Faculty of Engineering & Technology
Electrical & Computer Engineering Department

ENEE2103

PreLab#03

Sinusoidal Steady State Circuit Analysis

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Section : 5

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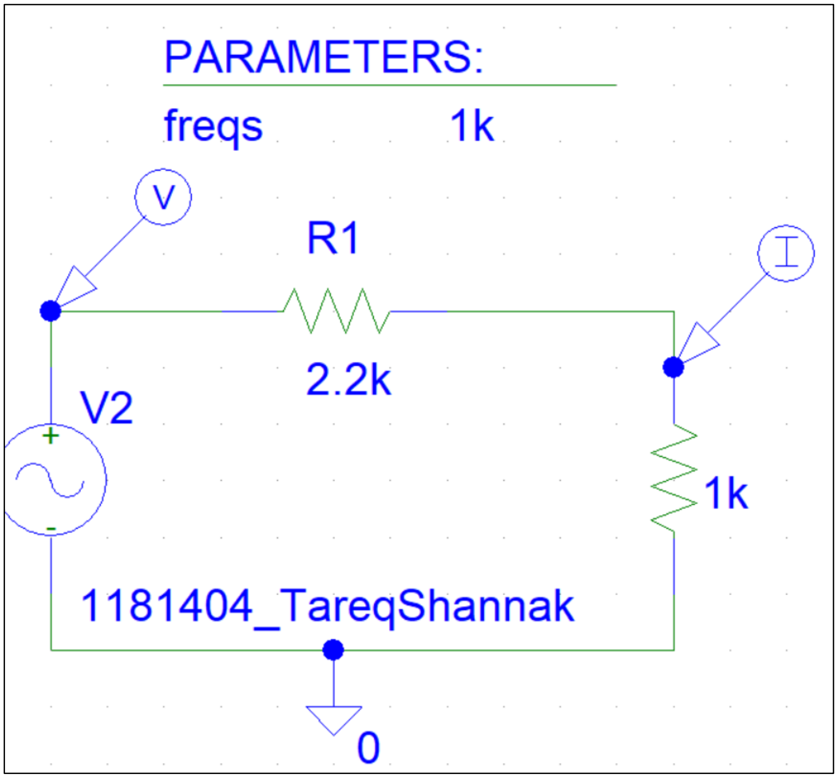
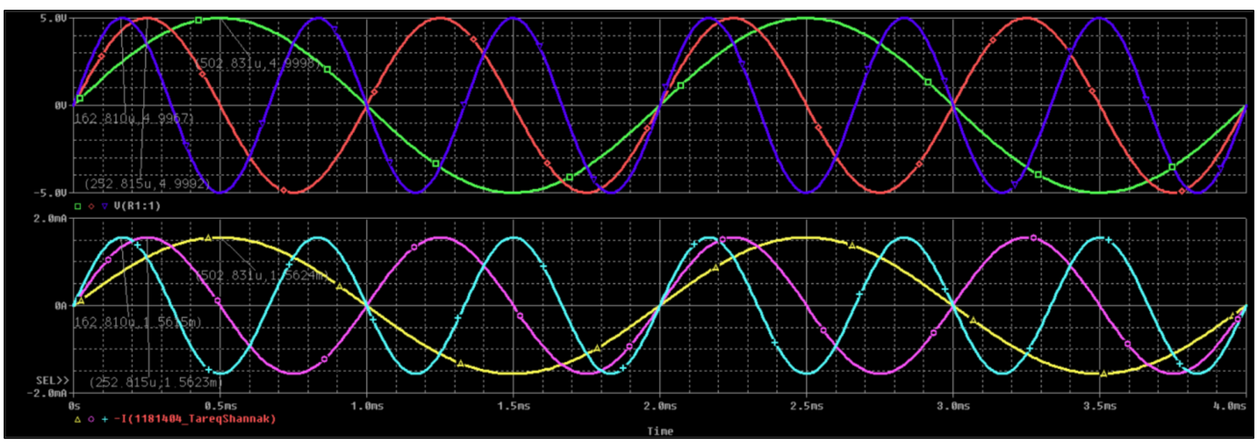
Part A: Impedance

Simple AC Circuit



{Freqs} is a variable has a list: 0.5k, 1k, 1.5k.

