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Experiment 1 Part 1

Aim: Verification of Maximum Power Transfer Theorem.

Theory: In a given circuit, with a load and a resultant impedence, if we want the load to have the maximum possible power transferred across it then, we need to consider the following 3 scenarios:

1) Only the Reactive Part of the Load can be changed.
2) Only the Resistive Part of the Load can be changed
3) Both, the Reactive and the Resistive Parts of the Load can be changed.

Case 1: Only Reactive Part (X_L) can be changed.

$$\text{Power } (P) = |I|^2 R_L$$

$$= \frac{V_s^2 \cdot R_L}{(R_i+R_L)^2+(X_i+X_L)^2}$$

For P to be max, $(X_i + X_L)^2$ should be minimum. Thus,

$$(X_i + X_L)^2 = 0$$

$$\Rightarrow X_L = -X_i \quad \text{—(1)}$$

Case 2: Only Resistive Part (R_L) can be changed.

$$P = \frac{V_s^2 R_L}{(R_i+R_L)^2+(X_i+X_L)^2}$$

Differentiating P w.r.t. R_L and equating $\frac{dP}{dR_L} = 0$

$\Rightarrow$ we get $R_L = \sqrt{R_i^2 + (X_i + X_L)^2}$ —(2)

Case 3: Both X_L and R_L can be changed

Then we put $X_L = -X_i$ - from (1)

and from (2), $R_L = R_i$

This can also be achieved by putting $Z_L = Z_i^*$

where Z_i^* is the complex conjugate of Z_i.

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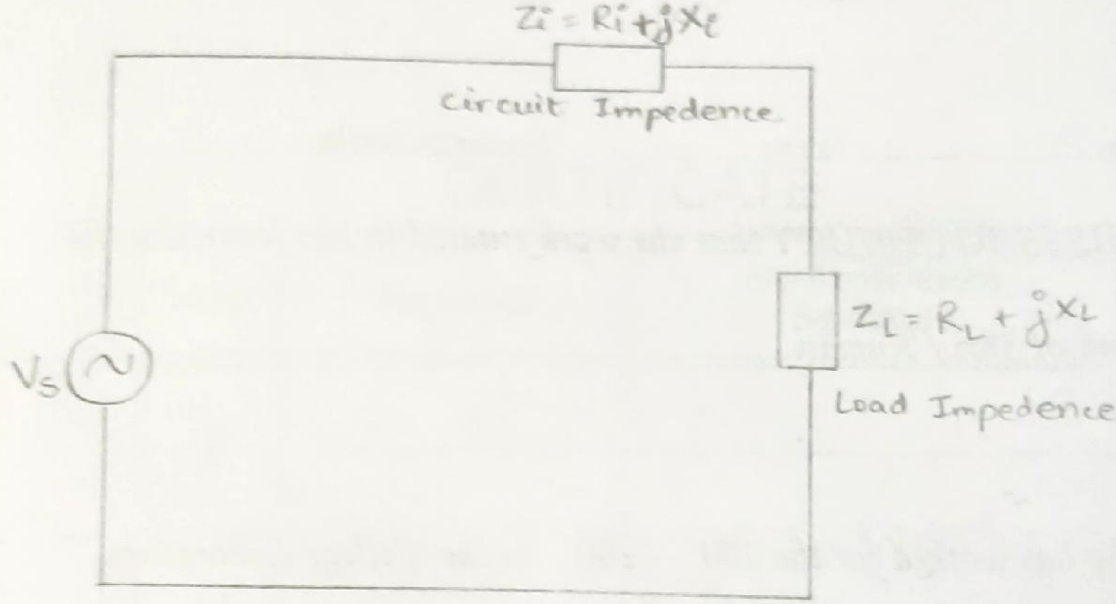

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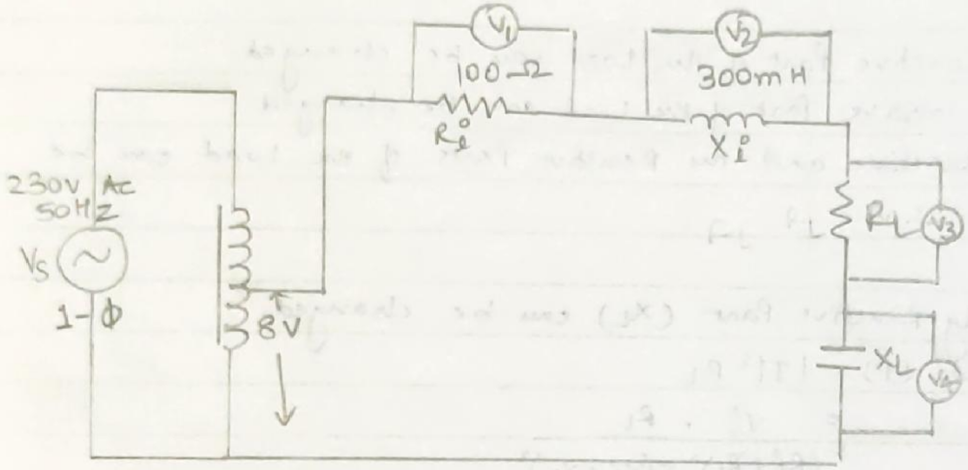

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Observation Tables : (for $k = 0.99$)

Case 1 : Only X_L / C_L variable with $R_L = 50\ \Omega$

Sl. No.	C_L (in μF)	V_1 (in V)	V_3 (in V)	$(V_1 . V_3)$ (in V^2)	Maximum $(V_1 . V_3)$
1.	25	5.242	2.620	13.734	
2.	28	5.298	2.657	14.077	
3.	30	5.309	2.654	14.090	
4.	33.77	5.315	2.652	14.095	⇒ 14.095 V^2 for $C_L = 33.77$ μF
5	35	5.300	2.649	14.041	
6	38	5.269	2.635	13.886	
7	40	5.238	2.620	13.717	
8	45	5.190	2.593	13.460	

∴ value of C_L for maximum power transfer = 33.77 μF.

Case 2 : Only R_L variable with $C_L = 50$ μF

Sl. No.	R_L (in Ω)	V_1 (in V)	V_3 (in V)	$(V_1 . V_3)$ (in V^2)	Maximum $(V_1 . V_3)$
1	95	3.999	3.800	15.198	
2	98	3.939	3.860	15.205	
3	100	3.901	3.901	15.221	
4	104.57	3.817	3.990	15.230	⇒ 15.230 V^2 for $R_L = 104.57\ \Omega$
5	108	3.746	4.049	15.168	
6	110	3.711	4.080	15.141	
7	115	3.635	4.179	15.191	
8	120	3.556	4.268	15.177	

∴ value of R_L for maximum power transfer = 104.57 Ω

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Case 3: Both R_L and X_L / C_L variable :

Sl. No.	R_L (in Ω)	C_L (in μF)	V_1 (in V)	V_3 (in V)	$(V_1 . V_3)$ (in V^2)	Maximum $(V_1 . V_3)$
1	80	25	4.385	3.508	15.383	
2	90	28	4.187	3.776	15.810	
3	95	30	4.083	3.878	15.834	
4	100	33.77	3.988	3.988	15.904	⇒ 15.904 V^2 for $R_L = 100$ Ω and $C_L = 33.77$ μF.
5	105	35	3.871	4.074	15.770	
6	110	40	3.765	4.150	15.624	
7	120	45	3.579	4.297	15.379	
8	125	48	3.490	4.361	15.230	

∴ Value of $R_L = 100$ Ω and $C_L = 33.77$ μF, for maximum power transfer.

Inference and Sample Calculations :

For Case 1, $C_L = 33.77$ μF, which is the same value that comes when we equate $|X_C| = |X_L|$

$$\Rightarrow C = \frac{1}{L\omega^2} = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\pi^2(50)^2(300)\times10^{-3}}$$

$$= 33.77 \times 10^{-6} F.$$

Also, here $V_2 = 4.97$ V

and $V_4 = 4.97$ V ∴ $V_2 = V_4$

For Case 2, $R_L = 104.57$ Ω, which is the same value that comes when we equate $R = \sqrt{R_i^2 + (X_i + X_L)^2}$

$$= \left[(100)^2 + \left(800\times10^{-3}\times2\pi\times50 - \frac{1}{50\times10^{-6}\times2\pi\times50}\right)^2\right]^{1/2}$$

$$= \left[10000 + (94.248 - 63.662)^2\right]^{1/2}$$

$$= \left[10000 + 935.505\right]^{1/2}$$

$$= 104.57\ \Omega$$

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For case 3, $R_L = 100\,\Omega$ and $C_L = 33.77\,\mu F$, which are the same values we get when ~~do~~ equate

$R = R_i = 100\,\Omega$ and $|X_i| = |X_L|$

$$\Rightarrow C = \frac{1}{L\omega^2} = 33.77\,\mu F$$

Also, $V_1 = 3.988\,V$

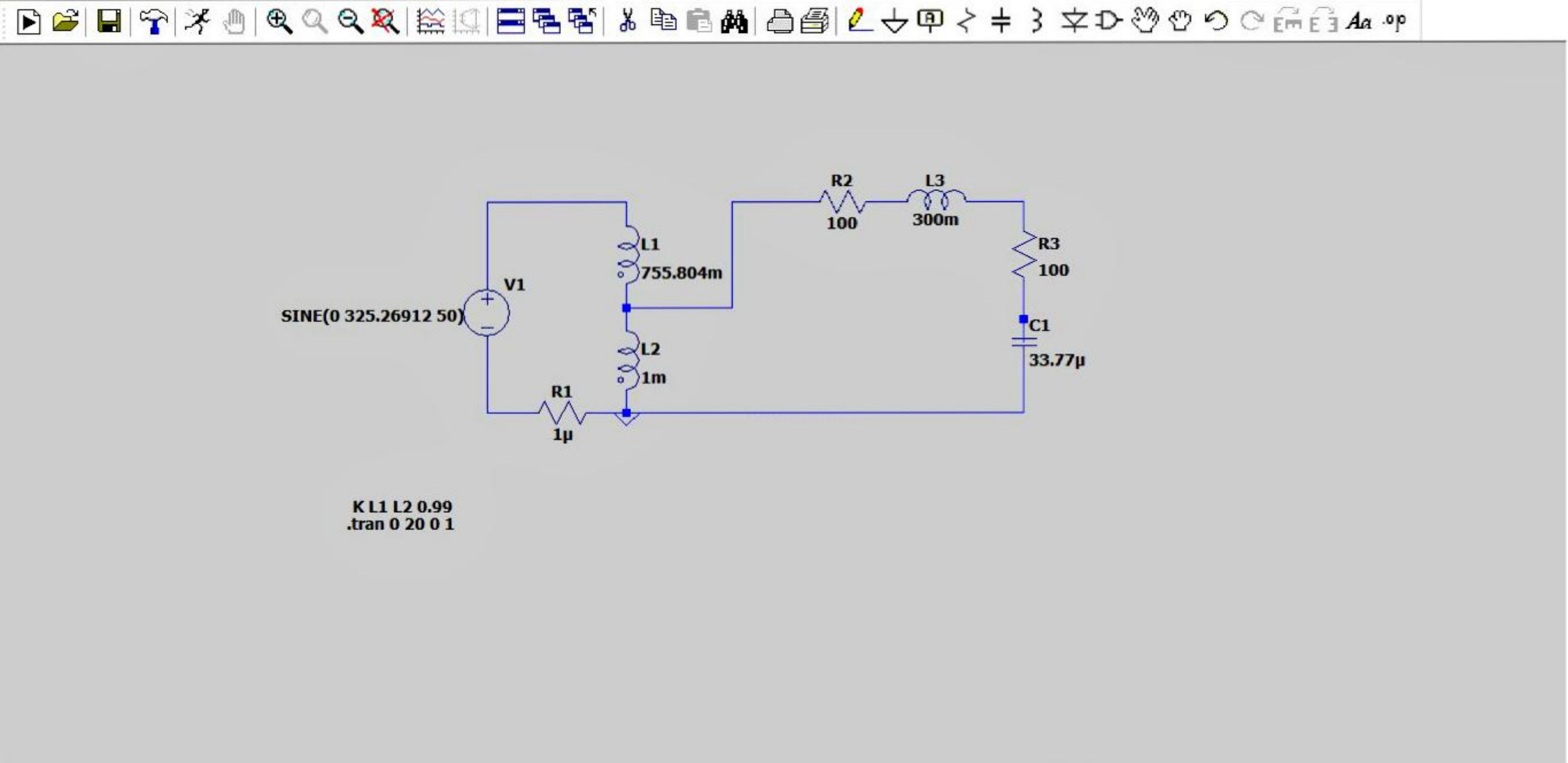
and $V_3 = 3.988\,V$ $\therefore V_1 = V_3$

Also, $V_2 = 3.701$

$V_4 = 3.701\,V$ $\therefore V_2 = V_4$

Discussion and comments: from the above experiment, we have understood that for maximum power to be transferred through a load ~~resistance~~ impedence, we need to consider 3 cases and appropriately set up the values of load parameters.

One point to note, while doing this experiment in the LTSpice Environment, is that the environment gives waveforms and we have to take amplitude of the waveforms and then calculate the RMS values from it. It doesn't directly gives the RMS values.



R2
100
L3
300m
L1
755.804m
R3
100
V1
SINE(0 325.26912 50)
C1
33.77µ
L2
1m
R1
1µ
K L1 L2 0.99
.tran 0 20 0 1