



THE ISLAMIC UNIVERSITY OF GAZA

FACULTY OF ENGINEERING

Electrical Circuits Lab 2

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Major	Electrical Engineering
Course Name	Electrical Circuits Lab 2
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Experiment 5: RLC Series / Parallel A/C Circuits

1. Objectives

- To study and analyze combination AC circuits that integrate both series and parallel connections of Resistors (R), Inductors (L), and Capacitors (C).
- To understand and determine the phasor and directional relationships between frequency, total impedance (Z), voltages, and currents within the circuit.
- To practice drawing and analyzing phasor diagrams geometrically to connect theoretical concepts with practical lab measurements.

2. Theory

In combination **AC circuits**, the network is analyzed and simplified in stages. First, the equivalent impedance of the parallel branches is calculated, and then it is vectorially added (**Phasor Addition**) to the elements connected in series. Based on the circuit topology, **three fundamental** cases are analyzed:

Case 1: Parallel RC >> Series with L

In this configuration, the resistor R and the capacitor C are connected in parallel, and the entire group is connected in series with the inductor

- **Parallel Branch Analysis (R parallel C):** The voltage is common and identical across both parallel branches, serving as the horizontal phase reference:

$$V_1 = V_R = V_C$$

- **Currents:** The resistor current **IR** is in phase with the voltage **V1** (aligned horizontally), while the capacitor current **Ic** **leads the voltage by 90 Degree** (directed vertically upward).
- **Total Circuit Current (IT):** This is equal to the inductor current **IL** and represents the orthogonal geometric resultant of the two parallel currents according to the Pythagorean theorem:

$$|I_T| = |I_L| = \sqrt{(I_R)^2 + (I_C)^2}$$

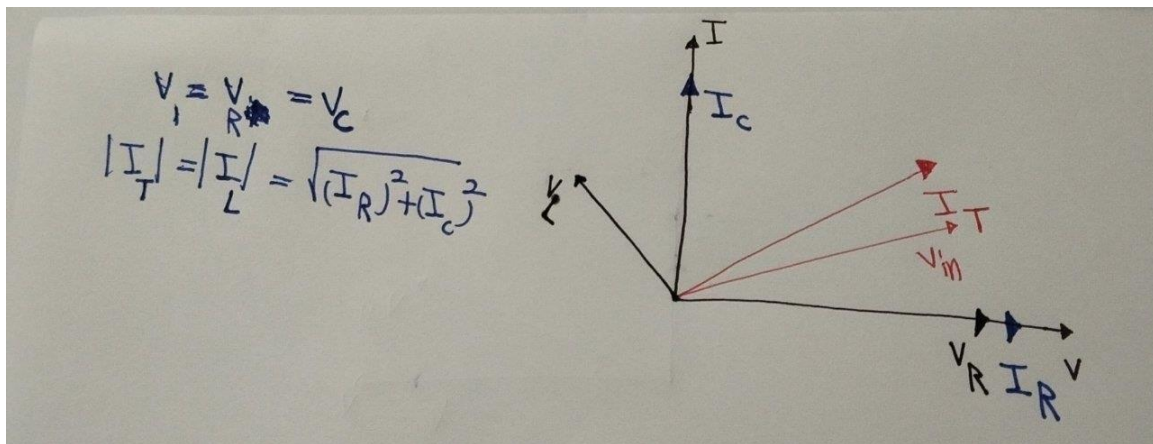
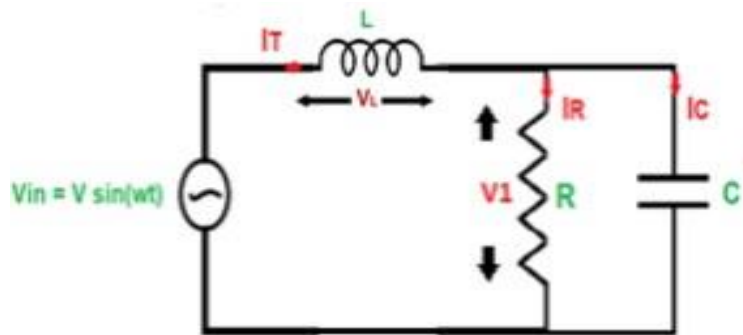
- **Total Impedance and Voltage:** The equivalent impedance of the parallel section **Zp** is calculated first, then added to the inductive reactance:

$$Z_p = \frac{R \cdot (-jX_C)}{R - jX_C} = \frac{V_1}{I_T}$$

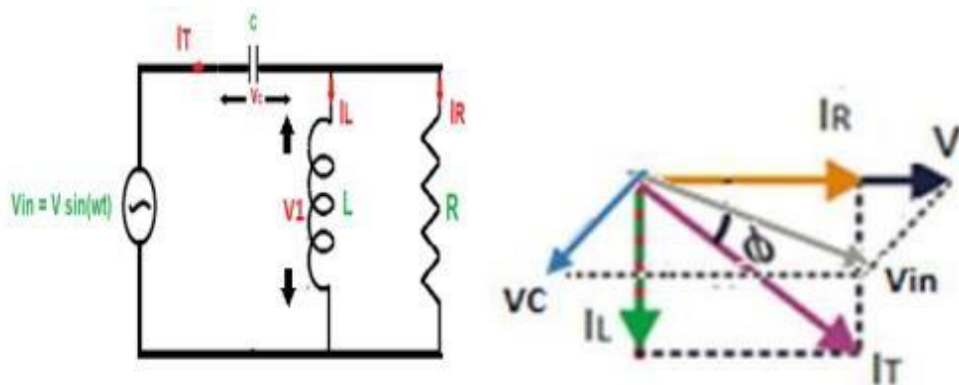
$$Z_{total} = jX_L + Z_p$$

$$V_{in} = I_T \cdot (X_L + Z) = V_L + V_1$$

Where the inductor voltage **VL** **leads** the total current **IT** by 90 degree and the total source voltage **Vin** is obtained from the **phasor sum** of **VL** and **V1**.



Case 2: Parallel RL >> Series with C



In this configuration, the resistor R and the inductor L are connected in parallel, and the entire group is connected in series with the capacitor C.

- **Parallel Branch Analysis (R parallel L):** The voltage is common and constant across both parallel branches:

$$V_1 = V_R = V_L$$

- **Currents:** The resistor current I_R is in phase with the voltage horizontally, while the inductor current I_L lags the voltage by 90 (directed vertically downward)
- **Total Circuit Current (I_T):** This is equal to the capacitor current I_C and represents the geometric resultant of the parallel branch currents:

$$|I_T| = |I_C| = \sqrt{(I_R)^2 + (I_L)^2}$$

- **Total Impedance and Voltage:**
- Where the capacitor voltage V_C lags the total current I_T by 90 and the total source voltage **V_{in}** is the phasor resultant of the capacitor voltage and the parallel branch voltage.

$$Z_p = \frac{R \cdot (jX_L)}{R + jX_L} = \frac{V_1}{I_T}$$

$$Z_{total} = -jX_C + Z_p$$

$$V_{in} = I_T \cdot (X_C + Z) = V_C + V_1$$

Case 3: Parallel LC >> Series with R

In this configuration, the inductor L and the capacitor C are connected in parallel, and the entire parallel network is connected in series with the resistor R.