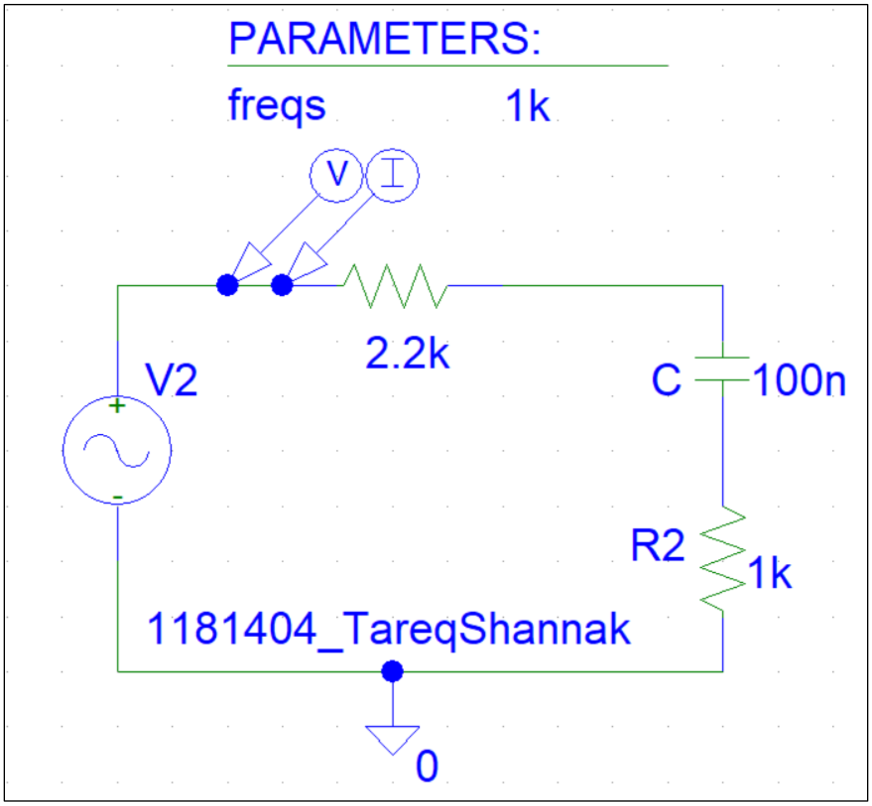


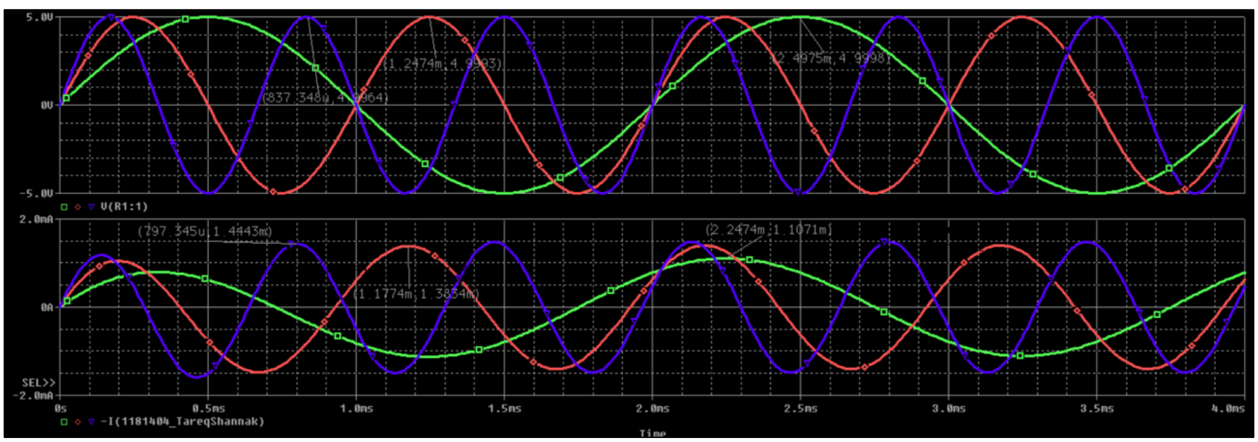
In three frequency cases, there are in-phase and the impedance is almost the same:

$$Z = \frac{V_{max}}{I_{max}} = \frac{4.99}{1.562m} = \mathbf{3.196k\Omega} \text{ from } \textbf{graph}$$

$$\text{Z} = \text{R} = (2.2 + 1)k\Omega = \mathbf{3.2k\Omega} \text{ from } \textbf{theory} \text{ (Too Close)}$$

RC Circuit





Because it’s a capacitive circuit, current in all cases leads the voltage by a phase shift

Note: when a phase shift is positive, then voltage leads current (inductive), otherwise is the opposite.

F=0.5KHZ

$$\textbf{From Graph}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{1.1071\text{m}} = \mathbf{4.515k\Omega}$$

$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(2.2474\text{m} - 2.4975\text{m}) \times 360}{2\text{m}} = \mathbf{-45.018\ degrees}$$

$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + \frac{1}{j2\pi fc} = 2.2k + 1k + \frac{1}{j2\pi(0.5k)(100n)} = 3.2 - j\,(3.183)\,k\Omega$$

$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(3.2^2 + 3.183^2)}\,k\Omega = \mathbf{4.513k\Omega}$$

$$\text{Phase Shift} = \tan^{-1}\frac{X_c}{R} = \tan^{-1}\frac{-3.183k}{3.2k} = \mathbf{-44.847\ degrees}$$

F=1KHZ

$$\textbf{\textit{From Graph}}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{1.3834m} = \mathbf{3.614k\Omega}$$

$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(1.1774\text{m} - 1.2474\text{m}) \times 360}{1\text{m}} = \mathbf{-25.2\ degrees}$$

$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + \frac{1}{j2\pi fc} = 2.2k + 1k + \frac{1}{j2\pi(1k)(100n)} = 3.2 - j\,(1.5915)\,k\Omega$$

$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(3.2^2 + 1.5915^2)}\,k\Omega = \mathbf{3.574k\Omega}$$

$$\text{Phase Shift} = \tan^{-1}\frac{X_c}{R} = \tan^{-1}\frac{-1.5915k}{3.2k} = \mathbf{-26.443\ degrees}$$

F=1.5KHZ

$$\textbf{\textit{From Graph}}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{1.4443m} = \mathbf{3.461k\Omega}$$

