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 80μF are connected in series across a 100V, 60Hz supply.
Calculate:
i) The total circuit current
ii) V_R, V_L & V_C
iii) Power factor
iv) Draw the voltage phasor diagram

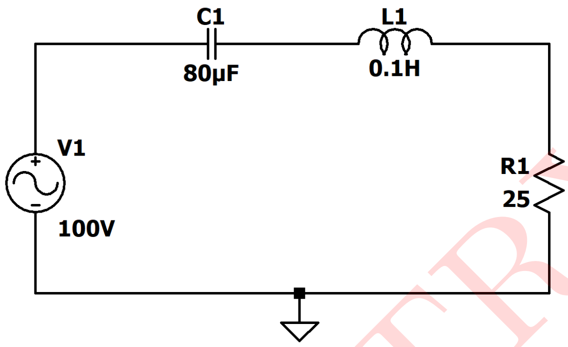


Figure 1: Circuit 1

Solution:

Finding Reactance for L_1,

$X_L = 2\pi f L_1 = 2\pi \times 60 \times 0.1$

$X_L = 37.6991\Omega$

Finding Reactance for C_1,

$X_C = \dfrac{1}{2\pi f C_1} = \dfrac{1}{2\pi \times 60 \times 80 \times 10^{-6}}$

$X_C = 33.1572\Omega$

Finding Total Impedance,

$Z = \sqrt{R_1^2 + (X_L - X_C)^2} = \sqrt{25^2 + (37.6991 - 33.1572)^2}$

$\therefore Z = 25.409\Omega$

Finding total current I,

$I = \dfrac{V_{in}}{Z} = \dfrac{100}{25.409}$

$I = 3.9356$A

$V_R = I \times R_1 = 3.9356 \times 25$

$\therefore V_R = 98.39V$

$V_L = I \times X_L = 3.9356 \times 37.6991$

$\therefore V_L = 148.368V$

$V_C = I \times X_C = 3.9356 \times 33.1572$

$\therefore V_C = 130.4934V$

$$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{37.6991 - 33.1572}{25}\right)$$

$\phi = 10.269°$

Power factor $= \cos(\phi) = \cos(10.269)$

$\therefore$Power factor$= 0.9839$

Voltage Phasor diagram,

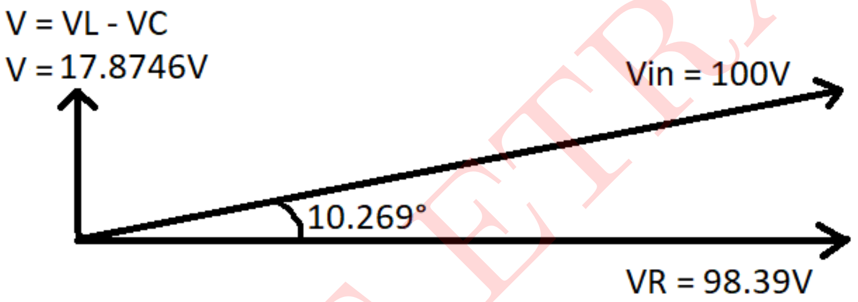
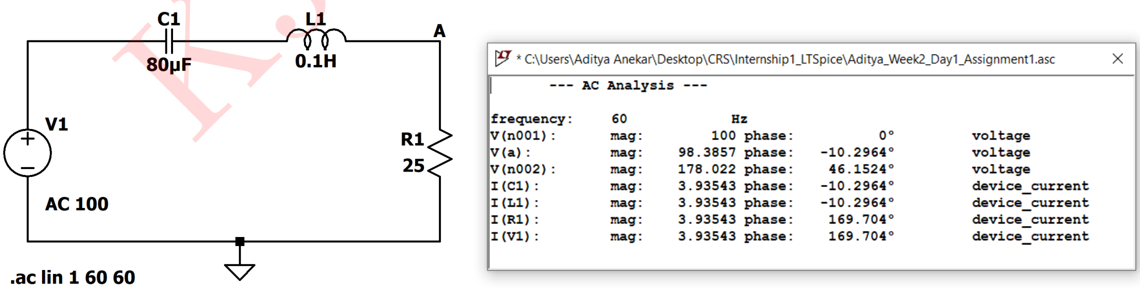


Figure 2: Voltage Phasor diagram

SIMULATED RESULTS

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



frequency:	60	Hz			
V(n001):	mag:	100	phase:	0°	voltage
V(a):	mag:	98.3857	phase:	-10.2964°	voltage
V(n002):	mag:	178.022	phase:	46.1524°	voltage
I(C1):	mag:	3.93543	phase:	-10.2964°	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

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_R	98.39V	98.3857V
V_L	148.368V	148.362V
V_C	130.4934V	130.488V
I	3.9356A	3.93543A
ϕ	10.269°	10.2964°
Power Factor	0.9839	0.98389

Table 1: Numerical 1

Numerical 2: A 50 Hz sinusoidal voltage V = 141 sinωt is applied to a series R-L circuit. The values of the resistance and the inductance are 4Ω and 0.01 H respectively Calculate:

a) The RMS value of the current in the circuit.

b) The RMS value of the voltages appearing across the resistance and the inductance.

c) Power factor of the circuit.

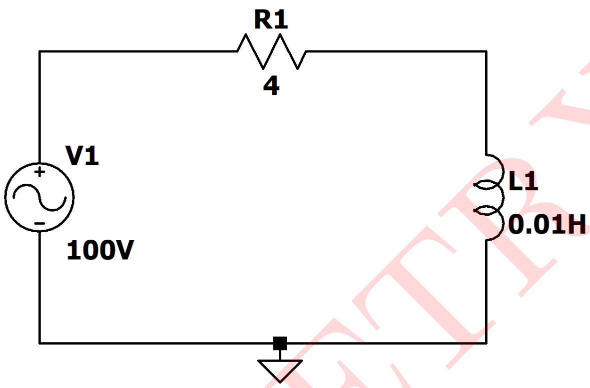


Figure 4: Circuit 2

Solution:

Finding Reactance for L_1,

X$_L$ = $2\pi f L_1 = 2\pi \times 50 \times 0.01$

X$_L$ = 3.14159Ω

Finding Total Impedance,

Z = $\sqrt{R^2 + (X_L)^2} = \sqrt{4^2 + (3.14159)^2}$

$\therefore Z = 5.0862\Omega$

Finding RMS current I_{rms},

$I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{100}{5.0862}$

I_{rms} = 19.661A

V$_R$ = $I_{rms} \times R_1 = 19.661 \times 4$

$\therefore V_R = 78.644V$

V$_L$ = $I_{rms} \times X_L = 19.661 \times 3.14159$

$\therefore V_L = 61.7668V$

Power factor $= \dfrac{R}{Z} = \dfrac{4}{5.0862}$

$\therefore$Power factor$= 0.7864$

$\phi = \cos^{-1}(0.7864)$

$\therefore \phi = 38.1496°$

SIMULATED RESULTS

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

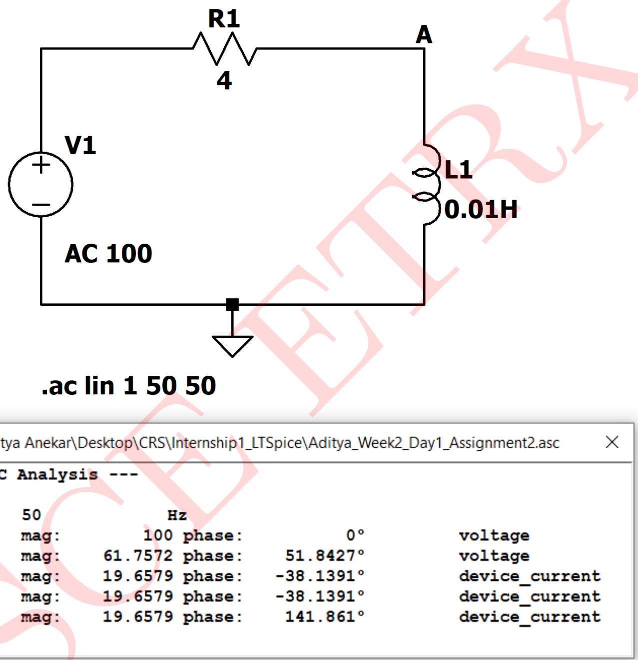


Figure 5: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
Z	5.0862Ω	5.087Ω
V_R	78.644V	78.6318V
V_L	61.7668V	61.7572V
I	19.661A	19.6579A
ϕ	38.1496°	38.1391°
Power Factor	0.7864	0.7865

Table 2: Numerical 2

Numerical 3: A pure resistance of 55 ohms is in series with a pure capacitance of 100uF. The series combination is connected across 150V, 60 Hz supply.
Calculate:
(a) Impedance
(b) Current
(c) Power factor
(d) Phase angle
(e) Voltage across resistor
(f) Voltage across capacitor.