- **Parallel Branch Analysis (L parallel C):** The voltage across the parallel branches is common and taken as the horizontal reference line:

- **Currents:** I_C points upward 90 and I_L points downward 90
- **Under the condition $X_L > X_C$, I_C is larger than I_L .** Thus, the net total current I_T points **vertically upward** by direct subtraction:

$$V_1 = V_L = V_C$$

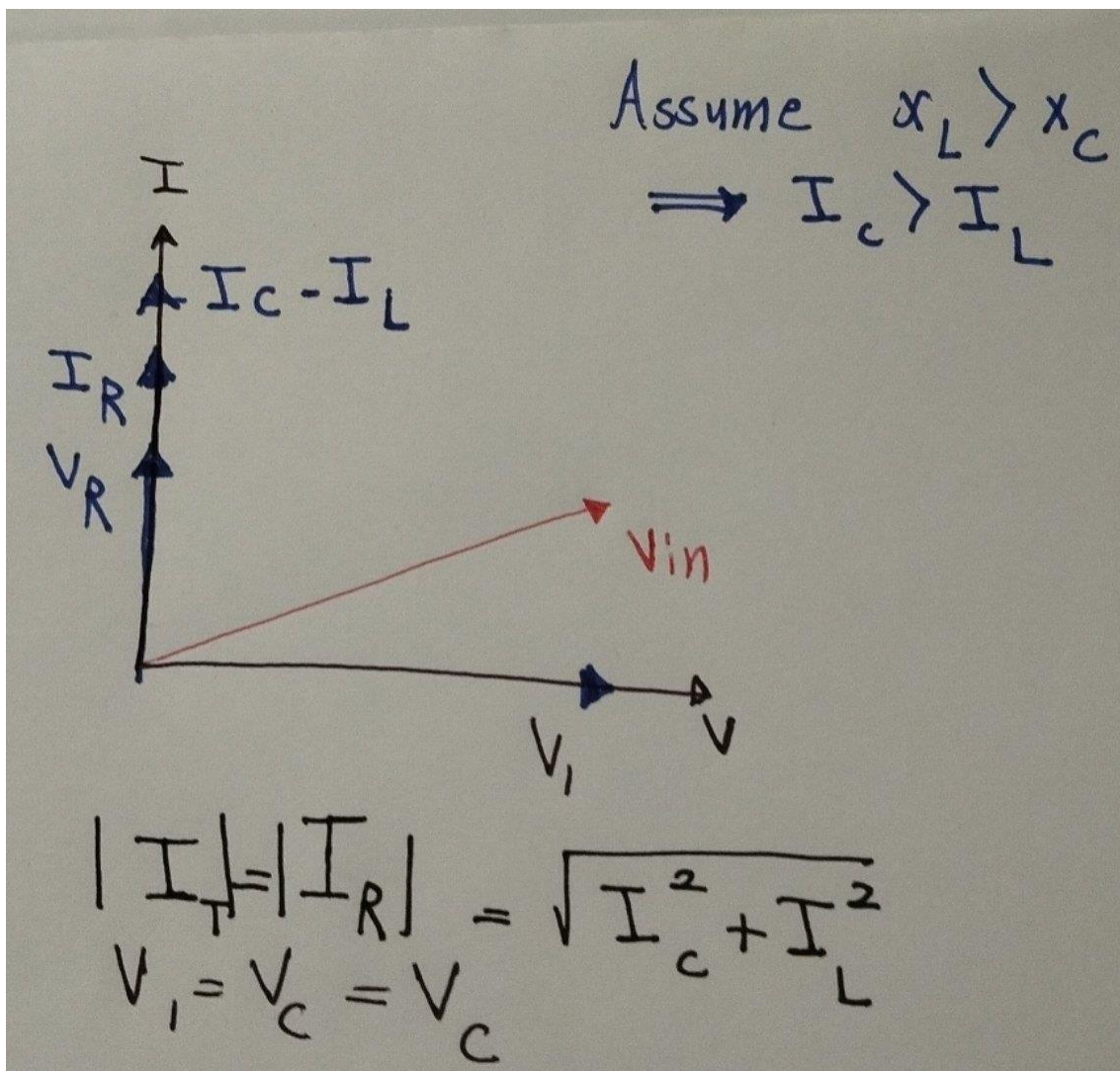
- **Series Resistor Voltage (V_R):** The total current I_T flows through the resistor R. Since they are in phase, the resistor voltage V_R is geometrically forced to point **vertically upward**.

$$I_T = I_C - I_L$$

- Impedance & Source Voltage

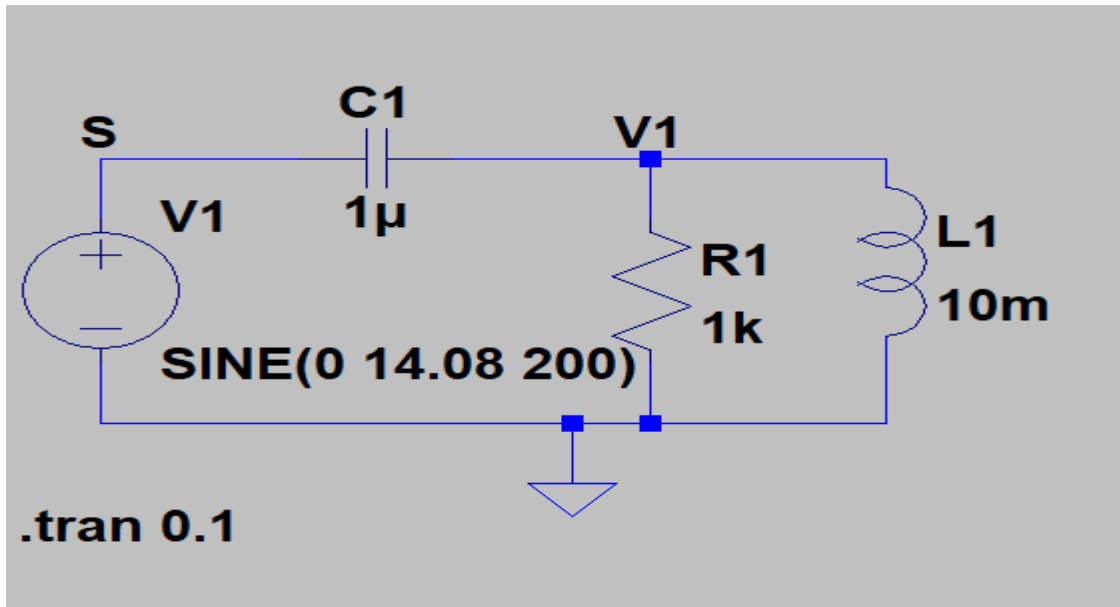
$$Z_p = \frac{(jX_L) \cdot (-jX_C)}{jX_L - jX_C}, \quad Z_{total} = R + Z_p$$

$$|V_{in}| = \sqrt{(V_1)^2 + (V_R)^2}$$



Simulation :

