IC160P-Electrical Systems Around Us Lab

Verification of (A) Thevenin's theorem and (B) Maximum Power Transfer Theorem using MATLAB/Simulink

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1. Objectives

To Verify Thevenin's Theorem and Maximum Power Transfer Theorem from the given circuits.

2. Theory

2.1 Thevenin's theorem

Thevenin's theorem states that, a two-terminal network consisting of voltage and current sources and linear passive elements, can be replaced by a simplified equivalent network consisting of a single voltage source (say VTH) in series with an impedance ZTH (Thevenin equivalent impedance). Values of VTH and ZTH can be found out as given below.

- VTH: Open circuit voltage across the two terminals
- ZTH: Equivalent impedance across the two terminals, when all sources are replaced by their internal impedances

In this experiment, all circuit elements are assumed to be resistive. Thevenin's theorem thus can be modified by replacing impedance by resistance.

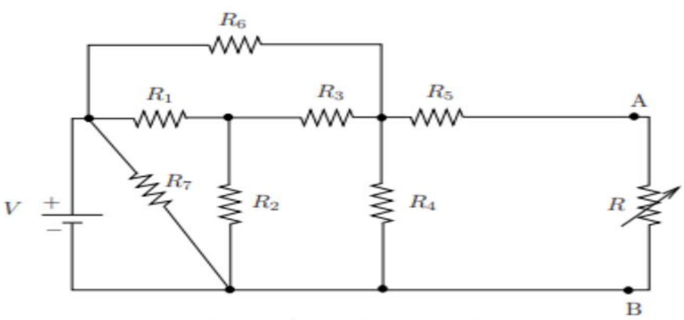


Fig.1: A complex network

Fig. 1 shows a complex network with one voltage source and some resistors. Assume that we want to calculate the current through resistance R as its value changes. Instead of node/mesh analysis of the whole circuit multiple times for different values of R, the circuit can be simplified across the two terminals A and B in the form of Thevenin equivalent circuit as shown in Fig. 2. As can be easily observed, this circuit is much easier to analyze than the original circuit.

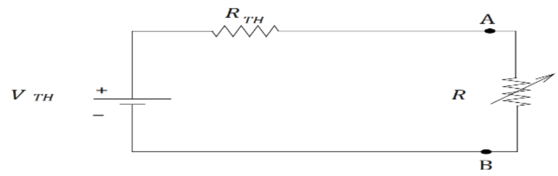


Fig. 2: Thevenin equivalent circuit

2.2 Maximum Power Transfer theorem

Maximum power transfer theorem states that, the power delivered from the source to the load is maximum when the load impedance is the complex conjugate of the source impedance. For a resistive circuit, the maximum power transfer takes place when the load resistance equals the source resistance (complex conjugate with zero imaginary part).

3. Procedure and Verification

3.1 Verification of Thevenin's theorem

Build the circuit as shown in fig. 3 using MATLAB/Simulink. While building the circuit, follow the steps that were discussed in lab session 1.

Steps for searching components, placing components into your model, connecting different components by wires and running the simulation are remain same (similar to lab manual 1). After building the Simulink circuit model, take readings of the current through resistance RL from the display connected to your current measurement block.

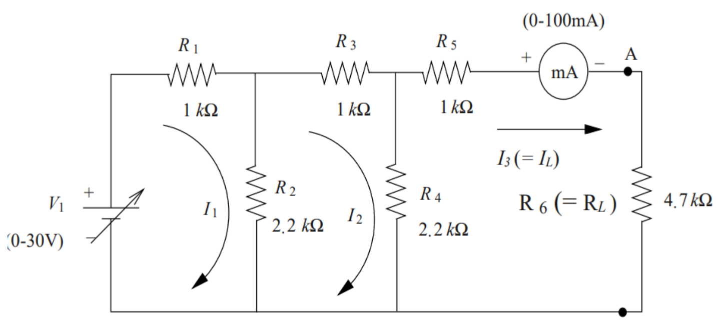


Fig.3: Original Circuit

To verify Thevenin's theorem, basically the circuit shall be represented as Thevenin's equivalent circuit across points A and B. To do that, we need to know the values of VTH and RTH across these points. Disconnect R 6 (= RL) and measure the open circuit voltage across A and B for the same values of input voltage (refer to Fig. 4).

