University of California, Los Angeles

School of Engineering and Applied Science

Department of Electrical and Computer Engineering

ECE11L Lab Manual
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Experiment 2: Simple Resistive Networks

Topics

- Equivalent source transformations
- Principle of superposition
- Wheatstone bridge

Objectives

- To understand how to apply Thevenin and Norton equivalence theorems
- To measure and experimentally verify the principle of superposition
- To understand the operation of the Wheatstone bridge, and to apply to constructing circuits with sensors

Background

i. Superposition: For a linear circuit, the voltage at any node (or current at any branch) can be calculated as the algebraic sum of the voltages (or currents) caused by each source acting alone. One at a time, isolate each source by removing other sources (short circuit voltage sources and open circuit current sources). The sum of the responses will give you the same solution as if all sources were active at once. This can simplify the analysis of circuits containing multiple sources.

ii. Equivalent Source Transformation: With Ohm's Law in mind, a voltage source in series with a resistance R, is equivalent to a current source with current V/R, in parallel with R. This equivalency is illustrated below.

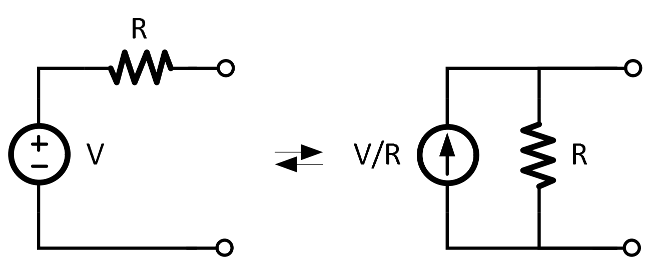

Figure.1: Equivalent source transformations

iii. Thevenin Equivalent Theorem: Thevenin Equivalent circuits can be used to convert a source circuit network down to an equivalent circuit containing only a single voltage source and resistor such that the current and voltage as seen at the load will remain the same. Similarly, Norton Equivalent circuits can convert a circuit into an equivalent circuit consisting of a single current source and a resistance parallel. To find the equivalent resistance, Set all sources to zero (short voltage sources, open current sources). Then, determine the equivalent resistance of the circuit with removed sources as seen from the terminals. This equivalent resistance gives the Thevenin/Norton resistance. With the sources in place, the open circuit voltage (with no load across the terminals) gives the Thevenin Voltage. Similarly, if we short circuit the load, the short circuit current is equal to the Norton Current. With these values known, one can construct the equivalent circuits as pictures in Figure 1, with a single source and resistor.

Lab

1. Superposition

Build the circuit illustrated in Figure 2. Choose $R_1 = 1.2k\Omega$, $R_2 = 4.7k\Omega$, $R_3 = 3.3k\Omega$. Measure the voltage and compute the branch current across the middle resistor (R_3) with both sources in place. Zero out the +5V source, and once again record the voltage and current across the middle resistor (R_3). Next, replace the +5V source, and this time zero out the -5V voltage source. Repeat measurements across the middle resistor. Make sure you have connected ground to the circuit.

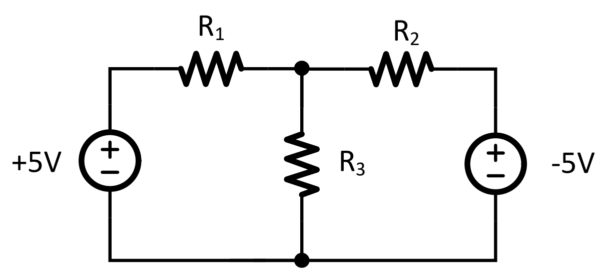

Figure 2: Superposition test circuit

Compare the theoretical analysis of superposition by analyzing the circuit with each source acting alone and compare with the acquired experimental data.

Sources	R_3 Voltage	R_3 Current (Computed)
+5V only		
-5V only		
Sum of above		
Both sources		

Discussion

- How did the theoretical results compare with experimental values?

2. Thevenin/Norton Equivalent

Build the circuit illustrated in Figure 3. Choose $R_1 = 5.6k\Omega$, $R_2 = 680\Omega$, $R_3 = 2.2k\Omega$. Measure and record the values of resistance of each resistor you use. Use $R_L = 10k\Omega$.

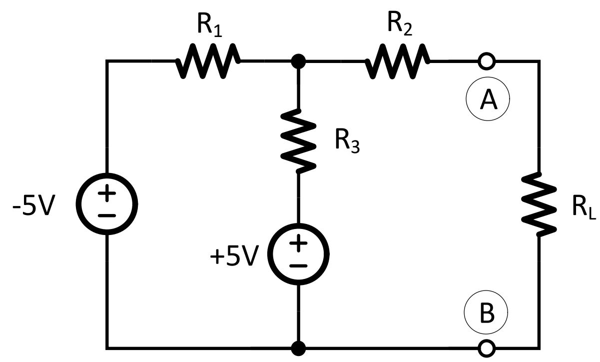

Figure 3: Thevenin/Norton equivalent circuit analysis

Calculate the Thevenin equivalent voltage (V_{TH}), Norton equivalent current (I_N), and Thevenin resistance ($R_{TH/n}$) values using theoretical analysis, and record these values in the table below. Also measure the actual values of the open circuit voltage (V_{OC}), and equivalent resistance (R_{eq}) across the nodes A and B of the circuit using the voltmeter and impedance analyzer in Analog Discovery 2. Note that to measure the equivalent resistance, you need to short both voltage sources. Compute the short-circuit current (I_{SC}) accordingly.

V_{TH}, V	I_N, mA	$R_{TH/N}$, Ω	V_{OC}, V	I_{SC}, mA	R_{eq}, Ω

Now, build the Thevenin equivalent circuit. Use the closest resistor value to the required one. To build the variable voltage supply needed for the Thevenin Equivalent circuit, adjust the power supply in Analog Discovery 2 as appropriate. Verify the equivalency by measuring the voltage across the load resistor for the constructed Thevenin equivalent circuit, and compare with the results of the original circuit.

Discussion

- How did the voltage across the load compare between the original circuit and Thevenin equivalent circuit?
- If our goal is to achieve maximum power dissipation across the load resistance, what load is the best choice? How does this value compare with the Thevenin equivalent resistance?

3. Wheatstone Bridge

Derive the output voltage (V shown below) in terms of the four resistances of the Wheatstone Bridge circuit illustrated below using Kirchhoff's Laws.

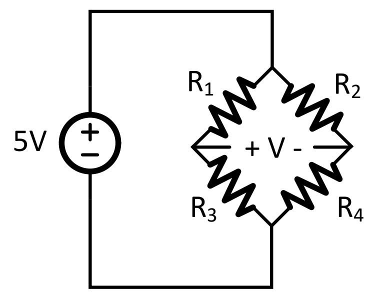

Figure 4: Wheatstone bridge

Use a thermistor in place of one of the resistors in the Wheatstone Bridge (R_4). The thermistor is a sensor that varies in resistance based on temperature. Build a sensor circuit using the 5V power supply and available resistors such that the output is roughly 0 volts at room temperature, and a higher voltage (about 0.2V) at body temperature (you could also blow into the thermistor slowly and steadily). If you have issues balancing the Bridge voltage, you may consider using a Potentiometer (variable resistor) in place of R_3.

Discussion

- The light sensing circuit built earlier was susceptible to input voltage change, and was also biased away from zero. Both characteristics are not desirable in general. How does the temperature sensing circuit employing Wheatstone bridge compare?