BME 211 Circuit Analysis Laboratory

Experiment #4: Thevenin and Norton Equivalent Circuits,

Maximum Power Transfer

Objective

The objective of this experiment to learn equivalent circuits, determine and utilize Thevenin and Norton equivalent circuits, understand the concept of maximum power transfer and find components to achieve maximum power transfer.

Background

1. Thevenin's Theorem

Thevenin's theorem states that a linear two-terminal circuit in Fig. 4.1 (a) can be replaced by an equivalent circuit consisting of a voltage source, V_{Th}, in series with a resistor, R_{Th}, as shown in Fig. 4.1 (b) which is called the Thevenin equivalent circuit. The aim of using an equivalent circuit is to reduce the complexity of the circuit.

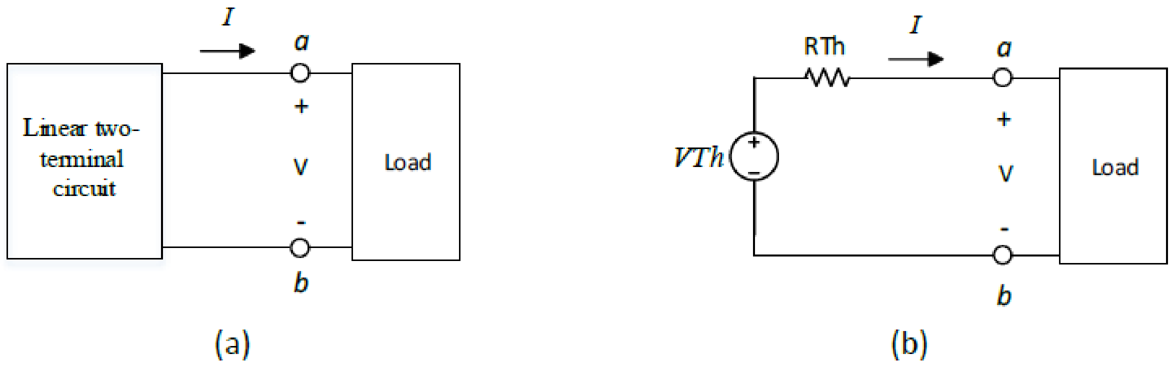


Figure 4.1 (a) Original circuit, (b) the Thevenin equivalent circuit.

In order to find V_{Th} and R_{Th} in the Thevenin equivalent circuit, following steps are carried out:

Step 1: The a-b terminals are open-circuited (by removing the load) to find the V_{Th}. There is no current at the output and therefore the open-circuit voltage (V_{OC}), measured across the terminals a-b in Fig. 4.2 is equal to V_{Th}.

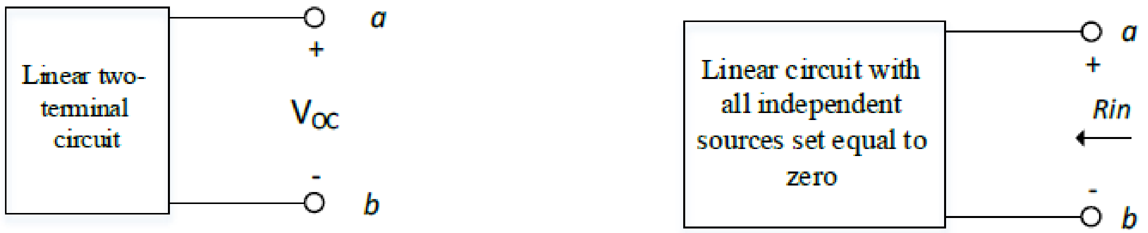


Figure 4.2 (a) Finding V_{Th} (b) Finding R_{Th}

Step 2: There are different approaches to calculate R_{Th} in the equivalent circuit. One method is to disconnect the load so that the a-b terminals are open-circuited; to deactivate all the indepent source and to calculate/measure the equivalent resistance seen from terminals a-b, which is equal to R_{Th}.

2. Norton's Theorem

Norton's theorem states that a linear two-terminal circuit in Fig. 4.3 (a) can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N in Fig. 4.3 (b), where I_N is the short-circuit current through the terminals and R_N is the input or equivalent resistance at the terminals when the independent sources are turned off [1].

