K. J. SOMAIYA COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRONICS ENGINEERING
ELECTRONIC CIRCUITS
AC CIRCUITS

Numerical 1:
A series RLC circuit containing an inductance of 0.4H, a resistance of 10Ω, and a capacitor of 20μF are connected across a 220V, 60Hz supply. Find,
a. current drawn by the circuit,
b. V_R, V_L and V_C
c. Power Factor
d. Draw the Voltage Phasor Diagram

SOLUTION:

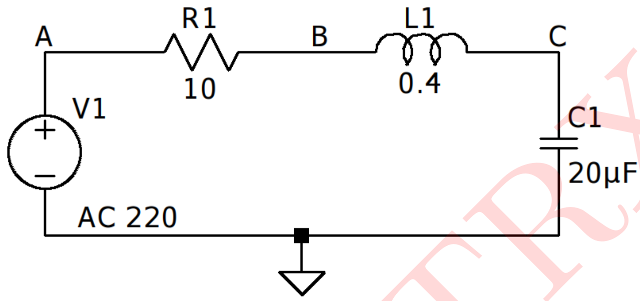


Figure 1: Series RLC Circuit

$$X_L = 2\pi \times f \times \mathrm{L}_1$$
$$= 2\pi \times 60 \times 0.4$$
$$= 150.78\Omega$$
$$X_C = \frac{1}{2\pi \times f \times C_1}$$
$$= \frac{1}{2\pi \times 60 \times 20 \times 10^{-6}}$$
$$= 132.63\Omega$$
$$\mathrm{Z} = \sqrt{R_1^2 + (X_L - X_C)^2} = 20.7225\Omega$$
$$\mathrm{I} = \frac{V_1}{Z}$$
$$= \frac{220}{20.7225}$$
$$= 10.6164\mathrm{A}$$

$$V_{R_1} = \mathrm{I} \times \mathrm{R}_1 = 106.164\mathrm{V}$$
$$V_{L_1} = \mathrm{I} \times \mathrm{X}_L = 1600.7518\mathrm{V}$$
$$V_{C_1} = \mathrm{I} \times \mathrm{X}_C = 1408.053132\mathrm{V}$$
$$\text{Power Factor} = \cos\phi = \frac{R_1}{Z} = \frac{10}{20.7225} = 0.48256$$
$$\therefore \phi = \cos^{-1}(0.48256) = 61.14679166°$$

SIMULATED RESULTS:
The given circuit is simulated in LTSpice and the results obtained are as follows:

For V_{C_1}:

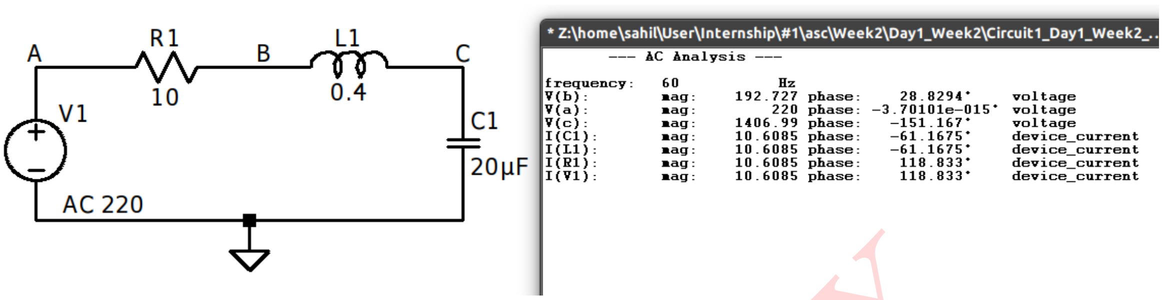


Figure 2: Circuit Schematic and Simulated Results to find V_C

For V_{L_1}:

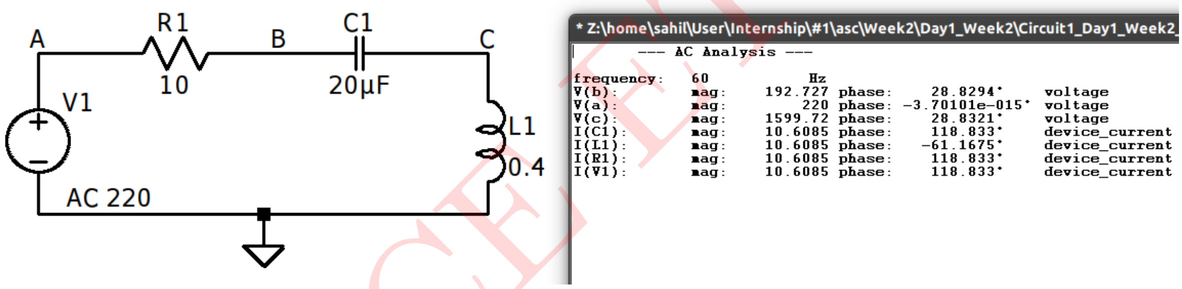


Figure 3: Circuit Schematic and Simulated Results to find V_L

For V_{R_1}:

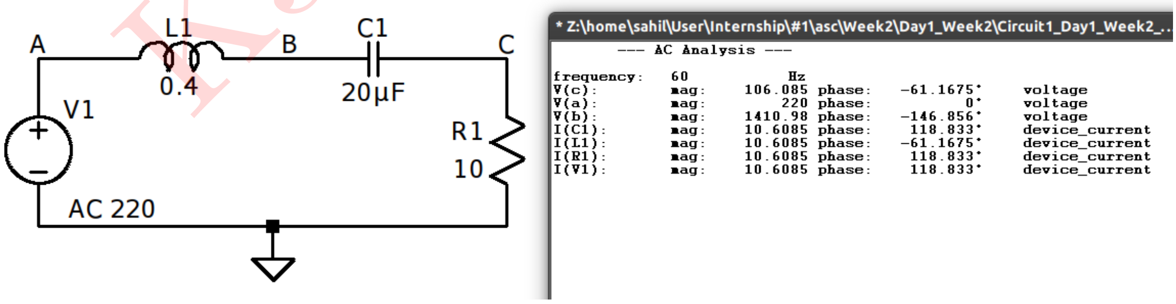


Figure 4: Circuit Schematic and Simulated Results to find V_R

Phasor Diagram:

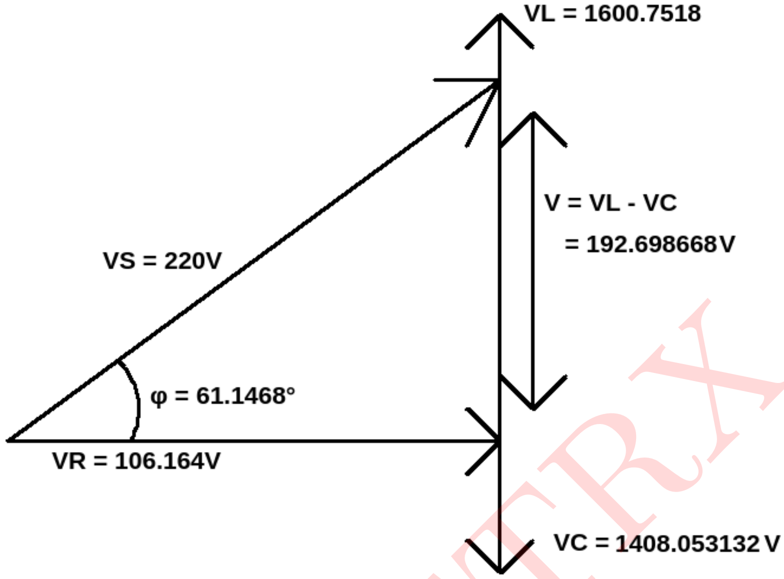


Figure 5: Phasor Diagram for the given circuit

Comparison of theoretical and simulated values:

Parameters	**Theoretical Values**	**Simulated Values**
V_{R_1}	106.164V	106.085Va
V_{L_1}	1600.7518V	1599.72V
V_{C_1}	1408.053132V	1406.99V
I	10.6164A	10.6085A

Table 1: Numerical 1

Numerical 2:
In given RL circuit $R_1 = 10\Omega$ and $L_1 = 0.4$H, then find,
a. the current through the circuit.
b. Power Factor,
if a 60Hz A.C. voltage $V_1 = 120\ \angle 60°$ is applied across the circuit.

