basic-electrical/parallel-rlc-circuit-analysis/