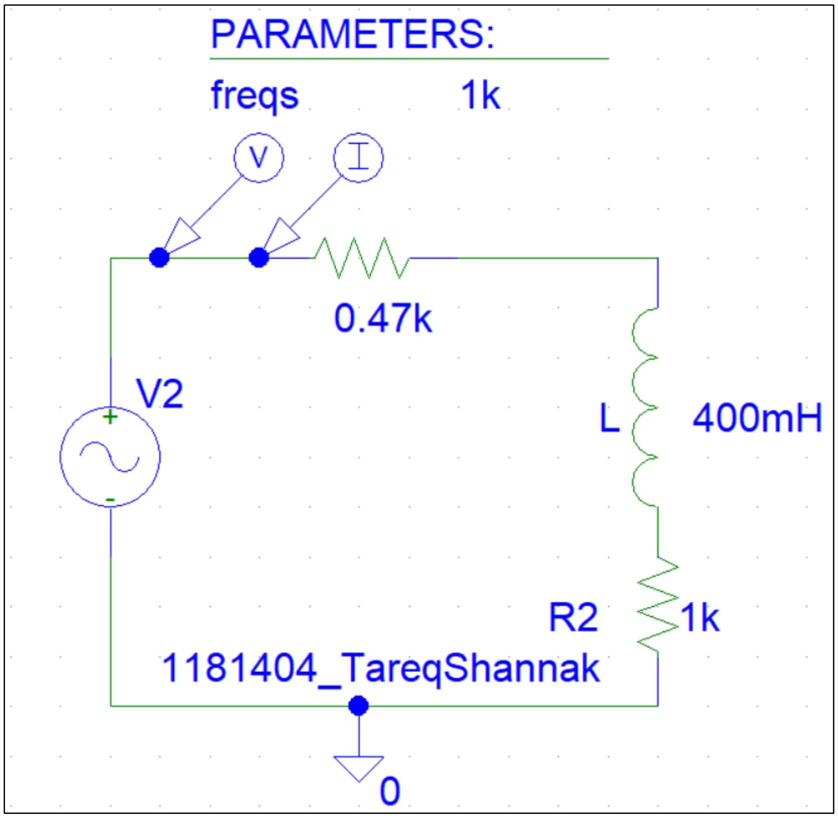
$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(0.7973\text{m} - 0.8373\text{m}) \times 360}{0.6667\text{m}} = \mathbf{-21.6\ degrees}$$

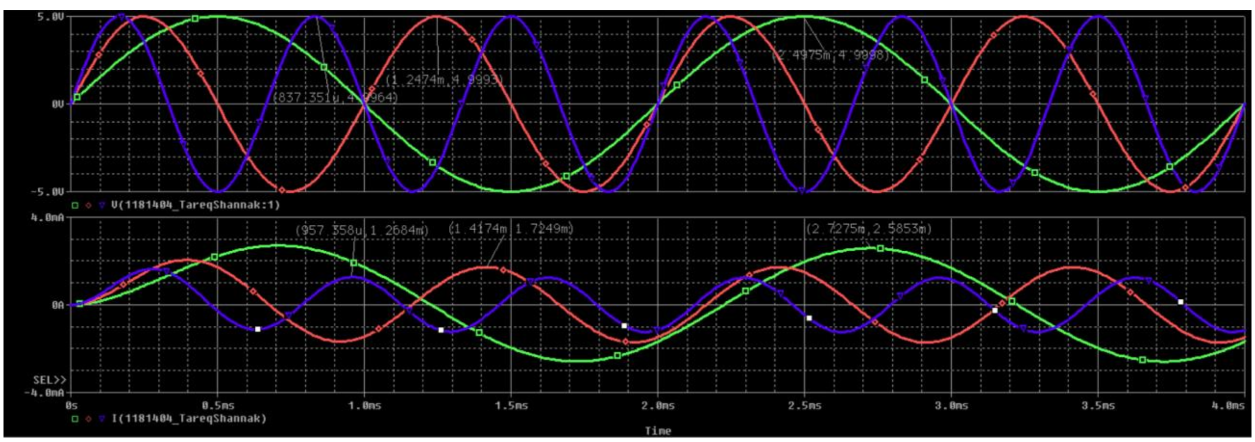
$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + \frac{1}{j2\pi fc} = 2.2k + 1k + \frac{1}{j2\pi(1.5k)(100n)} = 3.2 - j\,(1.061)k\Omega$$

$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(3.2^2 + 1.061^2)}\,k\Omega = \mathbf{3.371k\Omega}$$

$$\text{Phase Shift} = \tan^{-1}\frac{X_c}{R} = \tan^{-1}\frac{-1.061k}{3.2k} = \mathbf{-18.344\ degrees}$$

RL Circuit





Because it's an inductive circuit, voltage in all cases leads the current by a phase shift

F=0.5KHZ

$$\textbf{From Graph}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{2.5853\text{m}} = \mathbf{1.934k\Omega}$$

$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(2.7275\text{m} - 2.4975\text{m}) \times 360}{2\text{m}} = \mathbf{41.4\ degrees}$$

$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + j2\pi fl = 0.47k + 1k + j2\pi(0.5k)(400m) = 1.47 + j\,(1.257)k\Omega$$
$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(1.47^2 + 1.257^2)}\ k\Omega = \mathbf{1.934k\Omega}$$

$$\text{Phase Shift} = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{1.257k}{1.47k} = \mathbf{40.534\ degrees}$$

F=1KHZ

$$\textbf{From Graph}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{1.7249\text{m}} = \mathbf{2.898k\Omega}$$

$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(1.4174\text{m} - 1.2474\text{m}) \times 360}{1\text{m}} = \mathbf{61.2\ degrees}$$

$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + j2\pi fl = 0.47k + 1k + j2\pi(1k)(400m) = 1.47 + j\,(2.514)k\Omega$$
$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(1.47^2 + 2.514^2)}\ k\Omega = \mathbf{2.912k\Omega}$$

$$\text{Phase Shift} = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{2.514k}{1.47k} = \mathbf{59.684\ degrees}$$