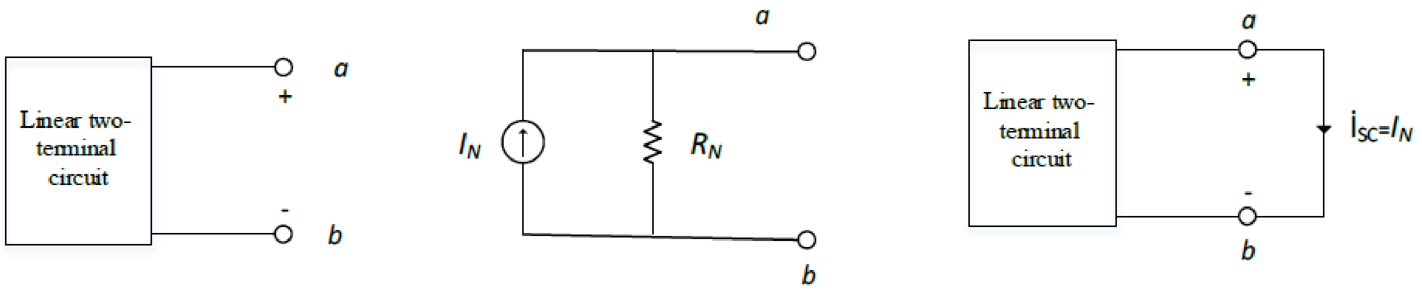


Figure 4.3 (a) Original circuit (b) Norton equivalent circuit (c) finding I_N

To find the Norton current I_N, load is removed and the a-b terminals are short-circuited. The short circuit current (I_{SC}) measured is equal to the Norton current I_N.

There is a close relationship between Norton's and Thevenin's Theorems and the Norton equivalent resistance (R_N) is calculated with the same way used for finding the Thevenin equivalent resistance (R_{Th}).

$$R_N = R_{Th}, \quad I_N = V_{Th} / R_{Th} \quad [1] \qquad (4.1)$$

3. Maximum Power Transfer Theorem

Maximum power transfer theorem states that, to acquire maximum power from a source through a resistor, the resistance of the load must be equal to the Thevenin equivalent resistance (R_{Th}). If the entire circuit is replaced by its Thevenin equivalent except for the load, as shown in Fig. 4.4, the power delivered to the load is

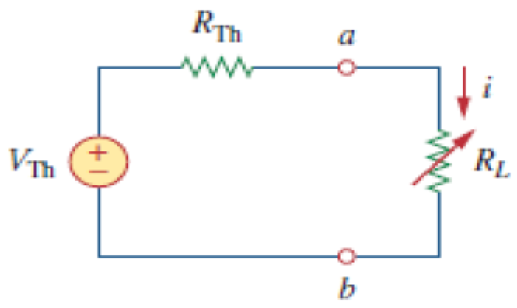


Figure 4.4 The circuit used to determine maximum power transfer

$$P = i^2 R_L = [V_{Th} / (R_{Th} + R_L)]^2 R_L \text{ [1]} \qquad (4.2)$$

For a given circuit, V_{Th} and R_{Th} are fixed. By varying the load resistance the power delivered to the load varies as sketched in Fig. 4.5.

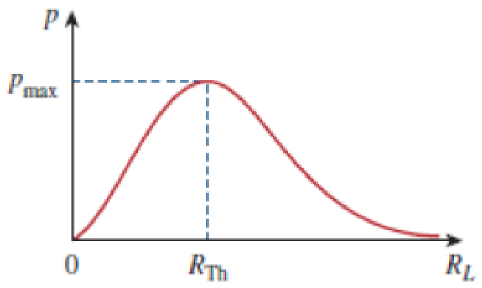
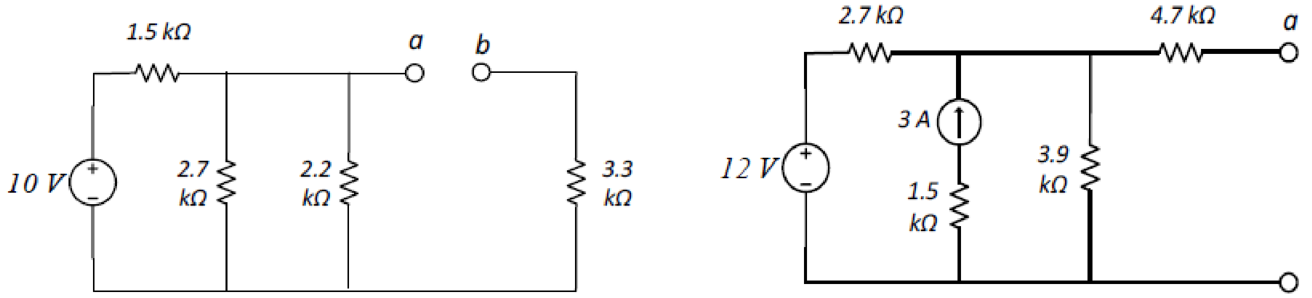


