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

Numerical 1: A series RLC circuit containing a resistance of 25Ω, an inductance of 0.1H and a capacitor of 80μ are connected in series across a 100V, 60Hz supply.
Calculate:
a) The total circuit current
b) V_R,V_L,V_C
c) Power factor
d) Draw the voltage phasor diagram

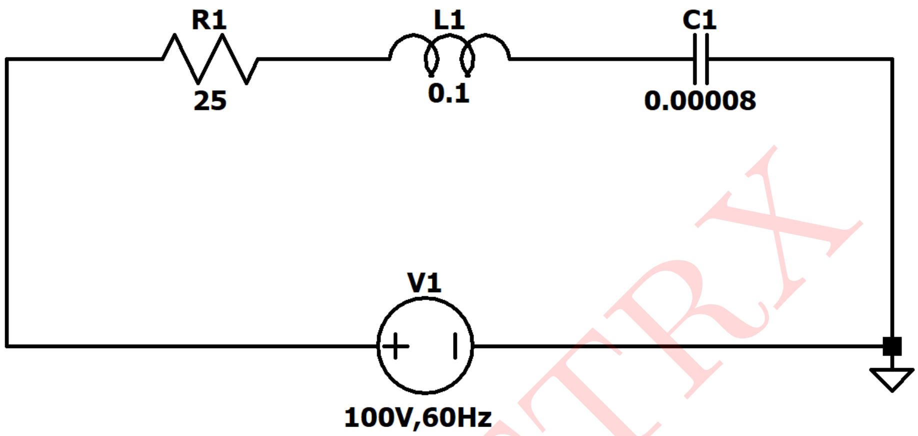


Figure 1: Circuit 1

Solution:

$\overline{V_1} = 100\angle 0$

$R_1 = 25\Omega$

$X_{L_1} = 2\pi f L_1 = 2\pi \times 60 \times 0.1 = 37.69\Omega\ (37.69\angle 90)$

$X_{C_1} = \dfrac{1}{2\pi f C_1} = \dfrac{1}{2\pi \times 80 \times 10^{-6}} = 33.157\Omega\ (33.157\angle -90)$

$\because \mathrm{X_{L_1}} > \mathrm{X_{C_1}}$ it is inductive.

$$\begin{aligned}\overline{Z} &= 25 + j(37.69 - 33.157)\\ &= 25 + 4.533j\\ &= 25.407\angle 10.277\end{aligned}$$

$$a)\ \overline{I} = \frac{\overline{V_1}}{\overline{Z}} = \frac{100\angle 0}{25.407\angle 10.277} = 3.93592\angle 169.723$$

$$\begin{aligned}b)\ \overline{V_{R_1}} = \overline{I} \times \overline{R_1} &= 3.93592\angle 169.723 \times 25\angle 0\\ &= 98.398\angle 169.723\end{aligned}$$

$$\begin{aligned}\overline{V_{L_1}} = \overline{I} \times \overline{X_{L_1}} &= 3.93592\angle 169.723 \times 37.69\angle 90\\ &= 148.34\angle 79.723\end{aligned}$$

$$\begin{aligned}\overline{V_{C_1}} = \overline{I} \times \overline{X_{C_1}} &= 3.93592\angle 169.723 \times 33.157\angle -90\\ &= 130.503\angle 79.723\end{aligned}$$

c) $Powerfactor(P.f) = \frac{R_1}{Z} = \frac{25\angle 0}{15.407\angle 10.277}$
$$= 0.983\angle 169.723$$

$\phi = \cos^{-1}(P.f) = \cos^{-1}(0.983) = 10.58°$

d)Voltage phasor diagram

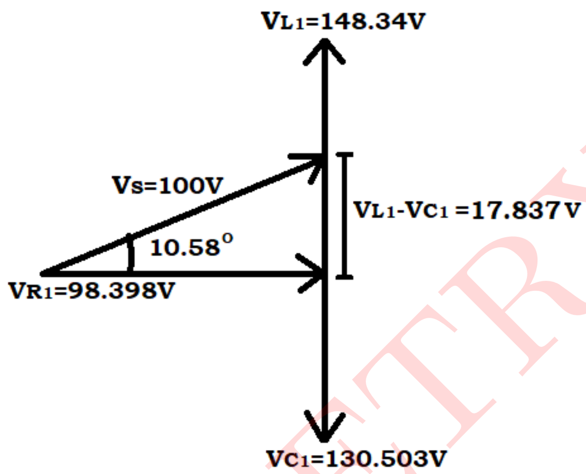
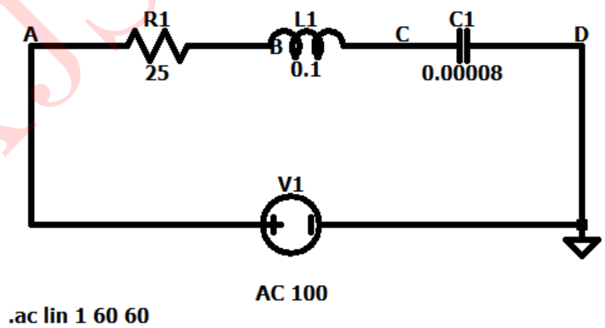
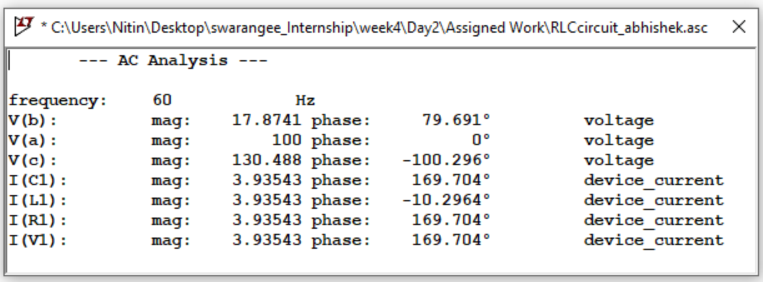


Figure 2: Voltage Phasor diagram

SIMULATED RESULTS:

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





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       --- AC Analysis ---

frequency:      60          Hz
V(b):           mag:    17.8741 phase:     79.691°      voltage
V(a):           mag:        100 phase:         0°      voltage
V(c):           mag:    130.488 phase:  -100.296°      voltage
I(C1):          mag:    3.93543 phase:   169.704°      device_current
I(L1):          mag:    3.93543 phase:  -10.2964°      device_current
I(R1):          mag:    3.93543 phase:   169.704°      device_current
I(V1):          mag:    3.93543 phase:   169.704°      device_current
```

Figure 3: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$\overline{I}$	$3.93592\angle 169.723A$	$3.9354\angle 169.704A$
$\overline{V_{R_1}}$	$98.398\angle 169.723V$	$98.835\angle 169.725V$
$\overline{V_{L_1}}$	$148.34\angle 79.723V$	$148.34\angle 79.69V$
$\overline{V_{C_1}}$	$130.503\angle -100.277V$	$130.488\angle -100.296V$

Table 1: Numerical 1

Numerical 2: A 50Hz sinusoidal voltage V=141ωt is applied to a series R-L circuit.The values of the resistance and the inductance are 5Ω and 0.02H respectively.
Calculate:
a) The rms value of the current in the circuit and its phase angle w.r.t to the voltage.
b) The rms value and the phase of the voltages appearing across the resistance and the inductance.
c) Power factor of the circuit.

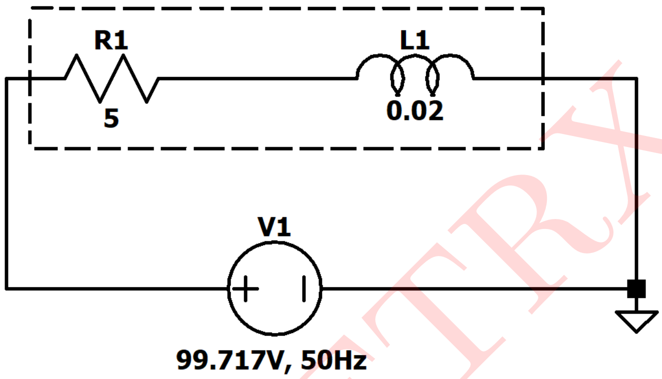

Figure 4: Circuit 2

Solution:

$V_1 = 141 \sin \omega t$

$V_{1rms} = 141V$

$V_1 = \dfrac{141}{\sqrt{2}} = 99.717V$

$\overline{V_1} = 99.717\angle 0$

$\mathrm{R}_1 = 5\Omega$

$\mathrm{L}_1 = 0.02\mathrm{H}$

$X_{L_1} = 2\pi f L_1 = 2\pi \times 0.02 \times 50 = 6.28\Omega(6.28\angle 90)$

$$\begin{aligned}\overline{Z} &= R_1 + jX_{L_1}\\ &= 5 + j6.28\\ &= 8.027\angle 51.47)\end{aligned}$$