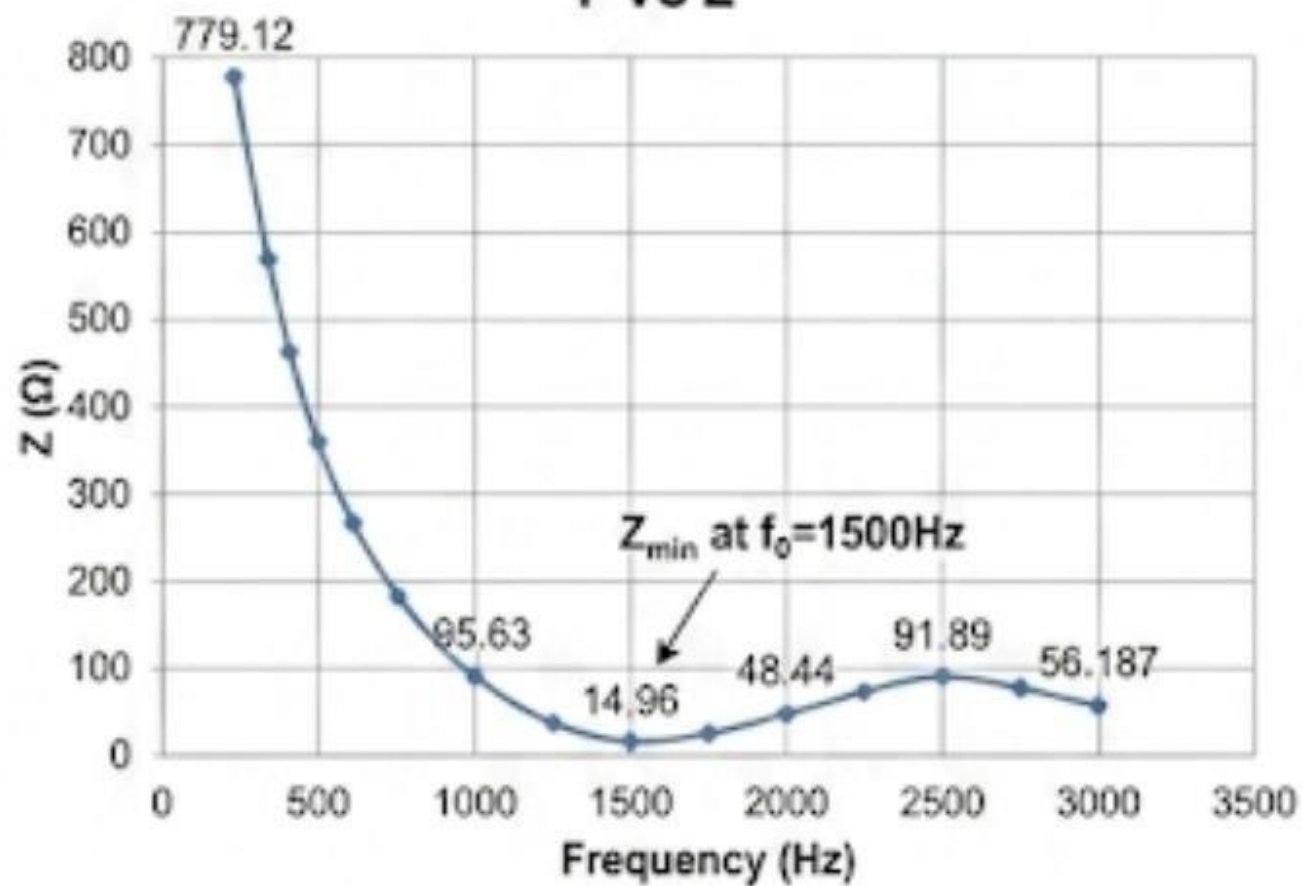
Question 1: RL-Parallel with C-Series circuit.

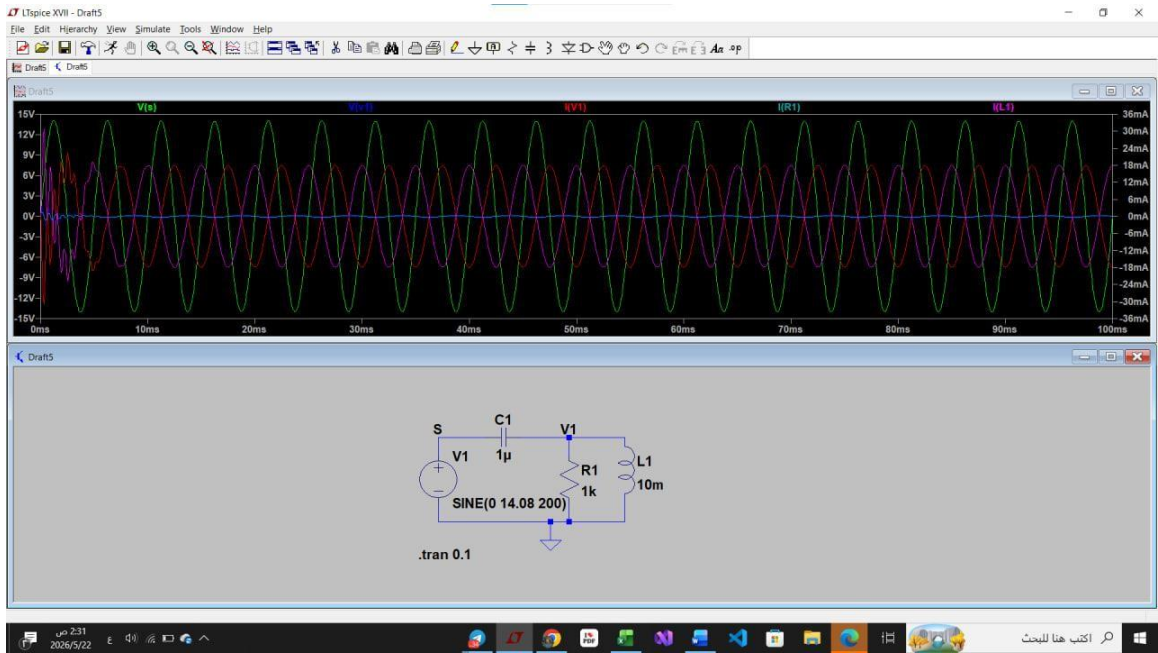


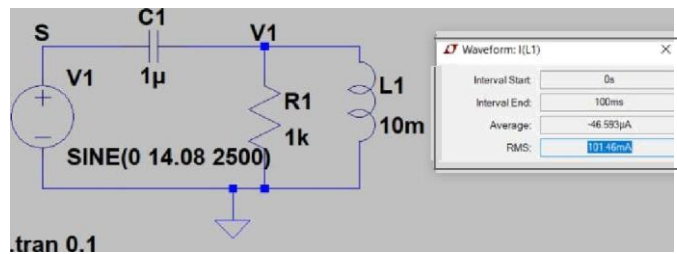
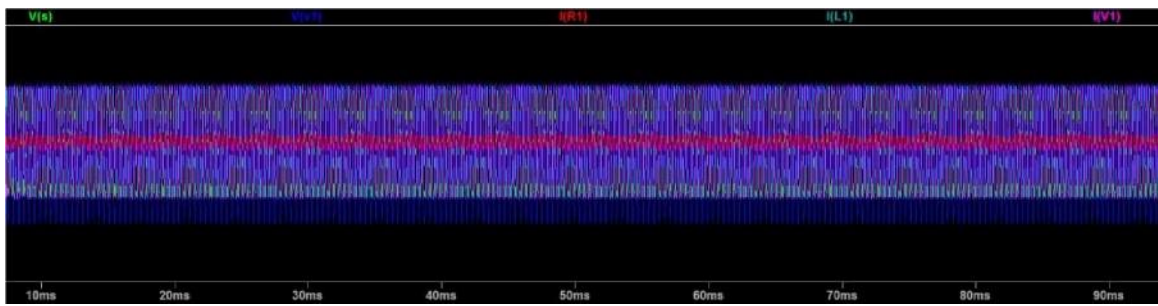
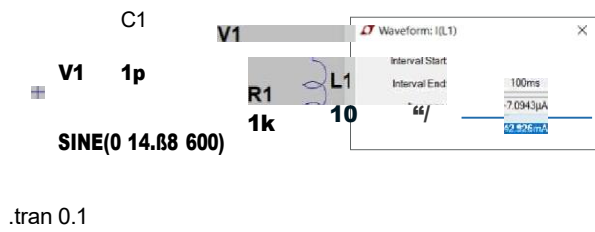
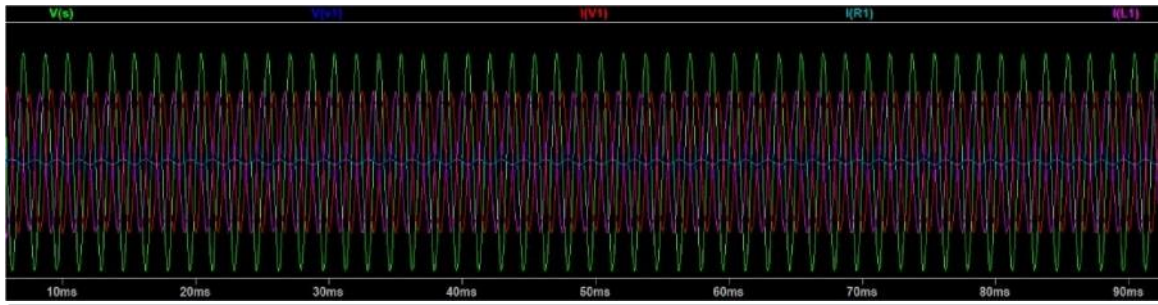
Frequency (Hz)	VC(V)	VR (v)	VS (v)	Ir (mA)	IL (mA)	IS (mA)	S calculated (V)	calculated (m)	Z = V/I (Ω)
200	9.9077V	200.79mV	9.9097V	0	12.716mA	12.719mA	9.91	12.716	779.12
400	9.7892V	715.36mV	9.8153V	0	26.442mA	26.455mA	9.815	26.442	370.99
600	9.6081V	1.6969V	9.7566V	1.6969mA	42.926mA	42.955mA	9.757	42.959	227.14
800	9.1415V	3.4143V	9.7575V	3.4143mA	65.922mA	65.968mA	9.758	66.01	147.91
1,000	7.2285V	6.5537V	9.7591V	6.5537mA	101.82mA	102.05mA	9.757	102.03	95.63
1,500	62.1820V	62.972V	9.939V	62.972mA	662.39mA	664.56mA	88.497	665.38	14.96
2,000	23.5350V	25.479V	9.7614V	25.479mA	199.76mA	201.53mA	34.685	201.38	48.44
2,500	12.9030V	16.177V	9.7516V	16.177mA	101.46mA	102.77mA	20.692	102.74	94.89
3,000	7.4110V	12.24V	9.752V	12.24mA	54.838mA	56.193mA	14.305	56.187	173.54

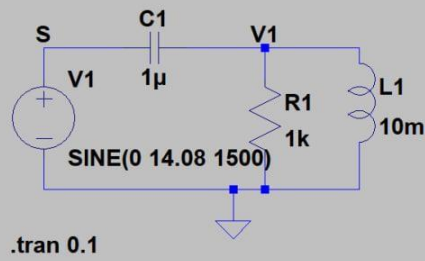
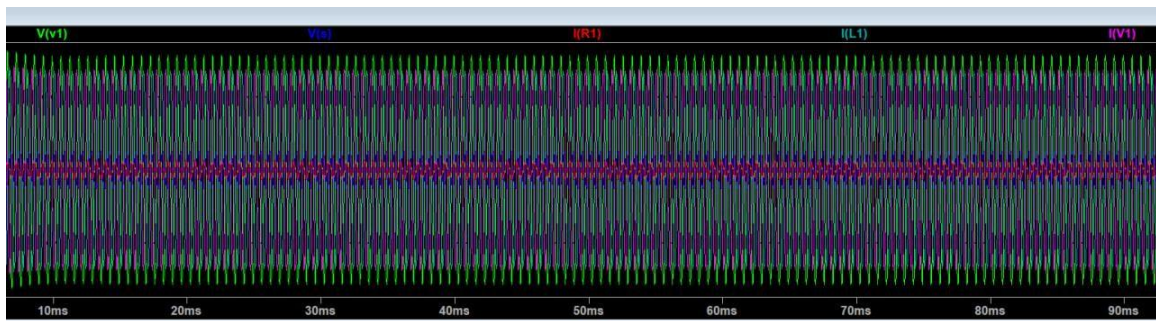
$$f_0 = 1500 \text{ Hz}$$

F VS Z

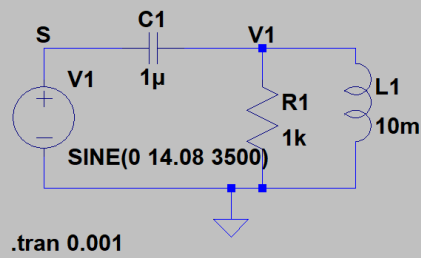
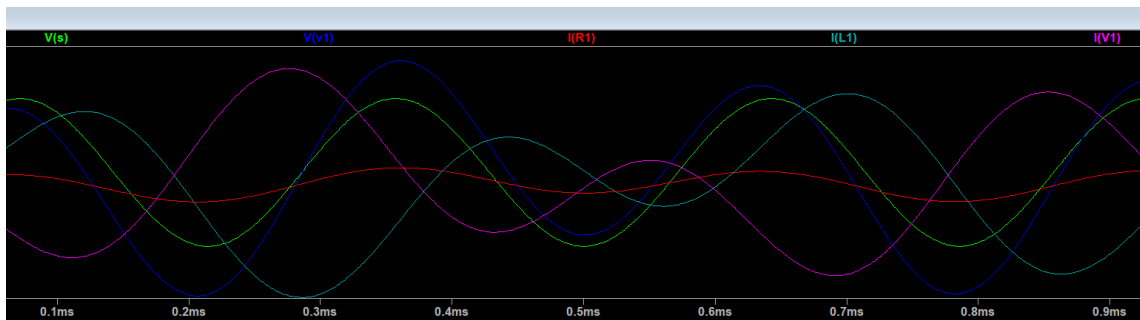








Waveform: I(R1)	
Interval Start:	0s
Interval End:	100ms
Average:	69.735 μ A
RMS:	62.972mA



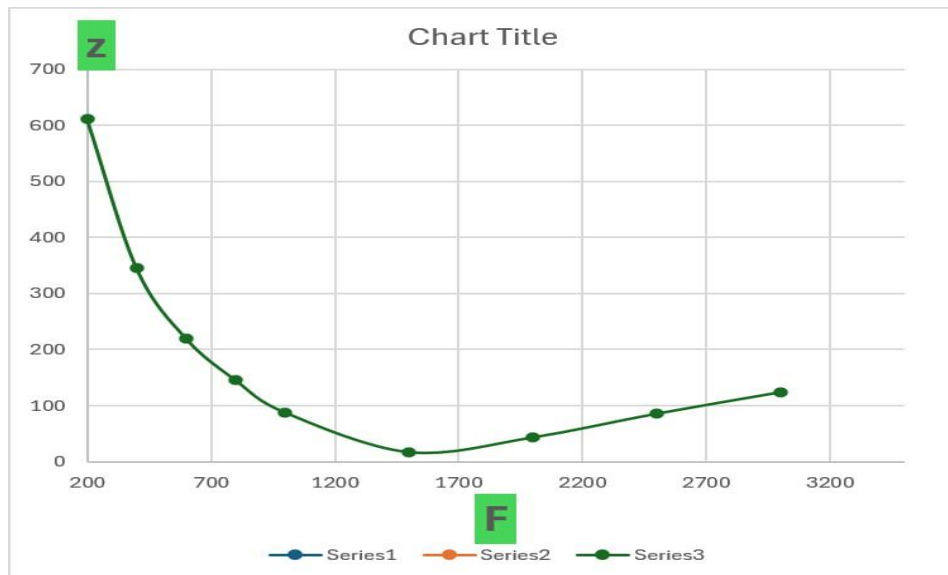
Conclusion

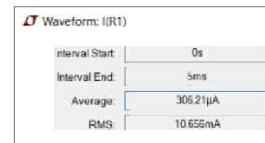
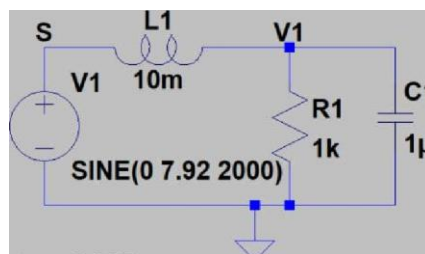
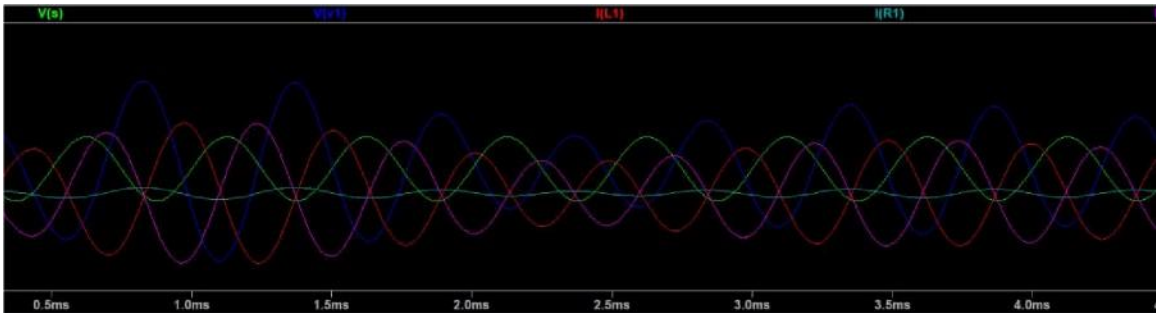
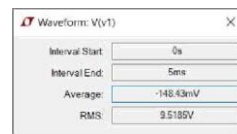
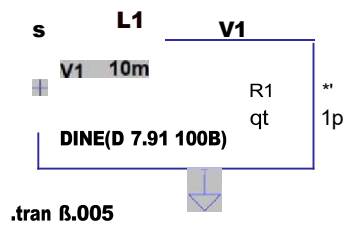
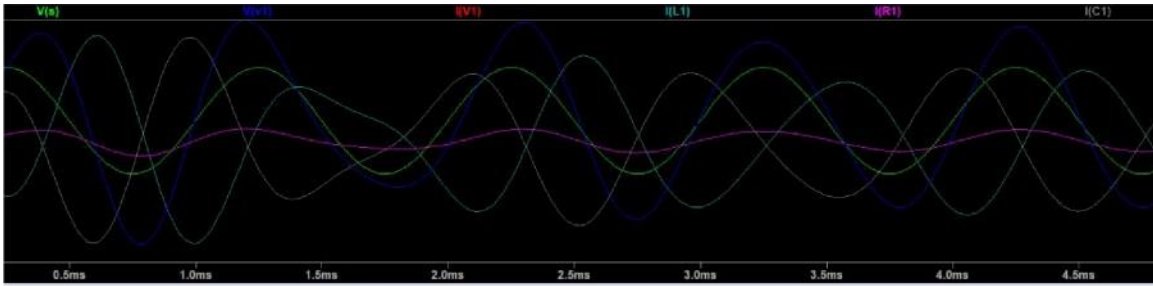
- **Voltage and Current Relations:** The resistor and inductor are in parallel, sharing the same voltage. The capacitor is in series, carrying the total circuit current.
- **Zero Resistor Current:** At low frequencies, the resistor current is zero because the inductor acts as a short circuit, pulling all the current through itself and leaving nothing for the resistor.
- **Resonance Point:** At 1500 Hz, the circuit reaches resonance. Total impedance drops to its minimum, causing the total current and component voltages to peak sharply.
- **Impedance Curve:** The curve is U-shaped. It is high at low frequencies due to the capacitor, drops at resonance, and rises again at high frequencies due to the inductor.
- **Simulation Difference:** The voltage difference at resonance happens because the manual uses a simplified formula assuming a fixed ninety-degree angle, while the simulation calculates the real shifting angles