SOLUTION:

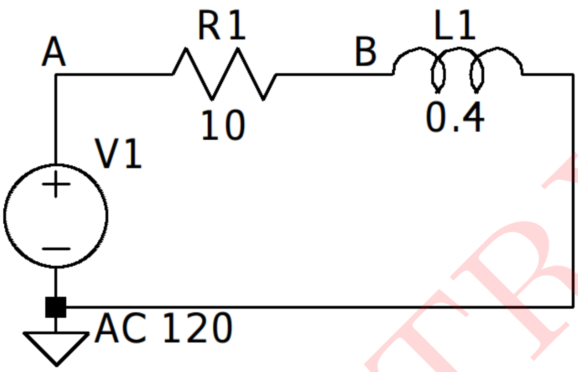


Figure 6: Series RL Circuit

$$X_L = 2\pi\ \times f \times \mathrm{L}_1$$
$$= 2\pi\ \times 60 \times 0.4$$
$$= 150.7964\Omega$$

$$\mathrm{Z} = \sqrt{R_1^2 + X_L^2}$$
$$= 151.1276565\Omega$$

$$\mathrm{I} = \frac{V_1}{Z}$$
$$= \frac{120}{151.1276565}$$
$$= 0.794\mathrm{A}$$

$$\phi = \tan^{-1}\left(\frac{X_L}{R_1}\right)$$
$$= 56.44982741°$$

Power Factor $= \cos\phi = 0.552664$

SIMULATED RESULTS:
The given circuit is simulated in LTSpice and the results obtained are as follows:

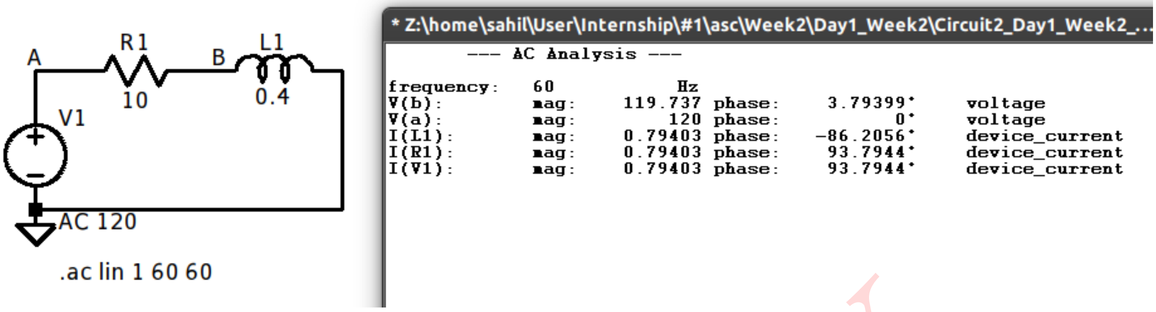


Figure 7: Circuit Schematic and Simulated Results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	0.794A	0.79403A

Table 2: Numerical 2

Numerical 3:
A voltage $V_1 = 200\ \sin 314t$ is applied to a circuit consisting of a 10Ω resistor and a 120µF capacitor in series. Determine,
a. an expression for the value of the current flowing at any instant.
b. V_{R_1} and V_{C_1}
c. Power Factor

SOLUTION:

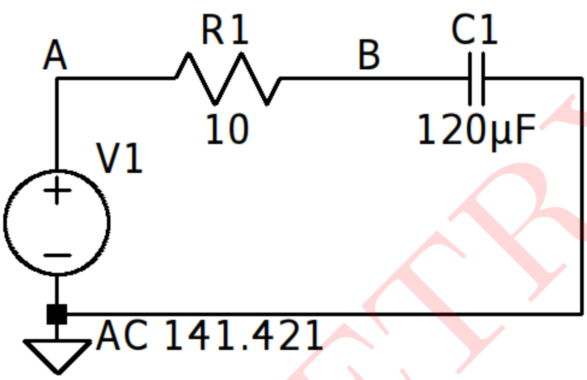


Figure 8: Series RC Circuit

$V_1 = 200\ \sin 314t$
Comparing with, $V_1 = V_0\ \sin\omega$t
$\omega = 314$

$2\pi \times f = 314$

$\therefore$ f = 50Hz

$$V_{RMS} = \frac{V_0}{\sqrt{2}} = 141.421V$$

$$I_{RMS} = \frac{V_{RMS}}{R} = 1.414V$$

$$X_{C_1} = \frac{1}{\omega C_1}$$

$$= \frac{1}{314 \times 12 \times 10^{-6}}$$

$$= 25.53928\Omega$$

$$\text{Z} = \sqrt{R_1^2 + X_{C_1}^2}$$

$$= 28.3605\Omega$$

$$\text{I} = \frac{V_{RMS}}{Z}$$

$$= 4.986546454\text{A}$$

$$\phi = \tan^{-1}\left(\frac{X_{C_1}}{R_1}\right)$$

$$= 1.21 rad$$

Thus, the equation for instantaneous current is,

$I = 4.98 \sin(314t + 1.21)$

Now,

$V_{R_1} = \mathrm{I} \times \mathrm{R}_1$

$\quad = 49.86546454\mathrm{V}$

$V_{C_1} = \mathrm{I} \times \mathrm{X}_{C_1}$

$\quad = 132.3393526\mathrm{V}$

$$\text{Power Factor} = \frac{R_1}{Z}$$

$$= \frac{10}{28.3605}$$

$$= 0.3526$$

SIMULATED RESULTS:

The given circuit is simulated in LTSpice and the results obtained are as follows:

For V_{C_1}:

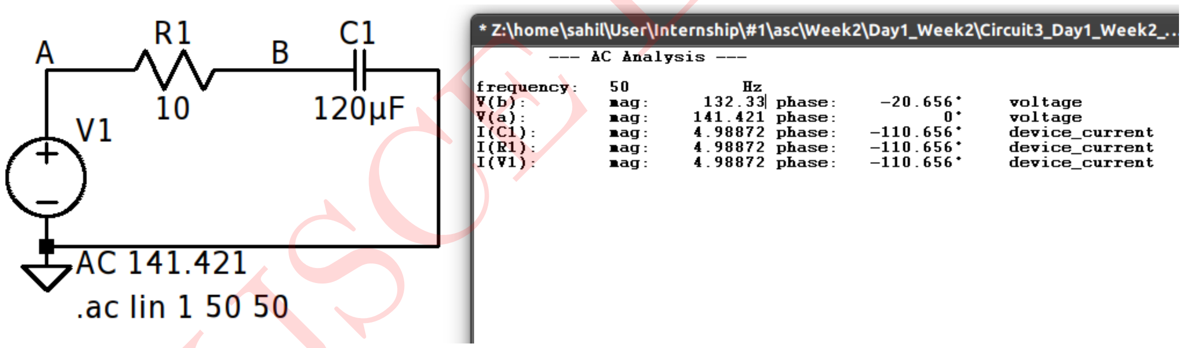
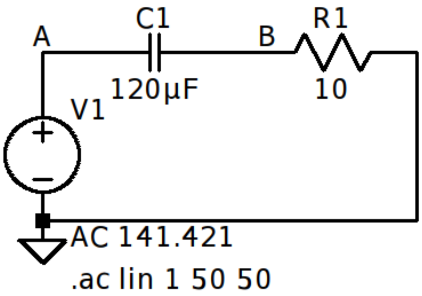


Figure 9: Circuit Schematic and Simulated Results to find V_C

For V_{R_1}:



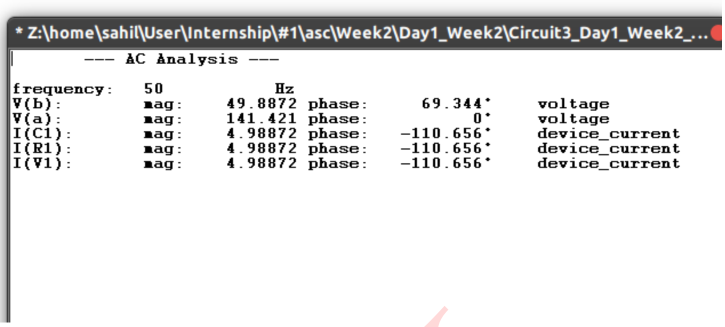


Figure 10: Circuit Schematic and Simulated Results to find V_R

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
V_{R_1}	49.8654V	49.8872V
V_{C_1}	132.339V	132.33V

Table 3: Numerical 3

Numerical 4:
A circuit consists of a resistance of 55Ω, an inductance of 74mH and a capacitor of 90μF are connected in parallel across a 110V, 50Hz supply. Calculate,
a. Individual currents drawn by each element,
b. Total current drawn by the supply,
c. Overall power factor of the circuit
d. Phasor Diagram

SOLUTION:

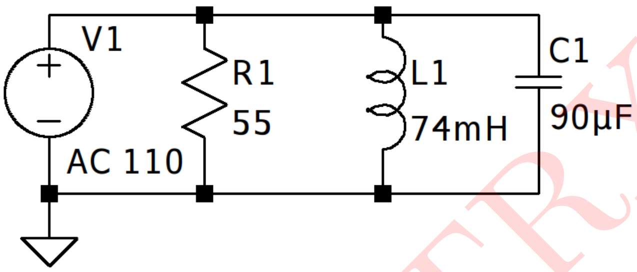


Figure 11: Parallel RLC Circuit

$X_{L_1} = 2\pi \times f \times \mathrm{L}_1 = 2\pi \times 50 \times 0.074 = 23.24778\Omega$

$$X_{C_1} = \frac{1}{2\pi \times f \times C_1} = \frac{1}{2\pi \times 50 \times 90 \times 10^{-6}} = 35.36776\Omega$$

$$\mathrm{Z} = \frac{1}{\sqrt{\left(\frac{1}{R_1}\right)^2 + \left(\frac{1}{X_{C_1}} - \frac{1}{X_{L_1}}\right)^2}} = 42.723328\Omega$$

Current through resistor, $I_{R_1} = \dfrac{V_1}{R_1} = \dfrac{110}{55} = 2A$

Current through inductor, $I_{L_1} = \dfrac{V_1}{X_{L_1}} = \dfrac{110}{23.24778} = 4.73163459A$

Current through capacitor, $I_{C_1} = \dfrac{V_1}{X_{C_1}} = \dfrac{110}{35.36776} = 3.110177A$

Total current, $I_S = \sqrt{I_{R_1}^2 + (I_{L_1} - I_{C_1})^2} = 2.574708666A$

Conductance, $\mathrm{G} = \dfrac{1}{R_1} = \dfrac{1}{55}$

Admittance, $\mathrm{Y} = \dfrac{1}{Z} = \dfrac{1}{42.72328}$

$\therefore \cos\theta = \dfrac{G}{Y} = \dfrac{42.72328}{55}$

$\theta = \cos^{-1}(0.776787) = 39.03267°$

This is the angle between supply current and voltage.

$$\text{Power Factor} = \cos\phi = \frac{Z}{R_1} = \frac{42.72328}{55} = 0.776787$$

$$\therefore \phi = \cos^{-1}(0.776787) = 39.03267°$$

SIMULATED RESULTS:

The given circuit is simulated in LTSpice and the results obtained are as follows:

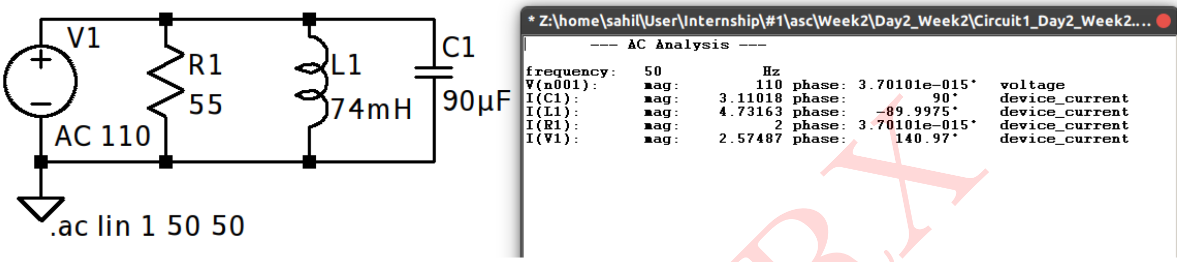


Figure 12: Circuit Schematic and Simulated Results

Phasor Diagram:

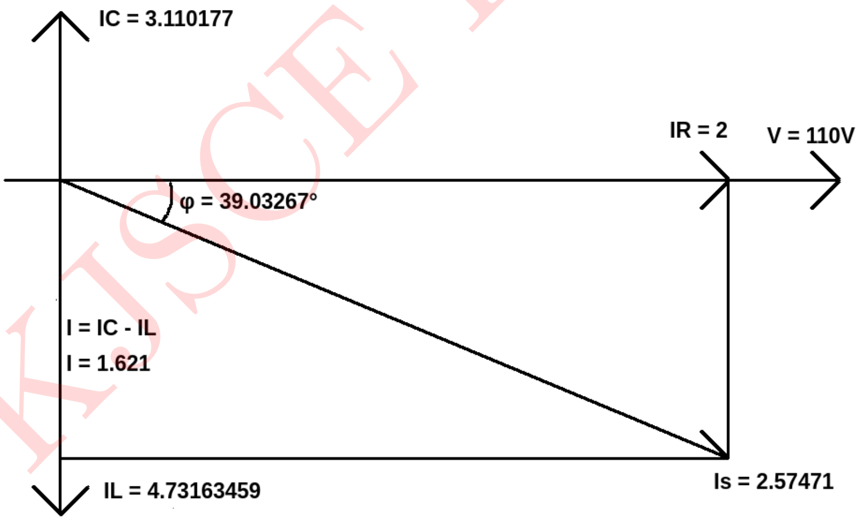


Figure 13: Phasor Diagram for the given circuit

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_S	2.54708666A	2.57487A
I_{L_1}	4.73163459A	4.73163A
I_{C_1}	3.110177A	3.11018A
I_{R_1}	2A	2A

Table 4: Numerical 4

Numerical 5:

Find I, I_1, I_2 and V(all branches) in the given figure 4, if, R_1 = 10Ω, L_1 = j10Ω, R_2 = 15Ω, L_2 = j25Ω, R_3 = 9Ω, C_1 = −j10Ω, V = 100V, frequency, f = 50Hz.

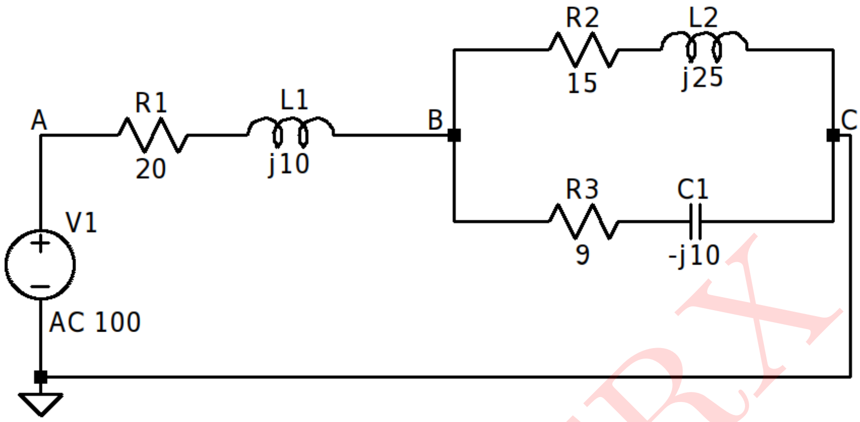


Figure 14: Circuit Diagram

SOLUTION:

Consider the following circuit,

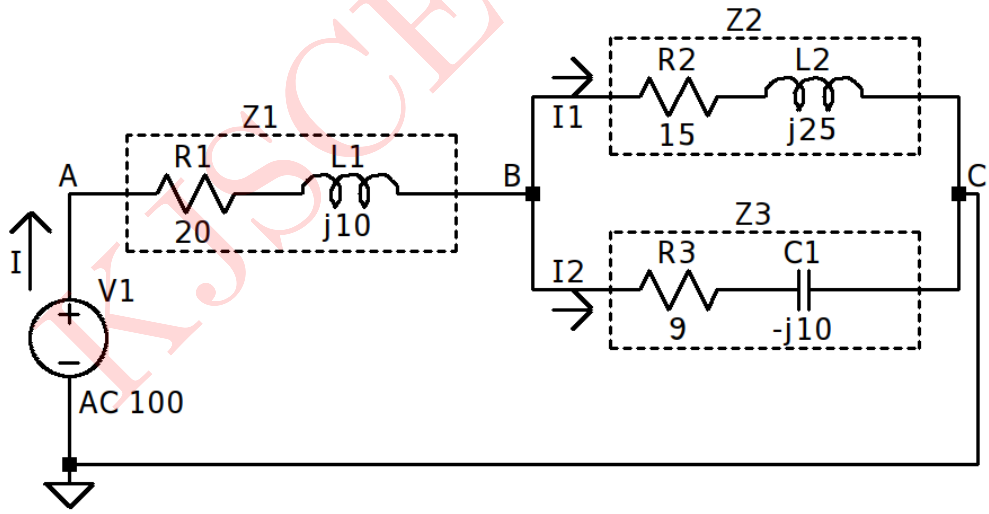


Figure 15: Modified Circuit Diagram

L_1 = j10Ω
X_{L_1} = 10Ω
$\therefore$ 2π ×f×L$_1$ = 10
$\therefore L_1$ = 0.031847H

L_2 = j25Ω
X_{L_2} = 25Ω
$\therefore$ 2π ×f×L$_2$ = 25
$\therefore L_2$ = 0.079577H

C_1 = −j10Ω
X_C = 10Ω
$\therefore \frac{1}{2}\pi \times f \times C = 10$
$\therefore$ C = 3.1831mF

Now,

Z_1 = 20 + j10 = 22.36068Ω∠26.565°

Z_2 = 15 + j25 = 29.15476Ω∠59.036°

Z_3 = 9 − j10 = 13.453624Ω∠−48.0127°

$$\therefore Z = Z_1 + \frac{Z_2 \times Z_3}{Z_2 + Z_3}$$

$$\therefore Z = 20 + j10 + \frac{(15 + j25) \times (9 - j10)}{(15 + j25) + (9 - j10)}$$

$\therefore$ Z = 32.941 + j5.03715092 = 33.3239Ω∠8.694°

$$I = \frac{V}{Z} = \frac{100\angle 0^\circ}{33.3239\angle 8.694^\circ} = 3.00085A\angle{-8.7}^\circ$$

V_{AB} = I × Z$_1$ = 3.00085 × 22.36068 = 67.1010V $\quad\quad \because$ Z$_1$ = Z_{AB}

Now,

$$y_2 = \frac{1}{Z_2} = \frac{1}{29.15476\angle 59.036^\circ} = 0.0343\angle{-59.036}^\circ$$

$$y_3 = \frac{1}{Z_3} = \frac{1}{13.453624\angle -48.0127^\circ} = 0.07433\angle 48.0127^\circ$$

$y_{BC} = y_2 + y_3 = 0.07214\angle 20.99^\circ$

$$\therefore Z_{BC} = \frac{1}{y_{BC}} = 13.862\Omega\angle{-20.99}^\circ$$

V_{BC} = I × Z$_{BC}$ = 3.00085 × 13.862 = 41.5977V

$$\therefore I_1 = \frac{V_{BC}}{Z_2} = \frac{41.5977}{29.15476} = 1.4268A$$

$$\text{And, } I_2 = \frac{V_{BC}}{Z_3} = \frac{41.5977}{13.453624} = 3.091932A$$

SIMULATED RESULTS:

The given circuit is simulated in LTSpice and the results obtained are as follows:

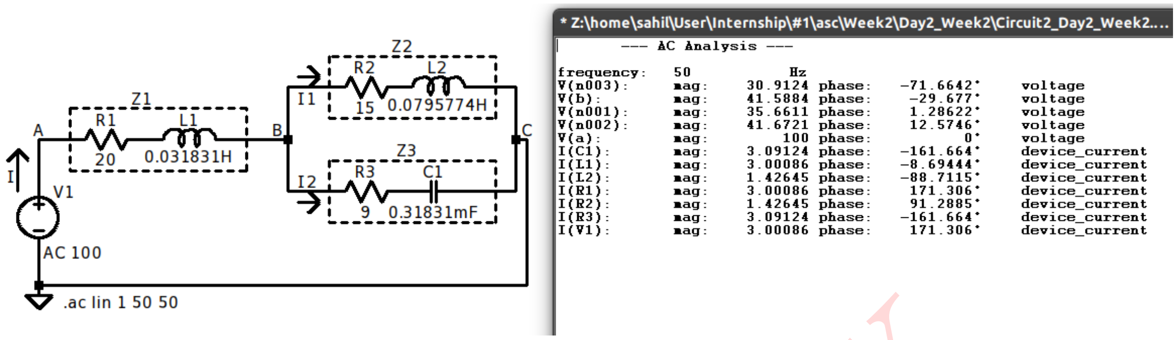


Figure 16: Circuit Schematic and Simulated Results

For V_{AB},

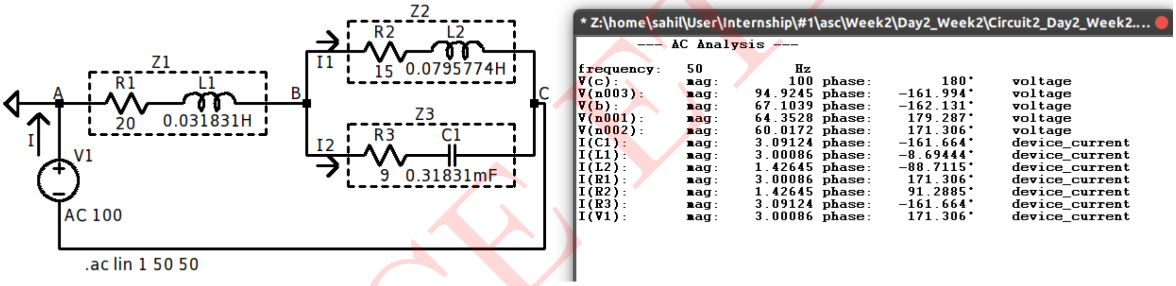


Figure 17: Circuit Schematic and Simulated Results for calculating V_{AB}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	3.00085A	3.00086A
I_1	1.4268A	1.42645A
I_2	3.091932A	3.09124A
V_{AB}	67.1010V	67.1039V
V_{BC}	41.5977V	41.5884V

Table 5: Numerical 5

Numerical 6:
A 60 Hz sinusoidal voltage $V_1 = 141 \sin \omega t$ is applied to a series R-L circuit.
The values of the resistance and the inductance are 3.3 and 0.0116 H respectively
Determine the following:

a. Calculate the peak voltage across resistor and inductor and also find the peak value of source current in LTSpice.
b. Plot input source voltage V_1 (t) Vs input source current I_1 (t) in LTSpice.
c. Measure the phase delay/difference between V_1 (t) Vs I_1 (t) in time and degrees
d. Plot input source voltage V_1 (t) Vs voltage across resistor V_{R_1} (t) in LTSpice.
e. Measure the phase delay/difference between V_1 (t) Vs V_{R_1} (t) in time and degrees
f. Plot input source voltage V_1 (t) Vs voltage across inductor V_{L_1} (t) in LTSpice.
g. Measure the phase delay/difference between V_1 (t) Vs V_{L_1} (t) in time and degrees
h. Calculate the power factor of the circuit.