$$\overline{I} = \frac{\overline{V_1}}{\overline{Z}} = \frac{99.717\angle 0}{8.027\angle 51.474} = 12.423\angle -51.474$$

$a)\ I_{rms} = \sqrt{2}I = \sqrt{2} \times 12.423 = 17.566A$

$\quad i = 1.566(\sin \omega t - 51.474)$

$$\begin{aligned} b)\ \overline{V_{R_1}} = \overline{I} \times \overline{R_1} &= (12.423\angle -51.474) \times (5\angle 0)\\ &= 62.115\angle -51.474\end{aligned}$$

$\quad V_{R_{1rms}} = 62.115 \times \sqrt{2}$

$\quad V_{R_{1rms}} = 87.83V$

$$
\begin{aligned}
\overline{V_{L_1}} &= \overline{I} \times \overline{X_{L_1}} = 12.423\angle - 51.474 \times 6.28\angle 90 \\
&= 78.016\angle 38.526
\end{aligned}
$$

$$V_{L_{1rms}} = 78.016 \times \sqrt{2}$$

$$V_{L_{1rms}} = 110.31V$$

$$
\begin{aligned}
c)\ Powerfactor(P.f) &= \cos\phi \\
&= \cos(-51.474) \\
&= 0.62287
\end{aligned}
$$

SIMULATED RESULTS:

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

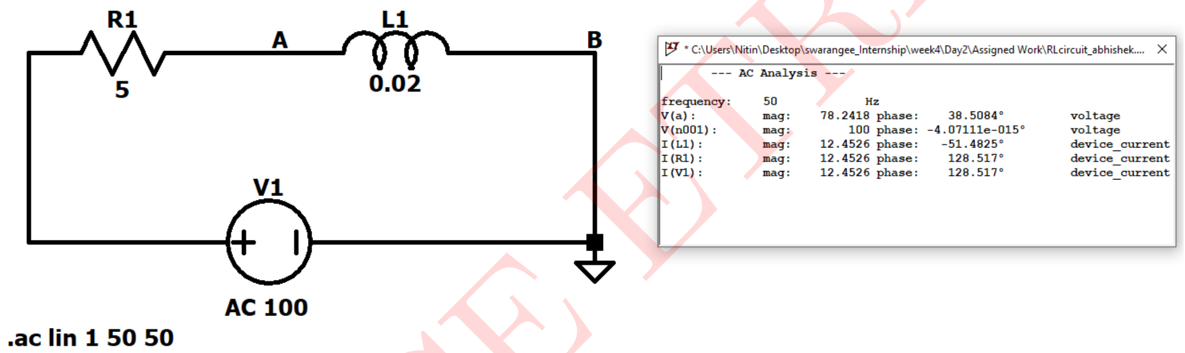

Figure 5: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$\overline{I}$	$12.423\angle - 51.474A$	$12.456\angle - 51.4825A$
$\overline{V_{R_1}}$	$62.115\angle - 51.474V$	$62.263\angle - 51.4825V$
$\overline{V_{L_1}}$	$8.016\angle 38.526V$	$78.202\angle 38.562V$

Table 2: Numerical 2

Numerical 3: A pure resistance of 40Ω is in series with a pure capacitance of 47μF. The series combination is connected across 220V, 50Hz supply.
Find:
a) The impedance.
b) Current
c) Power factor.
d) Phase angle.
e) Voltage across resistor.
f) Voltage across capacitor.

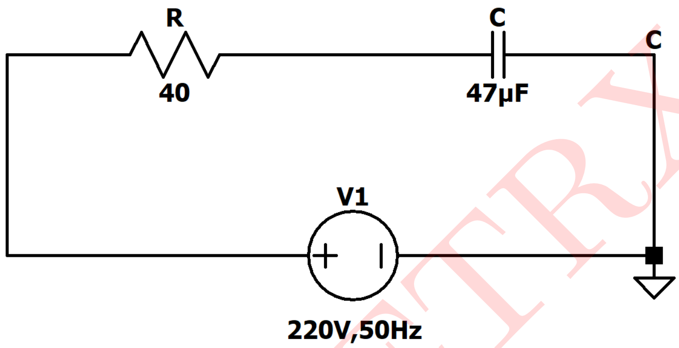

Figure 6: Circuit 3

Solution:

R = 40Ω

C = 47μF

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 47 \times 10^{-6}} = 67.7255\Omega(67.7255\angle-90)$$

$$\overline{V} = (220\angle 0)$$

$$a)\ \overline{Z} = R - jX_C$$
$$= 40 + j67.7255$$
$$= 78.655\angle-59.432$$