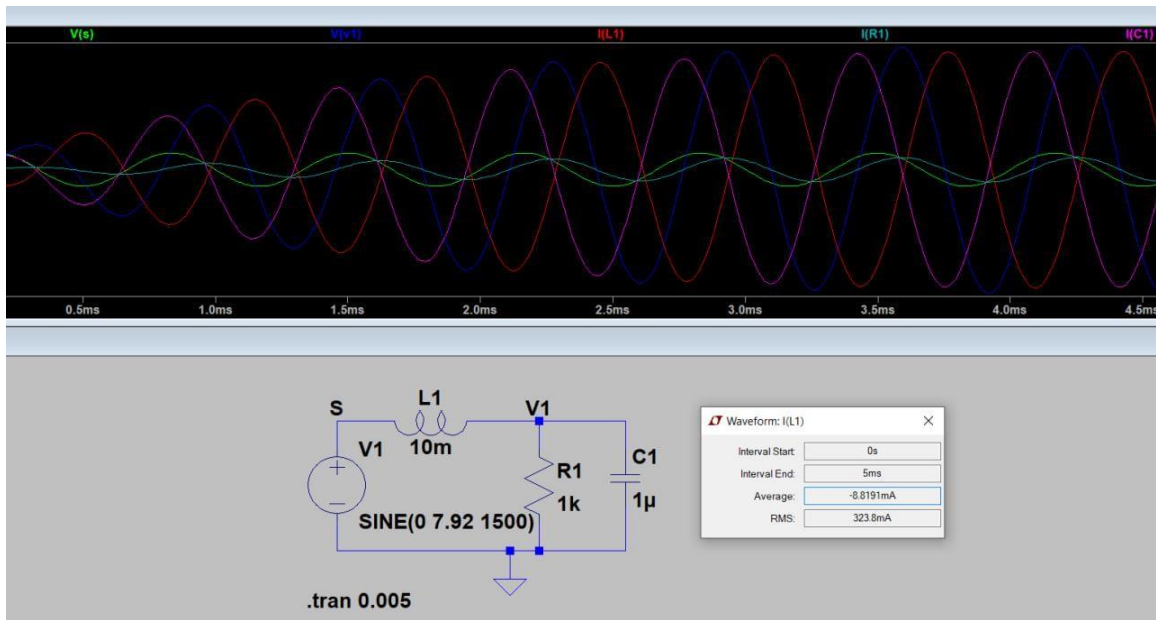
Question 2 Parallel RC >> Series with L

Frequency (Hz)	VL (V)	VR (V)	VS (V)	Ir (mA)	IC (mA)	IS (mA)	VS calculated (V)	IS calculated	Z=V/I (Ω)
200	1.1147	5.5739	5.5739	5.6634	7.1528	9.1223	5.6646	9.1234	611.02
400	2.0913	5.523	5.523	5.8982	14.876	16.001	5.9068	16.0026	345.17
600	3.4326	5.5026	5.5026	6.4263	24.189	25.043	6.4446	25.0298	219.73
800	5.4741	5.5021	5.5021	7.3845	37.094	37.845	7.4461	37.8214	145.39
1000	9.4582	5.5972	5.5972	9.5185	62.924	63.642	9.6517	63.641	87.95
1500	44.0754	34.227	5.5903	34.227	321.52	323.8	44.4288	323.339	17.26
2000	18.567	10.656	5.589	10.656	128.08	128.53	19.3878	128.522	43.48
2500	9.7341	4.6145	5.5893	4.6145	64.969	65.133	11.2332	65.1326	85.81
3000	7.0125	2.8436	5.5845	2.8436	44.927	45.017	9.1969	44.0169	124.05

Resonance Frequency=1500HZ



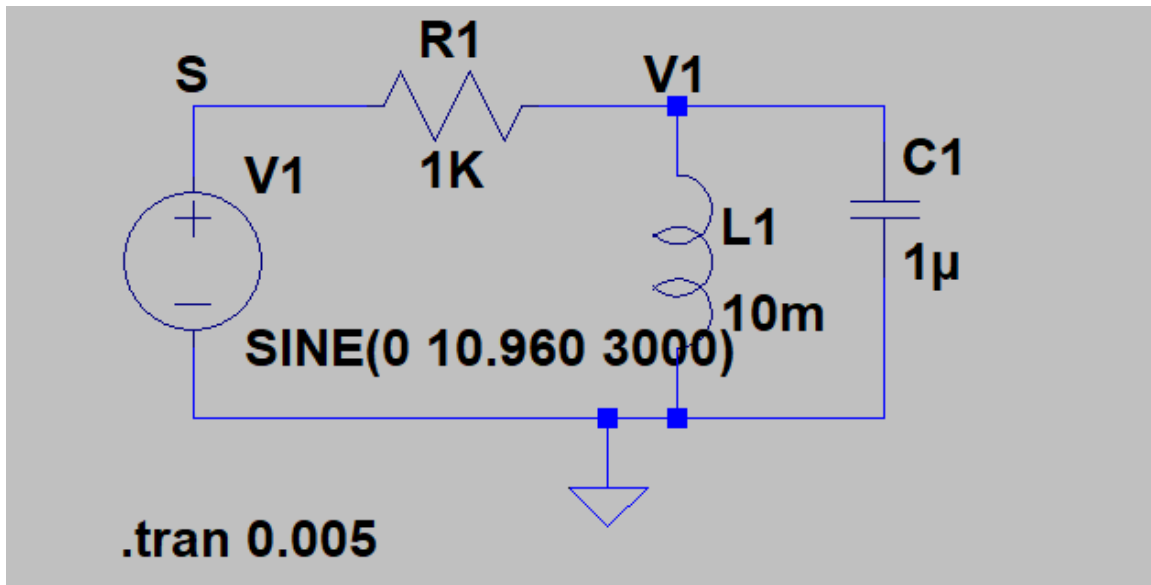




Conclusion

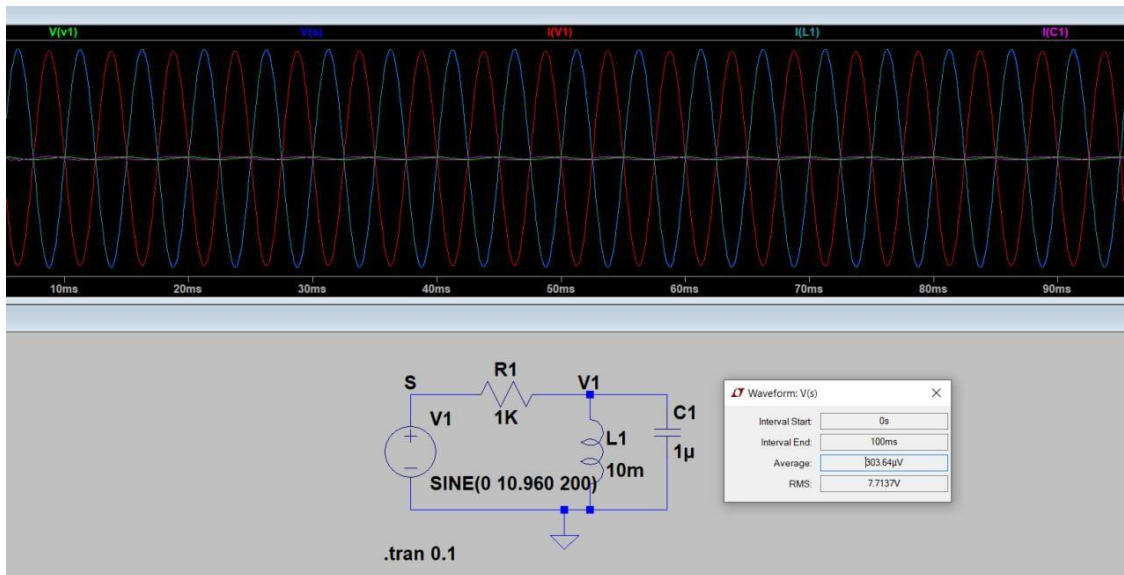
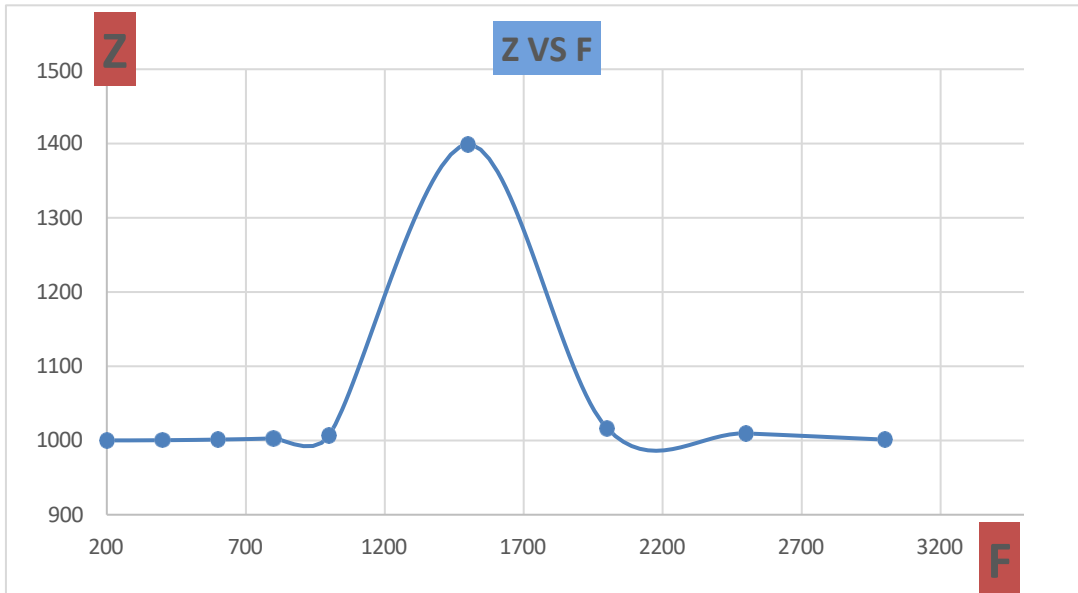
- **Voltage and Current:** V_R and V_C are equal because they are in parallel. I_L and I_S are also equal because the inductor is in series with the source.
- **Resonance Point:** At **1500 Hz**, the circuit reaches resonance. The total impedance drops to the lowest point, making the total current reach its highest value, and the parallel voltage magnifies.
- **Impedance Curve:** The curve looks like a U-shape. It is high at first because of the capacitor, goes to the lowest point at resonance, and then goes up again because of the inductor.
- **Simulation Error:** The difference between our calculations and the simulation is **very small**, which proves our results are correct.

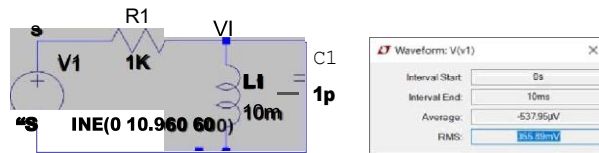
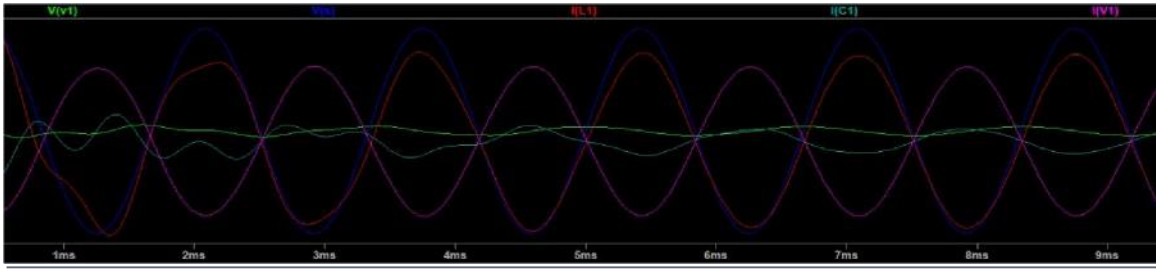
Question 3 LC-Parallel with R-Series circuit



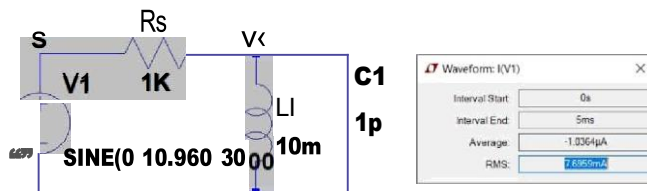
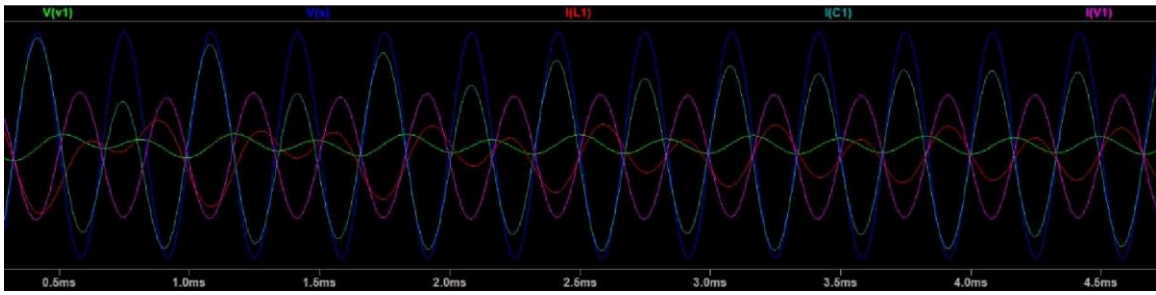
Frequency (Hz)	VL (V)	VR (v)	VS (v)	IL (mA)	IC (mA)	IS (mA)	VS calculated (V)	IS calculated (mA)	Z=V/I (Ω)
200	98.981mV	7.7137 V	7.7137V	7.8376mA	156.29μA	7.713mA	7.7143 V	7.6813 mA	1000.09
400	205.94mV	7.6414 V	7.6414V	8.1605mA	556.7μA	7.6385mA	7.6442 V	7.6038 mA	1000.38
600	335.11mV	7.5951 V	7.5951V	8.8691mA	1.3194mA	7.5857mA	7.6025 V	7.5497 mA	1001.24
800	543.53mV	7.7399 V	7.7399V	10.454mA	3.0821mA	7.7173mA	7.7590 V	7.3719 mA	1002.93
1,000	835.03mV	7.7355 V	7.7355V	12.937mA	5.6114mA	7.6819mA	7.7804 V	7.3256 mA	1006.98
1,500	4.8054V	7.7065 V	7.7065V	53.176mA	47.871mA	5.5093mA	9.0805 V	5.3050 mA	1398.82
2,000	1.5653V	7.5897 V	7.5897V	12.518mA	21.519mA	7.4686mA	7.7494 V	9.0010 mA	1016.21
2,500	899.07mV	7.7347 V	7.7347V	6.3857mA	13.391mA	7.6618mA	7.7867 V	7.0053 mA	1009.51
3,000	621.71mV	7.7048 V	7.7048V	3.9351mA	10.995mA	7.6959mA	7.7298 V	7.0599 mA	1001.16

Resonance Frequency=1500HZ

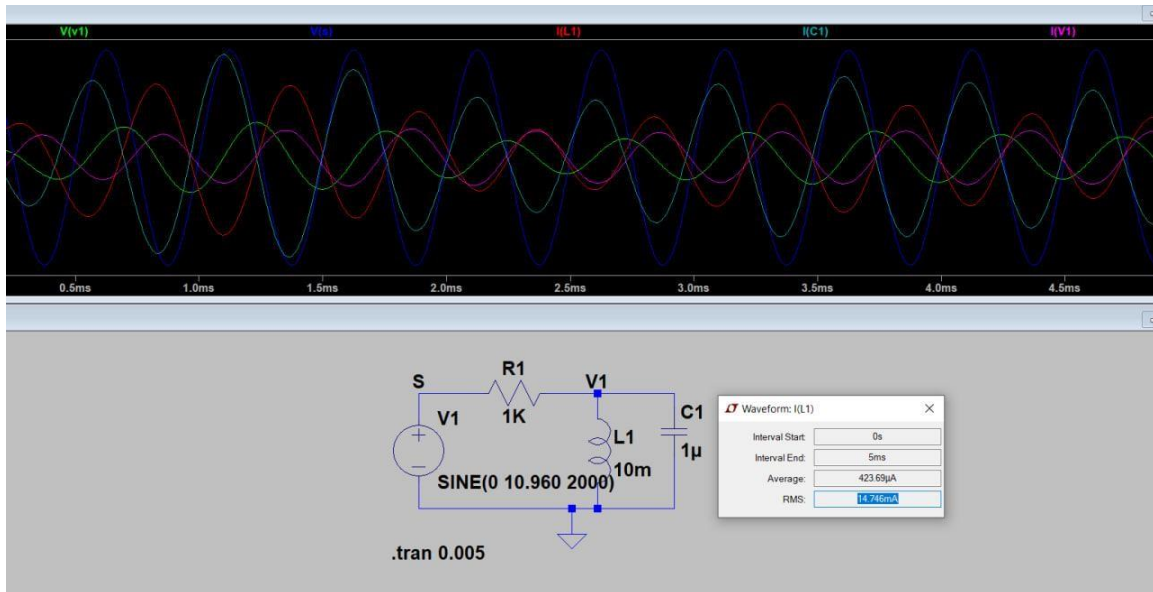




.tran 0.01



.tran 0.005



Conclusions

- **Resonance Frequency Constancy:** The resonance frequency is completely constant because it depends solely on the inductor (L) and capacitor (C) values, regardless of any changes in resistance or voltage.
- **Internal Current Amplification:** At resonance, the inductor and capacitor exchange energy rapidly, forcing their internal branch currents (IL and IC) to reach their maximum peak values.
- **Practical vs. Ideal Discrepancy:** The slight difference between theoretical calculations and simulation results occurs because the software includes the internal parasitic resistance of the inductor's copper wire.

Why Total Current (I_s) is Minimum at Resonance?

- **Maximum Impedance:** At the resonance frequency, the parallel LC network reaches its maximum possible impedance, acting as a major bottleneck for the current.
- **Open-Circuit Behavior:** Physically, the parallel resonance combination behaves like an open circuit, blocking the current coming from the source and forcing the total current to drop to its lowest value.
- **Source Role:** At this specific point, the source does not supply large currents to the components; it only delivers a minimal current to cover the small thermal losses in the circuit.

THE END