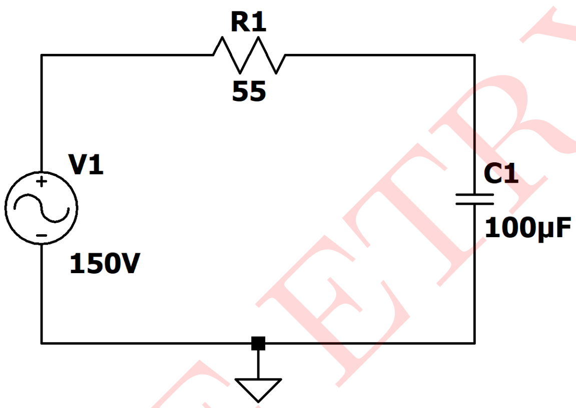


Figure 6: Circuit 3

Solution:

Finding Reactance for C_1,

$$X_C = \frac{1}{2\pi f C_1} = \frac{1}{2\pi \times 60 \times 100 \times 10^{-6}}$$

$$X_C = 26.5258\Omega$$

Finding Total Impedance,

$$Z = \sqrt{R_1^2 + (X_C)^2} = \sqrt{55^2 + (26.5258)^2}$$

$$\therefore Z = 61.06\Omega$$

Finding total current I,

$$I = \frac{V_{in}}{Z} = \frac{150}{61.06}$$

$$I = 2.4566\text{A}$$

$$V_R = I \times R_1 = 2.4566 \times 55$$

$$\therefore V_R = 135.113V$$

$$V_C = I \times X_C = 2.4566 \times 26.5258$$

$$\therefore V_C = 65.1632V$$

$$\text{Power factor} = \frac{R}{Z} = \frac{55}{61.06}$$

$$\therefore \text{Power factor} = 0.9$$

$\phi = \cos^{-1}(0.9)$

$\therefore \phi = 25.8419°$

SIMULATED RESULTS

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

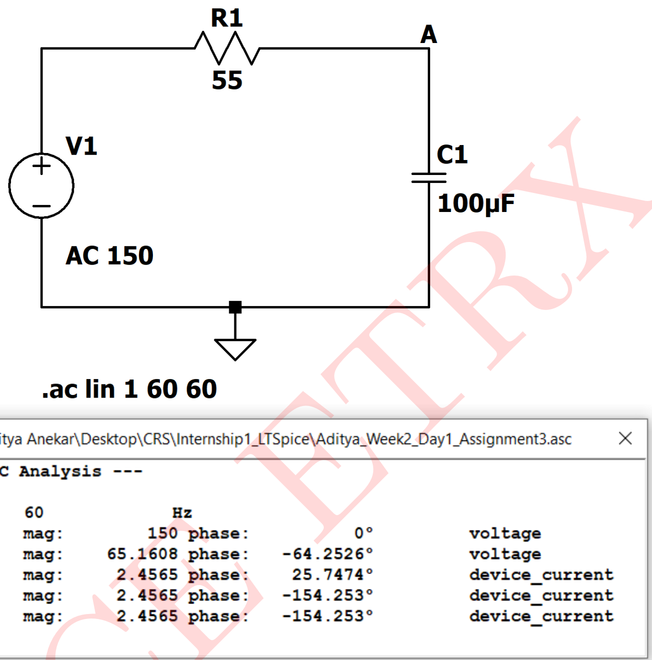


Figure 7: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
Z	61.06Ω	61.062Ω
V_R	135.113V	135.108V
V_C	65.1632V	65.1608V
I	2.4566A	2.4565A
ϕ	25.8419°	25.747°
Power Factor	0.9	0.9

Table 3: Numerical 3

Numerical 4: A circuit shown in Figure 8 consists of resistance of 35Ω, an inductance of 54mH and a capacitor of 100μF 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

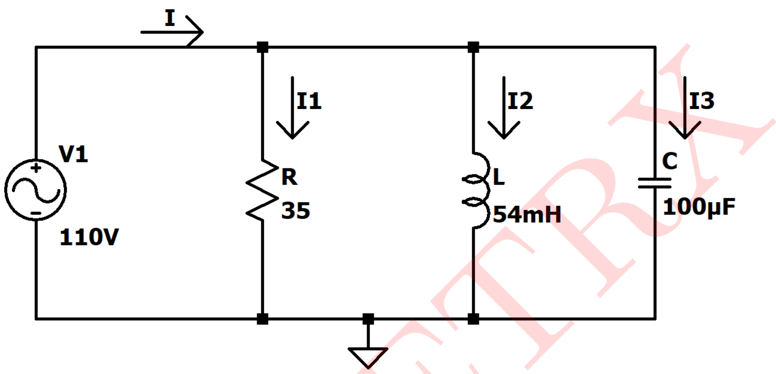


Figure 8: Circuit 4

Solution:

Finding Reactance for L,

$X_L = 2\pi fL = 2\pi \times 50 \times 54 \times 10^{-3}$

$X_L = 16.9646\Omega$

Finding Reactance for C,

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

$X_C = 31.8309\Omega$

Finding Total Impedance,

$$Z = \frac{1}{\sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}} = \frac{1}{\sqrt{\frac{1}{35^2} + \left(\frac{1}{16.9646} - \frac{1}{31.8309}\right)^2}}$$

$\therefore Z = 25.2\angle 43.936°\Omega$

Finding total current I,

$$I = \frac{V_{in}}{Z} = \frac{110}{25.2}$$

$\therefore I = 4.365\angle -43.936°A$

$$I_1 = \frac{V}{R} = \frac{110}{35}$$

$\therefore I_1 = 3.14285\angle 0°A$

$$I_2 = \frac{V}{X_L} = \frac{110}{16.9646}$$

$\therefore I_2 = 6.48409\angle{-90^\circ} A$

$I_3 = \dfrac{V}{X_C} = \dfrac{110}{31.9309}$

$\therefore I_3 = 3.45576\angle 90^\circ A$

Power factor $= \cos(\phi) = \cos(-43.936)$

$\therefore$Power factor $= 0.72$

Voltage Phasor diagram,

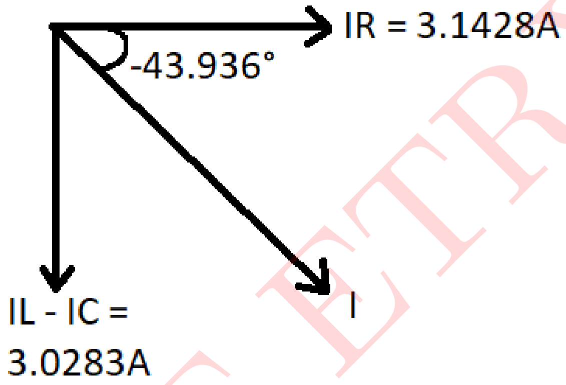


Figure 9: Phasor diagram

SIMULATED RESULTS

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

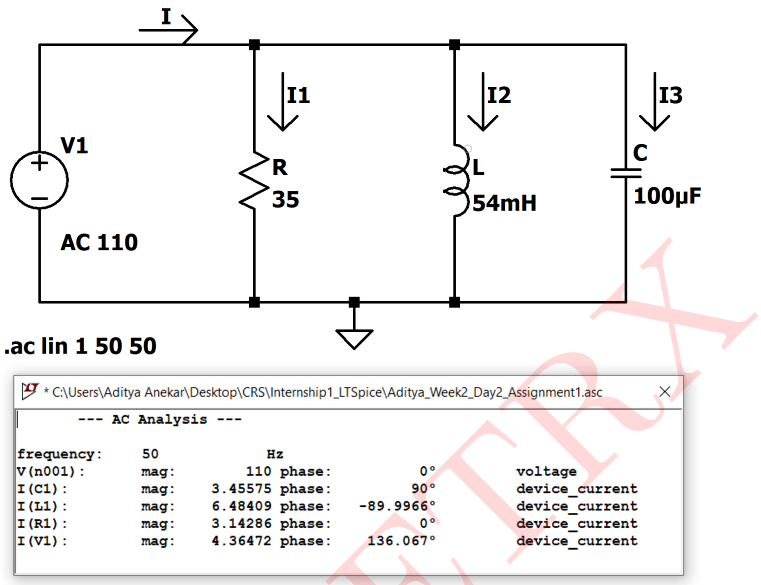


Figure 10: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I_1	3.14285A	3.14286A
I_2	6.4841A	6.48409A
I_3	3.45576A	3.45575A
I	4.365A	4.3647A
ϕ	$-43.936°$	$-43°$
Power Factor	0.72011	0.72015

Table 4: Numerical 4

Numerical 5: Find I, I_1 and I_2 in the Circuit 11, If
$\mathrm{R}_1 = 2\Omega$, $\mathrm{L}_1 = j8\Omega$, $\mathrm{R}_2 = 15\Omega$, $\mathrm{L}_2 = j10\Omega$, $\mathrm{R}_3 = 12\Omega$, $\mathrm{C}_1 = -j2\Omega$, frequency = 50Hz

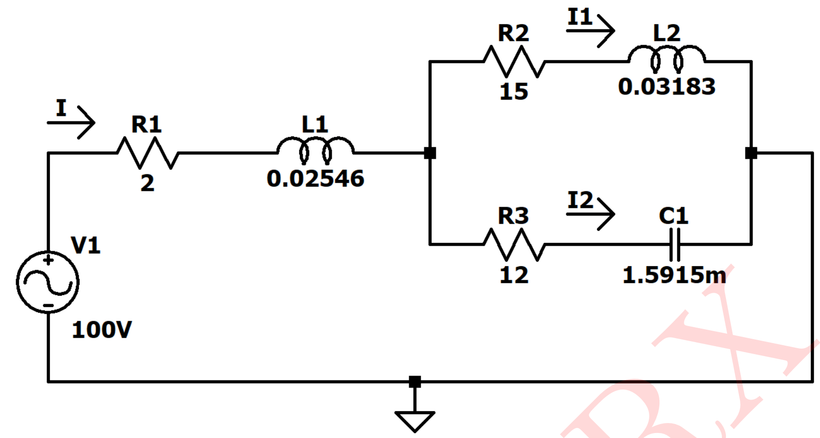


Figure 11: Circuit 5

Solution:

$\mathrm{Z}_1 = 2 + j8\Omega, Z_2 = 15 + j10\Omega, Z_1 = 12 - j2\Omega$

$\mathrm{Z} = \mathrm{Z}_1 + \dfrac{Z_2 \times Z_3}{Z_2 + Z_3} = 2 + j8 + \dfrac{(15 + j10) \times (12 - j2)}{15 + j10 + 12 - j2}$

$\therefore Z = 9.7175 + j9.0466 = 13.2767\angle 42.9523°$

Finding total current I,

$I = \dfrac{V}{Z} = \dfrac{100}{13.2767\angle 42.9523°}$

$I = 7.5319\angle -42.9523° A$

$\mathrm{I}_1 = I \times \dfrac{Z_3}{Z_2 + Z_3}$

$\therefore I_1 = 3.25386\angle -68.9189° A$

$\mathrm{I}_2 = I \times \dfrac{Z_2}{Z_2 + Z_3}$

$\therefore I_2 = 4.8218\angle -25.76659° A$

SIMULATED RESULTS

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

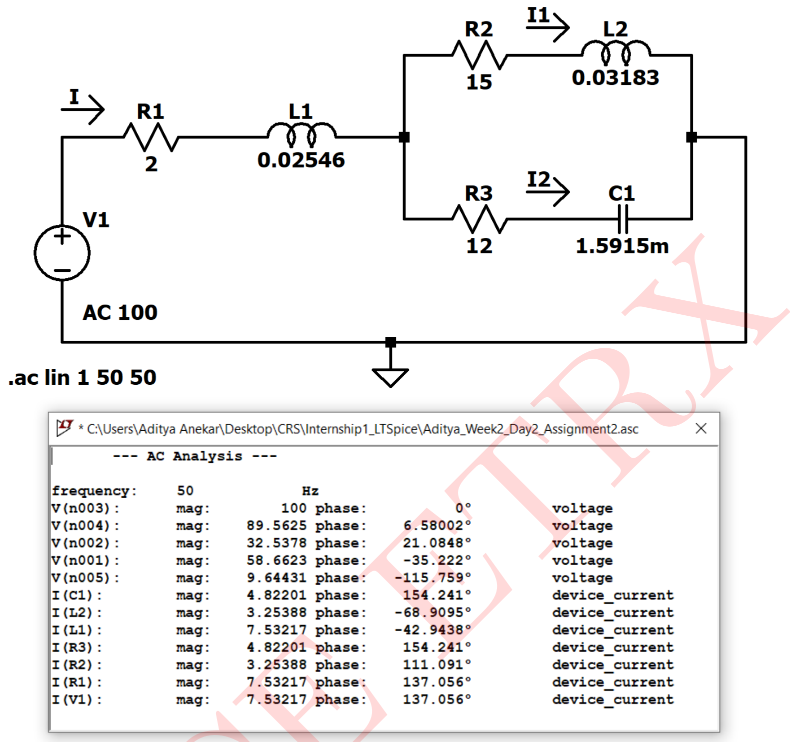


Figure 12: Circuit Schematic and Simulated Results

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I	$7.5319\angle{-42.9523}^{\circ}A$	$7.53217\angle{-42.944}^{\circ}A$
I_1	$3.25386\angle{-68.9189}^{\circ}A$	$3.25388\angle{-68.9095}^{\circ}A$
I_2	$4.8218\angle{-25.76659}^{\circ}A$	$4.82201\angle{-25.759}^{\circ}A$

Table 5: Numerical 5

Numerical 6: A series resonance network consisting of a resistor of 25Ω, a capacitor of 2.5μF and an inductor of 22mH is connected across a sinusoidal supply voltage which has a constant output of AC 9V 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.

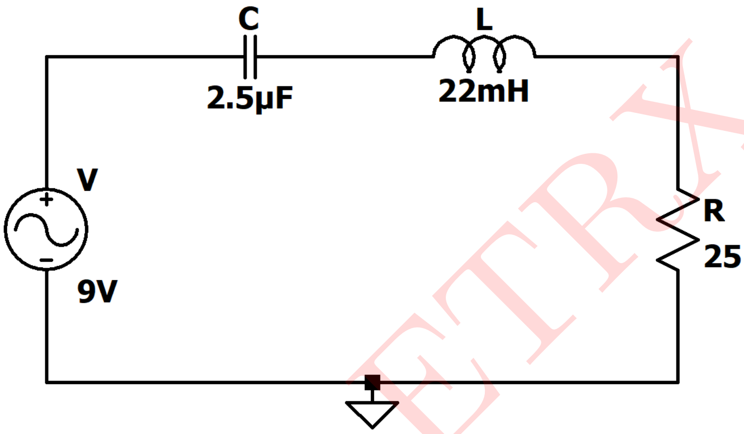


Figure 13: Circuit 6

Solution:

Finding Resonant Frequency,

$f_r = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{22\times10^{-3}\times2.5\times10^{-6}}}$

$\therefore f_r = 678.6389Hz$

Finding Reactance for L_1,

$X_L = 2\pi fL = 2\pi\times678.6389\times22\times10^{-3}$

$\therefore X_L = 93.8\Omega$

Finding Reactance for C_1,

$X_C = \dfrac{1}{2\pi fC} = \dfrac{1}{2\pi\times678.6389\times2.5\times10^{-6}}$

$\therefore X_C = 93.8\Omega$

At resonance,

$Z = R = 25\Omega$

Finding maximum current I_m,

$I = \dfrac{V}{Z} = \dfrac{9}{25}$

$I = 0.36A$

$I_m = 0.36\times\sqrt{2}$

$\therefore I_m = 0.509A$

$V_L = I_m \times X_L = 0.509 \times 93.8$

$\therefore V_L = 47.755V$

$V_C = I_m \times X_C = 0.509 \times 93.8$

$\therefore V_C = 47.755V$

Quality factor = Q = $\dfrac{X_L}{R} = \dfrac{93.8}{25}$

$\therefore Q = 3.752$

BW = $\dfrac{f_r}{Q} = \dfrac{678.6389}{3.752}$

$\therefore BW = 180.8739Hz$

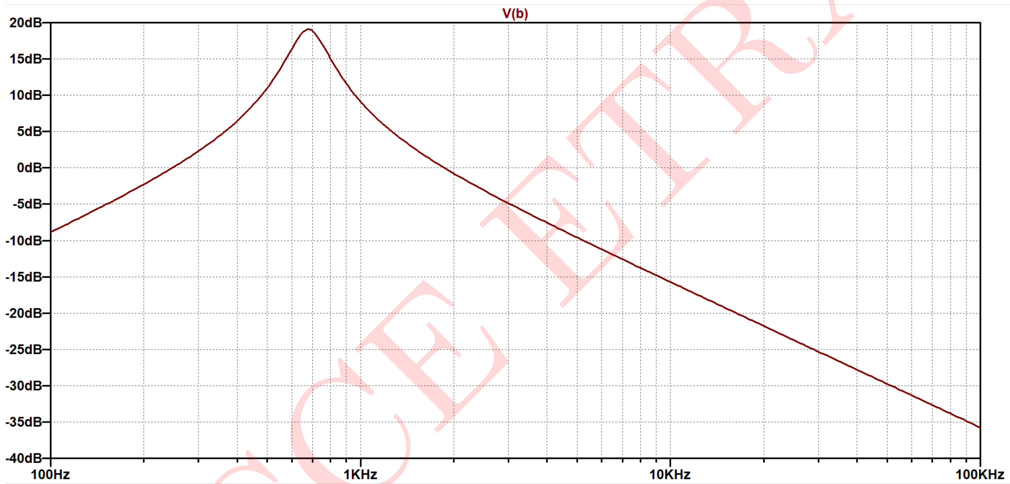


Figure 14: Resonance Curve

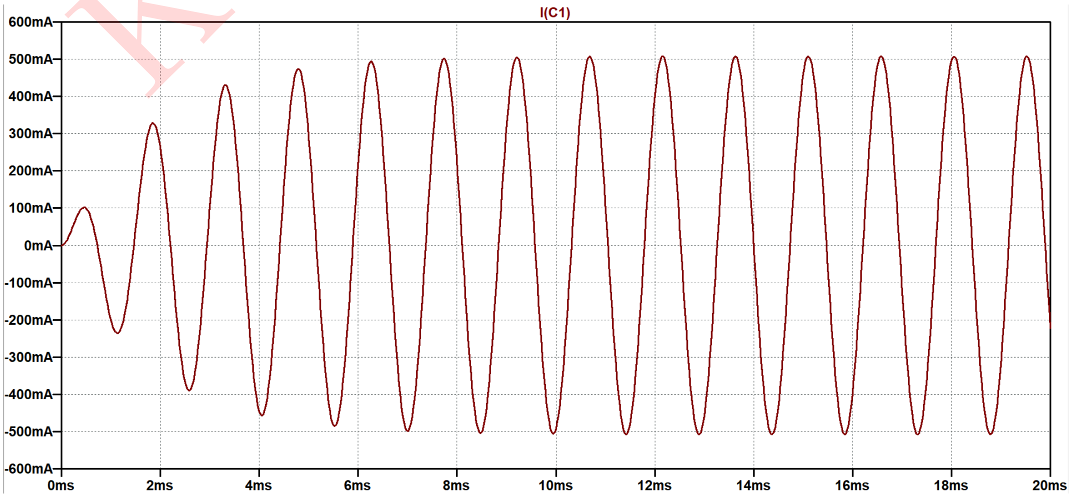


Figure 15: Current at Resonance

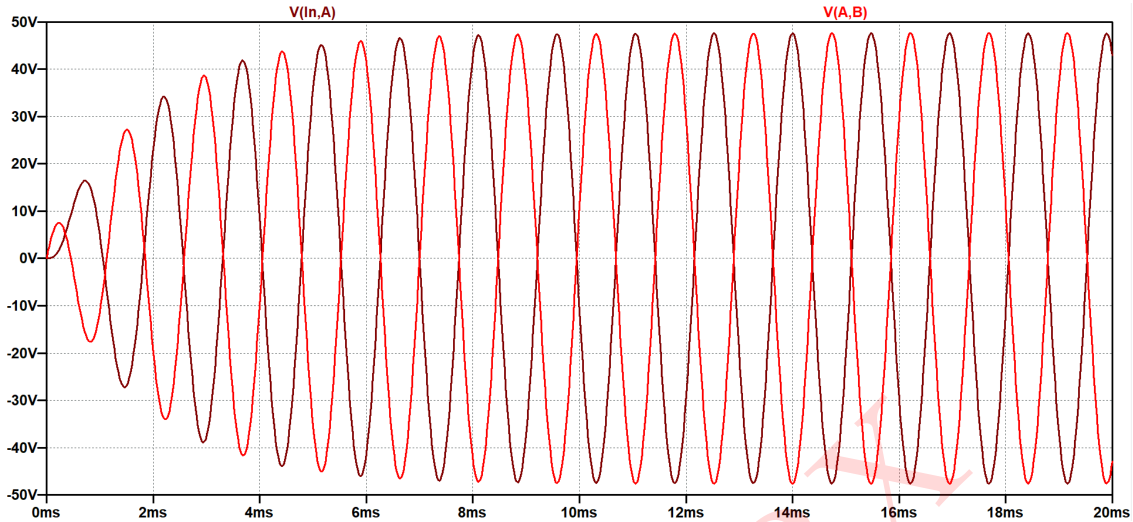


Figure 16: Voltage across Inductor and Resistor at Resonance

SIMULATED RESULTS

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

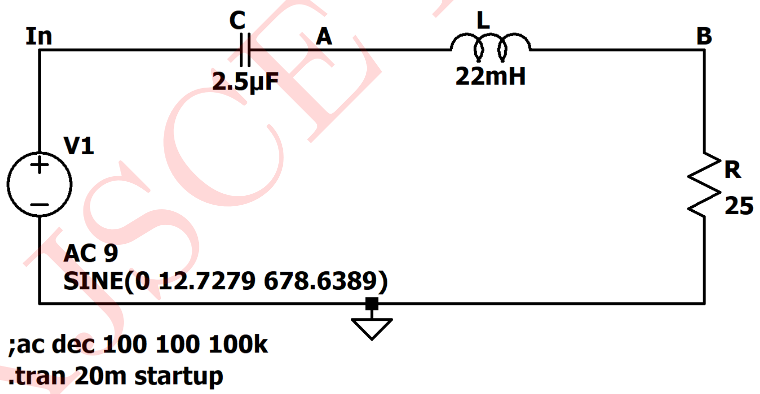


Figure 17: Circuit Schematic

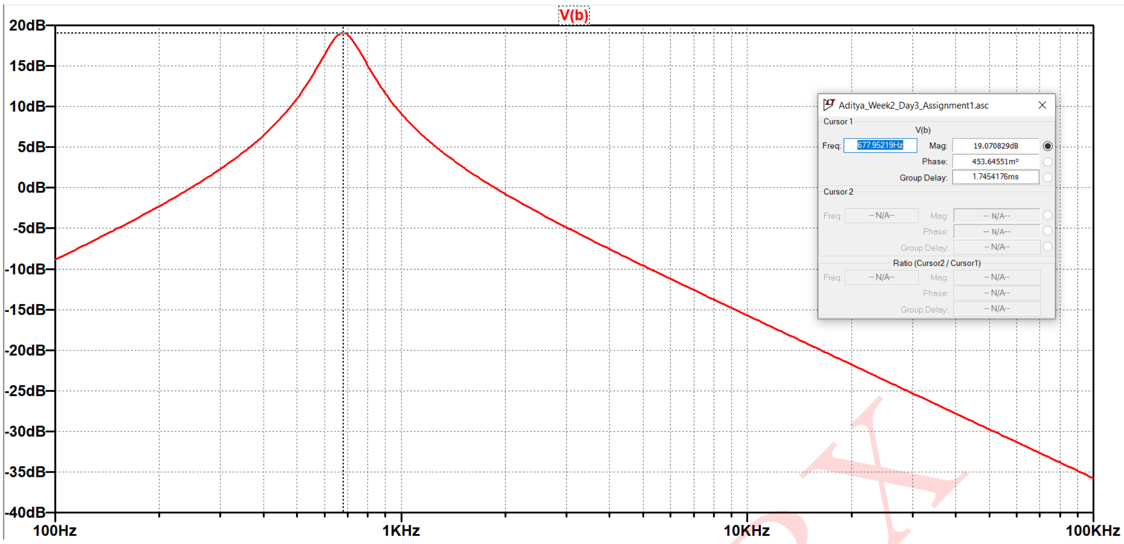


Figure 18: Simulated results for Resonance Curve

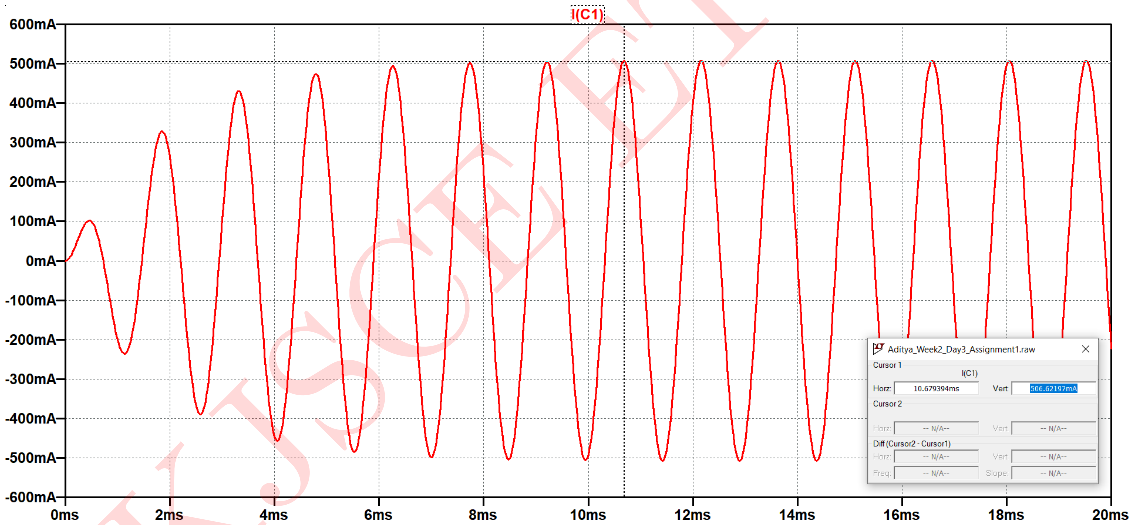


Figure 19: Simulated results for current at Resonance

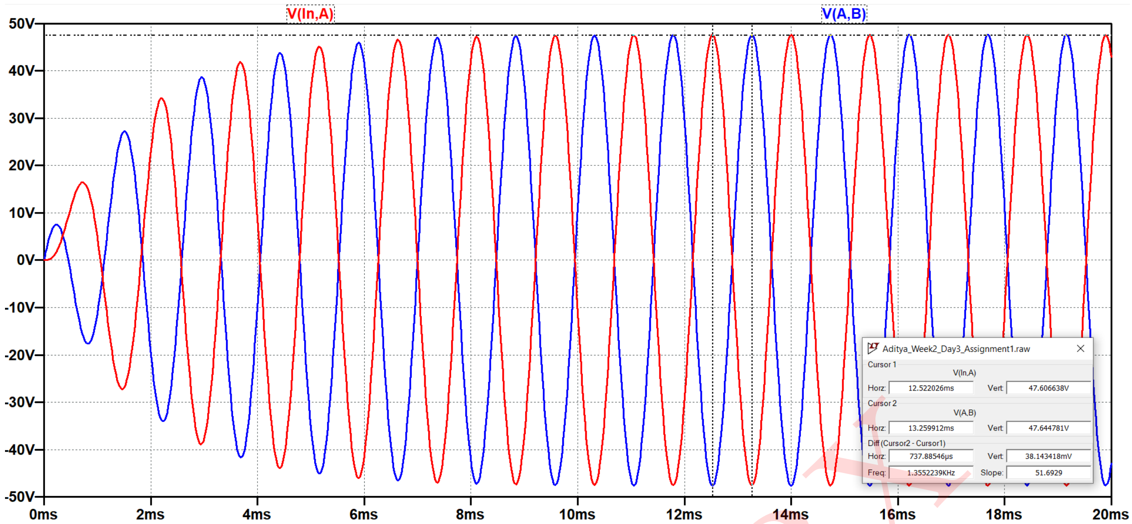


Figure 20: Simulated results for Voltage across Inductor and Resistor at Resonance

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
I_m	0.509A	0.5067A
V_L	47.755V	47.636V
V_C	47.755V	47.605V

Table 6: Numerical 6

Numerical 7: A 50Hz sinusoidal voltage V = 141sin(ωt) is applied to a series R-L circuit given in Circuit 7. The values of the resistance and the inductance are 5.6Ω and 0.018H 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 V_S vs input source current I_S in LTspice

c. Measure the phase delay/difference between V_S vs I_S in time & degrees

d. Plot input source voltage V_S vs voltage across resistor V_R in LTspice

e. Measure the phase delay/difference between V_S vs V_R in time & degrees

f. Plot input source voltage V_S vs voltage across inductor V_L in LTspice

g. Measure the phase delay/difference between V_S vs V_L in time & degrees

h. Calculate the power factor of the circuit.

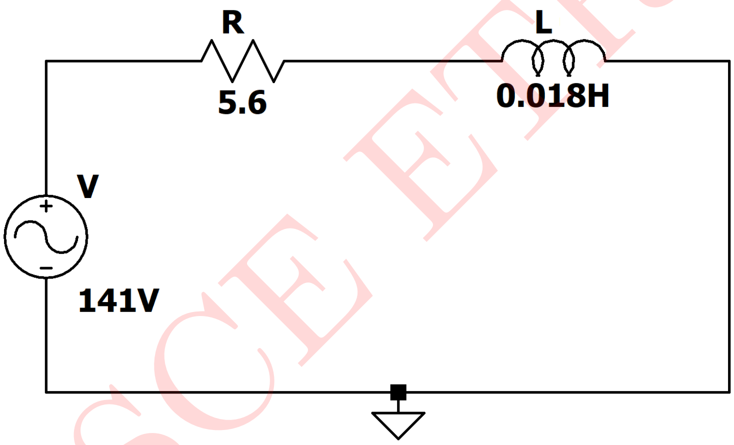


Figure 21: Circuit 7

Solution:

Finding Reactance for L_1,

$X_L = 2\pi f L = 2\pi \times 50 \times 0.018$

$\therefore X_L = 5.6548\Omega$

Finding Total Impedance,

$Z = R + jX_L = 5.6 + j(5.6548)$

$\therefore Z = 7.9536\angle(45.244°)\Omega$

Finding current I,

$$I = \frac{V}{Z} = \frac{141}{7.9536\angle(45.244°)}$$

$\therefore I = 17.7278\angle(-45.244°)A$

$V_R = I \times R = 17.7278\angle(-45.244°) \times 5.6$

$\therefore V_R = 100.247\angle(-45.244°)V$

$V_L = I \times X_L = 17.7278\angle(-45.244°) \times 5.6548$

$\therefore V_L = 99.2757\angle(-45.244°)V$

Power factor $= \dfrac{V_R}{V} = \dfrac{100.247}{141}$

$\therefore$Power factor $= 0.7109$

Calculating Phase difference for V_S & V_L,

$\Delta\theta = 90 - 45.244 = 44.756°$

$$\Delta T = \frac{\Delta\theta \times (T_{Period})}{360°} = \frac{44.756 \times \frac{1}{50}}{360}$$