$$b)\ \overline{I} = \frac{\overline{V}}{\overline{Z}} = \frac{220\angle 0}{78.655\angle-59.432} = 2.797\angle 59.432$$

$$c)\ Powerfactor(P.f) = \frac{R}{Z} = \frac{40\angle 0}{78.655\angle-59.432}$$
$$= 0.5085\angle 59.432$$

$$d)\ \phi = \cos^{-1}(P.f) = \cos^{-1}(0.5085) = 59.436°$$

$$e)\ \overline{V_R} = \overline{I} \times \overline{R} = 2.797\angle 59.432 \times 40\angle 0$$
$$= 111.88\angle 59.452$$

$$f)\ \overline{V_C} = \overline{I} \times \overline{X_C} = 2.797\angle 59.432 \times 67.7255\angle-90$$
$$= 189.43\angle-30.568$$

SIMULATED RESULTS:

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

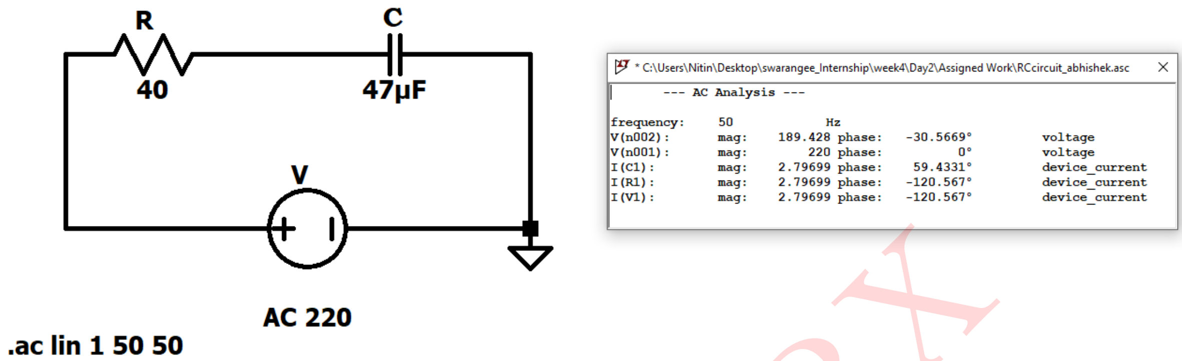

Figure 7: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$\overline{I}$	$2.7968\angle-120.568A$	$2.7969\angle-120.567A$
$\overline{V_R}$	$111.88\angle59.452V$	$111.876\angle59.452V$
$\overline{V_C}$	$189.43\angle-30.568V$	$189.428\angle-30.569V$

Table 3: Numerical 3

Numerical 4: Find I, I_1 and I_2 and V in the following Figure 1. If $R_1 = 6\Omega$, $L_1 = j4\Omega,\ R_2 = 20\Omega,\ L_2 = j8\Omega,\ R_3 = 9\Omega,\ C_1 = -j6\Omega,\ V = 100V,\ frequency = 50Hz$

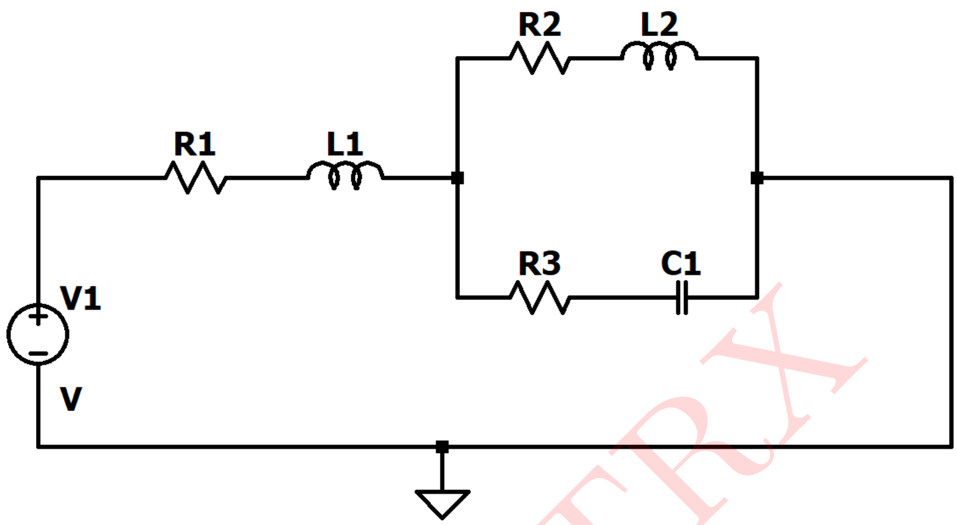

Figure 8: Circuit 4

Solution:

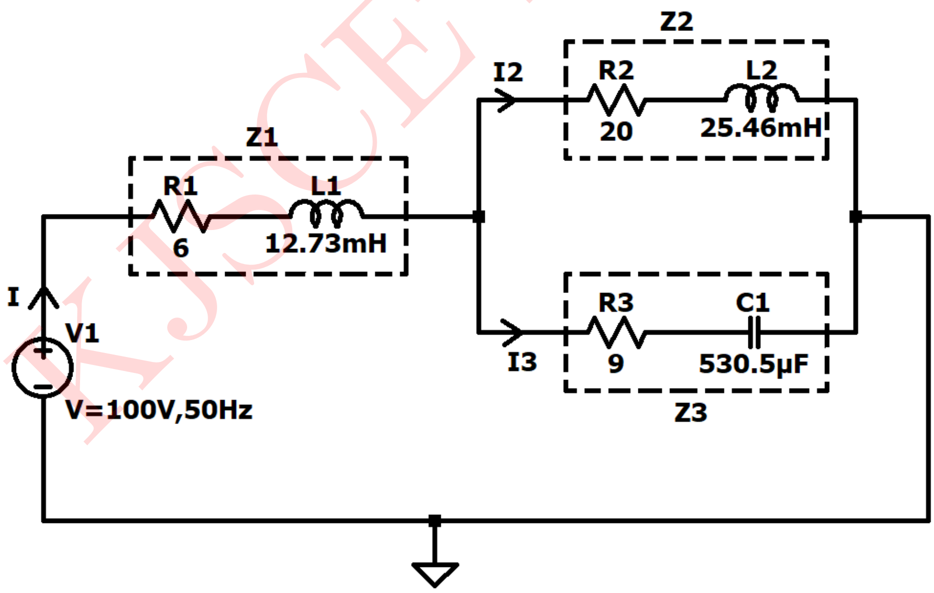

Figure 9: Circuit

$X_{L_1} = 4\Omega = 2\pi f L_1$

$\therefore L_1 = \dfrac{1}{2 \times \pi \times 50} \times 4 = 12.73mH$

$X_{L_2} = 8\Omega = 2\pi f L_2$

$\therefore L_2 = \dfrac{1}{2 \times \pi \times 50} \times 8 = 25.46mH$

$$X_{C_1} = \frac{1}{2 \times \pi f \times C_1}$$

$$\therefore\ C_1 = \frac{1}{2 \times \pi \times f \times X_{C_1}} = \frac{-1}{2 \times \pi \times 50 \times 6} = -0.05305\mu F$$

$$\overline{Z_1} = 6 + 4j = 7.211\angle 33.69$$

$$\overline{Z_2} = 20 + 8j = 21.54\angle 21.80$$

$$\overline{Z_3} = 9 - 6j = 10.8166\angle - 33.69$$

$$\overline{Y_2} = \frac{1}{\overline{Z_2}} = 0.0464\angle - 21.80 = 0.043 - j0.017$$