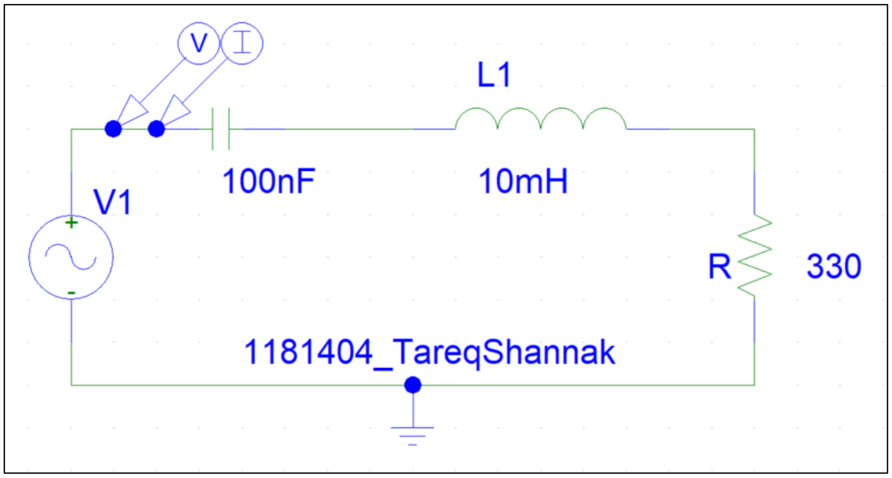
F=1.5KHZ

$$\textbf{From Graph}: Z = \frac{V_{max}}{I_{max}} = \frac{4.999}{1.2684\text{m}} = \mathbf{3.939k\Omega}$$

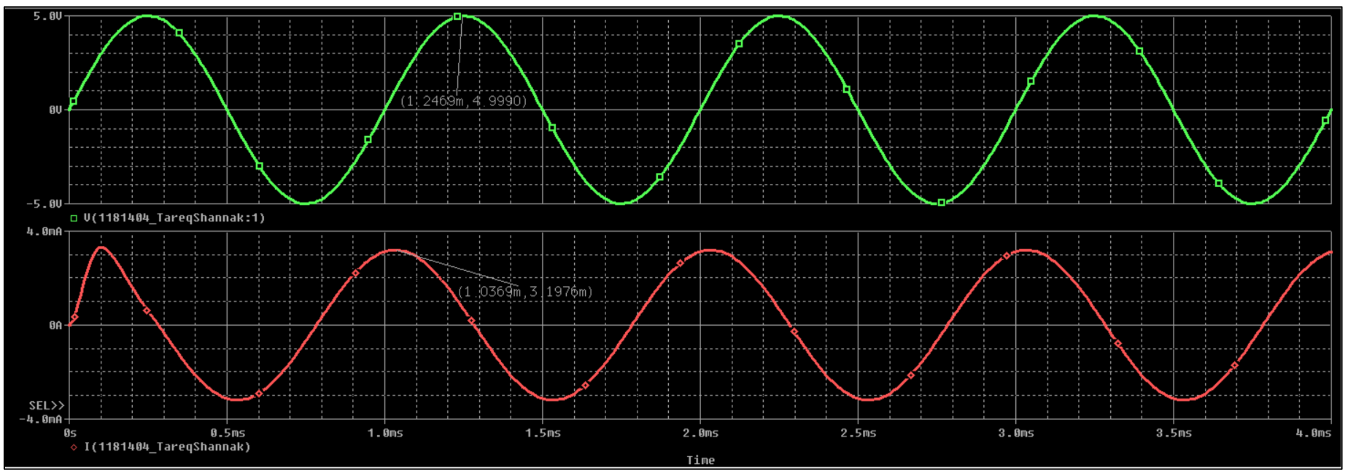
$$\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(0.9574\text{m} - 0.8374\text{m}) \times 360}{0.6667\text{m}} = \mathbf{64.8\ degrees}$$

$$\textbf{\textit{From Theory}}: Z = R_1 + R_2 + j2\pi fl = 0.47k + 1k + j2\pi(1.5k)(400m) = 1.47 + j\,(3.77)k\Omega$$
$$|Z| = \sqrt{(R^2 + X^2)} = \sqrt{(1.47^2 + 3.77^2)}\ k\Omega = \mathbf{4.046k\Omega}$$
$$\text{Phase Shift} = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{3.77k}{1.47k} = \mathbf{68.698\ degrees}$$

Capacitive and inductive behavior



F=1KHZ



$$\textbf{From Graph}\text{: Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(1.0369\text{m} - 1.2469\text{m}) \times 360}{1\text{m}} = \mathbf{-75.6\ degrees}$$

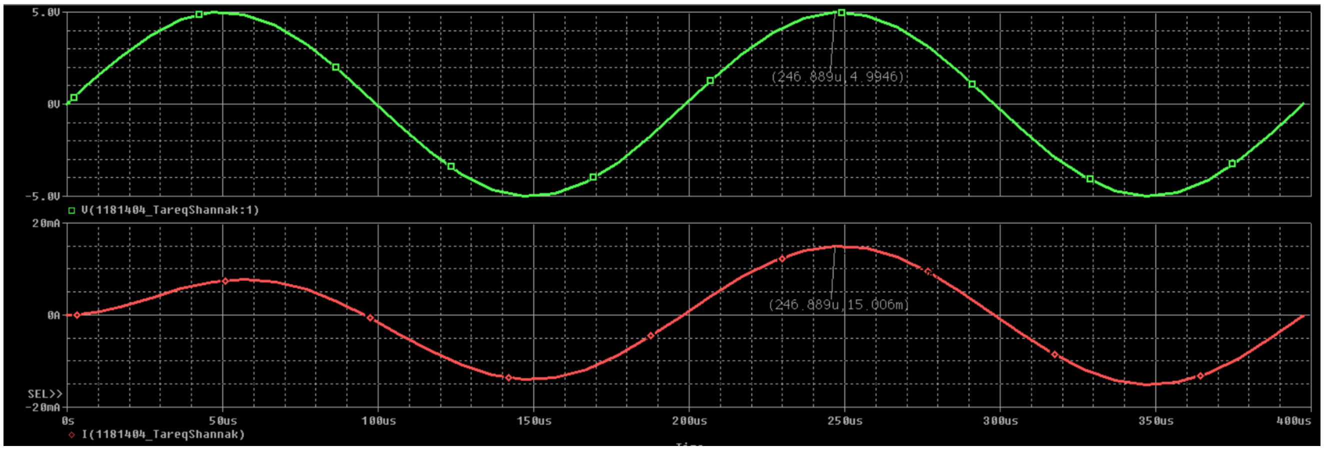
$$\boldsymbol{From\ Theory}: X = j2\pi fL + \frac{1}{j2\pi fc} = j2\pi(1k)(10m) - \frac{j}{2\pi(1k)(100n)}$$
$$= j(62.832 - 1591.5) = -j\ 1528.7$$

$$R = 330\Omega$$

$$\text{Phase Shift} = \tan^{-1}\frac{\text{X}}{R} = \tan^{-1}\frac{-1528.7}{330} = \mathbf{-77.82\ degrees}$$

Where current leads the voltage by 77.82 degrees, so it's a capacitive circuit.

F = F_0 (Resonance Frequency)



$$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(10m)(100n)}} \cong 5033HZ$$

From Graph: $\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(0.2469\text{m} - 0.2469\text{m}) \times 360}{0.1987\text{m}} = \mathbf{0\ degree}$

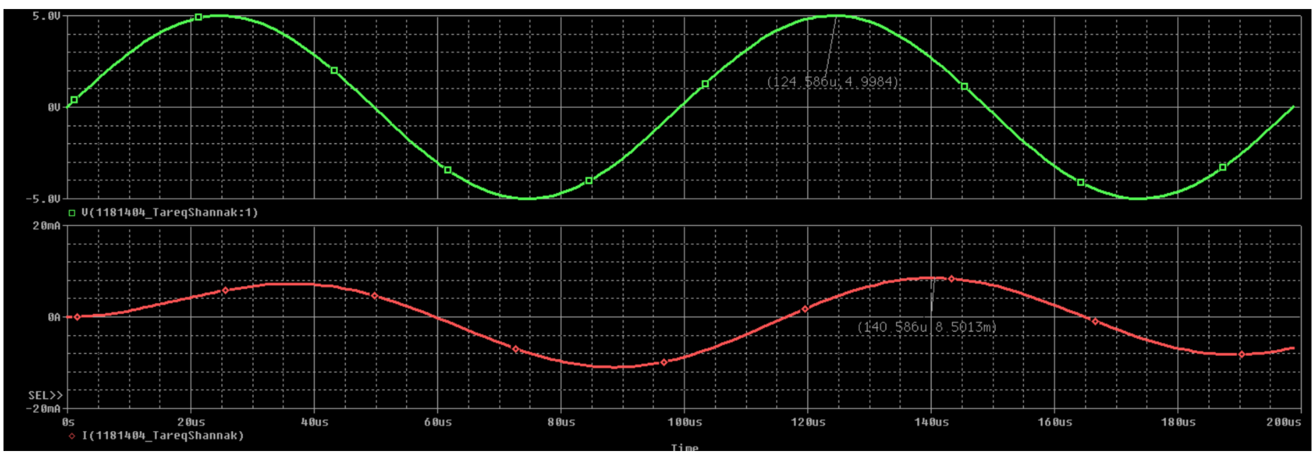
From Theory: $X = j2\pi fL + \frac{1}{j2\pi fc} = j2\pi(5.033k)(10m) - \frac{j}{2\pi(5.033k)(100n)}$

$$= j(316.232 - 316.232) = 0$$

$$\text{Phase Shift} = \tan^{-1}\frac{X}{R} = \tan^{-1}\frac{0}{330} = \mathbf{0\ degree}$$

The current and voltage signals are in phase.

F = $2F_0$



From Graph: $\text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(140.6\text{u} - 124.6\text{u}) \times 360}{99.344\text{u}} = \mathbf{57.98\ degrees}$

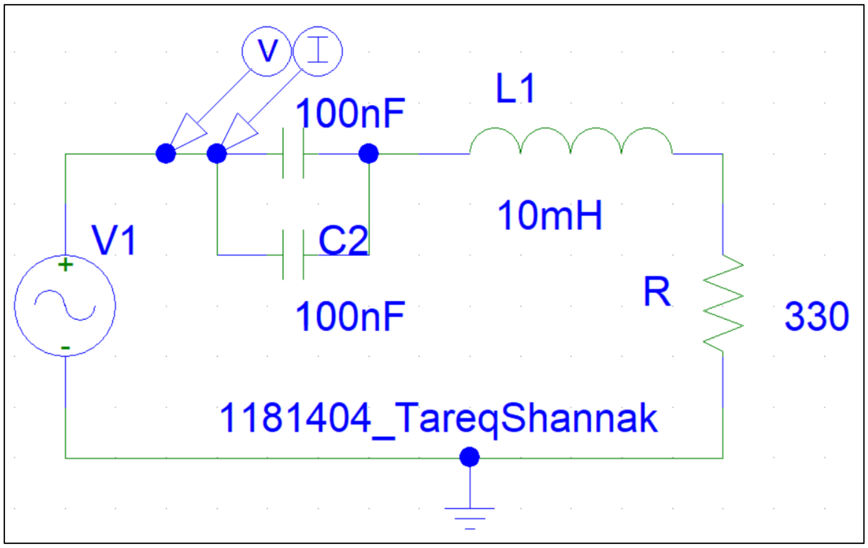
From Theory: $X = j2\pi fL + \frac{1}{j2\pi fc} = j2\pi(10.066k)(10m) - \frac{j}{2\pi(10.066k)(100n)}$

$$= j(632.465 - 158.111) = j\,474.354$$

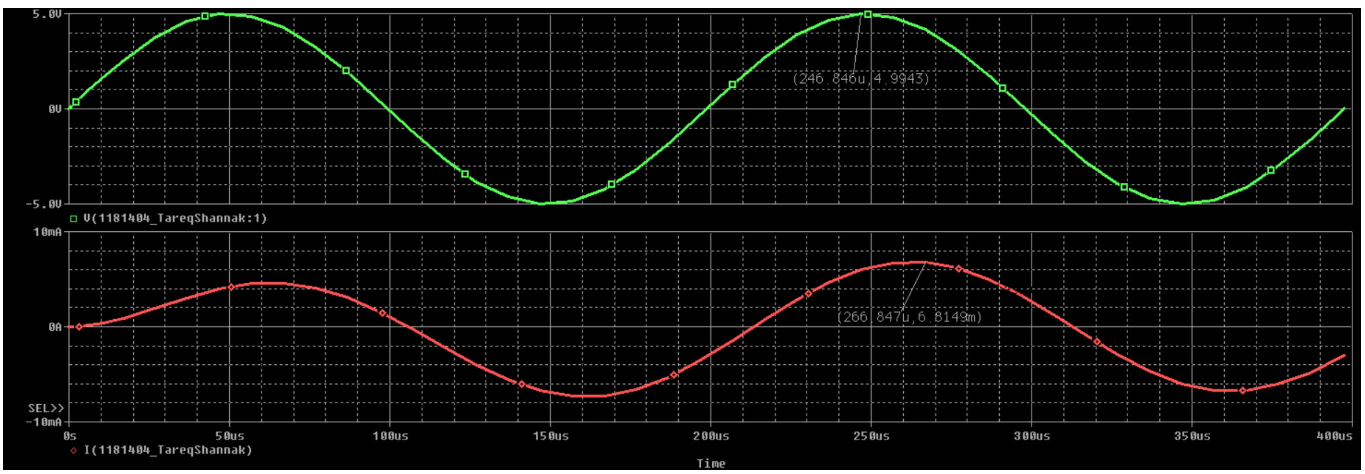
$$\text{Phase Shift} = \tan^{-1}\frac{X}{R} = \tan^{-1}\frac{474.354}{330} = \mathbf{55.17\ degrees}$$

Where voltage leads the current by 55.17 degrees, so it’s an inductive circuit.

Double the value of the capacitor



When we add a capacitor with value 100nF in a parallel with the old one, the total capacitance = 200nF.



$$\textbf{From Graph}: \text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(266.847\text{u} - 246.846\text{u}) \times 360}{198.689\text{u}} = \mathbf{36.24\ degrees}$$

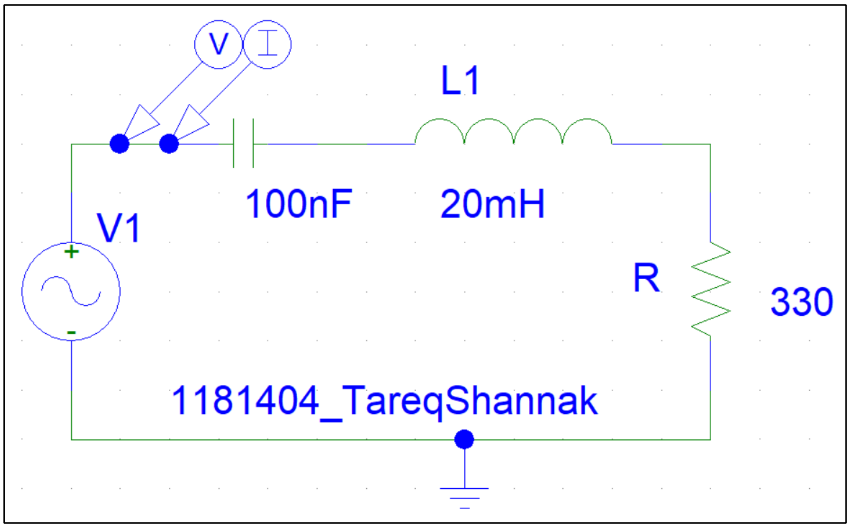
$$\textbf{\textit{From Theory}}: X = j2\pi fL + \frac{1}{j2\pi fc} = j2\pi(5.033k)(10m) - \frac{j}{2\pi(5.033k)(200n)}$$
$$= j(316.233 - 158.111) = j\ 158.122$$