$\Delta T = 2.486ms$

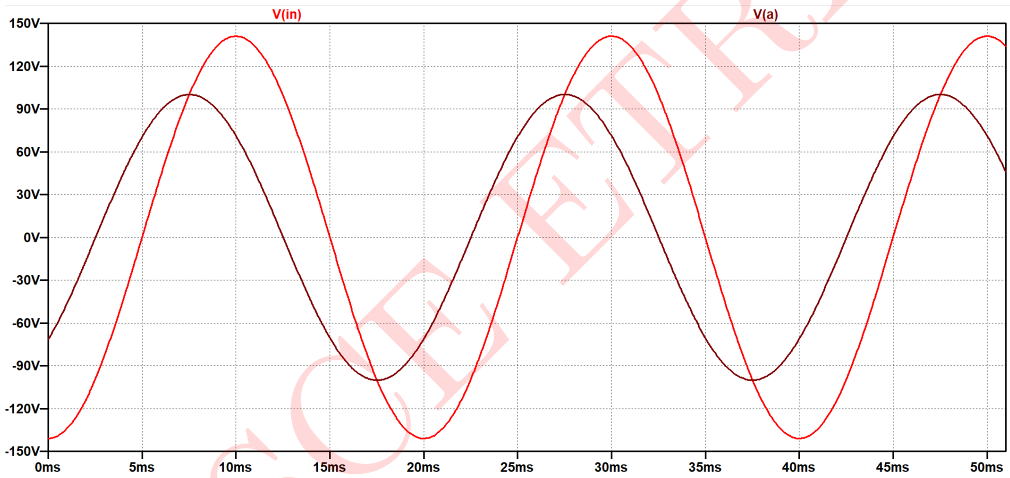


Figure 22: V_S & V_L

Calculating Phase difference for V_S & V_R,

$\Delta\theta = 45.244°$

$$\Delta T = \frac{45.244 \times \frac{1}{50}}{360}$$

$\Delta T = 2.5135ms$

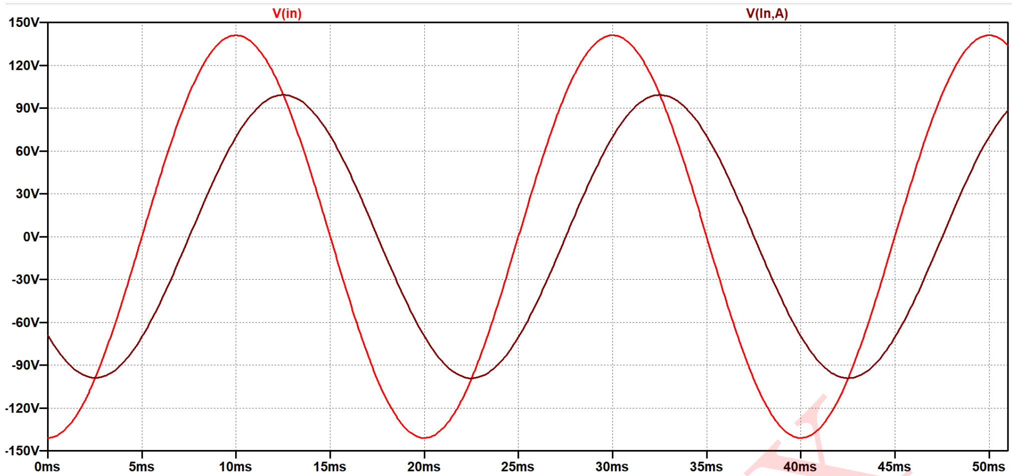


Figure 23: V$_S$ & V_R

Calculating Phase difference for V$_S$ & I_S,

$\Delta\theta = 180 - 45.244 = 134.756°$

$$\Delta T = \frac{134.756 \times \frac{1}{50}}{360}$$

$\Delta T = 7.4864ms$

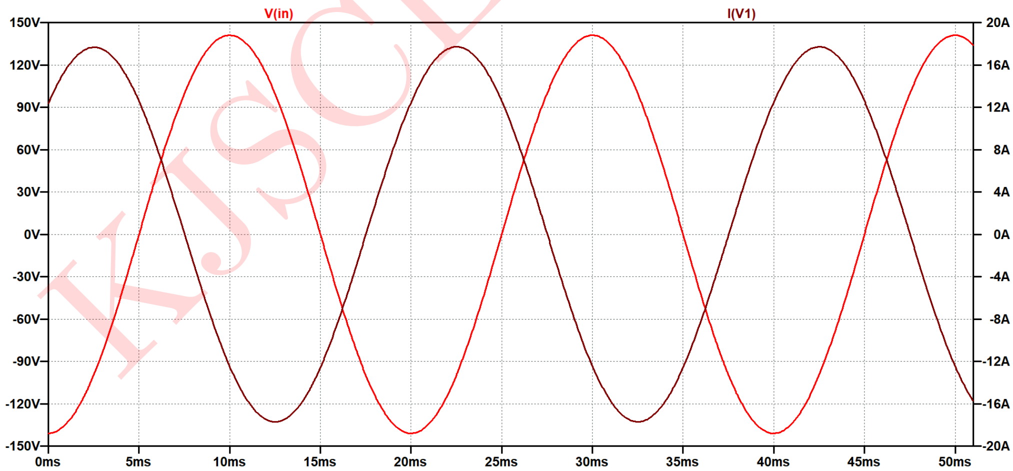


Figure 24: V$_S$ & I_S

SIMULATED RESULTS

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

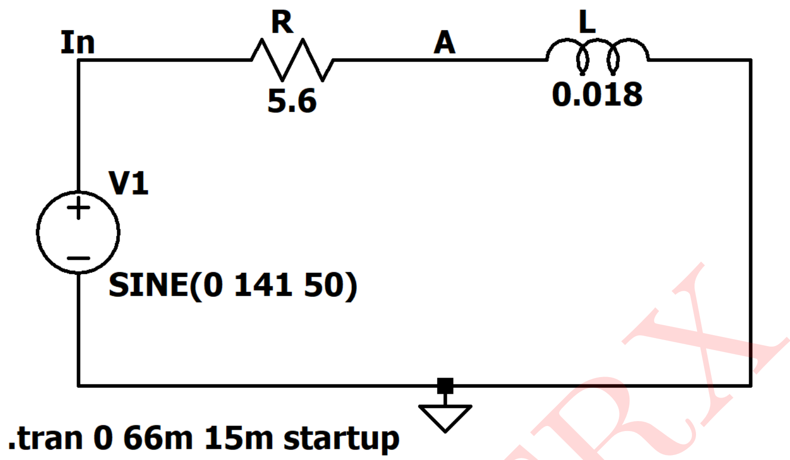


Figure 25: Circuit Schematic

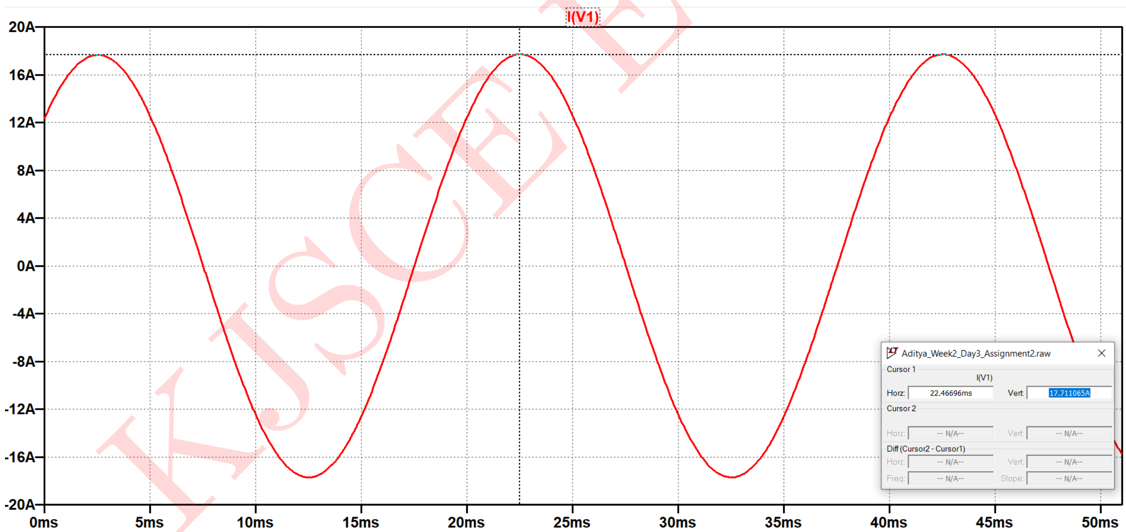


Figure 26: Simulated results for Source Current

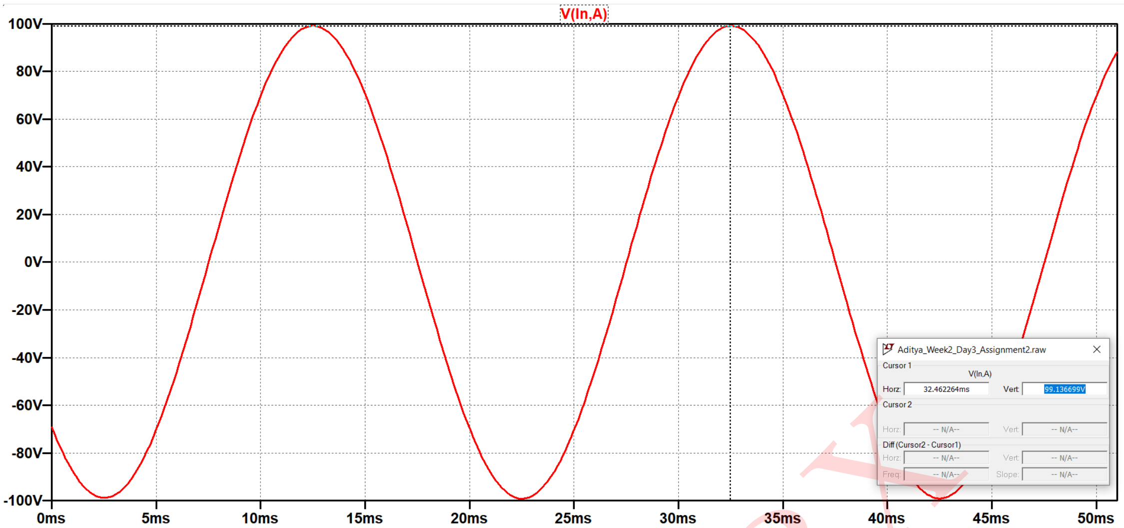


Figure 27: Simulated results for Voltage across Resistor

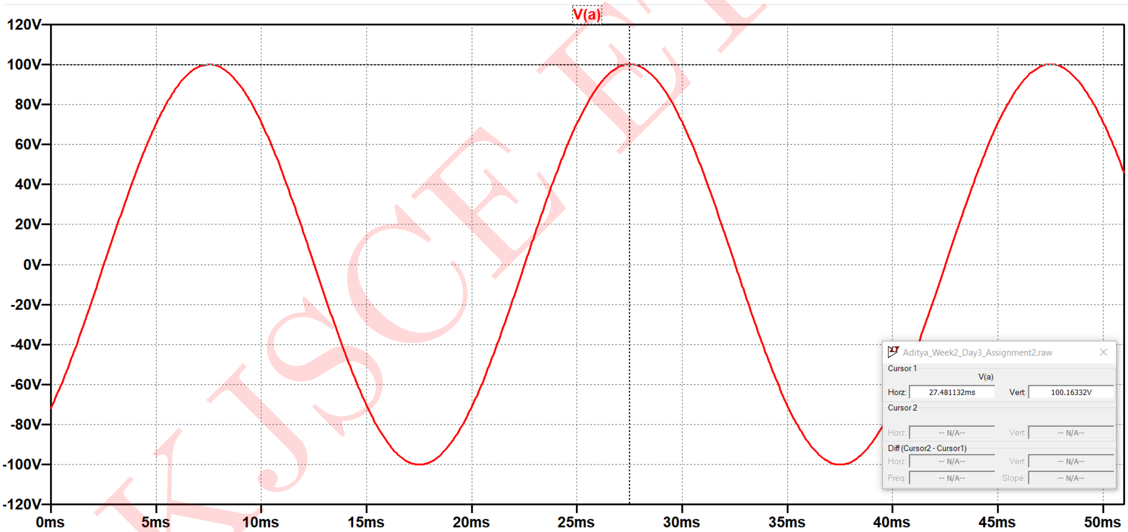


Figure 28: Simulated results for Voltage across Inductor

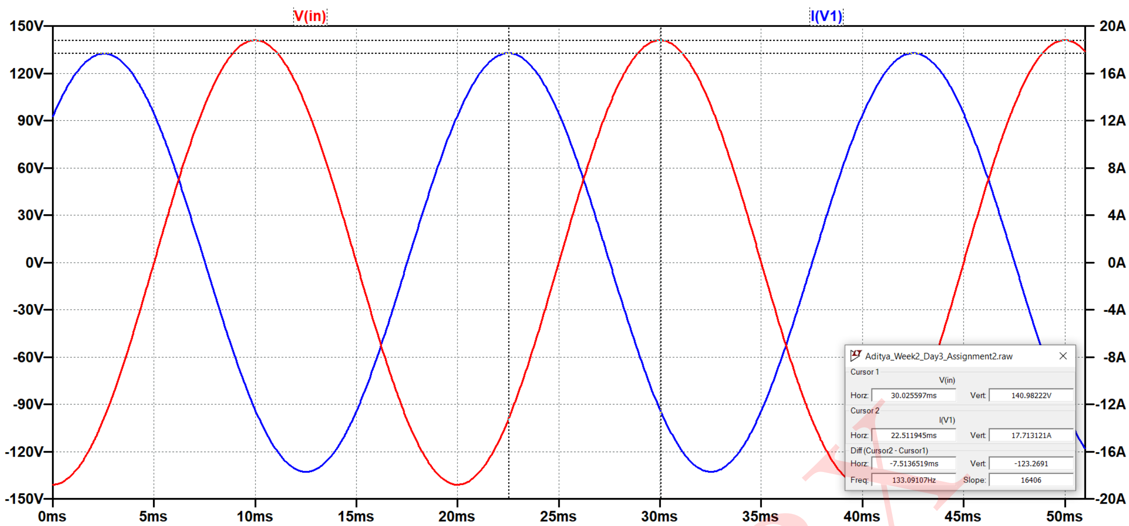


Figure 29: Simulated results for V_S & I_S

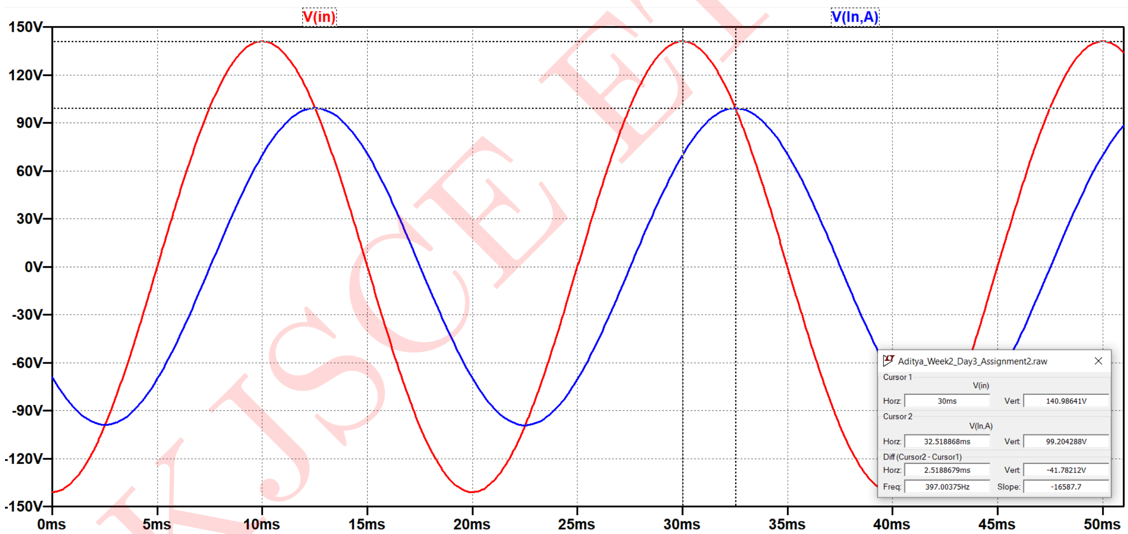


Figure 30: Simulated results for V_S & V_R

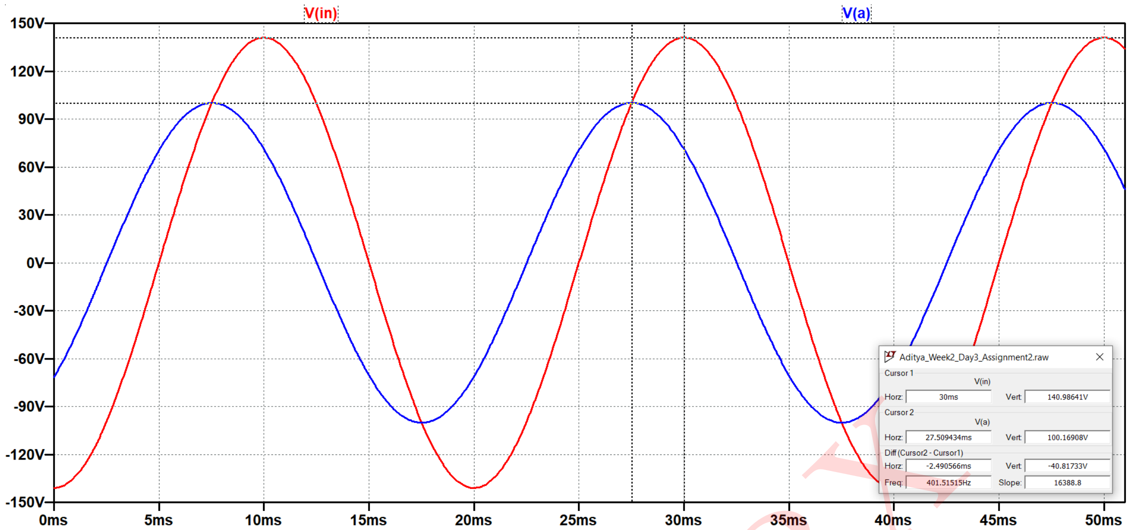


Figure 31: Simulated results for V_S & V_L

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_R	78.644V	78.6318V
V_L	61.7668V	61.7572V
I_S	19.661A	19.6579A
$\Delta\theta$ & ΔT for V_S & I_S	134.756° & 7.4864ms	132.588° & 7.366ms
$\Delta\theta$ & ΔT for V_S & V_R	45.244° & 2.5135ms	46.1214° & 2.5623ms
$\Delta\theta$ & ΔT for V_S & V_L	44.756° & 2.486ms	45.0792° & 2.5044ms

Table 7: Numerical 7

Numerical 8: A pure resistance of 56Ω is in series with a pure capacitance of 150μF shown in Circuit 8. The series combination is connected across 120V, 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 V_S vs input source current I_S in LTspice

c. Measure the phase delay/difference between V_S vs I_S in time & degrees

d. Plot input source voltage V_S vs voltage across resistor V_R in LTspice

e. Measure the phase delay/difference between V_S vs V_R in time & degrees

f. Plot input source voltage V_S vs voltage across capacitor V_C in LTspice

g. Measure the phase delay/difference between V_S vs V_C in time & degrees

h. Calculate the power factor of the circuit.

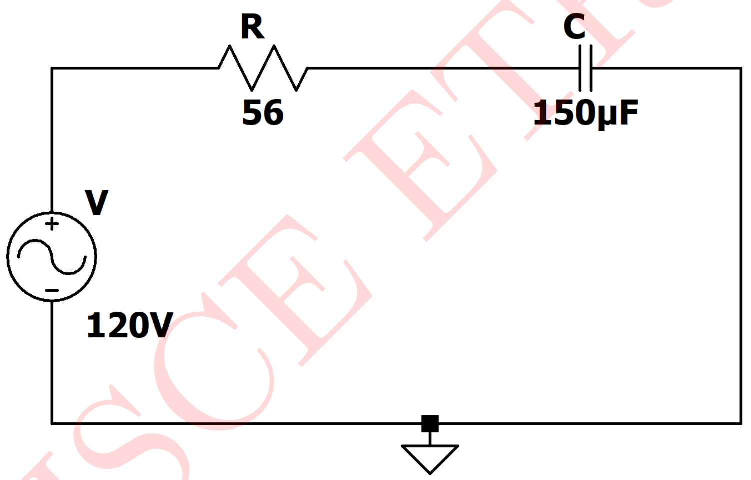


Figure 32: Circuit 8

Finding Reactance for C_1,

$X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{2\pi \times 50 \times 150 \times 10^{-6}}$

$X_C = 21.22\Omega$

Finding Total Impedance,

$Z = R + jX_C = 56 + j(21.22)$

$\therefore Z = 59.8856\angle(20.7531°)\Omega$

Finding current I,

$I = \dfrac{V}{Z} = \dfrac{120}{59.8856\angle(20.7531°)}$

$I = 2.0038\angle(-20.7531°)A$

$V_R = I \times R = 2.0038\angle(-20.7531°) \times 56$

$\therefore V_R = 112.2128\angle(-20.7531°)V$

$V_L = I \times X_L = 2.0038\angle(-20.7531°) \times 21.22$

$\therefore V_L = 42.5206\angle(-20.7531°)V$

Power factor $= \dfrac{V_R}{V} = \dfrac{112.2128}{120}$

$\therefore$Power factor $= 0.9351$

Calculating Phase difference for V_S & V_C,

$\Delta\theta = 90 - 20.7531 = 69.2469°$

$$\Delta T = \frac{\Delta\theta \times (T_{Period})}{360°} = \frac{69.2469 \times \frac{1}{50}}{360}$$