SOLUTION:

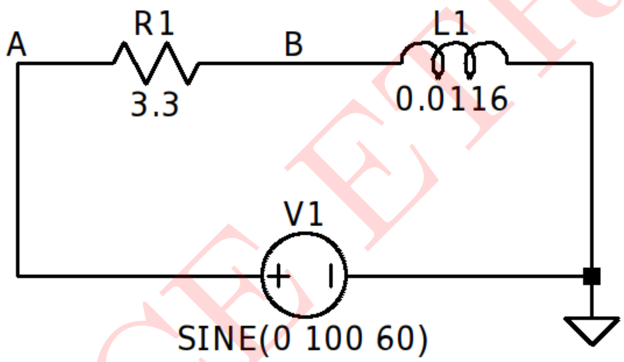


Figure 18: Series RL Circuit

$X_{L_1} = 2\pi \times f \times \mathrm{L}_1 = 2\pi \times 60 \times 0.0116 = 4.373\Omega$

$\mathrm{Z} = \sqrt{R_1^2 + X_{L_1}^2} = 5.4784\Omega$

$I_1 = \dfrac{V_1}{Z} = \dfrac{141}{5.4784} = 25.737A$

$V_{R_1} = R_1 \times \mathrm{I}_1 = 84.93\mathrm{V}$

$V_{L_1} = \mathrm{X}_{L_1} \times \mathrm{I}_1 = 112.5479\mathrm{V}$

Phase delay between V_1 and V_{R_1}, $\phi = \tan^{-1}\left(\dfrac{V_{L_1}}{V_{R_1}}\right) = 52.961°$

Phase delay between V_1 and V_{L_1}, $\theta = \tan^{-1}\left(\dfrac{V_{R_1}}{V_{L_1}}\right) = 37.03864°$

Phase delay between V_1 and I_1, $\angle = \tan^{-1}\left(\dfrac{\phi}{\theta}\right) = 55.032717°$

Power Factor $= \cos\phi = 0.602365$

SIMULATED RESULTS:
The given circuit is simulated in LTSpice and the results obtained are as follows:

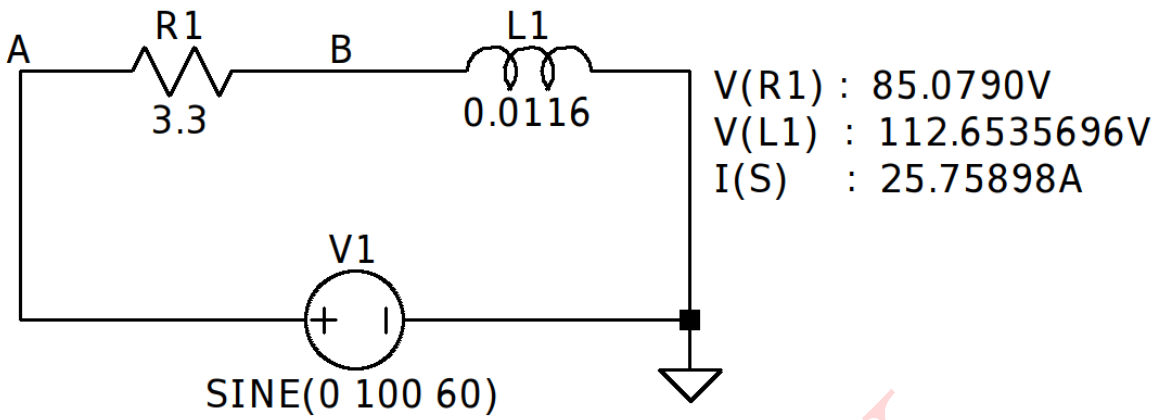


Figure 19: Circuit Schematic and Simulated Results

Waveforms:
Input source voltage V_1 Vs input source current I_1
$V_1 = V_a$ and $I_1 = I_{R1}$

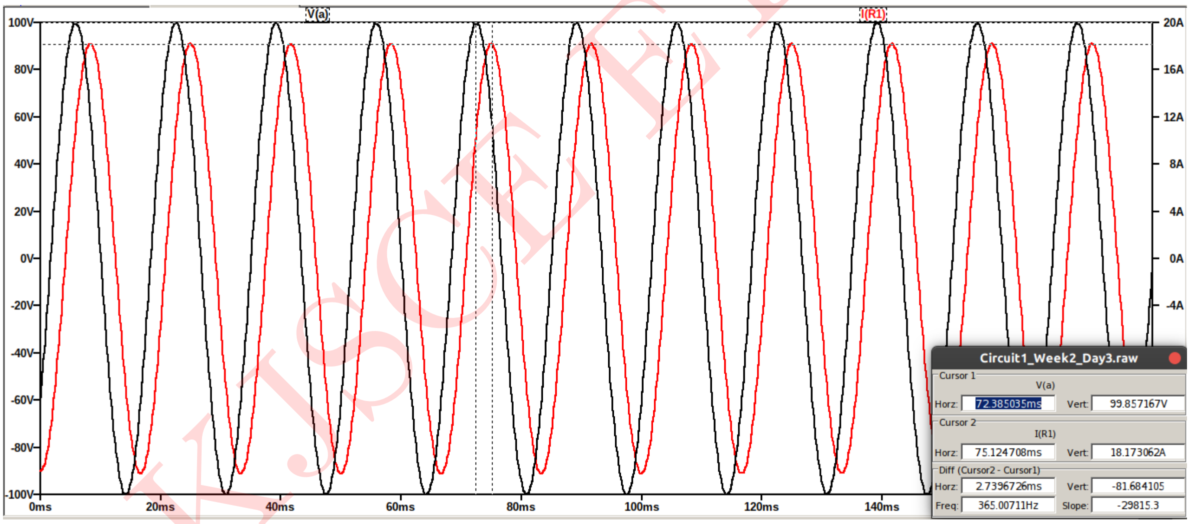


Figure 20: Simulated Waveform for V_1 Vs I_1

Input source voltage V_1 Vs voltage across inductor V_{L_1}
$V_1 = V_a$ and $V_{L_1} = V_b$

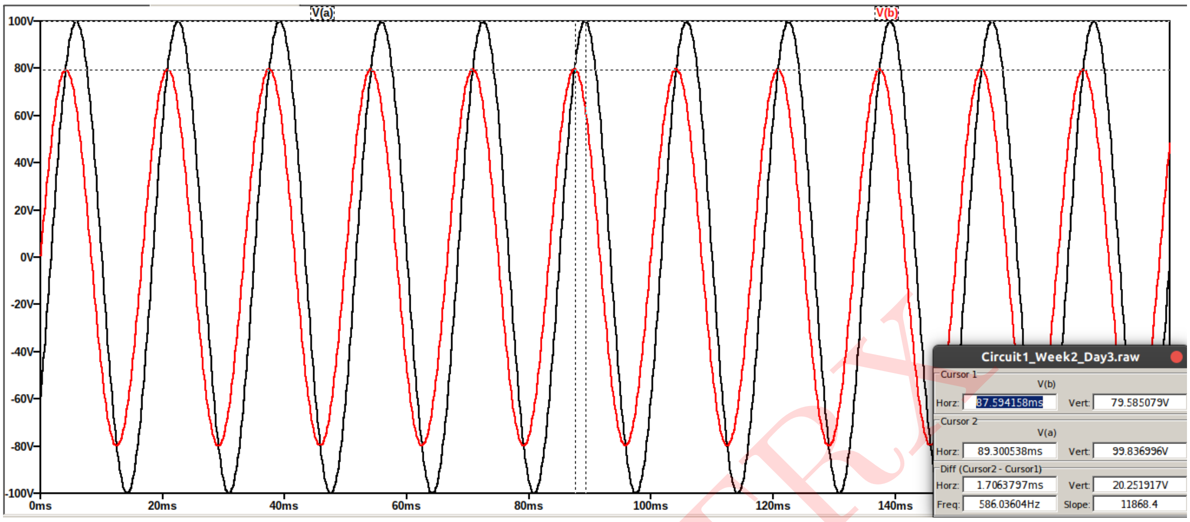


Figure 21: Simulated Waveform for V_1 Vs V_{L_1}

Input source voltage V_1 Vs voltage across resistor V_{R_1}
$V_1 = V_a$ and $V_{R_1} = V_{a,b}$