$$\overline{Y_3} = \frac{1}{\overline{Z_3}} = 0.0924\angle 33.96 = 0.0769 + j0.0512$$

$$\overline{Y_1} = \overline{Y_2} + \overline{Y_3} = 0.125\angle 15.920 = 0.1199 + j0.0342$$

$$\overline{Z}_{DB} = \frac{1}{\overline{Y_1}} = 8\angle - 15.920 = 7.693 - j2.194$$

$$\begin{aligned}\overline{Z_{eq}} &= \overline{Z_1} + \overline{Z}_{DB} \\ &= 13.693 + j1.806 \\ &= 13.812\angle 7.5135\end{aligned}$$

$$I = \frac{V}{Z_{eq}} = 7.24\angle 172.4865A$$

$$I_1 = I = 7.24\angle 172.4865A$$

$$I_2 = I \times \frac{Z_{eq}}{Z_2} = 2.69\angle 134.7665A$$

$$I_3 = I \times \frac{Z_{eq}}{Z_3} = 5.355\angle - 169.7435A$$

$$V_{Z_1} = I_1 \times Z_1 = 52.207\angle - 153.8235V$$

$$V_{Z_2} = I_2 \times Z_2 = 57.94\angle - 22.97V$$

$$V_{Z_3} = I_3 \times Z_3 = 57.922\angle 5.867V$$

SIMULATED RESULTS:

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

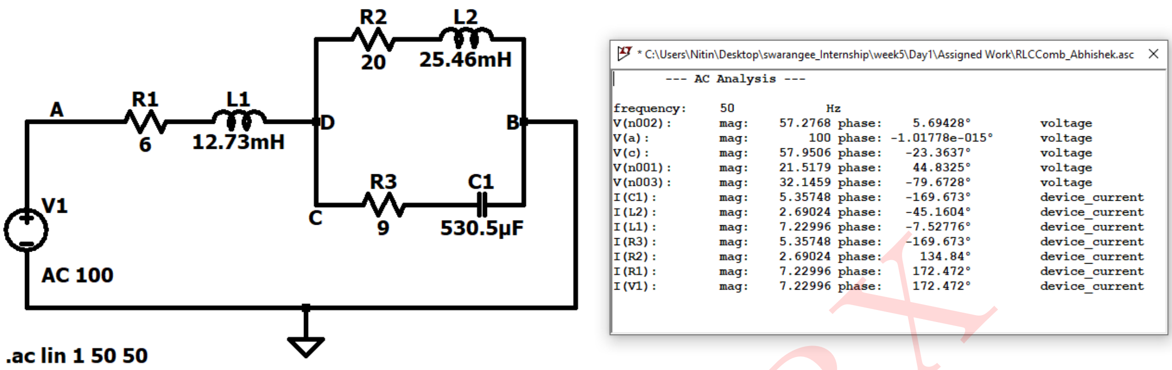

Figure 10: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
$\overline{I_1}$	$7.24\angle 172.4865A$	$7.22996\angle 172.472A$
$\overline{I_2}$	$2.69\angle -45.2335A$	$2.69\angle -45.1604A$
$\overline{I_3}$	$5.355\angle -169.7435A$	$5.3574\angle -169.673A$
$\overline{V_{Z_2}}$	$130.503\angle -100.277V$	$130.488\angle -100.296V$

Table 4: Numerical 4

Numerical 5: A circuit consists of a resistance of 15Ω, an inductance of 84mH and a capacitor of 60μF are connected in parallel across a 110V, 50Hz supply. Calculate:

i) individual currents drawn by each element
ii) total current drawn from the supply
iii) Overall power factor of the circuit
iv) Draw the phasor diagram

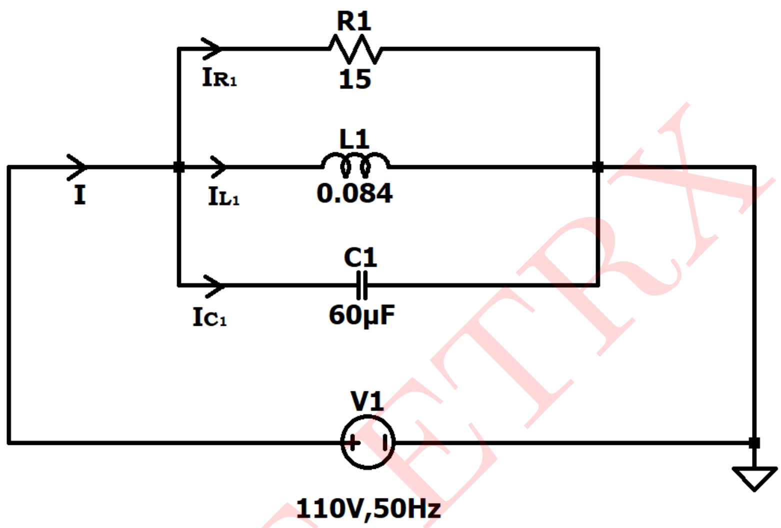

Figure 11: Circuit 5

Solution:

$\overline{V} = 110\angle 0V$

$R_1 = 15\angle 0\Omega = Z_R$

$X_{L_1} = 2\pi f L_1 = 2\pi \times 50 \times 84 \times 10^{-3} = 26.389\Omega\ (26.389\angle 90) = Z_L$

$$X_{C_1} = \frac{1}{2\pi f C_1} = \frac{1}{2\pi \times 60 \times 10^{-6}} = 53.052\Omega\ (53.052\angle -90) = Z_C$$

$$i)\ I(R_1) = \frac{V}{Z_R} = \frac{110\angle 0}{15\angle 0} = 7.333\angle 0A$$

$$I(L_1) = \frac{V}{Z_L} = \frac{110\angle 0}{26.389\angle 90} = 4.1684\angle -90A$$

$$I(C_1) = \frac{V}{Z_C} = \frac{110\angle 0}{53.0\angle -90} = 2.07344\angle -90A$$

$$\begin{aligned} ii)\ \text{Total current} = I_T &= I(R_1) + I(L_1) + I(C_1) \\ &= 7.333 + 0j + 0 + j4.1684 + 0 - j2.07334 \\ &= 7.333 + j2.09506 \\ &= 7.6264\angle 15.94479A \text{ or } 7.6264\angle 164.05A5 \end{aligned}$$

$$\begin{aligned} iii)\ \text{Power factor(P.f)} &= \cos(180 - 164.057) \\ &= 0.96153 \end{aligned}$$

iv) Phasor diagram

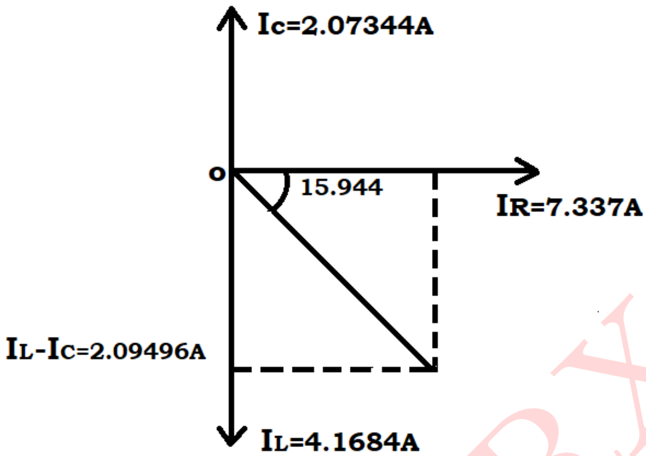

Figure 12: Phasor diagram

SIMULATED RESULTS:

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

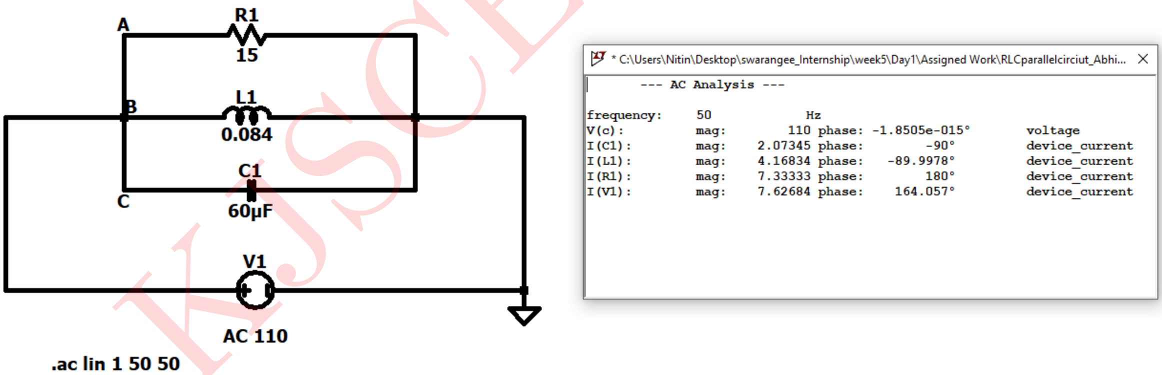

Figure 13: Circuit schematic and simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I(R_1)	$7.333\angle 180A$	$7.333\angle 180A$
I(L_1)	$4.1684\angle -90A$	$4.16834\angle -90A$
I(C_1)	$2.07344\angle -90A$	$2.07345\angle -90A$
I_T	$7.6264\angle 164.055A$	$7.62684\angle 164.057A$
p.f	0.96153	0.961535

Table 5: Numerical 5

Numerical 6: A pure resistance of 40Ω is in series with a pure capitance of 100μF.The series combination is connected across 120V, 50Hz 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 VS(t) Vs input source current IS(t) in Ltspice
c) Measure the phase delay/difference between VS(t) Vs IS(t) in time and degrees
d) Plot input source voltage VS(t) Vs voltage across resistor VR(t) in Ltspice
e) Measure the phase delay/difference between VS(t) Vs VR(t) in time and degrees
f) Plot input source voltage VS(t) Vs voltage across capacitor VC(t) in Ltspice
g) Measure the phase delay/difference between VS(t) Vs VC(t) in time and degrees
h) Calculate the power factor of the circuit

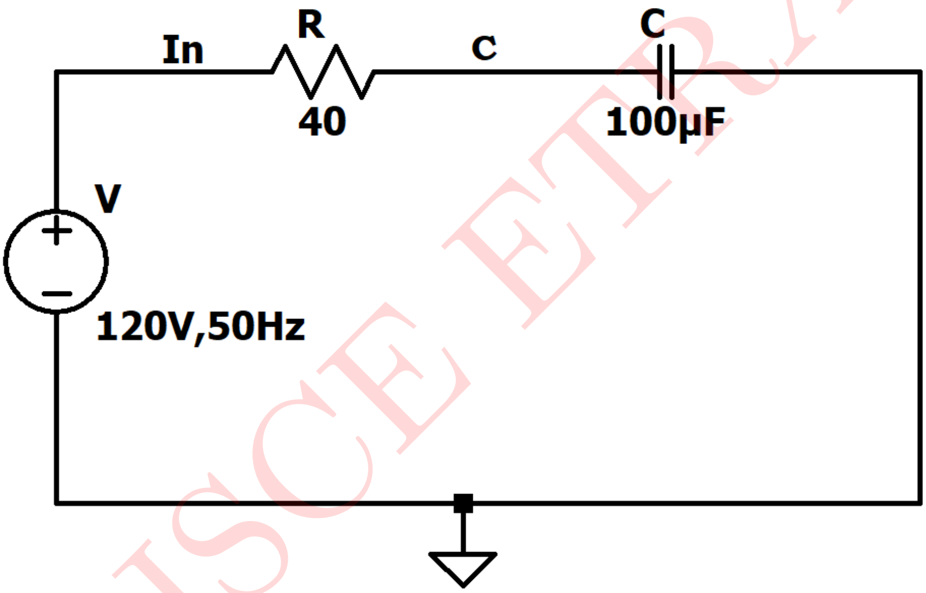

Figure 14: Circuit 6

Solution:

$V = 120\angle 0$

$$X_C = \frac{1}{2\pi\, fC} = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}} = 31.83\Omega$$

$$Z = 40 - j31.83 = 51.119\angle 38.51$$

$$I_{Peak} = \frac{V}{Z} = \frac{120\angle 0}{51.119\angle 38.51} = 2.3475\angle -38.51A$$

$$I_{Peak_r} = \sqrt{2} \times I_{Peak} = 3.319A$$

$$V_R = I_{Peak_r} \times R = 132.775\angle -38.51V$$

$$V_c = I_{Peak_r} \times X_C = 105.644\angle 51.49V$$

$$\phi_{(V,I)} = \frac{360}{20} \times 2.90178 = 38.516°$$

$$\phi_{(V,V_R)} = \frac{360}{20} \times 2.10989 = 37.978^{\circ}$$

$$\phi_{(V,V_C)} = \frac{360}{20} \times 2.98901 = 53.80^{\circ}$$

Power factor $= \cos\phi = 0.7825$

SIMULATED RESULTS:

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

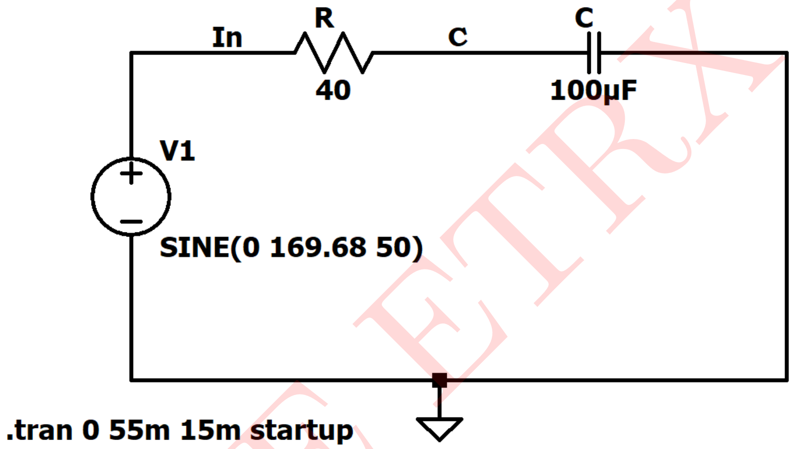

Figure 15: Circuit schematic

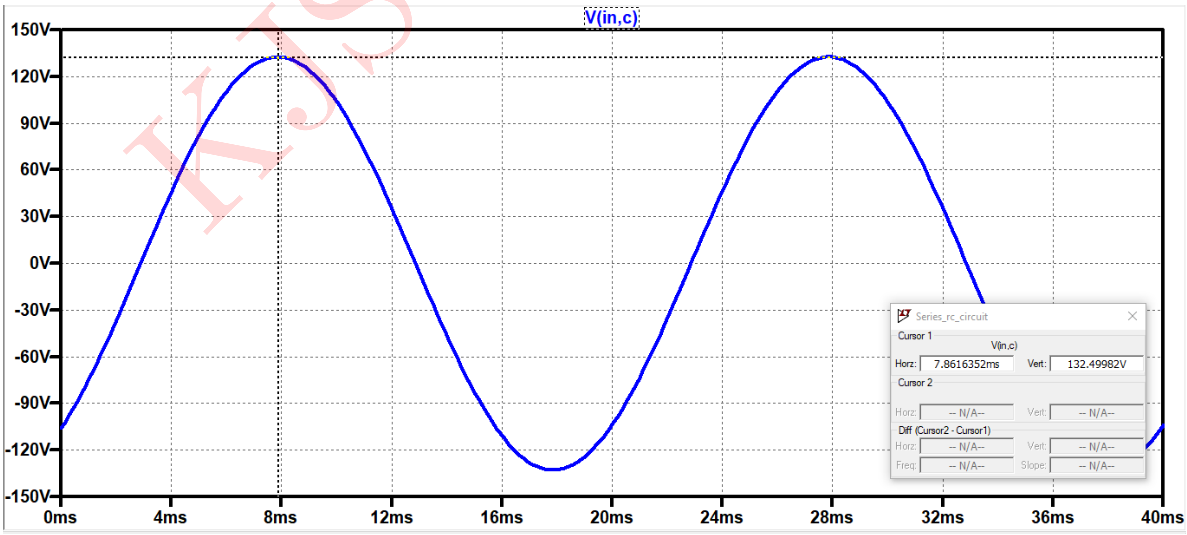

Figure 16: Simulated results for Voltage across resistor

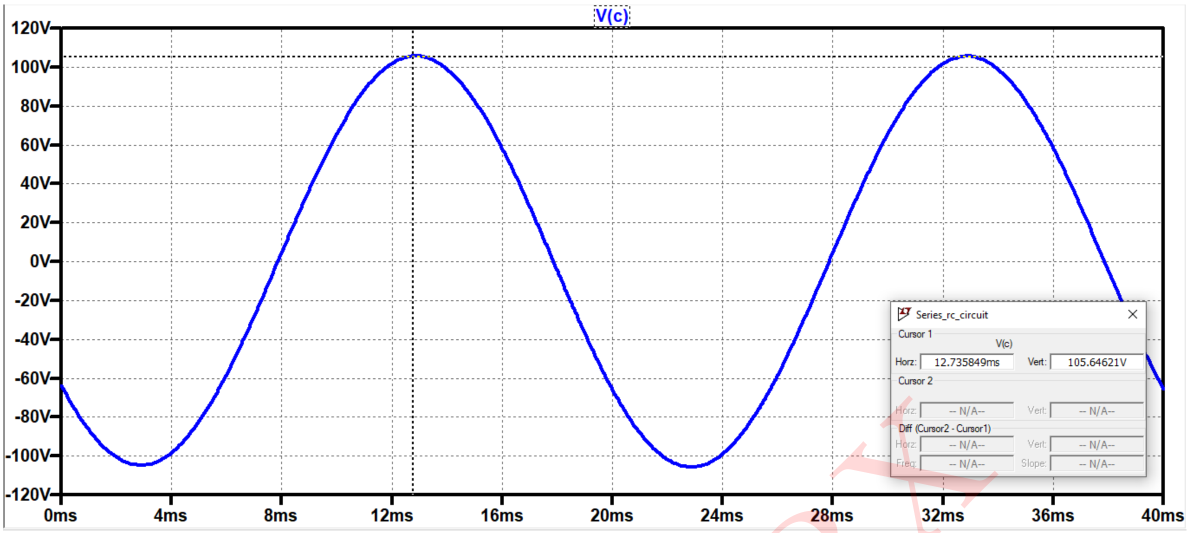

Figure 17: Simulated results for Voltage across capacitor

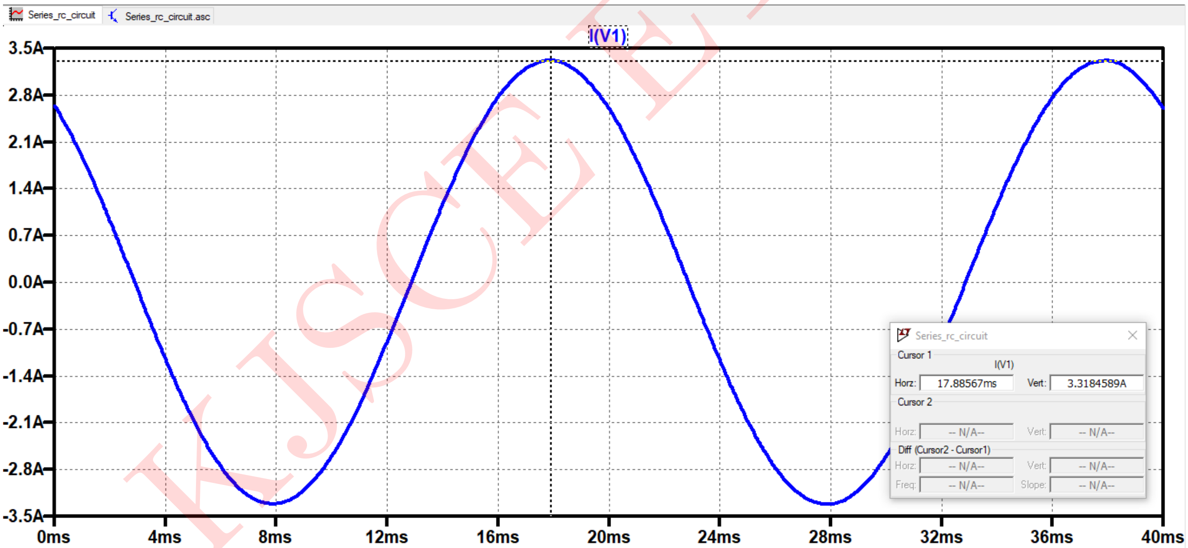

Figure 18: Simulated results for source current

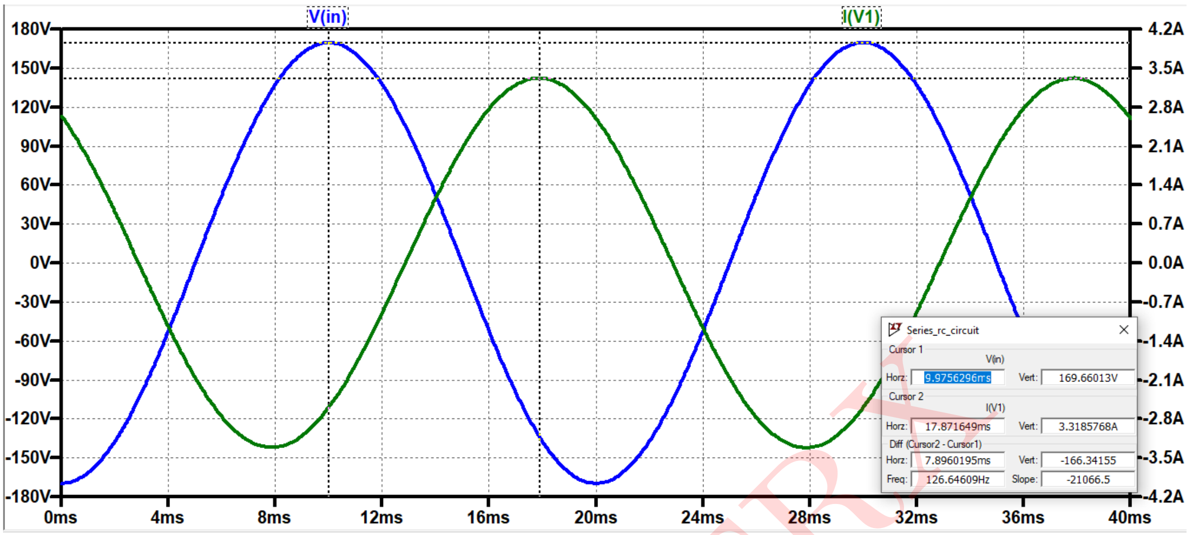

Figure 19: Simulated results for $V_S(t)$ Vs $I_S(t)$

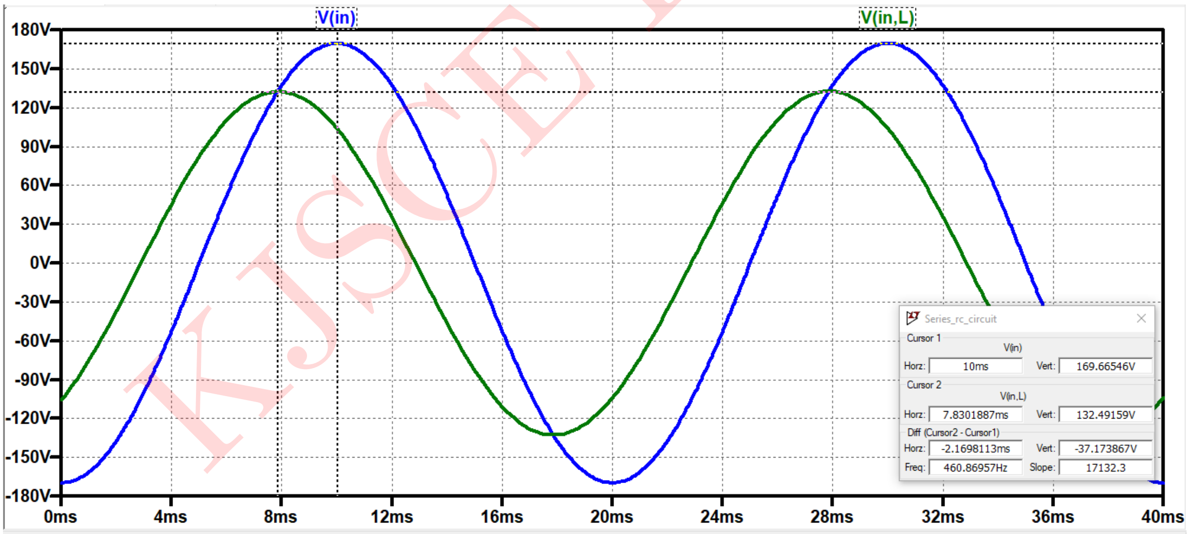

Figure 20: Simulated result for $V_S(t)$ Vs $V_R(t)$

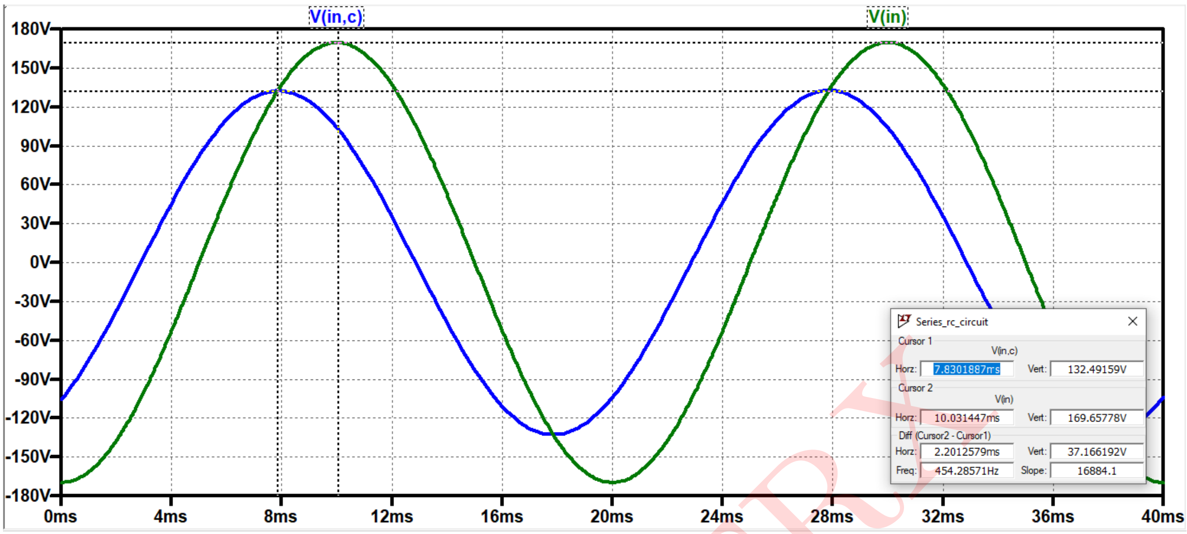

Figure 21: Simulated results for $V_S(t)$ Vs $V_C(t)$

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
Peak voltage across resistor	132.775V	132.498V
Peak voltage across capacitor	105.664V	105.664V
Peak voltage source current	3.319A	3.319A
Phase delay/difference between VS(t) Vs IS(t) in time and degrees	38.51°	38.516°
Phase delay/difference between VS(t) Vs VR(t) in time and degrees	37.97°	38.51°
Phase delay/difference between VS(t) Vs VC(t) in time and degrees	53.80°	51.49°

Table 6: Numerical 6

Numerical 7: A series resonance network consisting of a resistor of 30Ω, a capacitor of 1μF and an inductor of 30mH 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 inductor and capacitor at resonance in LTspice.

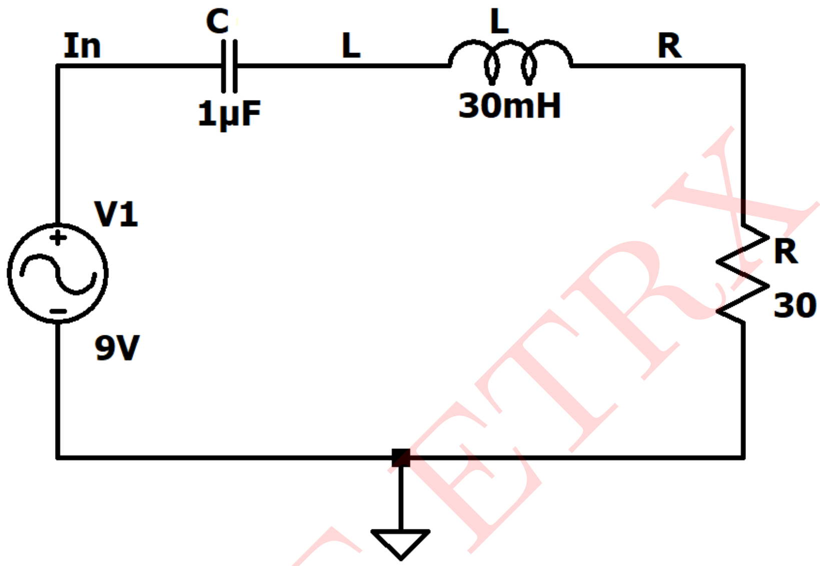

Figure 22: Circuit 7

Solution:

Resonant frequency:

$$f_r = \frac{1}{2\pi} \times \frac{1}{\sqrt{LC}} = \frac{1}{2\pi} \times \frac{1}{\sqrt{30 \times 10^{-3} \times 10^{-6}}} = 918.881Hz$$

Current at Resonance:

$$I = \frac{V}{R} = \frac{9}{30} = 0.3A = 300mA$$

$$I_r = \sqrt{2} \times I = 0.424A$$

Voltages at inductor and capacitor:

$$V_L = V_C = I \times X_L = 300 \times 10^{-3} \times 2\pi \times 918.881 \times 30 \times 10^{-3}$$

$$V_L = V_C = 51.9615V$$

$$V_r = V_L \times \sqrt{2} = 73.47V$$

Quality factor:

$$Q = \frac{X_L}{R} = \frac{2\pi \times 918.881 \times 30 \times 10^{-3}}{30} = 5.7735$$

Bandwidth:

$$Bandwidth = \frac{f_r}{Q} = \frac{918.881}{5.7735} = 159.155Hz$$

SIMULATED RESULTS:

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

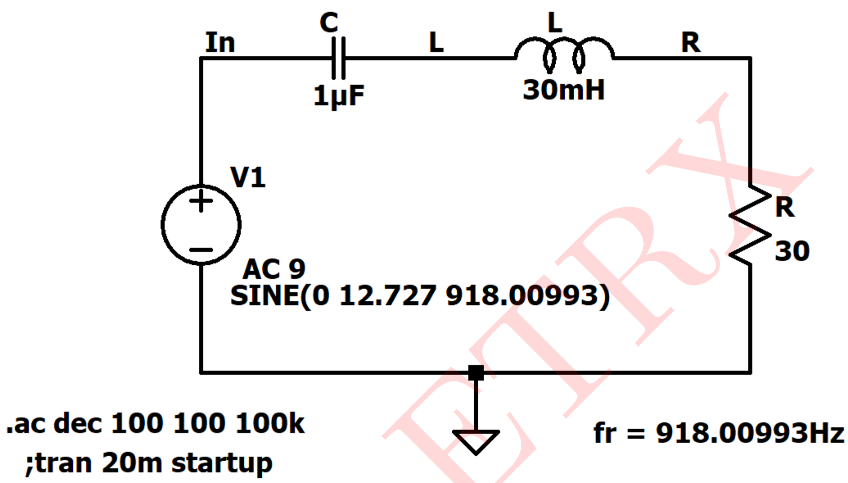

Figure 23: Circuit schematic

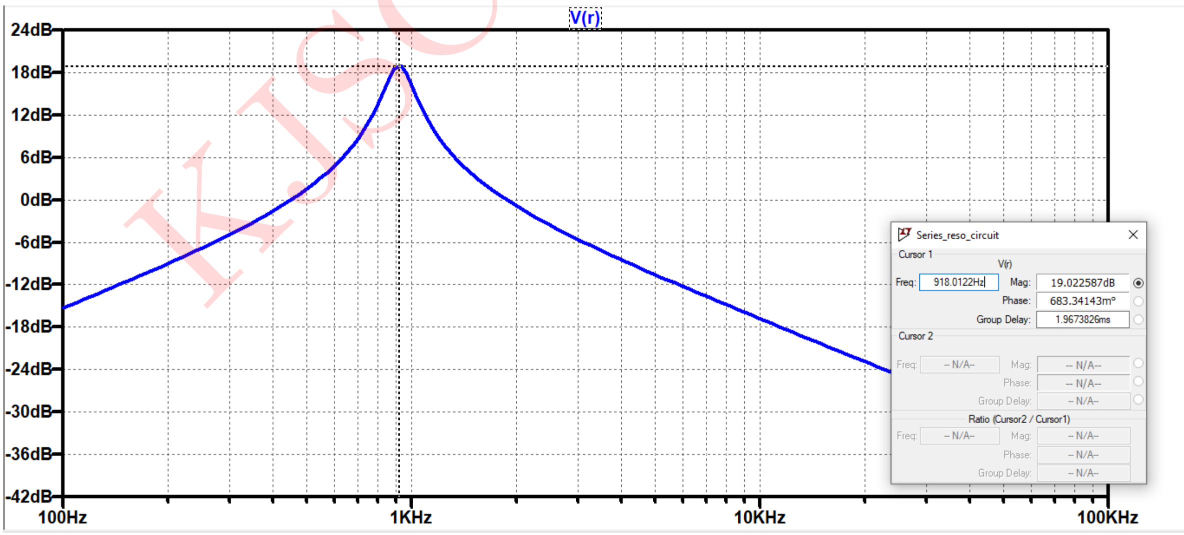

Figure 24: Simulated results for resonant frequency

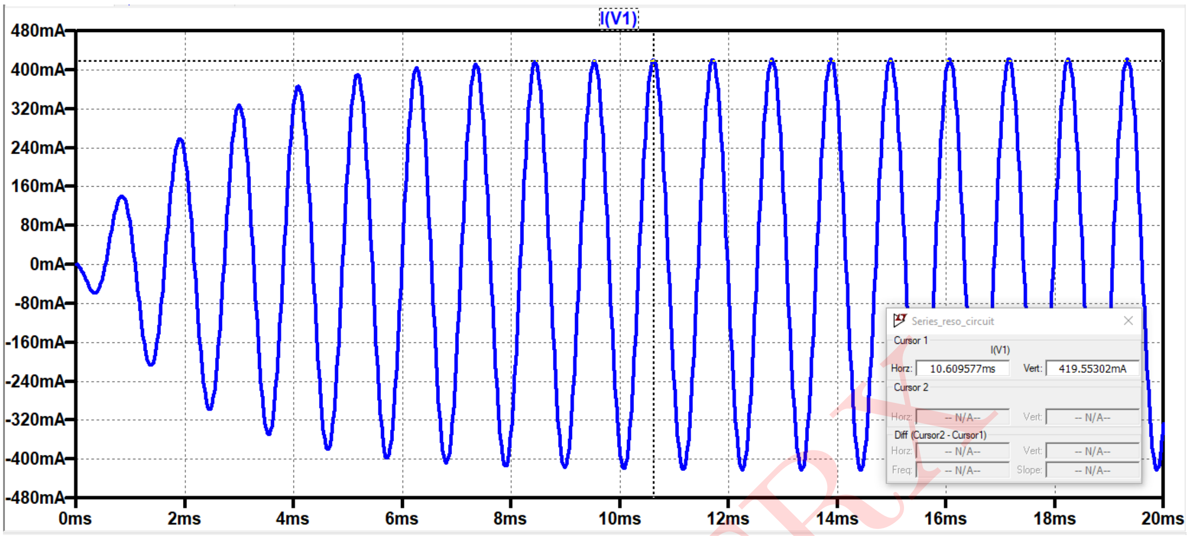

Figure 25: Simulated results for current at resonance

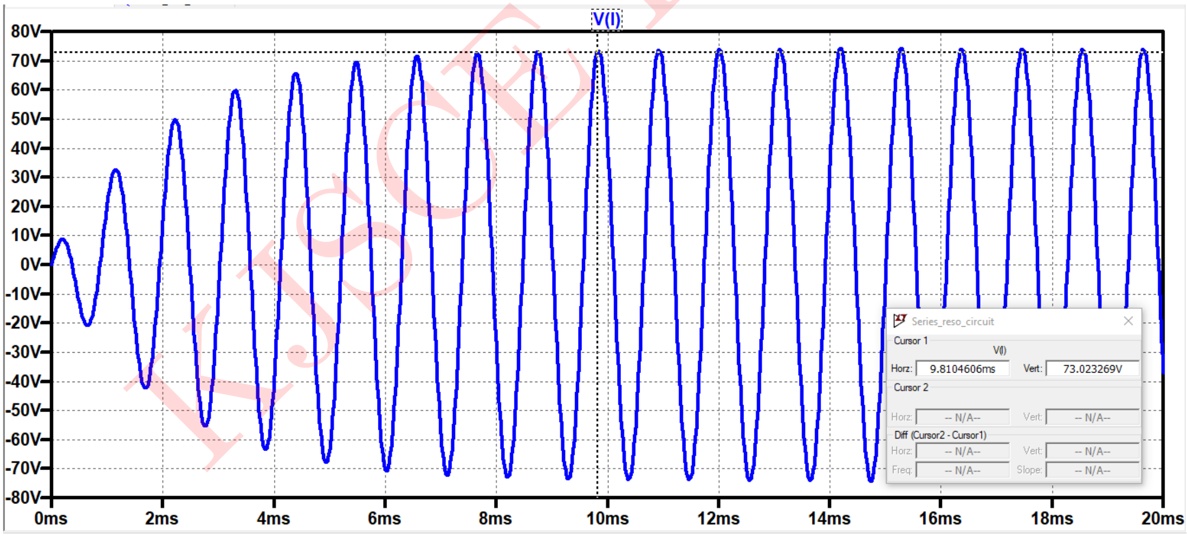

Figure 26: Simulated results for Voltage across inductor

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
Resontant frequency	918.881Hz	918.00993Hz
Current at resonance	424.2mA	419.589mA
Voltage across the inductor	73.47V	73.035V
Voltage across the capacitor	73.47V	73.035V
The quality factor	5.7735	5.7735
The bandwidth	159.004Hz	159.155Hz

Table 7: Numerical 7

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