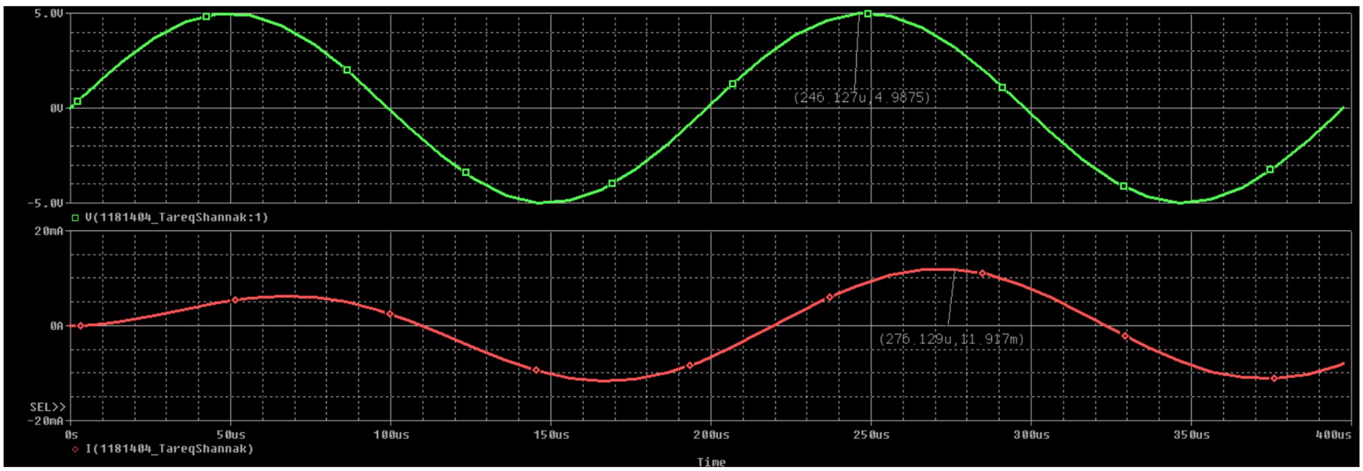
$$R = 330\Omega$$

$$\text{Phase Shift} = \tan^{-1}\frac{X}{R} = \tan^{-1}\frac{158.122}{330} = \mathbf{25.6\ degrees}$$

Where voltage leads the current by 25.6 degrees, so it’s an inductive circuit.

Double the value of the inductor





$$\textbf{From Graph}: \text{Phase Shift} = \frac{T_{\Delta pp} \times 360}{Period} = \frac{(276.129\text{u} - 246.127\text{u}) \times 360}{198.689\text{u}} = \textbf{54.36 degrees}$$

$$\textbf{\textit{From Theory}}: X = j2\pi fL + \frac{1}{j2\pi fc} = j2\pi(5.033k)(20m) - \frac{j}{2\pi(5.033k)(100n)}$$

$$= j(632.466 - 316.233) = j\,316.233$$

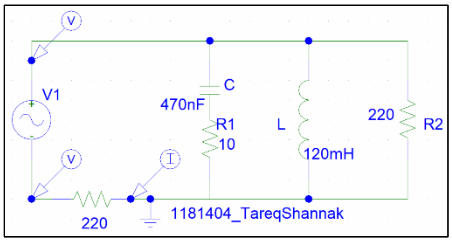
$$R = 330\Omega$$

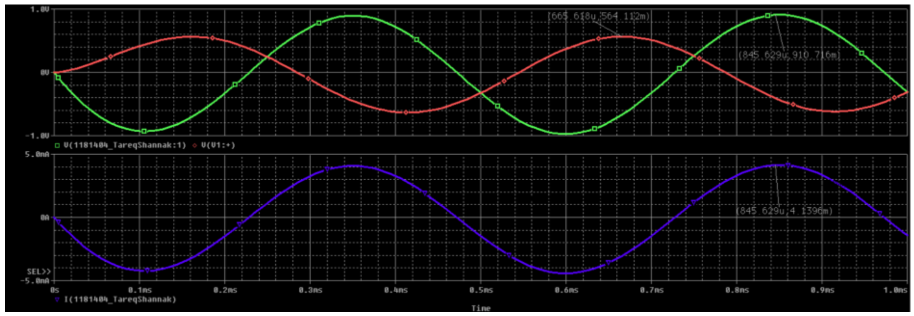
$$\text{Phase Shift} = \tan^{-1}\frac{X}{R} = \tan^{-1}\frac{316.233}{330} = \textbf{43.78 degrees}$$

Where voltage leads the current by 43.78 degrees, so it's an inductive circuit.

Sinusoidal steady state power

$$V_{RMS} = \frac{V_{Peak}}{\sqrt{2}} \rightarrow V_{Peak} = \sqrt{2} \times 1 = 1.4142v$$

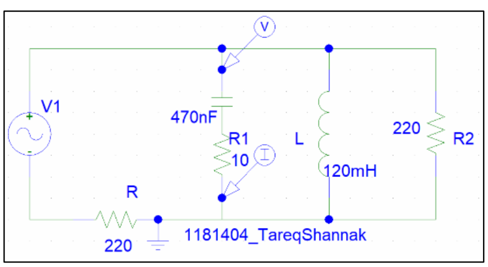


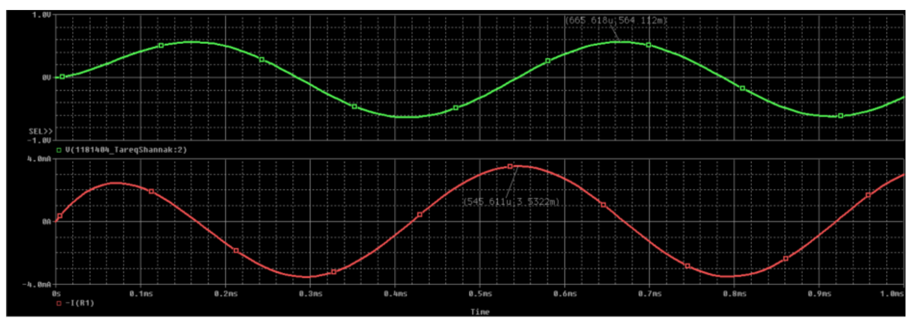


$$V_s = 564.112m, I_s = 4.1396mA, V_{220\Omega} = 910.716mv$$

From Graph: Phase Shift $= \frac{T_{\Delta pp} \times 360}{Period} = \frac{(845.629\text{u} - 845.629\text{u}) \times 360}{198.689\text{u}} =$ **0 degree**

