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

Numerical 1:
A series RLC circuit containing a resistance of 50Ω, an inductance of 0.2H and a capacitor of 120uF are connected in series across a 220V, 50Hz supply. Calculate
a) the current drawn by the circuit
b) V_R, V_L and V_C
c) Power factor
d) Draw the voltage phasor diagram

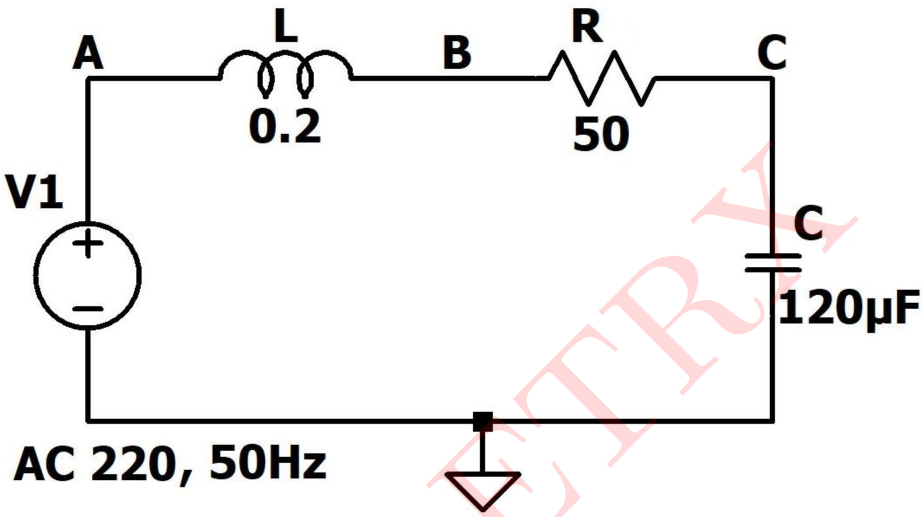

Figure 1: Circuit 1

Solution:

L = 0.2H

$X_L = 2\pi f L = 62.831\Omega$

C = 120uF

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{0.037} = 26.5252\Omega$

$Z = R + jX_L - jX_C$

$Z = 50 + j\,62.83 - j\,26.52$

$Z = 61.793 \angle 35.987$

a)

$I = \dfrac{V}{Z} = \dfrac{220}{61.793} = 3.5602A$

$\therefore$ $\mathbf{I = 3.5602 \angle -35.987}$

b)

$V_R = I \times R$

$V_R = 3.56 \times 50$

$\therefore \mathbf{V_R = 178V}$

$V_C = X_L \times I$

$V_R = 62.83 \times 3.56$

$\therefore \mathbf{V_C = 223.6748V}$

$V_C = X_C \times I$

$V_R = 26.52 \times 3.56$

$\therefore \mathbf{V_C = 94.411V}$

c) Power factor

$P.f = \cos\phi$

$P.f = \cos(35.987)$ $[\because \phi = 35.987°]$

$\therefore \mathbf{P.f = 0.809}$

d) Phasor diagram:

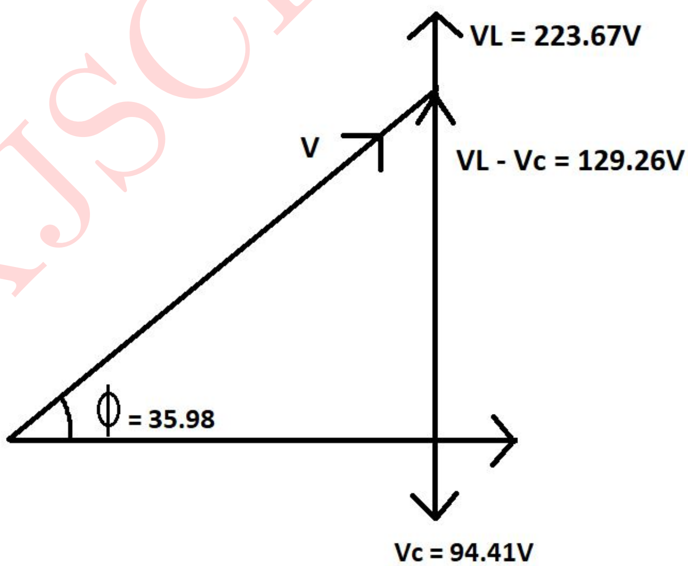

Figure 2: Phasor diagram

SIMULATED RESULTS:

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

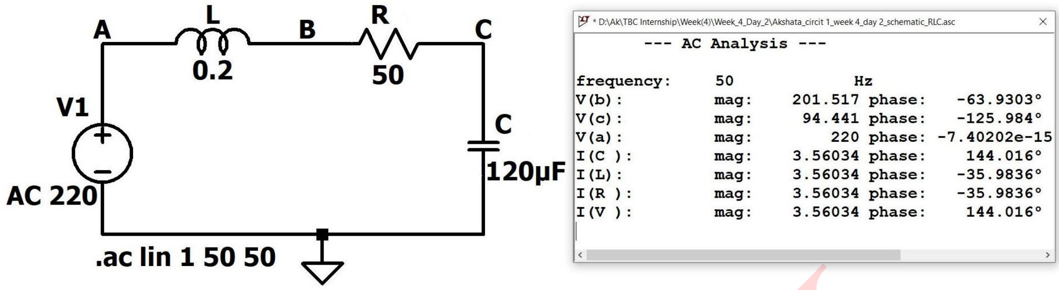

Figure 3: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	3.5602A	3.5603A
V_R	178V	178.017V
V_L	223.67V	223.703V
V_C	94.41V	94.411V
ϕ	35.981°	35.986°

Numerical 2:
A 60Hz sinusoidal voltage V = 141(sinωt) is applied to a series R-L circuit.
The values of the resistance and the inductance are 2Ω and 0.03H 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

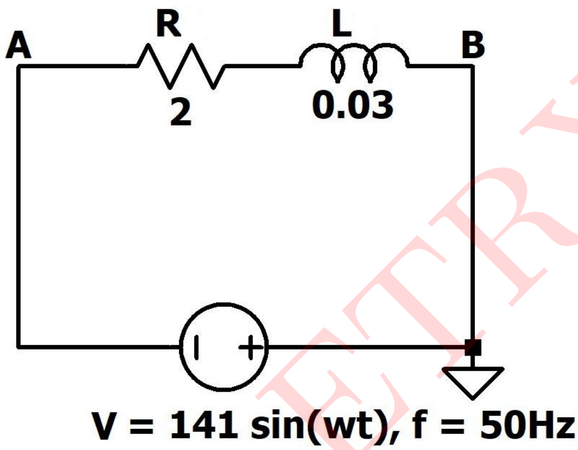

Figure 4: Circuit 2

Solution:

$V = V_m \text{ Sin}\omega t$

$V_m = 141$

$\therefore V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{141}{\sqrt{2}} = 100V$