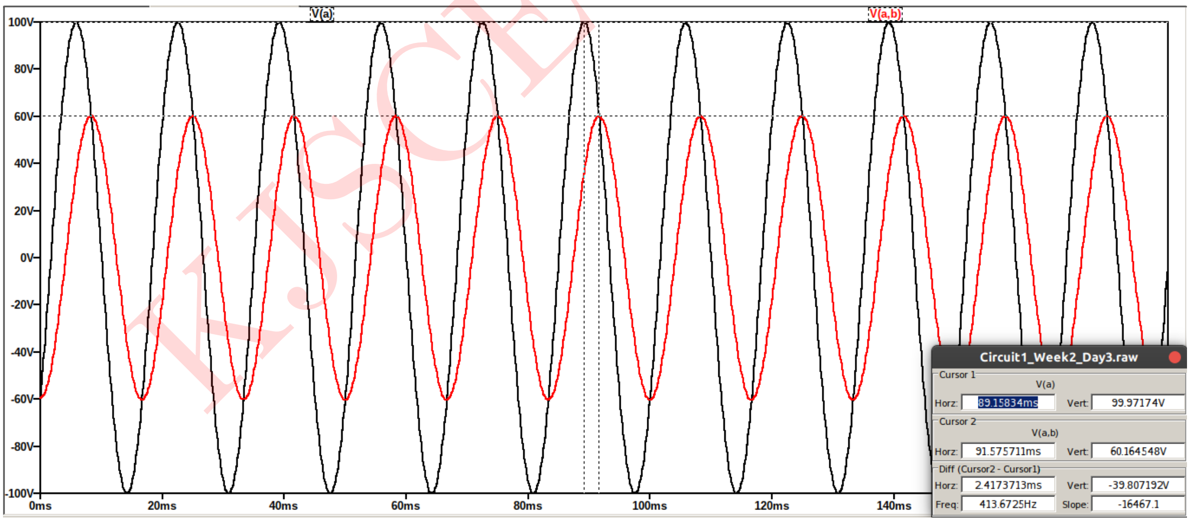


Figure 22: Simulated Waveform for V_1 Vs V_{R_1}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_1	25.737A	25.759A
V_{R_1}	84.93V	84.85V
V_{L_1}	112.5479V	112.653V
Phase delay between V_1 and V_{R_1}, ϕ	52.961°	50.9332°
Phase delay between V_1 and V_{L_1}, θ	37.03864°	38.098°
Phase delay between V_1 and I_1, $\angle$	55.032717°	55.1676°

Table 6: Numerical 6

Numerical 7:
A pure resistance of 33Ω is in series with a pure capacitance of 56µF.
The series combination is connected across 120V, 50 Hz supply.
Determine the following:

a. Calculate the peak voltage across resistor and capacitor and also find the peak value of source current in LTSpice.
b. Plot input source voltage V_1 (t) Vs input source current I_1 (t) in LTSpice.
c. Measure the phase delay/difference between V_1 (t) Vs I_1 (t) in time and degrees.
d. Plot input source voltage V_1 (t) Vs voltage across resistor V_{R_1} (t) in LTSpice.
e. Measure the phase delay/difference between V_1 (t) Vs V_{R_1} (t) in time and degrees.
f. Plot input source voltage V_1 (t) Vs voltage across capacitor V_{C_1} (t) in LTSpice.
g. Measure the phase delay/difference between V_1 (t) Vs V_{C_1} (t) in time and degrees.
h. Calculate the power factor of the circuit.

SOLUTION:

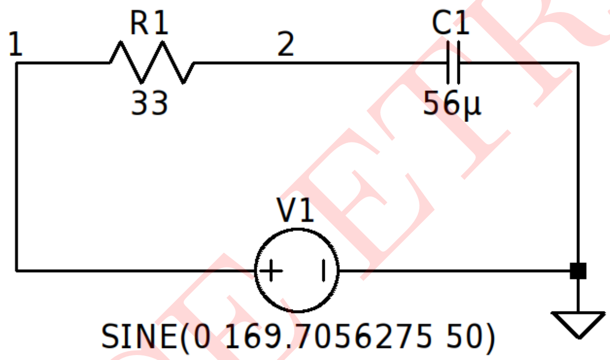


Figure 23: Series RC Circuit

$X_C = 2\pi \times f \times C_1 = 56.841\Omega$

$Z = \sqrt{R_1^2 + X_C^2} = 65.726\Omega$

$V_{max} = 120\sqrt{2}$

$I_{max} = \dfrac{V_{max}}{Z} = 2.582A$

$V_{R_m} = R_1 \times I_{max} = 85.2066V$

$V_{C_m} = X_C \times I_{max} = 146.763462V$

Power Factor $= \cos\phi = \dfrac{R_1}{Z} = 0.502084$

$\therefore$ Phase angle between V_1 and V_{R_1}, $\phi = 59.862°$

Phase angle between V_1 and V_{C_1}, $\theta = \tan^{-1}\left(\dfrac{V_{C_1}}{V_{R_1}}\right) = 30..1382°$

Phase angle between V_1 and I_1, $\angle = \tan^{-1}\left(\dfrac{\phi}{\theta}\right) = 63.27651°$

SIMULATED RESULTS:
The given circuit is simulated in LTSpice and the results obtained are as follows:

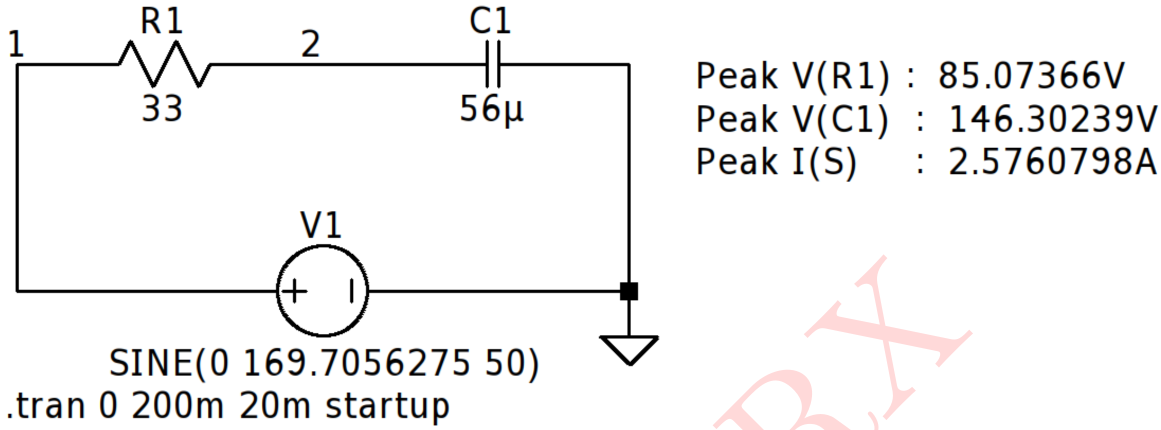


Figure 24: Circuit Schematic and Simulated Results

Waveforms:
Input source voltage V_1 Vs input source current I_1
$V_1 = V_1$ and $I_1 = I_{R1}$