$$\boldsymbol{R} = \frac{V_{220\Omega}}{I_s} = \frac{910.716mv}{4.1396mA} = \mathbf{220\Omega}$$

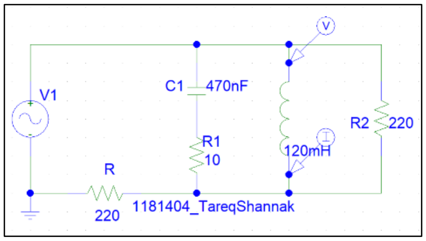


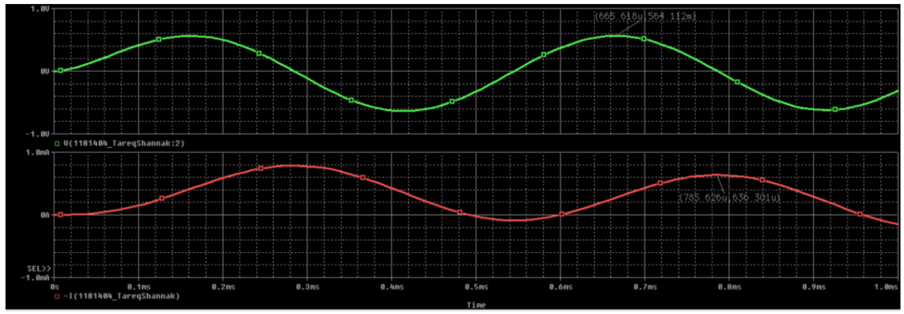


$$V_c = 564.112mv, I_c = 3.5322mA$$

From Graph: Phase Shift $= \frac{T_{\Delta pp} \times 360}{Period} = \frac{(545.611\text{u} - 665.618\text{u}) \times 360}{198.689\text{u}} =$ **−217.44 degrees**

$$X = \frac{V_c}{I_c} = \frac{564.112mv}{3.5322mA} = \frac{1}{2\pi f c} + 10(3.5322mA) \rightarrow c = \boldsymbol{499nF}$$

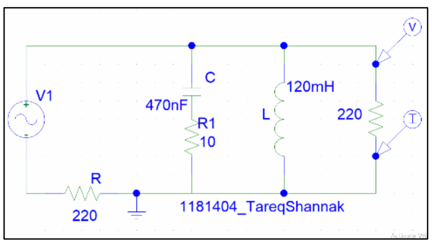


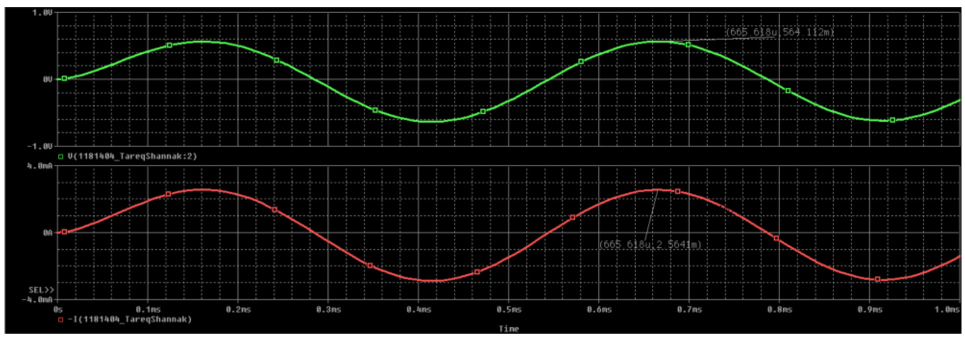


$$V_L = 564.112mv, I_L = 636.301uA$$

From Graph: Phase Shift $= \frac{T_{\Delta pp} \times 360}{Period} = \frac{(785.626\text{u} - 665.618\text{u}) \times 360}{198.689\text{u}} = $ **217.44 degrees**

$$X = \frac{V_c}{I_c} = \frac{564.112mv}{636.301uA} = 2\pi f l \rightarrow l = \mathbf{70mH}$$





$$V_L = 564.112mv, I_L = 2.5641mA$$

From Graph: Phase Shift $= \frac{T_{\Delta pp} \times 360}{Period} = \frac{(665.618\text{u} - 665.618\text{u}) \times 360}{198.689\text{u}} = $ **0 degree**

$$\boldsymbol{R} = \frac{V_{220\Omega}}{I_s} = \frac{564.112mv}{2.5641mA} = \mathbf{220\Omega}$$

	V	I	Practical Value	Phase Shift
S	$564.112mv$	$4.1396mA$	-	0
C	$564.112mv$	$3.5322mA$	499nF	-217.44
L	$564.112mv$	$636.301uA$	70mH	217.44
R	$564.112mv$	$2.5641mA$	220Ω	0
$R_{220\Omega}$	$910.716mv$			