**UNIVERSITY OF MIAMI**

Department of Electrical and Computer Engineering

EEN 203

*Name:*

*Section:*

*Date:*

EXPERIMENT 2

**THEVENIN, SUPERPOSITION, AND MAXIMUM**

**POWER THEOREMS**

**PURPOSE:** To introduce a student to the use of three fundamental network theorems: thevenin equivalent circuits, superposition, and the maximum power theorem for resistive circuits.

The analysis of some circuits could be greatly simplified by reducing the complexity of a circuit. The *Thevenin* equivalent circuit (and its dual the *Norton* equivalent circuit) can be used most of the time and can greatly simplify the circuit to be analyzed. The principle is as simple as replacing an entire network by an equivalent resistor and voltage source at the terminals of interest.

*Superposition* can be applied when linear networks consist of more than one input. The linearity property makes it possible, as we shall see, to obtain the responses in these circuits by analyzing only single-input circuits.

In many cases, we would like to know the conditions under which maximum power is transfer to a load or would like to obtain the maximum possible power that a given practical source can deliver.

The *Maximum Power Theorem* allows us to do this and it can be applied to any complex circuits by first obtaining the Thevenin equivalent network around the load of interest.

***Equipment***

1 Variable resistance box

1 Digital voltmeter

2 DC power supplies

1. Frequency generator
2. 270Ω resistors

3 15 kΩ resistors

2 3.3 kΩ resistors

1 10 kΩ resistor

***Preliminary Work***

a) Find expressions for RTH and VTH at terminal a-b for the circuit of Fig. 2.1 in terms of R1, R2, R3, and Vs.

b) Repeat part (a) for the circuit of Fig. 2.2.

c) By applying the principle of superposition to Fig. 2.3, find the voltages Vab and Vcd in terms of R1, R2, R3, R4, V1, and V2.

d) For the circuit in Fig. 2.4, find an expression for the power across RL in term of VDC, R1, and RL. Find the value of RL for **maximum** power transfer from this equation (*Hint:* use calculus).

***Experimental Procedure***

I. Thevenin’s Equivalent Circuit Theorem:

a) Set up the circuit shown in Fig. 2.1. Use R1 = 10 kΩ, R2 = 15 kΩ, R3 = 3.3 kΩ, and Vs a sinusoidal of 2 Vrms and frequency *f* = 1 kHz. Measure and record the values of the resistors in Fig. 2.1.

(a) (b)

R1 = R2 = R3 = Vs =

**Figure 2.1** (a) Resistive circuit and (b) its Thevenin equivalent circuit.

b) **Measure** the voltage across the open circuit (terminal a-b). This voltage is VTH. Record your value for VTH.

VTH = 1.2V (RMS)

c) **Disconnect** Vs and replace it by a short circuit. Measure RTH across terminal a-b with an ohmmeter. This resistive value is RTH. Record your value for RTH.

RTH = 9.3 kOhms

d) **Compute** VTH and RTH of the circuit using the formulas derived in your preliminary work (use the measured values of the components). What is the % error in VTH and RTH? Show your calculations below.

% error VTH =

% error RTH =

e) Give a different way to measure the value of RTH. Measure using this method and verify that the value you obtain is approximately equal to the value in I (C).

f) Repeat parts (b) to (d) for the circuit in Fig. 2.2 but this time use a DC power supply set to 5 V. Use R1 = 10 kΩ, R2 = R4 = 3.3 kΩ, R3 = R5 = 15 kΩ. Record the measured values of the resistors below.

R1 = R2 = R3 = R4 = R5 =

**Figure 2.2** Resistive circuit with DC power supply.

Use the expressions found in your preliminary work. Show all calculations below using the measured component values.

*Measured:*

VTH =

RTH =

*Calculated:*

VTH =

RTH =

% error VTH =

% error RTH =

II Superposition:

a) Set up the circuit shown in Fig. 2.3. Use V1 = 5 V, V2 = 10 V, R1 = R3 = R4 = 15 kΩ, and R2 = 10 kΩ. Record the measured values of the resistors below.

R1 = R2 = R3 = R4 =

**Figure 2.3** Two power supply resistive circuit to demonstrate superposition.

b) Measure the voltages across terminal a-b and c-d. Record your values.

Vab = 3.3V

Vcd = -3.3V

c) **Replace** V2 with a short circuit and measure

Vab1 = 1.66V

Vcd1 = 0.84V

d) Reconnect V2 = 10 V and **replace** V1 with a short circuit and measure

Vab2 = 1.66V

Vcd2 = -4.16V

***Note:*** Make sure that the polarities of the measured voltages in parts (c) and (d) are the same.

e) Add up the results of parts (c) and (d) and find Vab and Vcd as

Vab = Vab1 + Vab2 = 3.32V

Vcd = Vcd1 + Vcd2 = -3.32V

f) Find the % error between the results of parts (b) and (e).

% error Vab =

% error Vcd =

III Maximum Power Transfer Theorem:

a) Set up the circuit of Fig. 2.4 using one variable resistance box for RL with R1 set to be 270 Ω.

**Figure 2.4** Resistive circuit to demonstrate the maximum power theorem.

b) Vary RL to the values given in Table 2.1. Measure VL and compute PRL = VL2/RL in each case. Use the variable resistance box to obtain the values of RL shown in the table.

|  | **Measured** | | **Calculated** | |
| --- | --- | --- | --- | --- |
| **RL (Ω)** | **VL (Volts)** | **PL (mW)** | **VL (Volts)** | **PL (mW)** |
| 0 |  |  |  |  |
| 50 |  |  |  |  |
| 100 |  |  |  |  |
| 150 |  |  |  |  |
| 200 |  |  |  |  |
| 270 |  |  |  |  |
| 500 |  |  |  |  |
| 1000 |  |  |  |  |
| 2000 |  |  |  |  |
| 5000 |  |  |  |  |

**Table 2.1** Power versus Load data for the circuit of Fig. 2.4.

c) Plot PL vs RL (measured and calculated on the same graph). Use linear paper with RL values on the horizontal axis from 0 to 1000 Ω only (do not plot RL = 2000 and 5000 Ω).

***Discussion of Results***

1) In part I.d and I.f you were asked to calculate the %error in VTH and RTH. How do you explain these sources of error? What can be done to improve them?

2) Why does the superposition principle work and why is it useful?

3) If you were to connect the output of a power amplifier with output resistance Rout to a load, how would you pick the value of RL in order to drive it at maximum power? Why?

4) Would it have made a difference if you had measured the voltage across terminals (a-b) or across R2 for Part I (b)? Explain.

5) Write a conclusion.