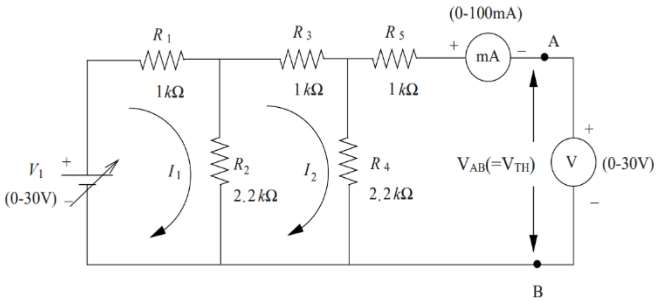
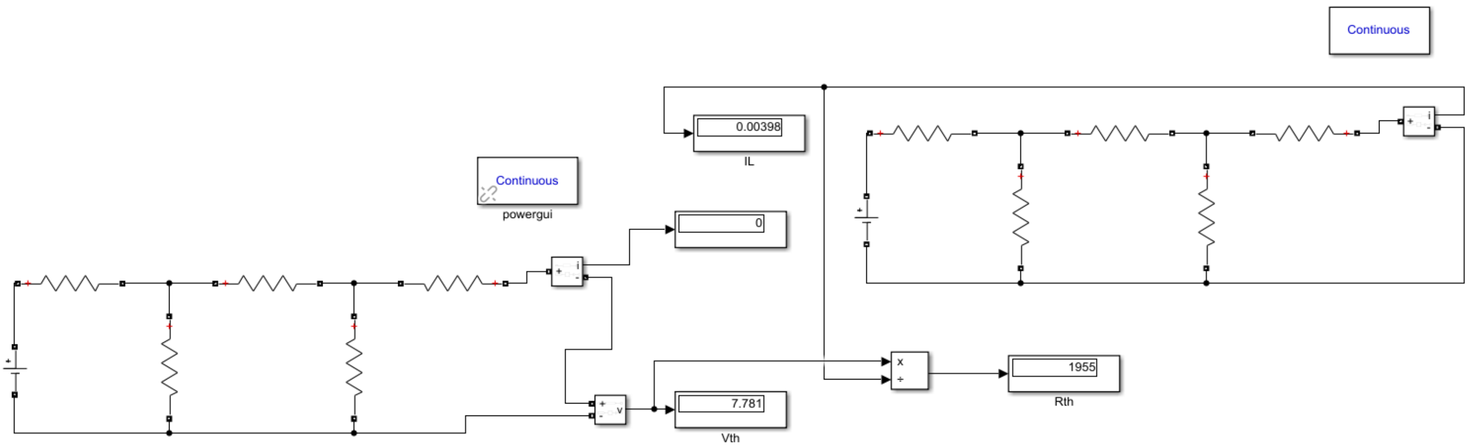


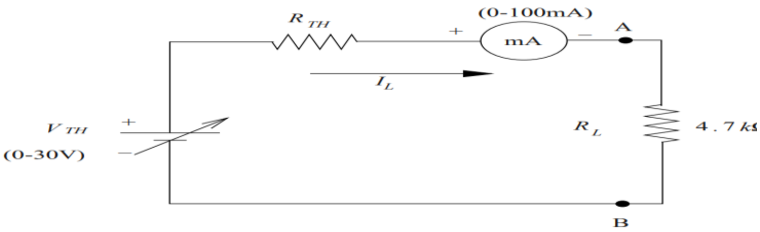
Fig.4: Measuring Open Circuit Voltage

1. Calculate RTH, VTH and IL from fig. 3 by using node/mesh analysis. Present the values in tabular form as shown in Table 1. 2. After knowing VTH and RTH, connect the circuit as shown in Fig. 5. Measure the current through RL and compare with the corresponding value measured in the original circuit. Present the values in tabular form as shown in Table 2.



V 1 (V)	IL(A)		VTH (V)	
	Theoretic al	Ideal Simulatio n	Theoretic al	Ideal Simulatio n
20	0.00398	0.00398	7.781	7.781
15	0.002985	0.002985	5.836	5.836
25	0.004975	0.004975	9.727	9.727

Table 1



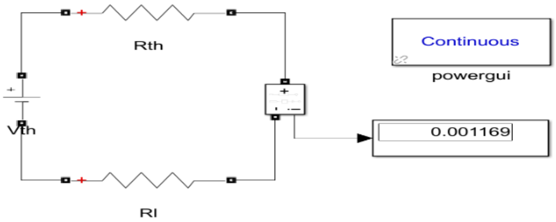


Table 2

VTH (V) (measured)	IL (A)	
	Theoretical	Ideal Simulation
7.781	0.001169	0.001169
5.836	0.0008769	0.0008769
9.727	0.001462	0.001462

Conclusion:

From the above observations, IL is always equal to Vth/(Rth +RL) in different cases by changing voltage source. Hence, Thevnin Theorem is verified.

3.2 Verification of Maximum Power Transfer theorem

1. Consider the Thevenin equivalent circuit derived in Part 2.1. After building the circuit shown in fig. 6 in MATLAB /Simulink, enter different values into the resistance RL in order to vary the resistance.

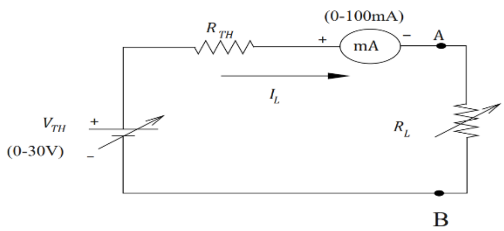
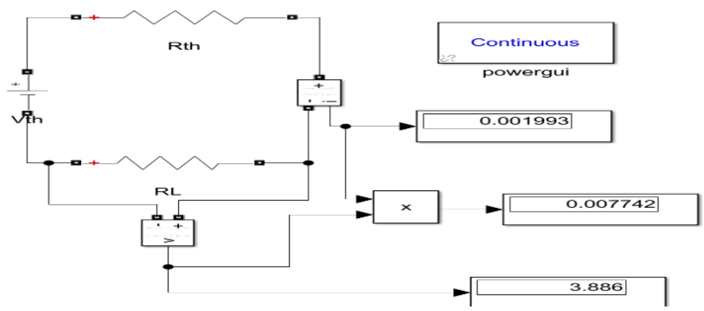


Fig. 6: Circuit for Verification of Maximum Power Transfer Theorem

2. Vary the resistance in steps and measure current IL for each value.

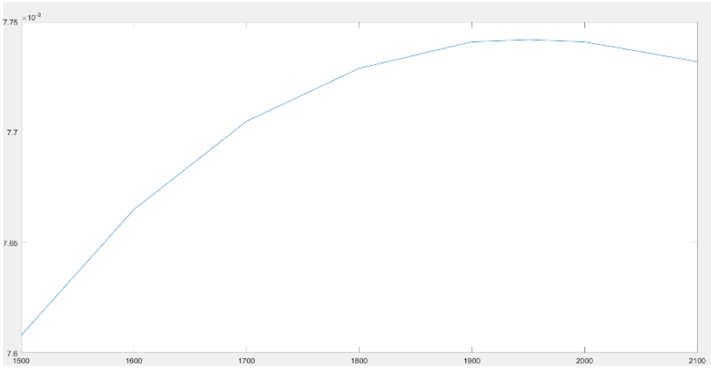
3. Assuming RTH as the source resistance, calculate the power transferred from the source to the load for each step. Present your results in tabular form as shown in Table 3.



RL (Ω)	IL (A)	PL (W)
1900	0.002018	0.007741
2100	0.001919	0.007732
1700	0.002129	0.007705

Table 3

4. Plot a graph of PL versus RL, RL represented along the x axis. Find the approximate value of RL at which PL is maximum. Compare it with theoretical value.



Conclusion:

From the above observations, it is clear that the maximum power delivered by the variable resistance occurs when it is equal to effective resistance around it as we move closer to it, power supplied increases. Hence, Maximum Power Transmission Theorem is verified.

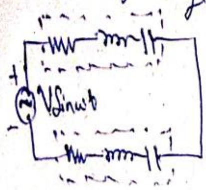
4.Questions

1. Consider the circuit shown in Fig. 3 and replace resistance R6 with a diode. Can you simplify this circuit as Thevenin's equivalent network across points A and B, considering diode as a load? If yes, how? If no, why not?

Soln:No, Thevenin's Law is an extension combination of KVL & KCL. Hence, can only be valid for linear elements and diode is an non-linear so it fails.

2. Using basic calculus, derive Maximum Power Transfer theorem for a circuit containing an ac voltage source with internal impedance connected to an R−L load.

2) $Z_f \rightarrow$ fixed



$Z_v \rightarrow$ variable

$$i = \frac{V \sin\omega t}{Z_f + Z_v}$$

$$P = \frac{V^2 \sin^2\omega t}{(Z_f + Z_v)^2} \times Z_v$$

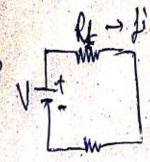
$$\Rightarrow \frac{dP}{dZ_v} = \frac{V^2 \sin^2\omega t}{(Z_f+Z_v)^4}\left((Z_f+Z_v)^2 - Z_v 2(Z_f+Z_v)\left(\frac{dZ_f}{dZ_v}+1\right)\right) = 0$$

$$\Rightarrow \cancel{(Z_f+Z_v)}\frac{V^2 \sin^2\omega t}{(Z_f+Z_v)^3}(Z_f - Z_v) = 0$$

$\therefore Z_f = Z_v \rightarrow$ max. power trans. thm. derived

3. For a resistive circuit, calculate the efficiency at maximum power transfer conditions. Is it a good idea to operate high power circuits at maximum power transfer conditions? What will be the condition for maximum efficiency instead?

3) $R_f \rightarrow$ fixed



$R_v \rightarrow$ variable

Acc. max. power trans. thm,

$R_f = R_v$

$$i = \frac{V}{2R_f} \qquad P = \frac{V^2}{4R_f^2} \times R_f = \frac{V^2}{2R_f} \quad -(1)$$

$$\therefore \text{Efficiency } (\eta) = \frac{\frac{V^2}{2R_f}}{\frac{V^2}{R_f}} = 0.5$$

$\therefore$ It is good idea to operate at this condn,

$\therefore$ for maximum efficiency, increase in voltage and decrease in resistance are favourable as shown in proportionality in eqn (1).