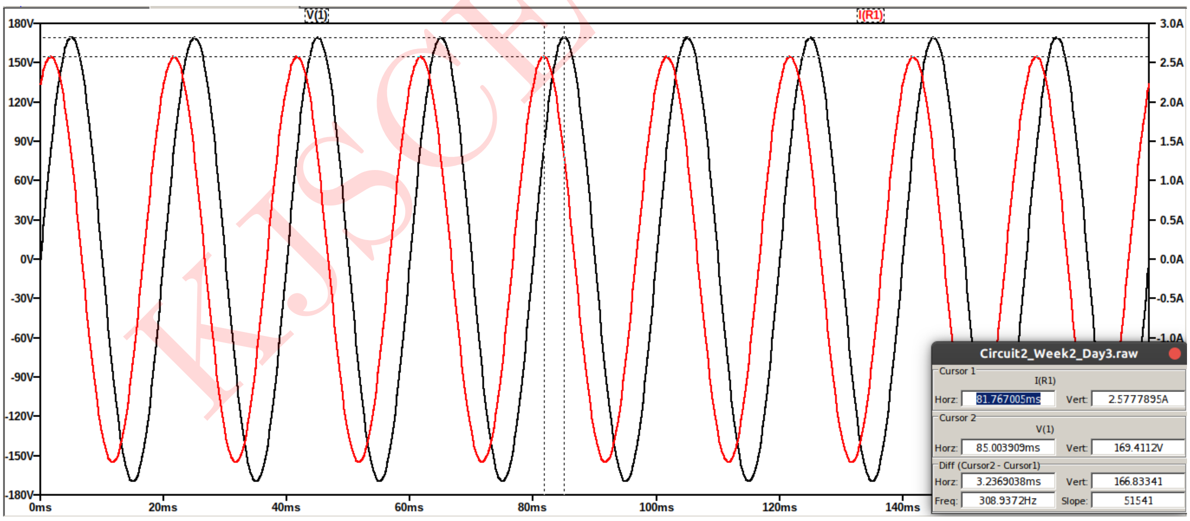


Figure 25: Simulated Waveform for V_1 Vs I_1

Input source voltage V_1 Vs voltage across inductor V_{C_1}
$V_1 = V_1$ and $V_{C_1} = V_2$

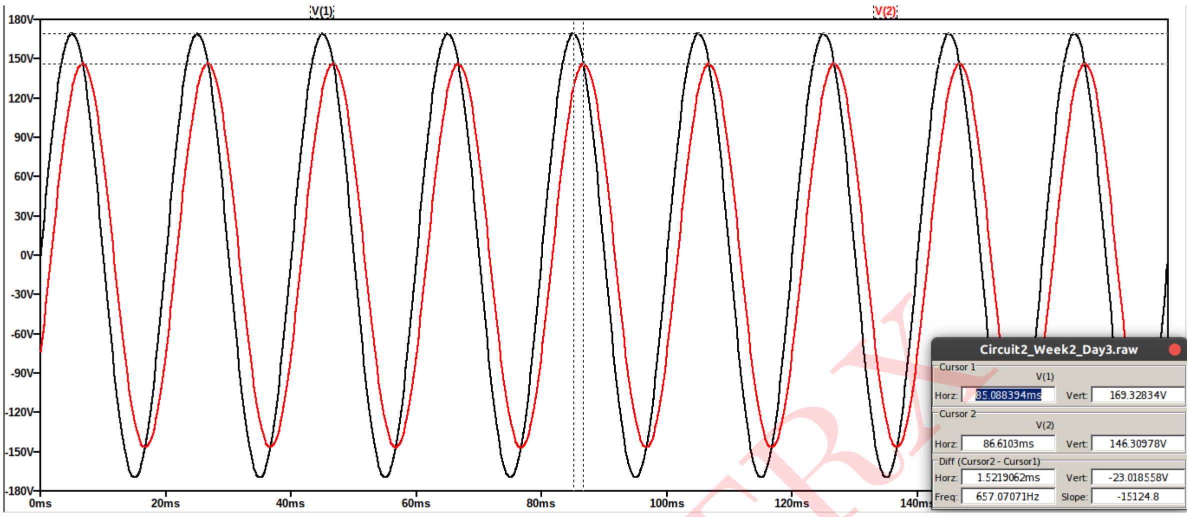


Figure 26: Simulated Waveform for V_1 Vs V_{C_1}

Input source voltage V_1 Vs voltage across resistor V_{R_1}
$V_1 = V_1 \quad V_{R_1} = V_{1,2}$

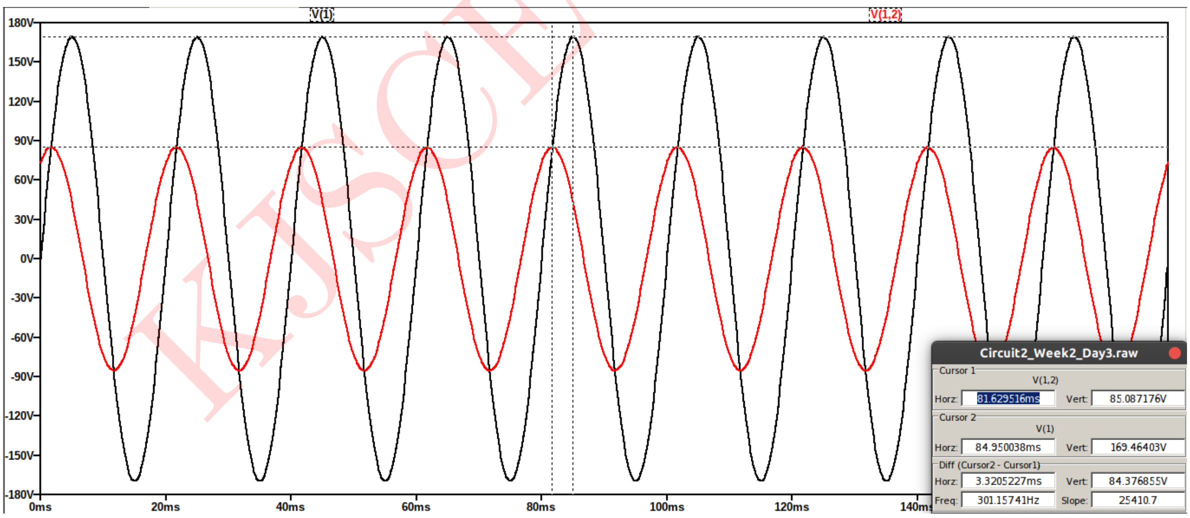


Figure 27: Simulated Waveform for V_1 Vs V_{R_1}

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_{S_m}	2.576A	2.582A
V_{R_m}	85.07366V	85.2066V
V_{C_m}	146.3024V	146.76346V
Phase angle between V_1 and V_{R_1}, ϕ	75.82257°	59.862°
Phase angle between V_1 and V_{C_1}, θ	36.9775°	30.1382°
Phase angle between V_1 and I_1, $\angle$	70.6289°	63.27651°

Table 7: Numerical 7

Numerical 8:
A series resonance network consisting of a resistor of 27Ω, a capacitor of 2.5µF and an inductor of 27mH is connected across a sinusoidal supply voltage which has a constant output of AC 9 volts at all frequencies. Calculate, the resonant frequency, the current at resonance, the voltage across the inductor and capacitor at resonance, the quality factor and the bandwidth of the circuit. Plot the resonance curve, the current at resonance, the voltage across the inductor and capacitor at resonance in LTSpice.