$\Delta T = 3.847ms$

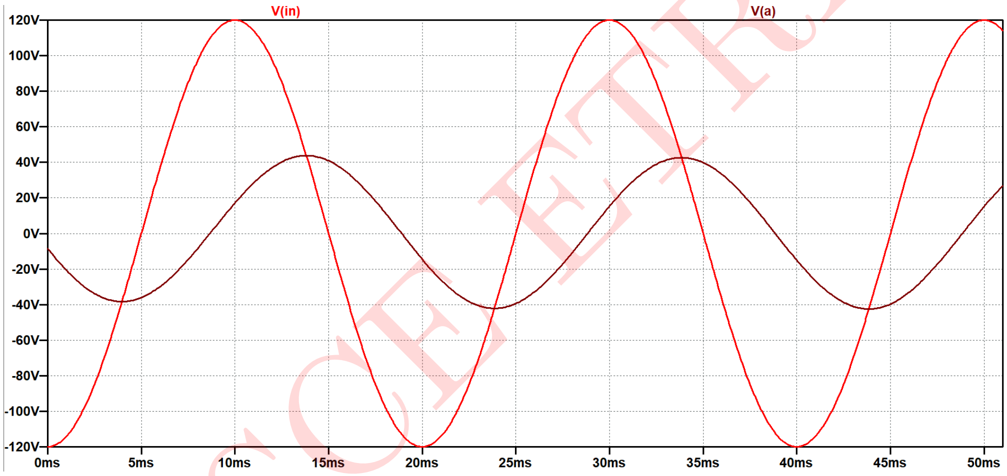


Figure 33: V_S & V_C

Calculating Phase difference for V_S & V_R,

$\Delta\theta = 20.7531°$

$$\Delta T = \frac{20.7531 \times \frac{1}{50}}{360}$$

$\Delta T = 1.1529ms$

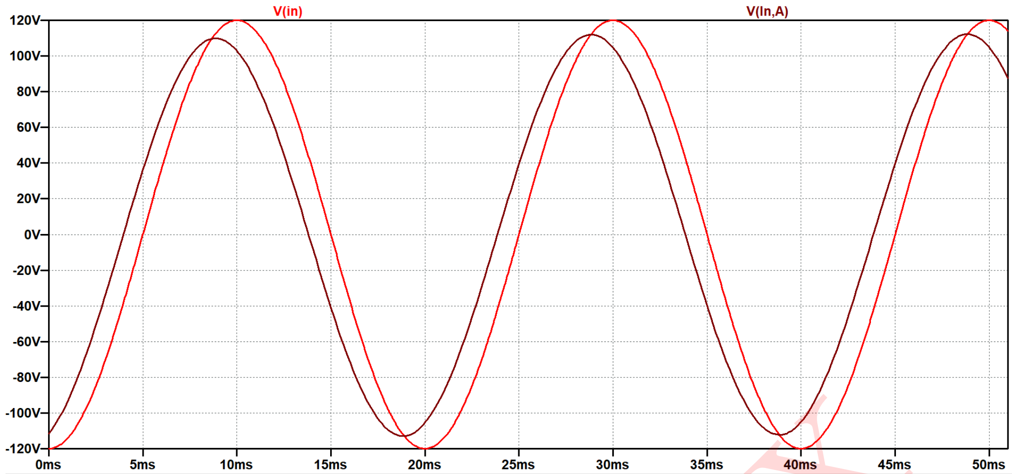


Figure 34: V$_S$ & V_R

Calculating Phase difference for V$_S$ & I_S,

$\Delta\theta = 180 - 20.7531 = 159.2469°$

$$\Delta T = \frac{159.2469 \times \dfrac{1}{50}}{360}$$

$\Delta T = 8.847ms$

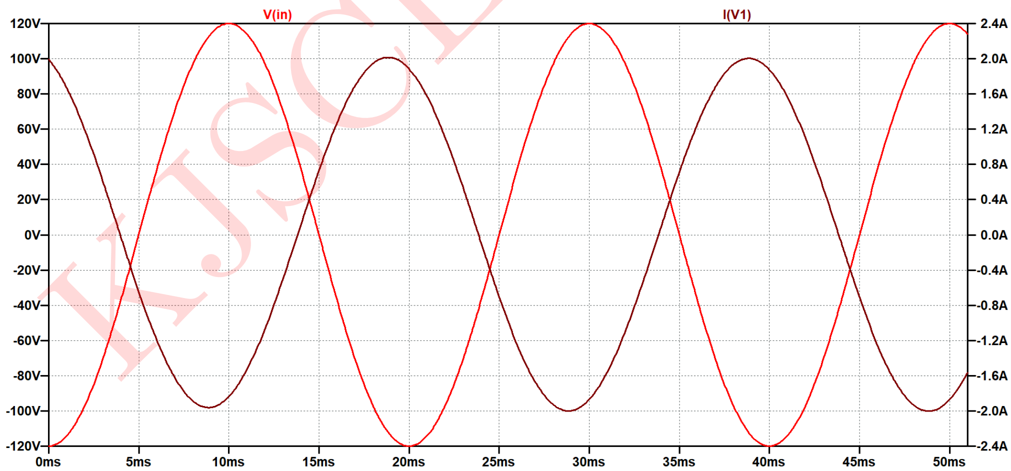


Figure 35: V$_S$ & I_S

SIMULATED RESULTS

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

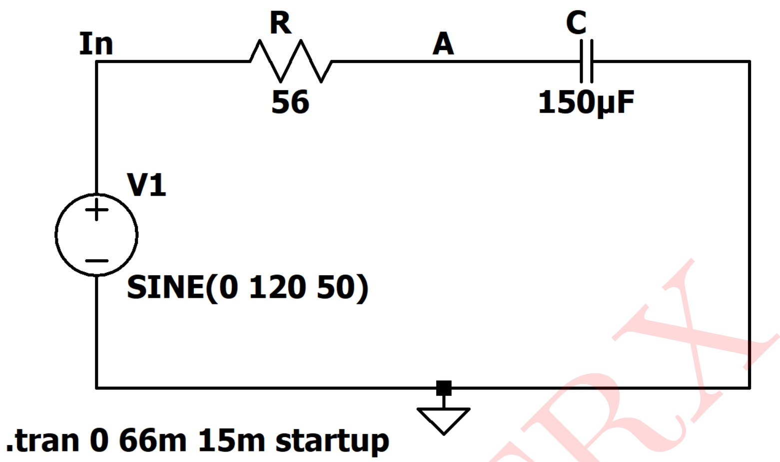


Figure 36: Circuit Schematic

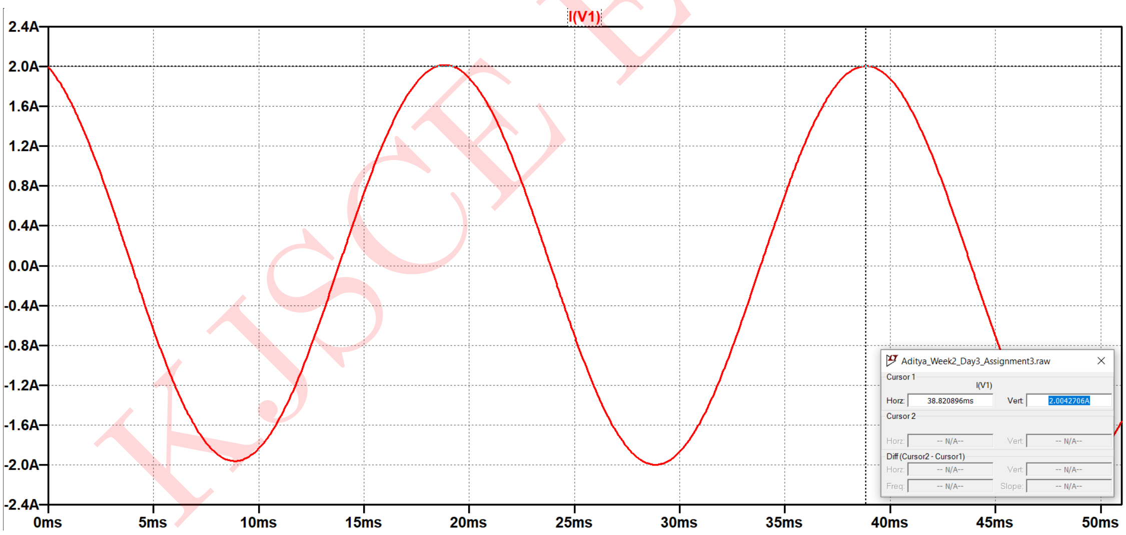


Figure 37: Simulated results for Source Current

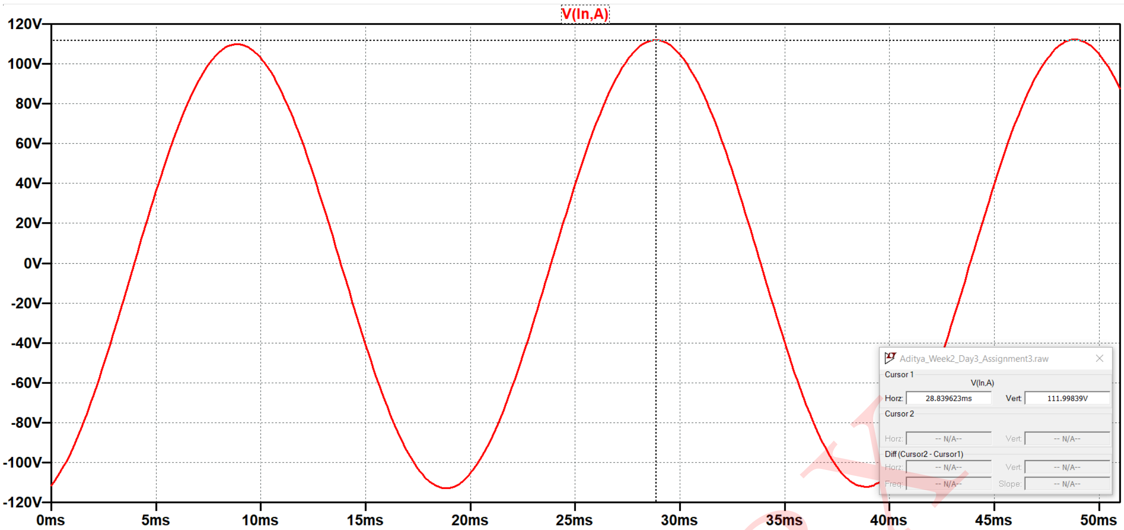


Figure 38: Simulated results for Voltage across Resistor

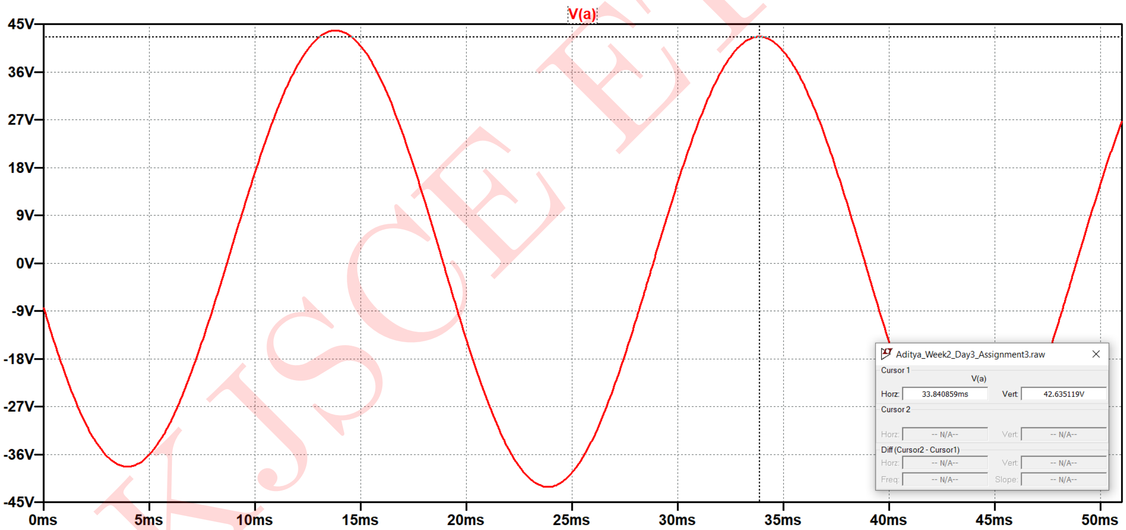


Figure 39: Simulated results for Voltage across Capacitor

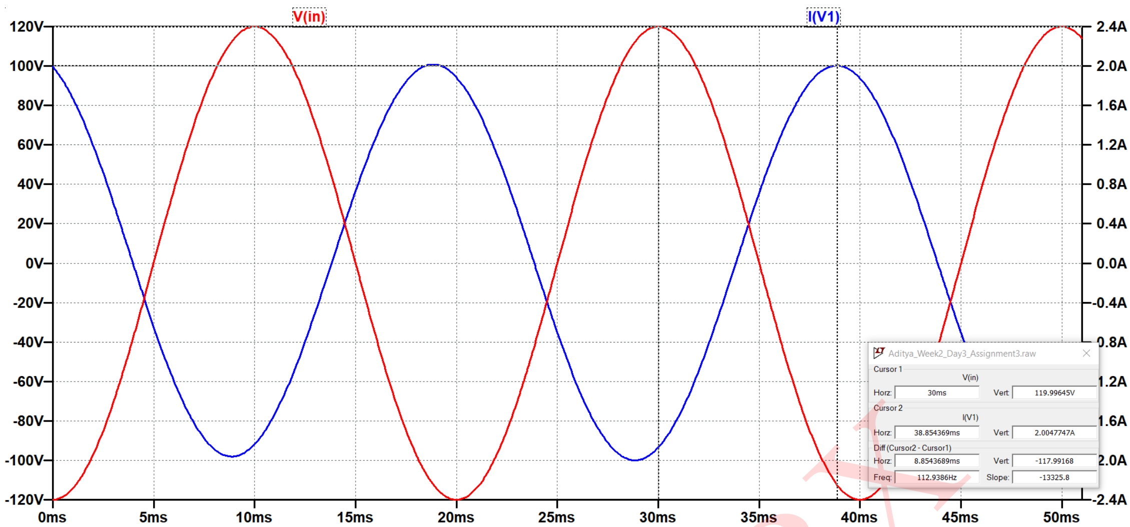


Figure 40: Simulated results for V$_S$ & I_S

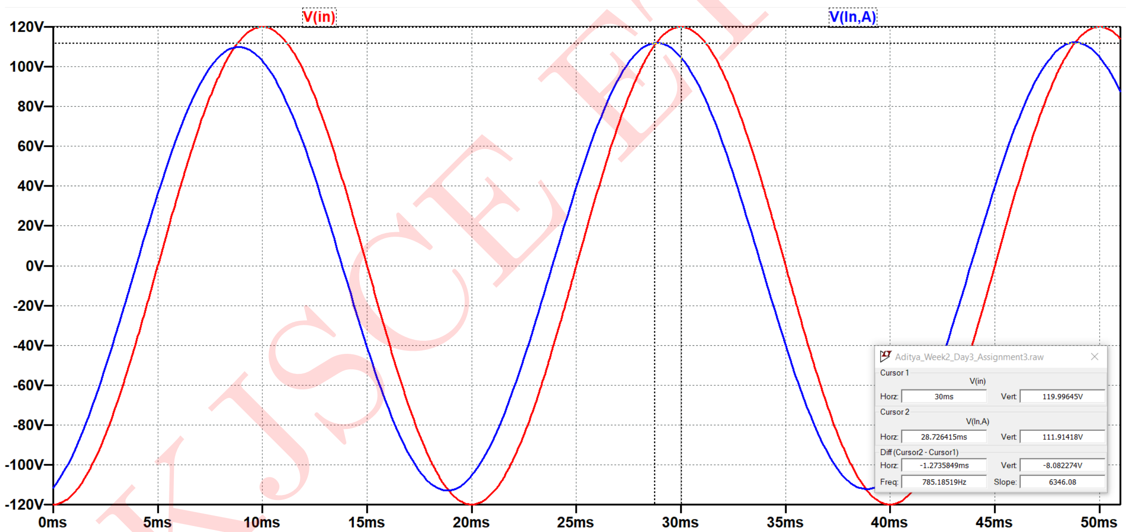


Figure 41: Simulated results for V$_S$ & V_R

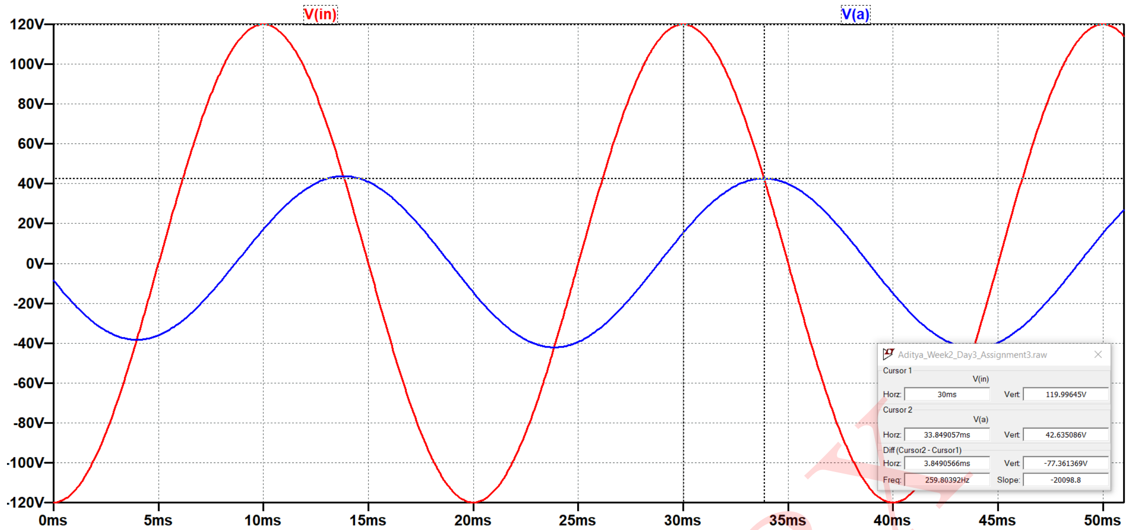


Figure 42: Simulated results for V_S & V_C

Verifying the Calculated Values with Simulated Values:

Quantity	Calculated Value	Simulated Value
V_R	112.2128V	111.9823V
V_C	42.5206V	42.6349V
I_S	2.0038A	2.004A
$\Delta\theta$ & ΔT for V_S & I_S	159.2469° & 8.847ms	158.328° & 8.796ms
$\Delta\theta$ & ΔT for V_S & V_R	20.7531° & 1.1529ms	21.6° & 1.2ms
$\Delta\theta$ & ΔT for V_S & V_C	69.2469° & 3.847ms	70.083° & 3.8935ms

Table 8: Numerical 8

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