

EXPERIMENT 5 THÉVENIN EQUIVALENT CIRCUITS AND MAXIMUM POWER TRANSFER

INTRODUCTION

Thévenin's Theorem states that a two terminal circuit may be replaced by an equivalent two terminal circuit consisting of a voltage source and a series resistance. The Thévenin equivalent circuit will deliver the same current and voltage to a load resistance placed between the terminals as the original circuit.

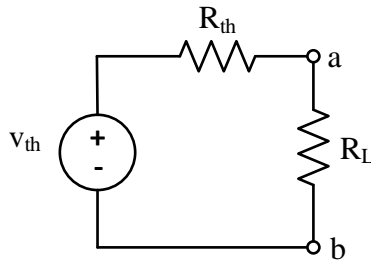


Figure 1: Thévenin Equivalent Circuit with an Attached Load

The Thévenin voltage can be calculated by determining the open circuit voltage, that is, the voltage across the output terminals with the load resistance removed.

If the original circuit contains only independent sources and resistors, then the Thévenin resistance can be calculated by replacing the independent sources by their internal resistances and using parallel and series combinations of the resistances to calculate a single equivalent resistance. For a DC voltage source, the internal resistance will (ideally) be a short circuit. A DC current source would ideally be replaced by an open circuit.

In a DC circuit, maximum power is delivered to the load resistance when the load resistance matches (equals) the equivalent resistance of the driving circuit. In other words, the Thévenin resistance of the driving circuit. A load resistance either greater than or less than this will result in a smaller load power.

Efficiency is the ratio of the power absorbed by the load to the total power supplied by the source. The efficiency of the system (generally denoted as η), is 50% in the maximum power case. That is, half of the power generated is absorbed by the load resistance. The remaining 50% is absorbed by the source resistance. Increasing the load resistance beyond the maximum power value will result in a larger load voltage but a smaller load current producing a reduced load power. The efficiency of the system is greater in this case however as a larger percentage of the power produced is absorbed by the load.

PROCEDURE

1. **Measuring the Thévenin equivalent voltage.** Construct the circuit shown in Figure 2. Use resistor values $R_1=10\text{ k}\Omega$, $R_2=20\text{ k}\Omega$, and $R_3=47\text{ k}\Omega$. Use the DC power supply adjusted to 10 V. Use the DMM to measure the open circuit voltage $V_{oc}=V_{ab}$ across the terminals a and b. Record this voltage value. This is the voltage of the Thévenin equivalent.

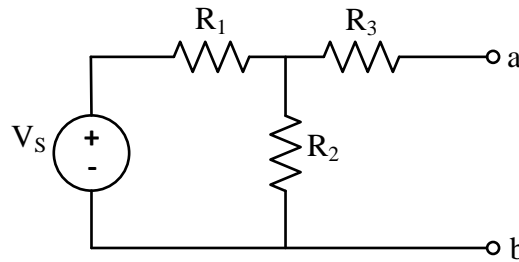


Figure 2: Resistive Driving Circuit with Attached Load

2. **Measuring the Thévenin equivalent resistance (method 1).** Disconnect the DC power supply from the circuit and replace it with a short circuit (a wire). Use the LCR meter to measure the resistance between the terminals a and b. Record this resistance value. This is the Thévenin resistance.
3. **Measuring the Thévenin equivalent resistance (method 2).** Remove the short and reconnect the DC power supply in the circuit. Adjust the DC power supply to 10 V. An ohmmeter cannot be used effectively in a powered circuit, so to measure the Thévenin resistance, attach the decade box between terminals a and b. Use the DMM to measure the voltage across the decade box. Vary the resistance on the decade box until the voltage across the decade box is half of the voltage measured in step 1. Record this resistance value. This is the Thévenin resistance and should be the same (or very close to) the value from step 2.
4. Replace the decade box with a $20\text{ k}\Omega$ resistor. Use the DMM to measure the voltage across the resistor. Record this voltage value.
5. Repeat step 4 with a $100\text{ k}\Omega$ resistor.
6. Construct the circuit in Figure 1. Use the DC power supply set to the $V_{th}=V_{oc}=V_{ab}$ value measured in step 1. Use the decade box in place of the R_{th} resistor set at the approximate resistance value found in step 2. Use a resistance value of $20\text{ k}\Omega$ for R_L . Use the DMM to measure the voltage across R_L . Record this value.
7. Repeat step 6 with a $100\text{ k}\Omega$ resistor as your load resistor.
8. Construct the circuit shown in Figure 3. Use a $20\text{ k}\Omega$ resistor for R_1 and the decade box for R_L . Use the DC power supply adjusted to 10 V. Set the decade box as close as

possible to the measured value of R_1 . Use the DMM to measure the voltage across the decade box. Record this voltage.

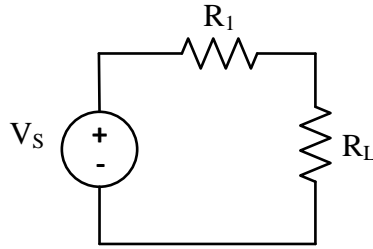


Figure 3: Circuit for Maximum Power Calculations

9. Change the decade box resistance to 5 k Ω , 10 k Ω , 50 k Ω , 100 k Ω . Record the voltage across the decade box at each of these resistance values.

CALCULATIONS

1. Using the actual resistor values from procedure step 1, calculate the Thévenin equivalent voltage and resistance.
2. Calculate the percent deviation of your measured value from procedure step 1 with the calculated Thévenin voltage value. Explain any significant deviation from the calculated value.

$$\% \text{ deviation} = \frac{\text{measured-calculated}}{\text{calculated}} \times 100$$

3. Calculate the percent deviations of your measured values from procedure steps 2 and 3 with the calculated Thévenin resistance value. Explain any significant deviations from the calculated value.
4. Calculate the percent deviation between the load voltage in the original circuit (procedure steps 4 and 5) and the load voltage in the Thévenin equivalent circuit (procedure steps 6 and 7) for each of the load resistor values. The voltages should be the same for a given load resistance so your percent deviation should be nearly zero. Explain any significant differences.

$$\% \text{ deviation} = \frac{\text{Thevenin-original}}{\text{original}} \times 100$$

5. Construct a table with columns for the resistor values from procedure steps 8 and 9, their measured voltages, the calculated power P_L absorbed by each resistor, the total power P_T in the system, and the efficiency η . You will need to calculate P_L , P_T and η for each resistor value.

$$P_L = \frac{V_L^2}{R_L} \quad P_T = \frac{V_S^2}{R_1 + R_L} \quad \eta = \frac{P_L}{P_T} \times 100$$

ADDITIONAL QUESTIONS

1. In Calculation Step 5, which load resistance produces the maximum load power? Is this what you would expect? Why or why not?
2. In Calculation Step 5, what is the efficiency of the circuit which delivers the maximum power to the load? Is this what you would expect? Why or why not?