SOLUTION:

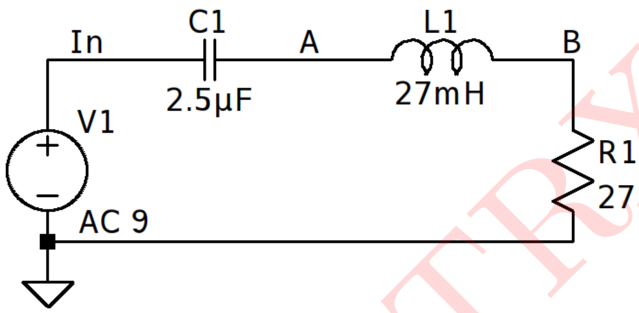


Figure 28: Series Resonance Circuit

$$f_R = \frac{1}{2\pi \times \sqrt{L_1 \times C_1}} = 612.5876616Hz$$

$$I_m = \frac{V}{R_1} = 333mA$$

$$X_L = 2\pi \times f \times \mathrm{L}_1 = 103.923\Omega$$

We know that, $V_L = V_C$

$\therefore V_L = \mathrm{I} \times \mathrm{X}_L = 34.606\mathrm{V}$

Quality Factor, $\mathrm{Q} = \frac{X_L}{R_1} = 3.849$

Bandwidth $= \frac{f_R}{Q} = 159.155Hz$

SIMULATED RESULTS:
The given circuit is simulated in LTSpice and the results obtained are as follows:

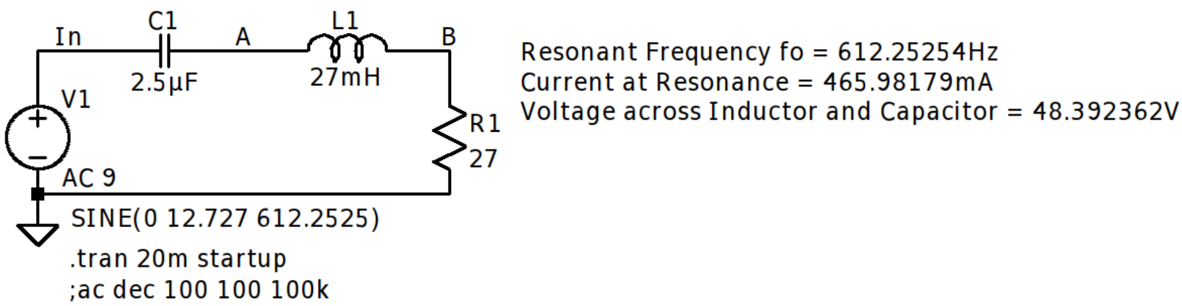


Figure 29: Circuit Schematic and Simulated Results

Waveforms:

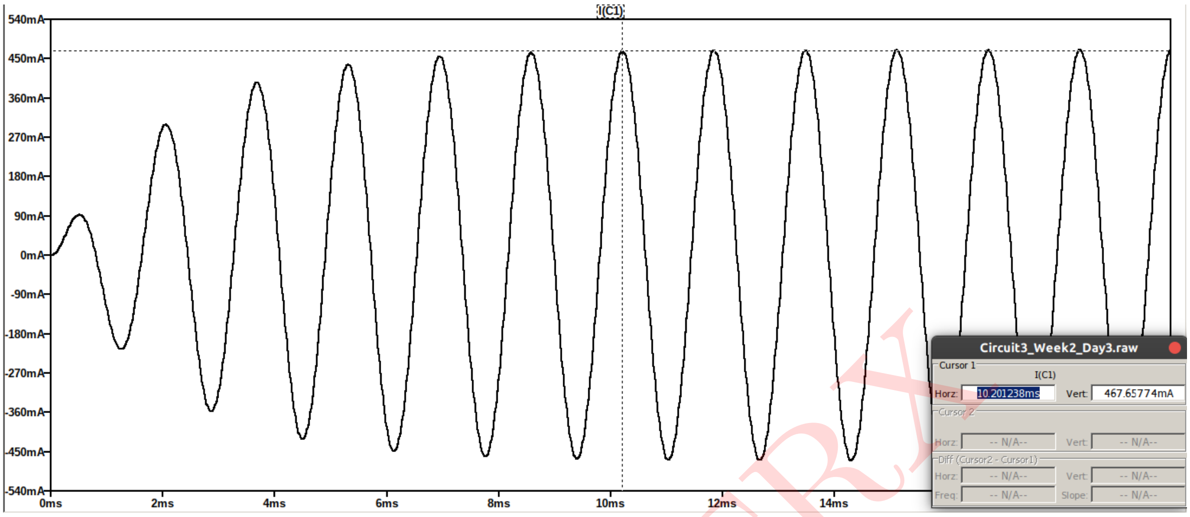


Figure 30: Current at Resonance

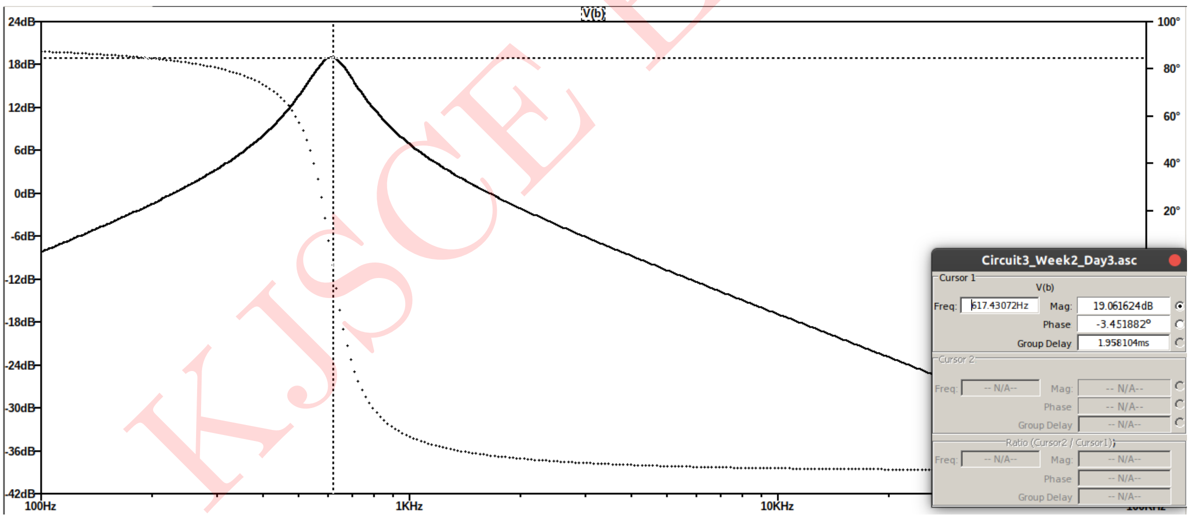


Figure 31: Resonant Frequency

In the waveform below, $V_L = V_{a,b}$ and $V_C = V_{in,a}$

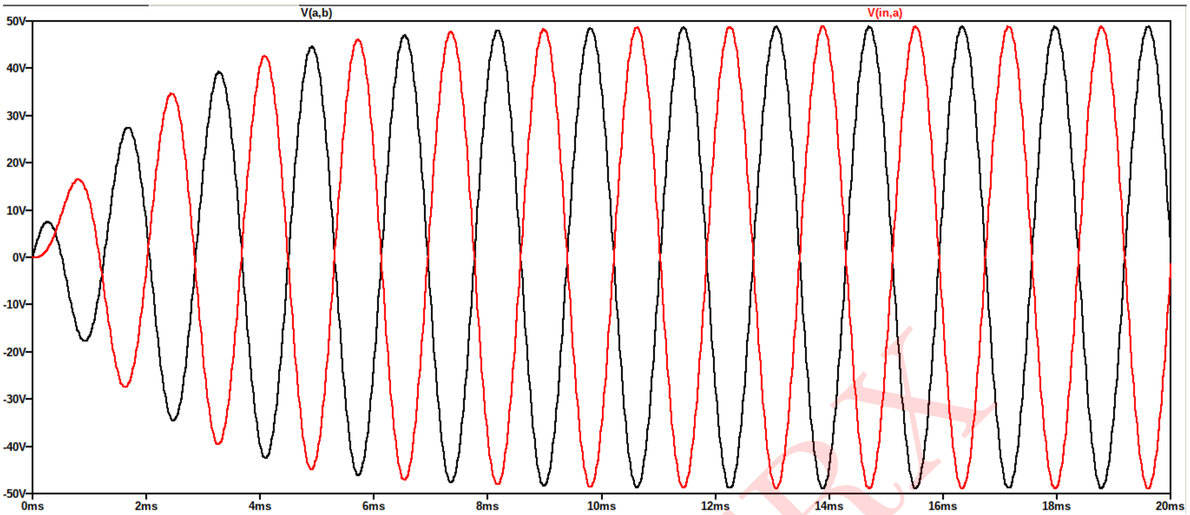


Figure 32: V_L and V_C at Resonance

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	0.47135A	0.46598A
f_R	612.58766Hz	612.2525Hz
$V_L = V_C$	48.94V	48.39V

Table 8: Numerical 8