EXPERIMENT 5:
NETWORK THEOREMS

This experiment verifies some important network theorems: the Thévenin equivalent of a circuit, the maximum power transfer theorem, and the source superposition.

I. BACKGROUND

I.1 Representation of a Linear Resistive Circuit by a Thévenin Source.

A linear resistive circuit seen (observed) from two of its terminals (a two-terminal circuit) is equivalent to a Thévenin or a Norton source connected between the two terminals. These are called Thévenin or Norton equivalents respectively of the circuit.

Definitions: If a circuit contains only ohmic resistors, dependent, and independent sources (that is no capacitors or inductors) the circuit is called a linear resistive circuit.
The terminal voltage and current of a two-terminal linear resistive circuit are related by a linear equation. The Thévenin or Norton equivalency imply that a two-terminal linear resistive circuit can be replaced by a Thévenin or Norton source connected between the circuit terminals. Equivalency means that the circuit and the Thévenin source have identical V-I characteristics at their terminals.

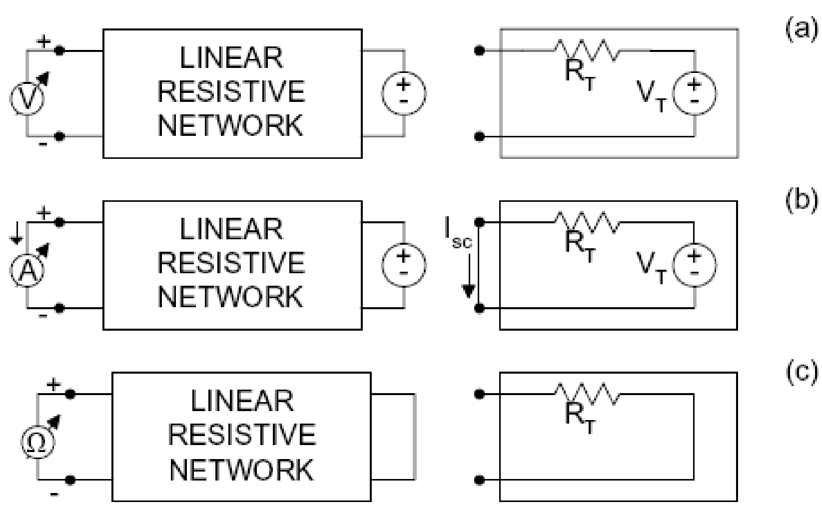

Fig. A. Derivation of the Thévenin equivalent. (a) The circuit and its equivalent Thévenin source. (b) The short circuit measurement. (c) The terminal resistance measurement.

Figure A(a) shows a two-terminal linear-resistive circuit. When observed from its terminals the circuit appears as a Thévenin source with voltage VT (termed the Thévenin voltage) and resistance RT (termed the Thévenin resistance). The relation between the terminal voltage and current of the circuit is given by (1).

$$V=-R_TI+V_T \qquad (1)$$

Figure B shows the terminal characteristic of (1). The intercept of this line on the V-axis is the Thévenin voltage. Figure A(a) shows that the Thévenin voltage can be measured directly across the open terminals of the network.

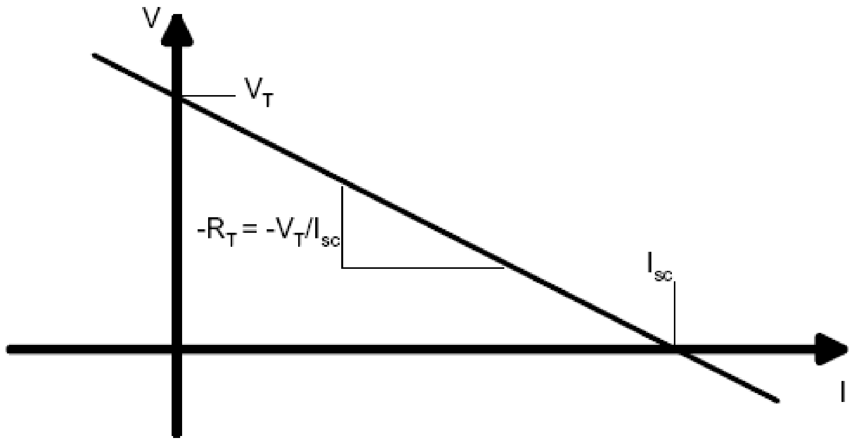

Fig. B. The V-I characteristic of the linear circuit.

The intercept of the circuit characteristic on the I-axis is the short circuit current (also equal to the Norton current). Figure A(b) shows that this current is measured when we short the terminals of the circuit. The short circuit current is given by (2).

$$I_{sc} = \frac{V_T}{R_T} \tag{2}$$

The slope of the characteristic is the opposite of the Thévenin resistance, RT. The Thévenin resistance can be measured either (a) from the ratio of the Thévenin voltage to the short circuit (Norton) current:

$$R_T = \frac{V_T}{I_{sc}} \tag{3}$$

Or (b) with an ohmmeter across the circuit terminals, as shown in Figure A(c): all independent sources of the circuit are made zero (voltage sources are replaced by a short circuit, current sources by an open circuit). The resistance measured at the terminals is, then, the Thévenin resistance.

The experimental determination of the Thévenin equivalent of a circuit requires, therefore, these measurements: (a) Open circuit voltage (Figure A(a)); and one of the following: (b) short circuit current (Figure A(b)), or (c) terminal resistance (Figure A(c)).

PROCEDURE

A. Experimental Determination of the Thévenin Equivalent

1. Construct the circuit shown in Figure 1, where R1= 1.2 kΩ, R2=2.4 kΩ, and R3=4.7 kΩ. Set the supply at 8 V. Perform the following measurements:

a. Measure the voltage across the open terminals a-b.

b. Short the terminals a-b through an ammeter. Measure the current.

c. Disconnect the supply from the circuit and replace it by a short circuit. Measure the resistance of Terminals a-b using an ohmmeter.

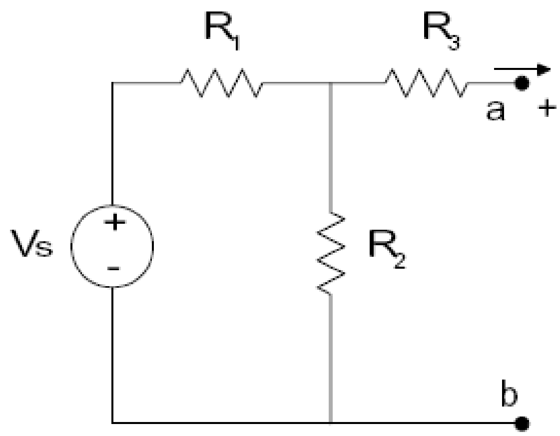

Fig. 1. Experimental arrangement.

B. Maximum Power Transfer.

2. Connect a variable resistor between the terminals a-b of the previous circuit. Vary its value in the range from 1 kΩ to 10 kΩ by increments of 1000 Ω. For each value of the resistance, measure the voltage, V, across it. Use Table 1.

Table 1.
Measurements for the maximum power transfer.

R										
V										

REPORT

A. Theoretical Development.

1. (a) Discuss the Thévenin and Norton equivalents and source transformation. Give an example of a two-terminal circuit for which no-equivalent Thévenin source exists.

B. Determination of Thévenin equivalent.

2. Calculate the Thévenin equivalent of Figure 1 from:

(a) The measurements in Procedures 1a and 1b.

(b) The measurements in Procedures 1a and 1c.

Compare with the theoretical Thévenin equivalent.

C. Maximum Power Transfer.

3. Plot the power dissipated on the variable resistor vs the resistance in Procedure 2. Tabulate your calculations. At what value of the resistor does maximum power occur? How much is the maximum power?