Thévenin's Theorem and Interface Circuit Design

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Purpose:

Verify Thévenin's Theorem, practice elementary interface circuit design and demonstrate maximum power transfer.

Equipment Required:

- 1 - Agilent 34401A Digital Multimeter
- 1 - Agilent E3631A Power Supply
- 1 - Protoboard
- 1 - 1 kΩ   1/4 W Resistor
- 1 - 4.7 kΩ   1/4 W Resistor
- 1 - 10 kΩ   1/4 W Resistor
- 1 - 27 kΩ   1/4 W Resistor

Selection of 1/4 W resistors available for the design:

100 Ω	680 Ω	1 kΩ
3.3 kΩ	5.6 kΩ	8.2 kΩ
10 kΩ	15 kΩ	27 kΩ
100 kΩ	180 kΩ	390 kΩ

Prelab:

Review the sections in Chapter 3 of the text[*] on Thévenin's Theorem, maximum signal transfer, and interface circuit design. In the exercise "Proportionality and Superposition", superposition was used to analyze the circuit of Fig. 1. The superposition method was verified by measuring the output for each voltage source separately, and comparing the sum of these measurements to the output voltage of the complete circuit. In this exercise, a Thévenin equivalent for this circuit will be constructed.
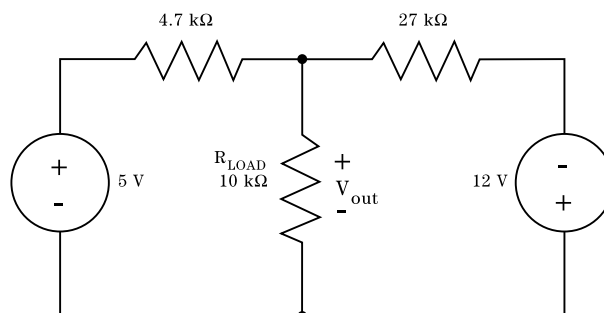

Figure 1

For the circuit of Fig. 1, find the Thévenin equivalent circuit seen by the 10-kΩ load resistor. Record the Thévenin circuit schematic along with R_{TH} and V_{TH} in your lab journal. Use the Thévenin equivalent circuit to compute the current through and voltage across the 10-kΩ load resistor R_{LOAD}. Record these values in your lab journal.

Procedure:

1. Thévenin equivalent circuit

   a. Construct the Thévenin circuit using Fig. 2 as a guide. (Note that this lab manual uses a subscripted TH (e.g. R_{TH}) to indicate Thévenin equivalent elements. The text* uses a subscripted T for this purpose.)
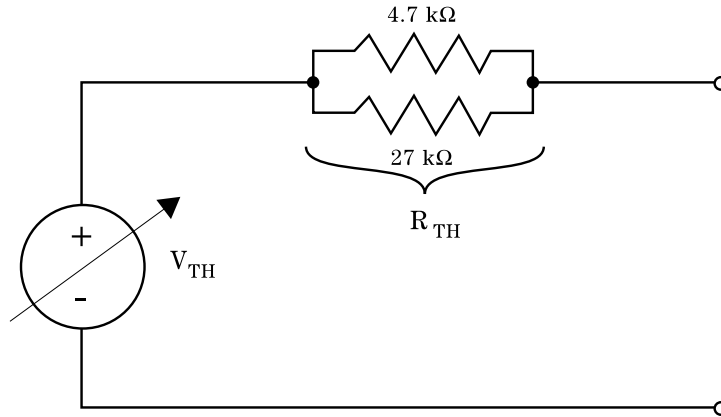
   b.

Figure 2

   b. Adjust the variable DC supply to output the calculated value, V_{TH}.

   c. Connect the 10-kΩ resistor R_{LOAD} across the output of your Thévenin circuit. Measure the voltage across and current through R_{LOAD}. Record these values.

   d. You now have experience using both superposition, and the Thévenin method of analysis in this exercise. Both methods are useful. However if you expected the load resistance R_{LOAD} to change and repeated output voltage calculations were therefore required, which method would you choose to analyze the circuit of Fig. 1? Why?

2. Interface design

   a. Design an interface circuit, as shown in Fig. 3, using only the resistors listed in the Equipment Required section. The goal of the design is to provide 100 µA ±10% to the 10-kΩ resistor R_{LOAD}. Resistors cost six cents each. Your design should minimize cost — but cannot exceed 18¢.
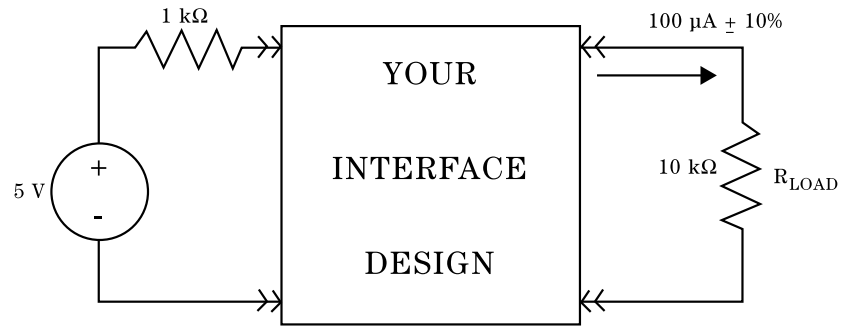
Figure 3

b.   Build your interface circuit and verify its performance. Record all of the results.

c.   For the circuit of Fig. 4, design an interface circuit so that a load connected to it will "see" a Thévenin resistance of 600Ω ±5%. You may only use the fixed resistors available. Again, each resistor costs six cents and the cost of your solution may not exceed 24¢.
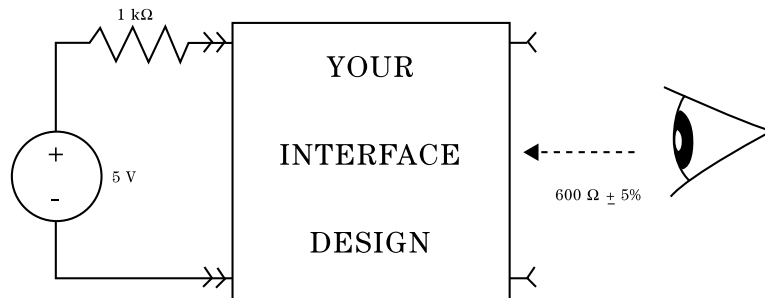

Figure 4

d.   Build your circuit and demonstrate your results to your lab instructor. Fully document the results in your lab journal.

3. Maximum power transfer

In this portion of the exercise, you are going to verify the maximum power theorem. In your journal, determine the resistance value for the potentiometer that will transfer maximum power to the pot. Use the maximum power theorem to mathematically prove your claim.
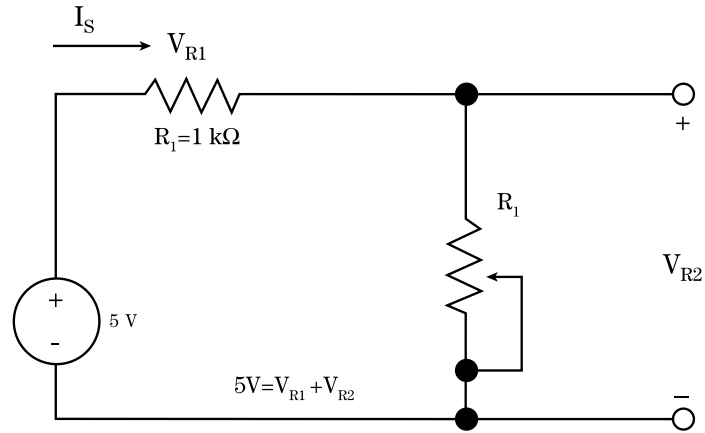
a. Build the circuit shown below.

Figure 5

b. Create a data table in your journal to record the voltage across R_1, (V_{R1}) and the potentiometer, (V_{R2}).

c. Starting at a V_{R1} of 5 Vdc, record V_{R1} and V_{R2}. Adjust the potentiometer so that V_{R1} is 4.5 Vdc, and record V_{R1} and V_{R2}. Decrement V_{R1} by another 0.5 Vdc, and record this new point. Follow this procedure until you have reached and recorded the minimum voltage that can be obtained for V_{R1}.

d. Enter your data into a spreadsheet program, and calculate the current in the series circuit, I_s, the apparent resistance of the potentiometer, R_2, and the power delivered to the potentiometer in mW.

e. Use the program to plot the power delivered to R_2 in mW, as a function of the resistance of R_2. Print out the results and tape them into your lab journal.

In your conclusion, comment on whether your plot of P vs. R in the potentiometer verifies the Maximum Power Theorem.

[*] Roland E. Thomas and Albert J. Rosa, The Analysis and Design of Linear Circuits, Prentice Hall, (New Jersey, 1994)