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

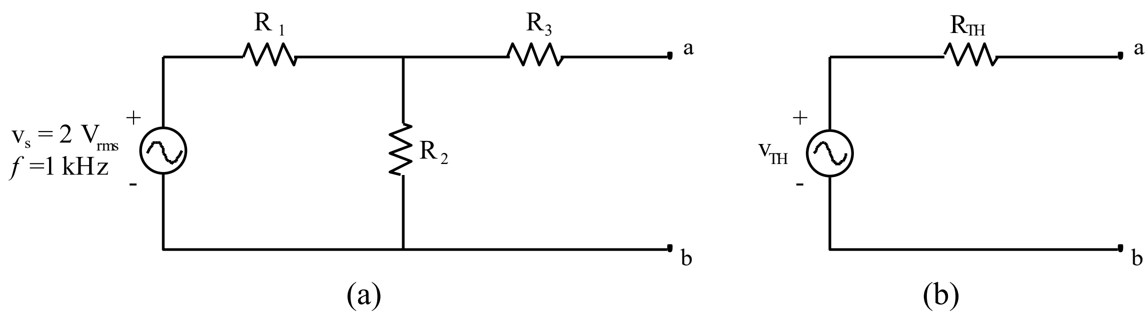
Preliminary Work

a) Find expressions for R_{TH} and V_{TH} at terminal a-b for the circuit of Fig. 2.1 in terms of R_1, R_2, R_3, and V_s.
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 V_{ab} and V_{cd} in terms of R_1, R_2, R_3, R_4, V_1, and V_2.
d) For the circuit in Fig. 2.4, find an expression for the power across R_L in term of V_{DC}, R_1, and R_L. Find the value of R_L 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 R_1 = 10 kΩ, R_2 = 15 kΩ, R_3 = 3.3 kΩ, and V_s a sinusoidal of 2 V_{rms} and frequency f = 1 kHz. Measure and record the values of the resistors in Fig. 2.1.



R_1 = ________ R_2 = ________ R_3 = ________ V_s = ________

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 V_{TH}. Record your value for V_{TH}.

V_{TH} = 1.2V (RMS)

c) **Disconnect** V_s and replace it by a short circuit. Measure R_{TH} across terminal a-b with an ohmmeter. This resistive value is R_{TH}. Record your value for R_{TH}.

R_{TH} = 9.3 kOhms

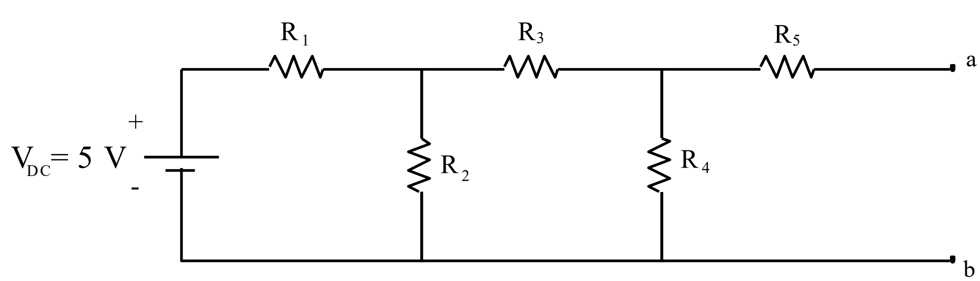
d) **Compute** V_{TH} and R_{TH} of the circuit using the formulas derived in your preliminary work (use the measured values of the components). What is the % error in V_{TH} and R_{TH}? Show your calculations below.

% error V_{TH} = ___________

% error R_{TH} = ___________

e) Give a different way to measure the value of R_{TH}. 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 R_1 = 10 kΩ, $R_2 = R_4$ = 3.3 kΩ, $R_3 = R_5$ = 15 kΩ. Record the measured values of the resistors below.



R_1 = _______ R_2 = _______ R_3 = _______ R_4 = _______ R_5 = _______

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:

V_{TH} = ____________

R_{TH} = ____________

Calculated:

V_{TH} = ____________

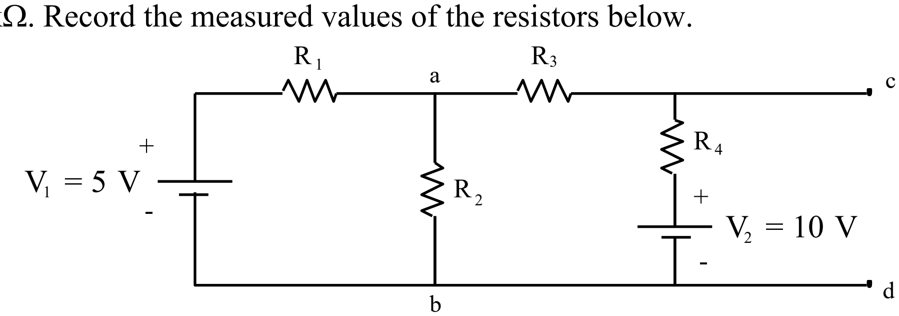
R_{TH} = ____________

% error V_{TH} = ___________

% error R_{TH} = ___________

II Superposition:

a) Set up the circuit shown in Fig. 2.3. Use V_1 = 5 V, V_2 = 10 V, $R_1 = R_3 = R_4$ = 15 kΩ, and R_2 = 10 kΩ. Record the measured values of the resistors below.



R_1 = _______ R_2 = _______ R_3 = _______ R_4 = _______

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.

V_{ab} = 3.3V____________

V_{cd} = -3.3V____________

c) **Replace** V_2 with a short circuit and measure

V_{ab1} = 1.66V____________

V_{cd1} = 0.84V____________

d) Reconnect V_2 = 10 V and **replace** V_1 with a short circuit and measure

V_{ab2} = 1.66V____________

V_{cd2} = -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 V_{ab} and V_{cd} as

$V_{ab} = V_{ab1} + V_{ab2}$ = 3.32V____________

$V_{cd} = V_{cd1} + V_{cd2}$ = -3.32V____________

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

% error V_{ab} = ___________

% error V_{cd} = ___________

III Maximum Power Transfer Theorem:

a) Set up the circuit of Fig. 2.4 using one variable resistance box for R_L with R_1 set to be 270 Ω.

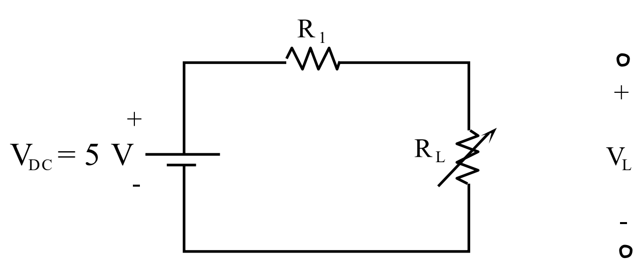


Figure 2.4 Resistive circuit to demonstrate the maximum power theorem.

b) Vary R_L to the values given in Table 2.1. Measure V_L and compute $P_{RL} = V_L^2/R_L$ in each case. Use the variable resistance box to obtain the values of R_L shown in the table.

	Measured		Calculated	
R_L (Ω)	**V_L (Volts)**	**P_L (mW)**	**V_L (Volts)**	**P_L (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 P_L vs R_L (measured and calculated on the same graph). Use linear paper with R_L values on the horizontal axis from 0 to 1000 Ω only (do not plot R_L = 2000 and 5000 Ω).

Discussion of Results

1) In part I.d and I.f you were asked to calculate the %error in V_{TH} and R_{TH}. 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 R_{out} to a load, how would you pick the value of R_L 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 R_2 for Part I (b)? Explain.

5) Write a conclusion.