Figure 4.5 Power delivered to the load as a function of *RL*. [1]

Preliminary Work

1. Calculate the V_{Th}, R_{Th} and find the Thevenin equivalent circuit of the circuits in Fig. 4.6.



(a) (b)

Figure 4.6

2. Calculate the I_L, R_L and find the Norton equivalent circuits of the circuit in Fig. 4.6.

3. Consider the value of R_L for maximum power transfer in the circuit of Fig. 4.7 and calculate the maximum power.

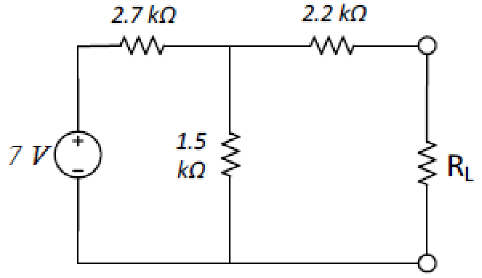


Figure 4.7

Procedure

Before starting, read the laboratory safety instructions on Page 4.

1. For the circuit in Figure 4.6 (a), measure V_{Th} and R_{th} and draw the Thevenin equivalent circuit. Compare your results with Preliminary Work.

2. For the circuit in Figure 4.6 (a), measure I_N and R_N and draw the Norton equivalent circuit. Compare your results with the Preliminary Work.

3. For the circuit in Figure 4.8,

(a) adjust the potantiometer for maximum power transfer; measure I_L and R_L. Calculate P_{max}.

(b) Draw the graph for R_L vs P using six different values of R_L. Choose R_L values so that one corresponds to P_{max}; two R_L values are less than R_L for maximum power transfer and three R_L values are more than R_L for maximum power transfer.

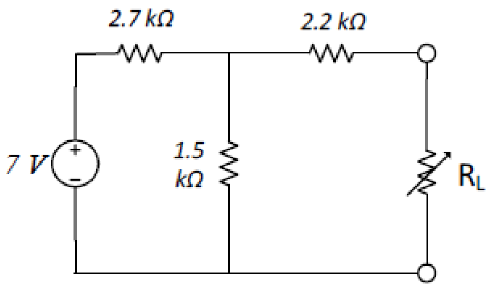


Figure 4.8

List of Components

Equipments: DC Voltage Supply, Digital Multimeter

Resistors: 1.5 kΩ, 2.2 kΩ, 2.7 kΩ, 3.3 kΩ, varying R or potantiometer

References

[1] Alexander K. Charles, Matthew N. O. Sadiku - Fundamentals of Electric Circuits (Tenth Edition)

BME 211 Report #4

Thevenin and Norton Equivalent Circuits, Maximum Power Transfer

Objective

Results

1. Comparison of calculated and measured values:

	Calculated	**Measured**
V_{Th}		
R_{th}		

Thevenin equivalent circuit and comments:

2. Comparison of calculated and measured values:

	Calculated	**Measured**
I_N		
R_N		

Norton equivalent circuit and comments:

3. a. Current, resistance measurement and power calculation:

$R_{measured}$	$I_{measured}$	$P_{calculated}$

b. Adjustment of R_L values and drawing R_L vs *P graph.*

	1.	2.	3.	4.	5.	6.
$R_{Ladjusted}$						
$P_{measured}$						

Comments: