

# Circuits and Electronic Laboratory

## Experiment #4

### The Purpose of the Experiment

The aim is to obtain an understanding of how works Thevenin, Norton, and Maximum Power Theorems.

### General Information

While all components are stable in a circuit, there may occur some situations that a component (it is generally called as the load) is changeable. As an example, plenty of different electrical devices (all of them have different resistor values) can be connected to the sockets in our homes. If we want to analyze the circuit (electrical infrastructure in the home and the device plugged into the socket), we have to analyze everything again whenever another device is plugged. We use the Thevenin theorem for avoiding this problem. The method behind it is to change the constant part of the circuit with the Thevenin equivalent circuit. In this way, the circuit that we examine is simplified to understand. Fig. 1 shows the situation.  $V_{Th}$  is the open circuit voltage between a and b points.  $R_{Th}$  is the equivalent (or input) resistor when independent sources are taken off.

Additionally, a two-port linear circuit can be changed with a Norton equivalent circuit. It can be seen in Fig. 2.  $I_N$  is the short circuit current flowing between terminals (a and b).  $R_N$  is the equivalent resistor when independent sources are taken off.

To sum up, Thevenin and Norton equivalent circuits can be found with the following methods:

- Open circuit voltage  $V_{oc}$  between a and b terminals
- Short circuit current  $I_{sc}$  between a and b
- Equivalent or input resistor  $R_{in}$  when all independent sources are off. Being sources off means that All independent voltage sources must be short circuits and independent current sources must be open circuits.

**Maximum Power Transfer:** If  $R_L = R_{Th}$ , maximum power transfer is obtained. The general formula is as follows.

$$P = i^2 R_L = \left( \frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L = \frac{V_{Th}^2}{4R_{Th}} \quad (1)$$

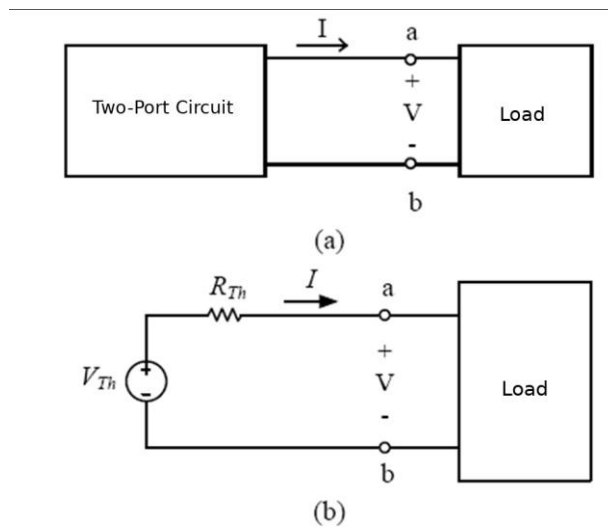


Figure 1: a) Original circuit b) Thevenin equivalent circuit

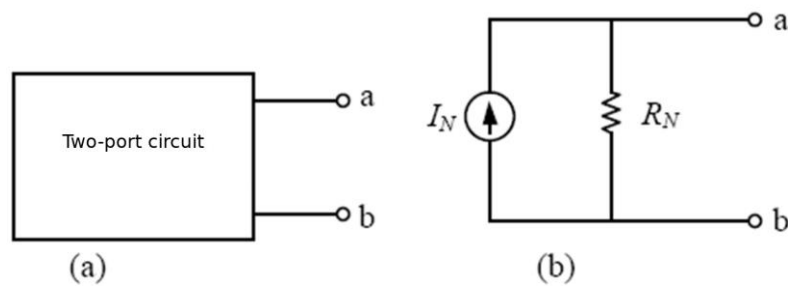


Figure 2: a) Original circuit b) Norton equivalent circuit

## Preparations Before the Experiment

- Why Thevenin and Norton Theorems are used in the circuits?
- How Norton current and Thevenin voltage are found in a circuit?

- Draw Norton and Thevenin equivalents of the following circuits before coming to the lab.
- Determine  $R_L$ 's in the following circuits for the maximum power transfer. Fill all the calculation columns in the following tables.
- Simulate and print the following circuit(Fig. 3) simulations.

## The Experiment

- Set up the circuit in the Fig. 3.
- Find  $V_{Th}$  by measuring the open circuit voltage between a and b terminals. You need to get rid of  $R_5$  to do this.
- Find  $R_{Th}$  via measuring the equivalent resistor between terminals. You have to measure the resistor with the ohmmeter property of the multimeter.
- Draw the Thevenin equivalent circuit with experimental results. Draw the Norton circuit using source transformation method.
- Measure  $I_N$  Norton short circuit current between a-b terminals. Compare it with the Norton circuit that you drew.
- Show your results to the teaching assistants up to now.
- Fill the table and try to understand the effects of the maximum power theorem on your experiment. Show the table to the TAs.

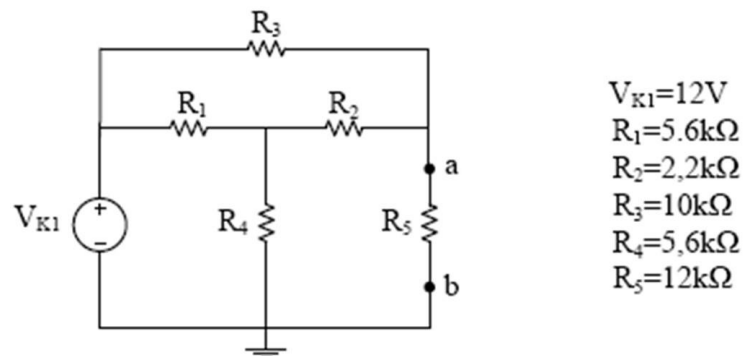


Figure 3:

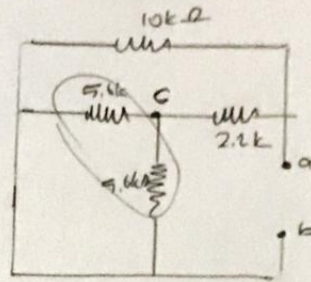
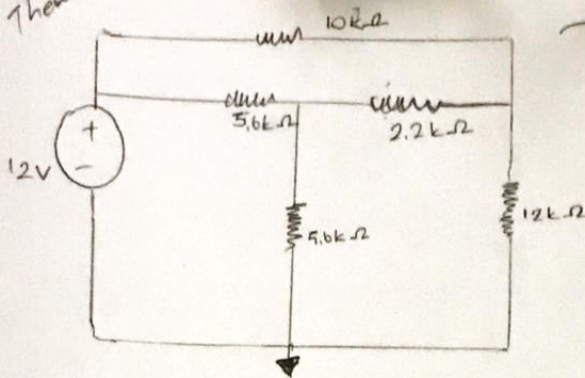
Load Res	Meas $I_{RL}$ (mA)	Meas $V_{RL}$ (V)	Meas $P_{RL}$ (mW)	Meas $P_{Rth}$ (mW)	Calc $I_{RL}$ (mA)	Calc $V_{RL}$ (V)	Calc $P_{RL}$ (mW)	Calc $P_{Rth}$ (mW)
$R_L = 0.1R_{Th}$	0.24mA	0.8V						
$R_L = R_{Th}$	2.4mA	8V				8V		
$R_L = 10R_{Th}$	24mA	80V						

## The Components Needed in This Lab

330 $\Omega$  x 1 piece, 1k $\Omega$  x 3 pieces, 2.2k $\Omega$  x 1 piece, 3.3k $\Omega$  x 1 piece, 5.6k $\Omega$  x 2 pieces, 10k $\Omega$  x 1 piece, 12k $\Omega$  x 2 pieces, 18k $\Omega$  x 1 piece, 33k $\Omega$  x 1 piece, breadboard are needed and a few jumper cable might be nice.

Do your simulations, some components may be missing. You can see in your simulations and filling the table if there is a missing component or not.

Thévenin



$$2.8k + 2.2k = 5k\Omega$$

$$\frac{1}{R} = \frac{1}{10} + \frac{1}{5} = \frac{3}{10} \Rightarrow \frac{10}{3} = 3.33k\Omega$$

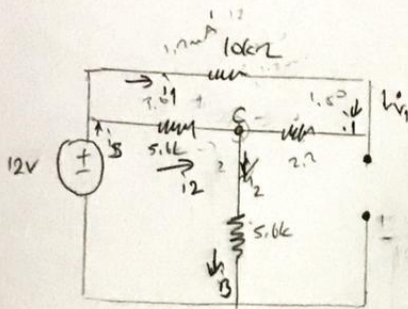
$$R_{Th} = 3.33\Omega$$

$$V_{Th} = 12 - V_{10k\Omega}$$

$i_1 = 0.4$

$$= 12 - 10(0.4)$$

$$= \underline{\underline{V_{Th} = 8V}}$$



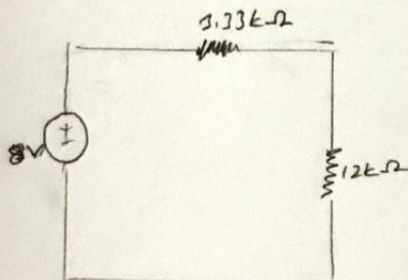
$$R_{eq} = 12.2k \parallel 5.6k$$

$$= 3.84k\Omega$$

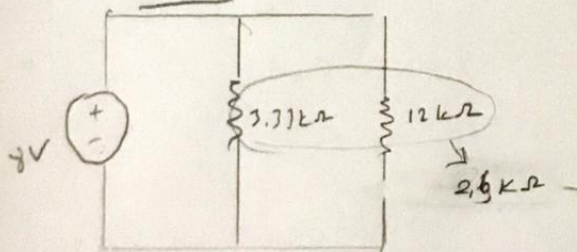
$$i_1 = \frac{12}{3.84k + 5.6k} = 1.27mA$$

$$R_{eq} = 15.33k\Omega$$

$$\frac{8}{15.33} = 0.52A$$



NORTON



$$I_N = \frac{8}{26} = 3.09A$$

$$i_1 = i_1 \cdot \frac{5.6k}{17.8k}$$

$\downarrow$

1.27

$$i_1 = 0.4$$