$L = 0.03H$

$X_L = 2\pi f L = 11.309\Omega$

$Z = R + j\ X_L = 2 + j\ 11.309$

$Z = 11.4844 \angle 79.97$

a)

$$\mathrm{I_{rms}} = \frac{V_{\mathrm{rms}}}{Z} = \frac{100}{11.4844\angle 79.97} = 8.71\mathrm{A}$$

$\therefore$ $\mathbf{I_{rms} = 11.4844 \angle -79.97}$

b)

$\mathrm{V_R} = \mathrm{I} \times R$

$\mathrm{V_R} = 8.71 \times 2$

$\therefore$ $\mathbf{V_R = 17.42 \angle -79.97}$

$\mathrm{V_L} = \mathrm{I} \times X_{\mathrm{L}}$

$\mathrm{V_L} = 8.71 \angle -79.97 \times 11.309\angle -90$

$\therefore$ $\mathbf{V_L = 98.50 \angle 10.03}$

c) Power factor

$\mathrm{P.f} = \cos\phi$

$\mathrm{P.f} = \cos(79.97)$ $[\because \phi = 79.97°]$

$\therefore$ $\mathbf{P.f = 0.17416}$

SIMULATED RESULTS:

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

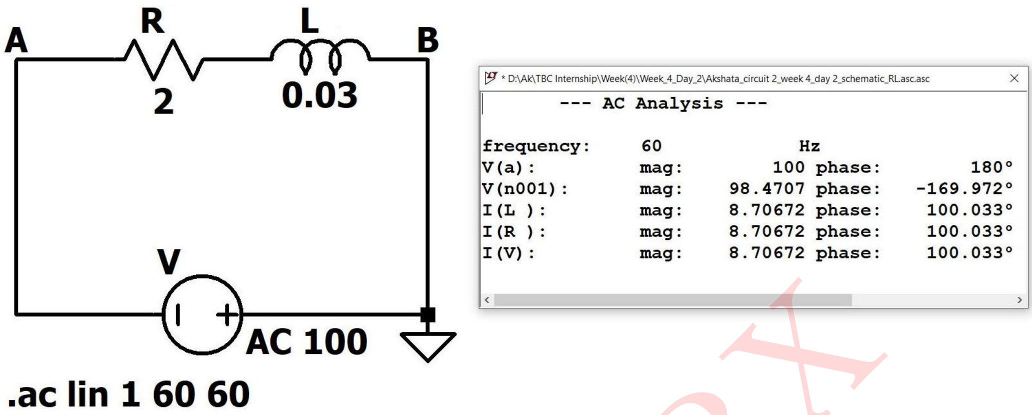

Figure 5: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	8.71A	8.706A
V_R	17.42V	17.41V
V_L	98.50V	98.47V
ϕ	79.97°	79.966°

Numerical 3:
A pure resistance of 35Ω is in series with a pure capacitance of 80uF. The series combination is connected across 100V, 60Hz supply.
Calculate:
a) The impedance
b) current
c) Power factor
d) Phasor angle
e) Voltage across resistor
f) Voltage across capacitor

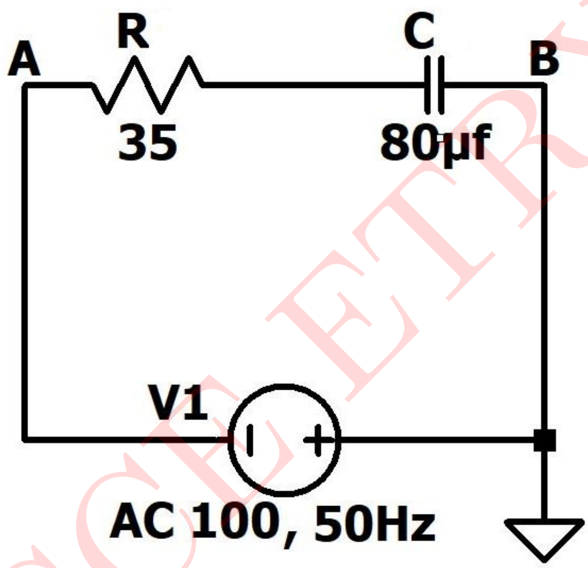

Figure 6: Circuit 3

Solution:

C = 80uF

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{0.030} = 33.157\Omega$

Z = R − jX_C = 35 − j 33.157

Z = 48.211 ∠ 43.451

a) Impedance

∴ Z = 48.211 ∠ 43.451

b) Current

$I = \dfrac{V}{Z} = \dfrac{100}{48.211\angle 43.451} = 2.074 \angle -43.45$

∴ $\mathbf{I = 2.074 \angle -43.45}$

c) Power factor

P.f $= \cos\phi$

P.f $= \cos(43.45)$

$\therefore$ **P.f = 0.7259**

d) Phasor angle

$\phi = 43.45°$

e)

$V_R = I \times R$

$V_R = 2.074 \angle -43.45 \times 35$

$\therefore \mathbf{V_R = 72.59V}$

f)

$V_C = I \times X_C$

$V_C = 2.074 \angle -43.45 \times 33.157$

$\therefore \mathbf{V_C = 68.76V}$

SIMULATED RESULTS:

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

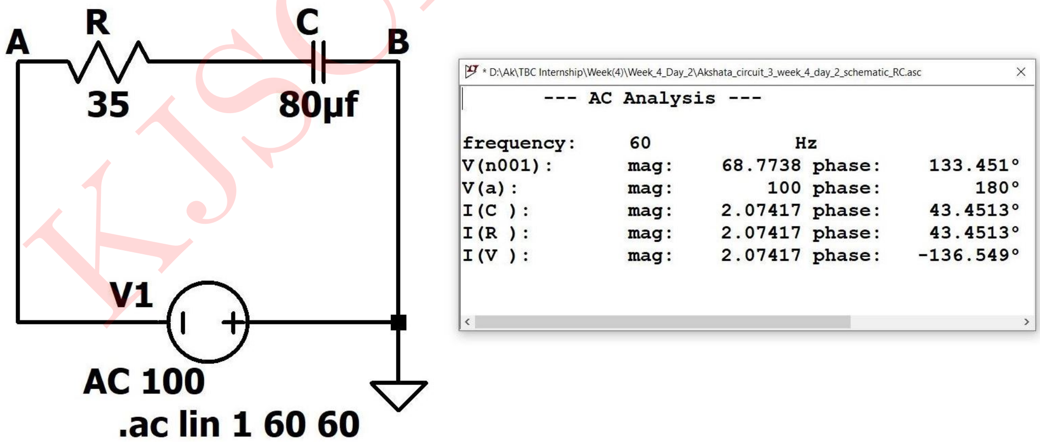

Figure 7: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	2.074A	2.0741A
V_R	72.59V	72.59V
V_C	68.76V	68.77V
ϕ	43.45°	43.451°

Numerical 4:

A current consists of resistance of 45Ω, an inductance of 34mH and a capacitor of 50uF are connected in parallel across a 110V, 50Hz supply. Calculate

a) Individual current drawn by each element

b) Total current drawn from the supply

c) Overall power factor of the circuit

d) Draw the phasor diagram

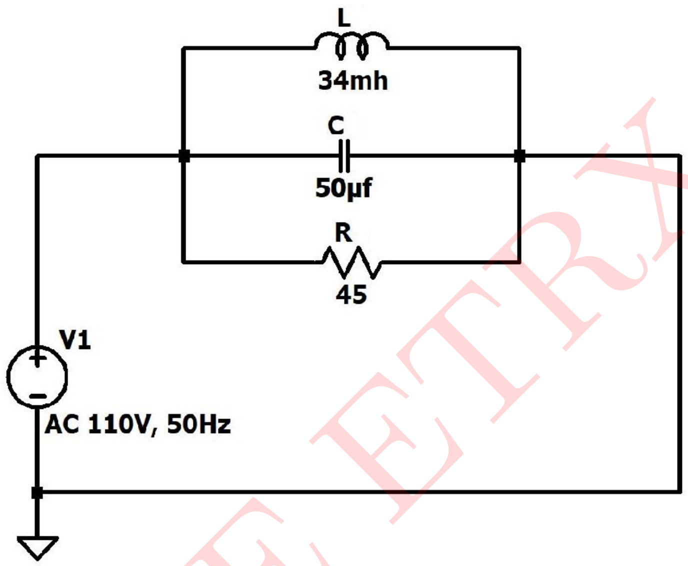

Figure 8: Circuit 4

Solution:

R = 45Ω

f = 50Hz

L = 34mH

$X_L = 2\pi fL = 2\pi \times 50 \times 34 \times 10\text{-}3 = 10.681\Omega$

C = 50uF

$$X_C = \frac{1}{2\pi fC} = \frac{1}{15.7} = 63.66\Omega$$

$Z = R + jX_L - jX_C$

Z = 45 + j 10.681 − j 63.66

a) Current flowing through resistor

$$I_R = \frac{V}{R} = \frac{110}{45\angle -0^\circ} = 2.444\text{A}$$

$\therefore \mathbf{I_R = 2.444 \angle -0^\circ A}$

Current flowing through inductor

$$I_L = \frac{V}{jX_L} = \frac{110}{10.681\angle 90^\circ} = 10.298 \angle 90^\circ A$$

$\therefore$ $\mathbf{I_L = 10.298 \angle -90^\circ A}$

Current flowing through capacitor

$$I_C = \frac{V}{-jX_C} = \frac{110}{63.66\angle -90^\circ} = 1.727 \angle 90^\circ A$$

$\therefore$ $\mathbf{I_C = 1.727 \angle 90^\circ A}$

b) Total current,

$I = I_R + I_L + I_C$

$\therefore$ $\mathbf{I = 8.9126} \angle -74.084^\circ$

c) Power factor

P.f = $\cos\phi$

P.f = $\cos(74.084)$

$\therefore$ **P.f = 0.27422**

d) Phasor diagram:

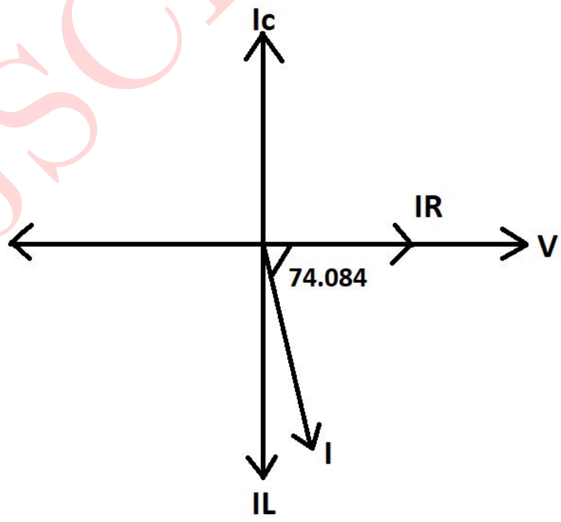

Figure 9: Phasor diagram

SIMULATED RESULTS:

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

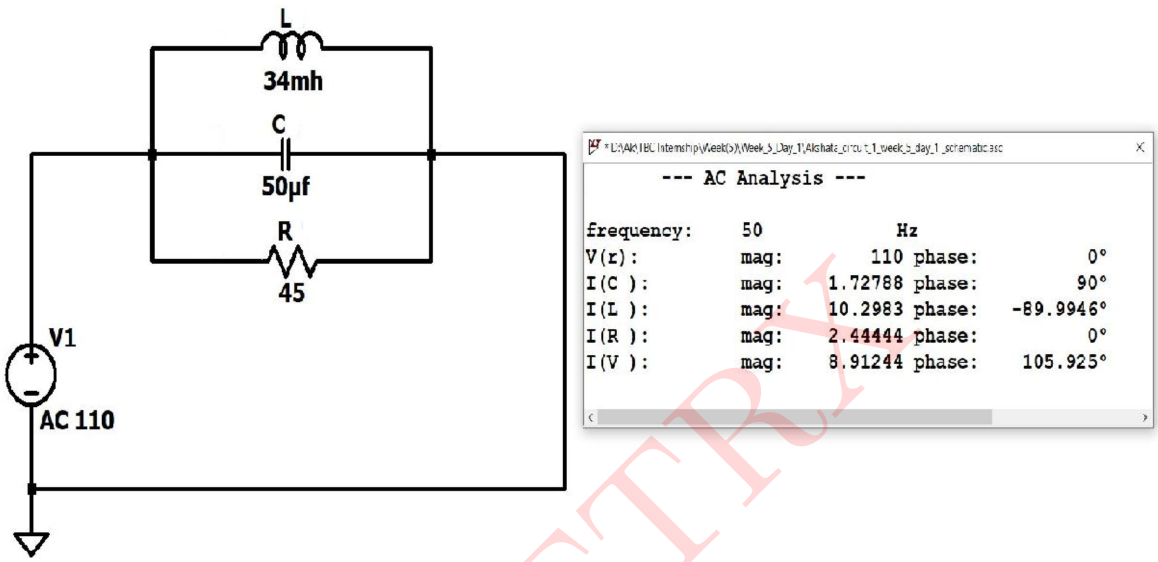

Figure 10: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I_R	$2.444 \angle -0^\circ A$	$2.44 \angle -0^\circ A$
I_L	$10.298 \angle -90^\circ A$	$10.297 \angle -90^\circ A$
I_C	$1.727 \angle 90^\circ A$	$1.727 \angle 90^\circ A$
I	$8.9126 \angle -74.084^\circ A$	$8.9124 \angle -74.084^\circ A$

Numerical 5:

Find I, I_1, I_2 and V in the following circuit 2. If $R_1 = 15\Omega$, $L_1 = j12\Omega$, $L_2 = j10\Omega$, $R_2 = 20\Omega$, $R_3 = 20\Omega$, $C_1 = -j8\Omega$, V = 100V, f = 50Hz

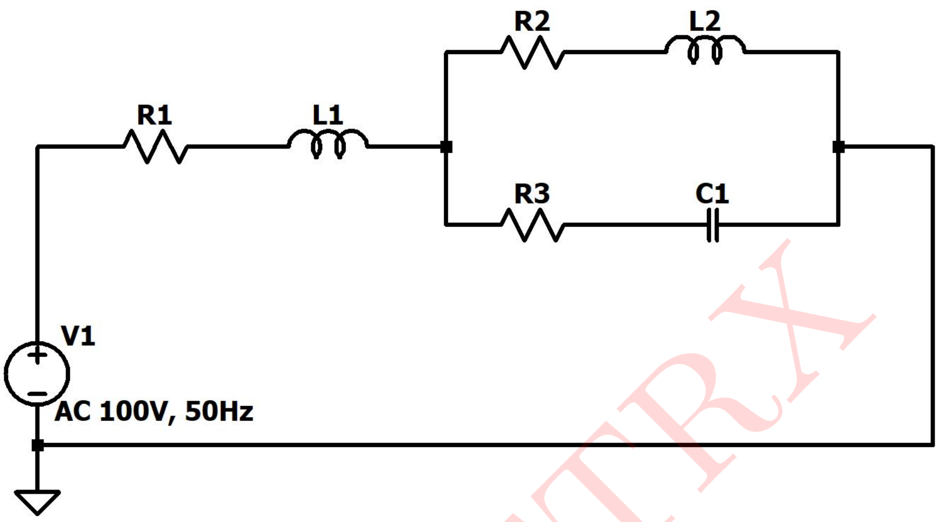

Figure 11: Circuit 5

Solution:

$Z_1 = 15 + j12 = 19.209 \angle 38.65°$

$Z_2 = 20 + j10 = 22.3606 \angle 26.56°$

$Z_3 = 20 - j8 = 21.540 \angle -21.8°$

$X_{L1} = 12$

$$\therefore L_1 = \frac{12}{2\pi \times 50} = 0.381\text{H}$$

$X_{L2} = 10$

$$\therefore L_2 = \frac{10}{2\pi \times 50} = 0.3018\text{H}$$

$X_{C1} = 8$

$$\therefore C_1 = \frac{12}{2\pi \times 50 \times 8} = 398\text{uF}$$

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

$$Z = 15 + j12 + \frac{(20 + j10) \times (20 - j8)}{(20 + j10) + (20 - j8)}$$

$Z = 15 + j12 + 12.0199 + 0.3990j$

$Z = 29.7288 \angle 24.6495°$

$$I = \frac{V}{Z} = \frac{100}{29.728\angle 24.6495^\circ}$$

$$\therefore\ \mathbf{I = 3.3637}\ \angle\ -24.64^\circ \mathbf{A}$$

$$I_1 = I \times \frac{Z_2}{Z_2 + Z_3}$$

$$I_1 = 3.3637\ \angle\ -24.64^\circ \times \frac{21.540\angle -21.801^\circ}{21.540\angle -21.801^\circ + 22.36\angle 26.56^\circ}$$

$$I_1 = 3.3637\ \angle\ -24^\circ\ \times 0.537\angle\ -24.663^\circ$$

$$\therefore \mathbf{I_1 = 1.809}\ \angle\ -49.303^\circ \mathbf{A}$$

$$\therefore \mathbf{I_2 = I_1 - I = 1.878}\ \angle\ -0.94^\circ \mathbf{A}$$

SIMULATED RESULTS:

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

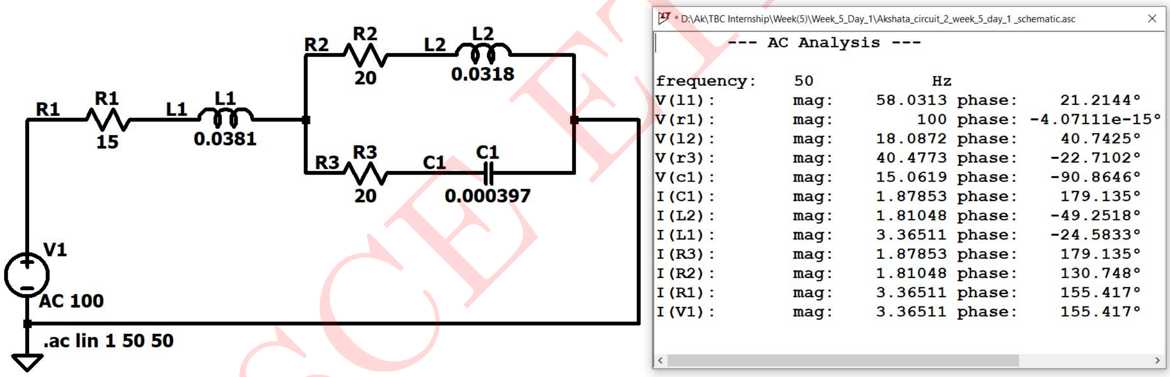

Figure 12: Circuit schematic and Simulated results

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
I	$3.3637\ \angle\ -24.64^\circ$A	$3.365\ \angle\ -24.64^\circ$A
I_1	$1.809\ \angle\ -49.303^\circ$A	$1.810\ \angle\ -49.303^\circ$A
I_2	$1.878\ \angle\ -0.94^\circ$A	$1.898\ \angle\ -0.94^\circ$A

Numerical 6:

A 60 Hz sinusoidal voltage V = 141(sint) is applied to a series R-L circuit. The values of the resistance and the inductance are 10 and 0.0124H respectively.

Determine the following:

a) Calculate the peak voltage across resistor and inductor 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 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 degrees

f) Plot input source voltage VS(t) Vs voltage across inductor VL(t) in LTspice

g) Measure the phase delay/difference between VS(t) Vs VL(t) in time degrees

h) Calculate the power factor of the circuit.

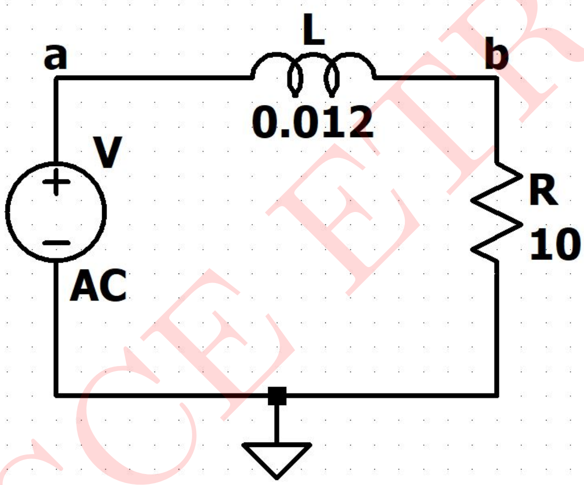

Figure 13: Circuit 6

Solution:

$\mathrm{X_L} = 2\pi f L = 2\pi \times 60 \times 0.0124 = 4.674\Omega$

$\mathrm{Z} = \mathrm{R} + \mathrm{jX_L} = 10 + 4.674\mathrm{j}$

$\therefore \mathbf{Z} = \mathbf{11.038} \angle 25.051^\circ$

$$\therefore \mathbf{V_{rms}} = \frac{V_{\mathbf{m}}}{\sqrt{2}} = \mathbf{100V}$$

$$\mathrm{I_{rms}} = \frac{V_{\mathrm{m}}}{Z} = \frac{100}{11.038}\angle 25.051^\circ$$

$\therefore \mathbf{I_{rms}} = \mathbf{9.059} \angle -25.051^\circ\mathbf{A}$

$\therefore \mathbf{I_m} = \mathbf{I_{rms}} \times\sqrt{2} = \mathbf{12.8122A}$

Peak value of V_r

$V_r = I \times R = 9.059\angle -25.051^\circ \times 10\angle 0^\circ$

$\therefore \mathbf{V_r = 90.596V}$

$(V_r)_m = 90.596 \times\sqrt{2}$

$\therefore \mathbf{(V_r)_m = 128.122V}$

Peak value of V_L

$V_L = I \times X_L$

$V_L = 9.059 \angle -25.051^\circ \times 4.674\angle 90^\circ$

$\therefore \mathbf{V_L = 42.3445} \angle 64.94^\circ$

$(V_L)_m = 42.3445 \times\sqrt{2}$

$\therefore \mathbf{(V_r)_m = 59.8842}$

Power factor

$P.f = \cos\phi$ $[\because \phi = 25.051^\circ]$

$P.f = \cos(25.051)$

$\therefore \mathbf{P.f = 0.90593}$

Phase difference between $V_s(t)$ and $I_s(t)$

$\therefore \phi = -25.051^\circ$

Phase difference between $V_s(t)$ and $V_R(t)$

$\therefore \phi = 25.051^\circ$

Phase difference between $V_s(t)$ and V_R

$\therefore \phi = -64.949^\circ$

SIMULATED RESULTS:

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

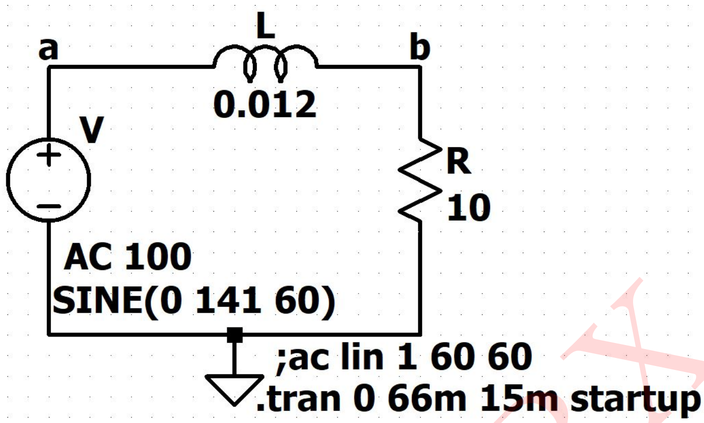

Figure 14: Circuit schematic for circuit 6

Figure 15: Peak value of voltage across R

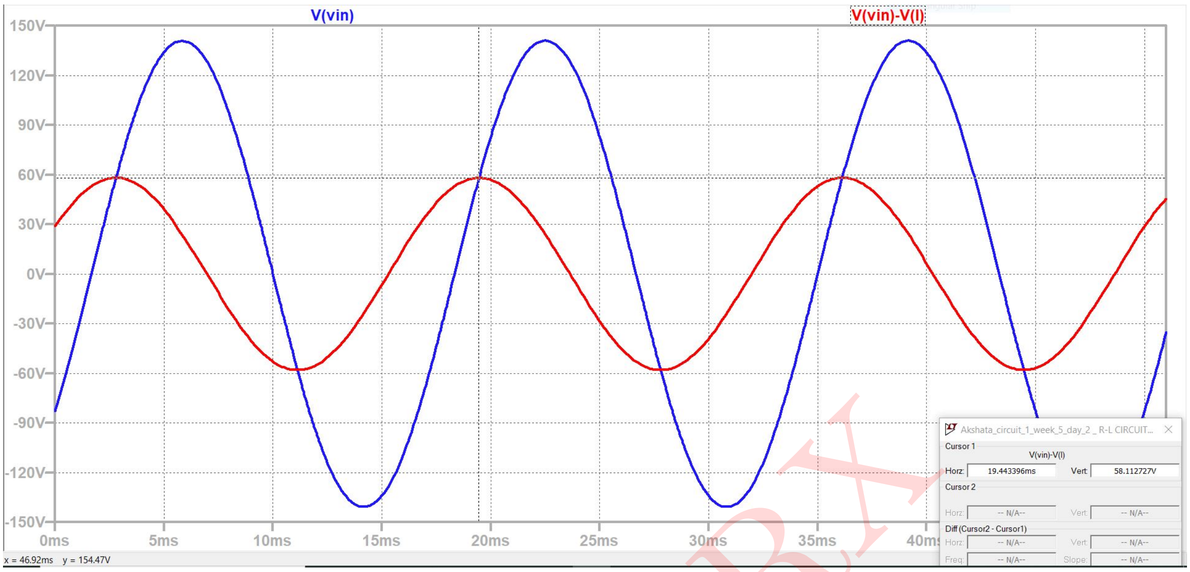

Figure 16: Peak value of voltage across L

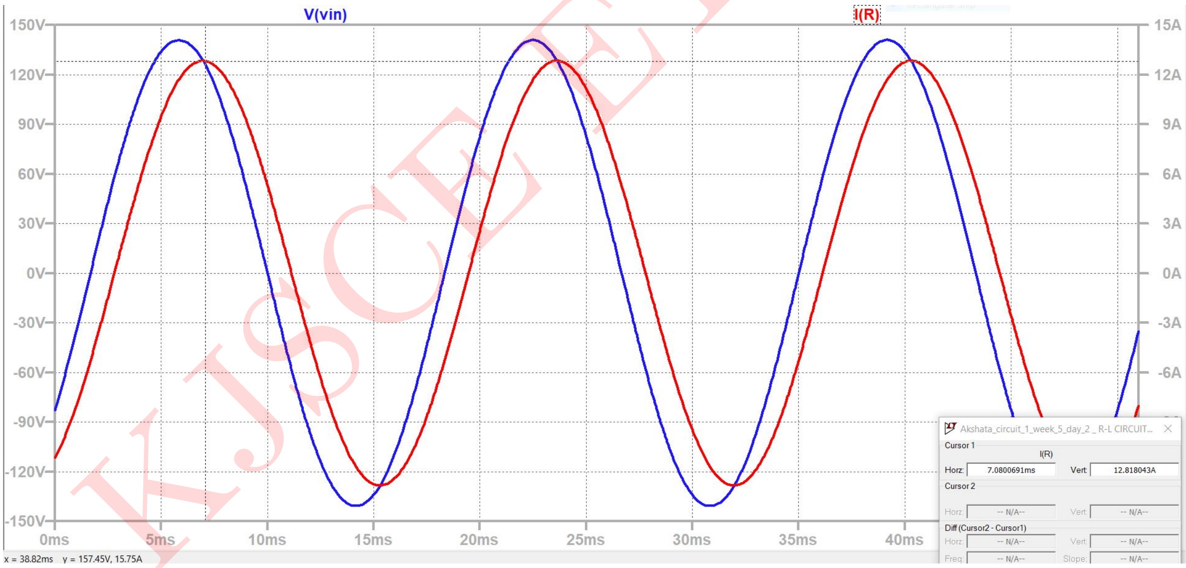

Figure 17: Peak value of current I

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
Peak voltage V_R	12.8122V	12.81V
Peak voltage V_L	128.122V	128.2898V
Peak voltage I	59.8842A	58.112A
Phase difference between V_s and I_s	$-25.051°$	$-26.0524°$
Phase difference between V_s and V_R	$25.051°$	$26.0524°$
Phase difference between V_s and V_L	$-64.949°$	$-64.57°$

Numerical 7:
A pure resistance of 110 ohms is in series with a pure capacitance of 80uF. The series combination is connected across 110V, 50 Hz supply
Determine the following:
a) Calculate the peak voltage across resistor and capacitor 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 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 degrees
f) Plot input source voltage VS(t) Vs voltage across inductor VL(t) in LTspice
g) Measure the phase delay/difference between VS(t) Vs VL(t) in time degrees
h) Calculate the power factor of the circuit.

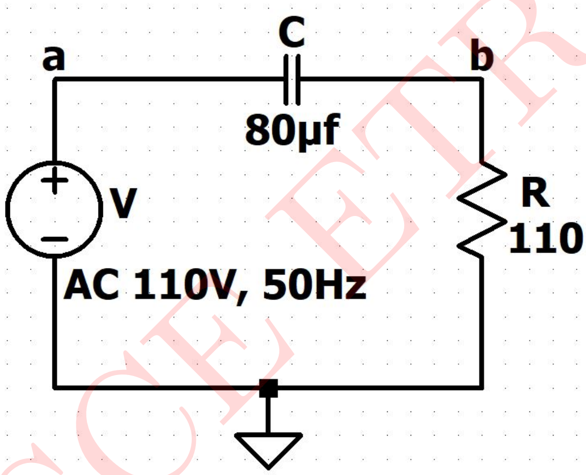

Figure 18: Circuit 7

Solution:

$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 80 \times 10}$-3

$Z = R - jX_C = 110 - 39.788j$

$\therefore \mathbf{Z = 116.9747} \angle -119.8855°$

$I_{rms} = \frac{V_{rms}}{Z} = \frac{110}{116.9747} \angle -119.8855°$

$\therefore \mathbf{I_{rms} = 0.9407} \angle 119.8855°\mathbf{A}$

$\therefore \mathbf{I_m = I_{rms}} \times\sqrt{2} \mathbf{= 1.330A}$

Peak value of V_r

$V_r = I \times R = 0.9407\angle\ 19^{\circ} \times 110\angle 0^{\circ}$

$\therefore \mathbf{V_r = 103.477V}$

$(V_r)_m = 103.477 \times \sqrt{2}$

$\therefore \mathbf{(V_r)_m = 146.338V}$

Peak value of V_C

$V_L = I \times X_C$

$V_L = 0.9407 \angle\ 19^{\circ} \times 39.788\angle\text{-}90^{\circ}$

$\therefore \mathbf{V_L = 37.42857} \angle -70.11^{\circ}\mathbf{V}$

$(V_L)_m = 37.42857 \times \sqrt{2}$

$\therefore \mathbf{(V_r)_m = 52.93199V}$

Power factor

$P.f = \cos\phi \qquad [\because \phi = -19.8855^{\circ}]$

$P.f = \cos(19.8855)$

$\therefore \mathbf{P.f = 0.94037}$

Phase difference between $V_s(t)$ and $I_s(t)$

$\therefore \phi = 19.8855^{\circ}$

Phase difference between $V_s(t)$ and $V_R(t)$

$\therefore \phi = 19.8855^{\circ}$

Phase difference between $V_s(t)$ and V_R

$\therefore \phi = -70.1145^{\circ}$

SIMULATED RESULTS:

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

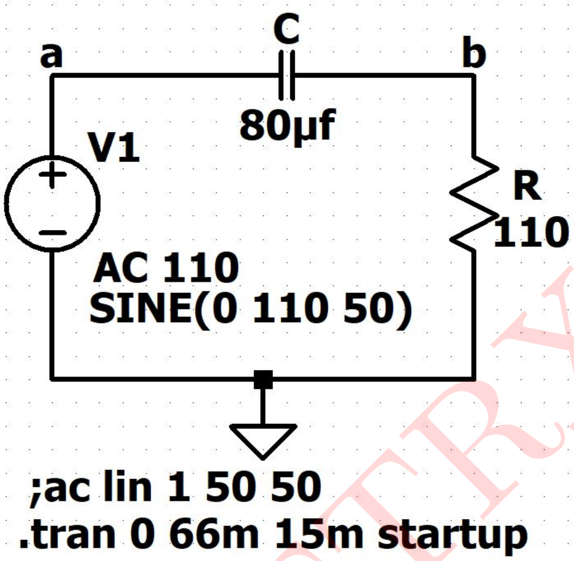

Figure 19: Circuit schematic for circuit 7

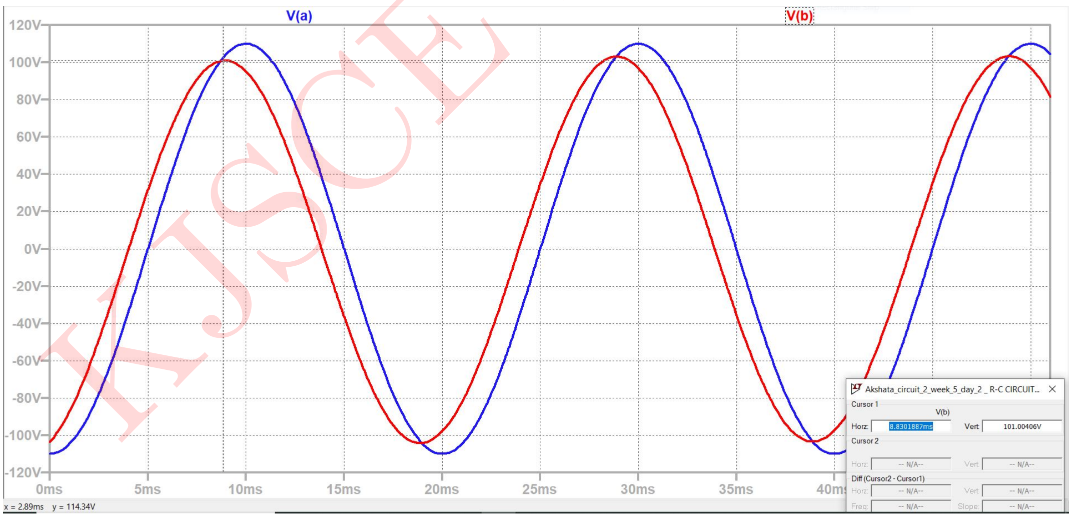

Figure 20: Peak value of voltage across R

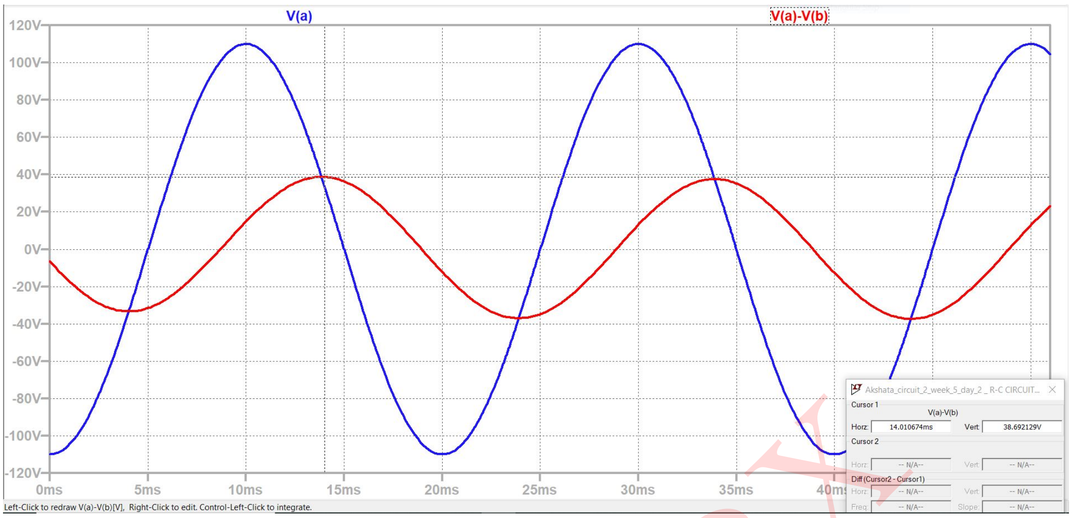

Figure 21: Peak value of voltage across C

Figure 22: Peak value of current I

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
Peak voltage V_R	103.477V	103.441V
Peak voltage V_L	37.428V	37.416V
Peak voltage I	0.9407A	0.94032A
Phase difference between V_s and I_s	19.885°	19.8859°
Phase difference between V_s and V_R	19.885°	19.8859°
Phase difference between V_s and V_L	-70.1145°	-70.11°

Numerical 8:
A series resonance network consisting of a resistor of 27, a capacitor of 2uF and an inductor of 25mH 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.

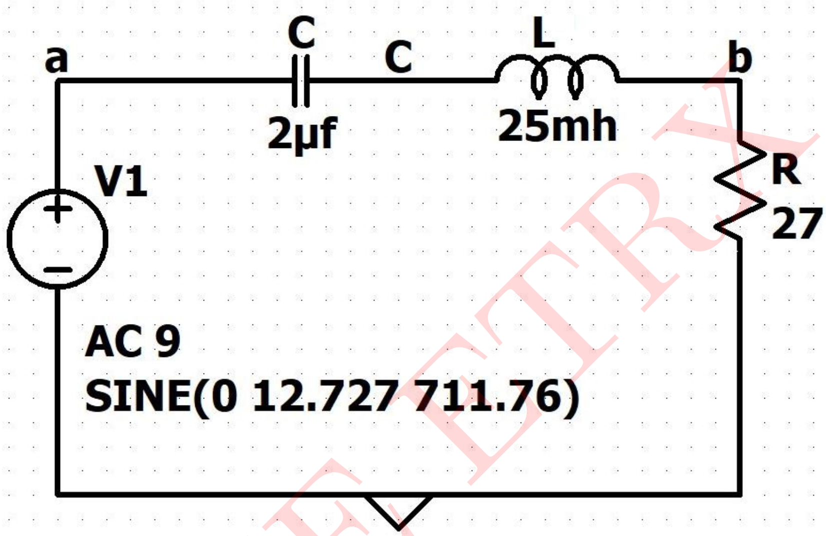

Figure 23: Circuit 8

Solution:

Resonant frequency

$$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{25\times10^{-3}\times2\times10^{-6}}}$$

$$\therefore \mathbf{f_o = 711.7625Hz}$$

Bandwidth

$$BW = \frac{R}{2\pi L} = \frac{27}{2\pi\sqrt{25\times10^{-3}}}$$

$$\therefore \mathbf{BW = 171.887}$$

Quality factor

$$Q_o = \frac{W_o L}{R} \qquad [W_o = \frac{1}{\sqrt{LC}}]$$

$$Q_o = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$Q_o = \frac{1}{27}\sqrt{\frac{25\times10^{-3}}{2\times10^{-6}}}$$

$$\therefore \mathbf{Q_o = 4.1408}$$

Current at resonance

$\therefore \mathbf{I_o} = \frac{9}{27} = \mathbf{0.333A}$

$\therefore \mathbf{I_m} = \mathbf{0.333} \times\sqrt{2} = \mathbf{0.4709A}$

Voltage across $\mathrm{V_{Ro}}$

$\mathrm{V_{Ro}} = \mathrm{I_o} \times R$

$\mathrm{V_{Ro}} = 0.333 \times 27$

$\therefore \mathbf{V_{Ro}} = \mathbf{8.991}$

Voltage across $\mathrm{V_{Lo}}$

$\mathrm{V_{Lo}} = \mathrm{I_o} \times X_{\mathrm{Lo}}$

$\mathrm{V_{Lo}} = 0.333 \times 2\phi f L$

$\therefore \mathbf{V_{Lo}} = \mathbf{37.2370V}$

$\therefore \mathbf{(V_{Lo})_m} = \mathbf{37.2370} \times\sqrt{2} = \mathbf{52.661V}$

Voltage across $\mathrm{V_{Co}}$

$\mathrm{V_{Co}} = \mathrm{I_o} \times X_{\mathrm{Co}}$

$\mathrm{V_{Co}} = 0.333 \times \frac{1}{2\phi f C}$

$\therefore \mathbf{V_{Lo}} = \mathbf{37.23053V}$

$\therefore \mathbf{(V_{Co})_m} = \mathbf{37.23053} \times\sqrt{2} = \mathbf{52.6519V}$

SIMULATED RESULTS:

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

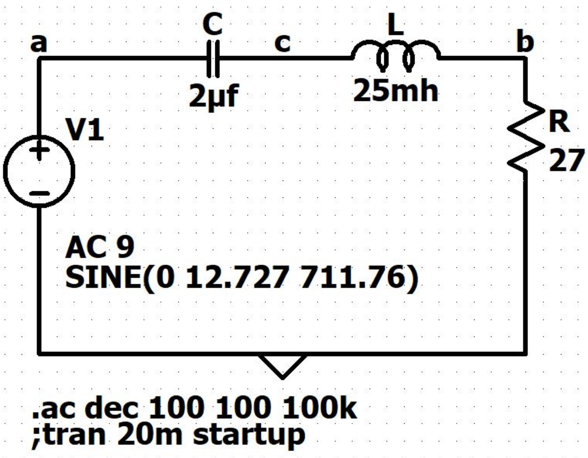

Figure 24: Circuit schematic for circuit 8

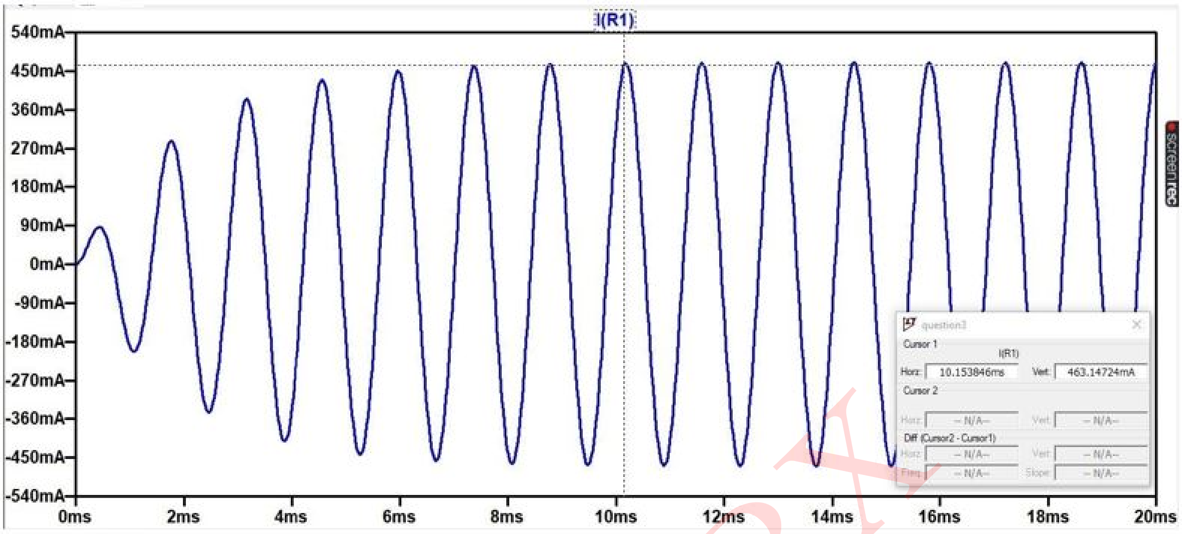

Figure 25: Current of resonance

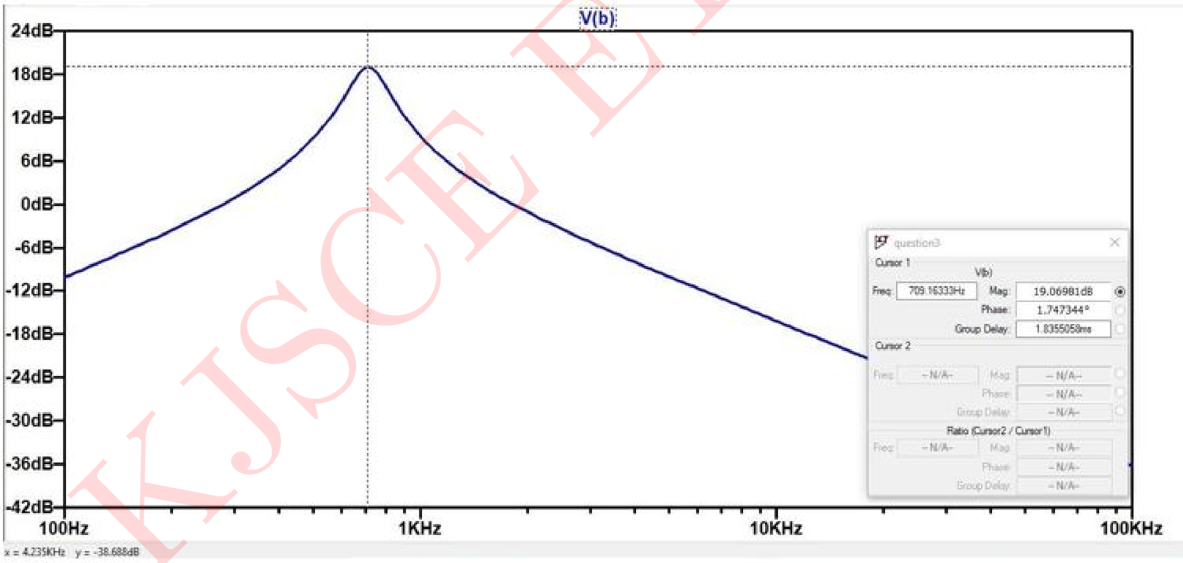

Figure 26: Resonant frequency

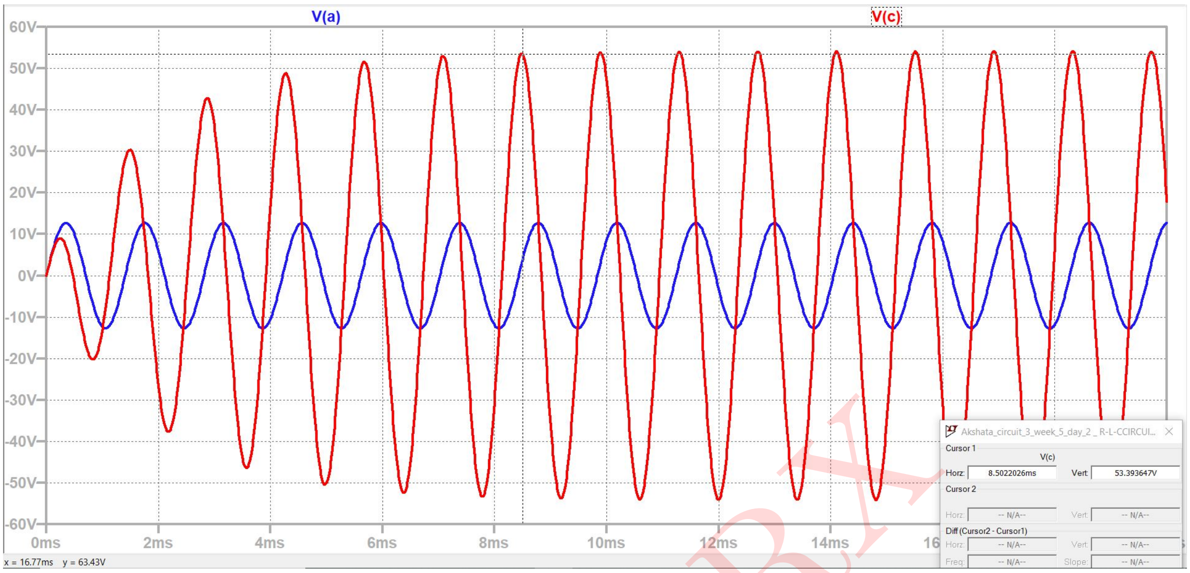

Figure 27: Peak value of voltage across C

Comparison of theoretical and simulated values:

Parameters	Theoretical Values	Simulated Values
Resonant frequency	711.76Hz	709.16Hz
Current at resonance	0.4709A	0.4613A
Voltage across V_{Lo}	52.661V	52.22V
Voltage across V_{Co}	52.651V	52.028V