Superposition and Thevenin

Lab Objectives

1. Identify a circuit that can be solved using superposition techniques.
2. Perform a superposition analysis to solve a multi-source circuit.
3. Apply Thevenin's Theorem to reduce a complex circuit to a simple one.
4. Use KVL, KCL and Ohm's law to check your answers.

Pre-Laboratory Preparation

Prior to your scheduled laboratory meeting time the following items need to be completed

1. Carefully read this entire handout ahead of time and review the sections in your notes/text regarding Superposition and Thevenin analysis.
2. In Excel, create a data table to record all of the calculated and measured voltage and current values called out in the circuits of Fig. 1a, 1b, and Fig. 1. Arrange the table so that you can show the calculated voltages directly next to the measured voltages. Leave space to show the % error for each comparison.
3. Create a second data table to record the calculated and measured data for the circuit of Fig. 2 and its Thevenin equivalent circuit shown in Fig. 3.
4. Note: Every data table must have a labeled circuit diagram on the same page for this lab. This helps avoid confusion, especially when comparing large amounts of similar data.
5. Use Superposition to analyze the circuit shown in Fig. 1 by determining the voltages and currents shown in Fig. 1a and Fig 1b first and then algebraically summing these results (see Lab Notes 1 and 3). Record the calculated voltage and current values in your data table. Make sure to leave spaces for comparing the calculated and measured voltages (% error numbers). Print this table for lab.
6. For the circuit shown in Fig. 2, determine the Thevenin equivalent voltage seen across terminals a and b (see Lab Notes 2 and 4). Also calculate the Thevenin Equivalent Resistance seen between terminals a and b (don't forget to relax all of the sources first). Record the calculated Thevenin equivalent voltage and resistance values in your data table (again leave spaces for measurements and % error). Print this table for lab.

DC Circuits Lab Procedure

Part 1: Superposition (Read Lab Note 1 First)

1. Build the circuit shown in Fig. 1a (E_1 acting alone) using good protoboard technique.
2. Carefully measure the voltages and currents called out in the circuit.
3. Record each measured voltage and current in the data table you created for prelab.
4. Repeat steps 1 through 3 for the circuit shown in Fig. 1b. (E_2 acting alone)
5. Repeat steps 1 through 3 for the circuit shown in Fig. 1, the original, complete circuit (with both E_1 and E_2 sources active).
6. Have your results signed by your lab instructor.

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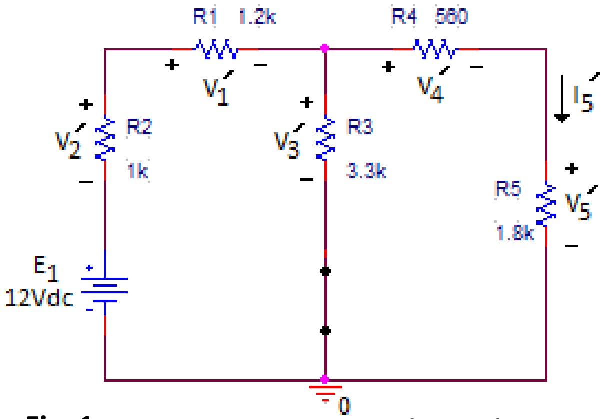

Fig. 1a - Superposition Circuit with E1 Only Active

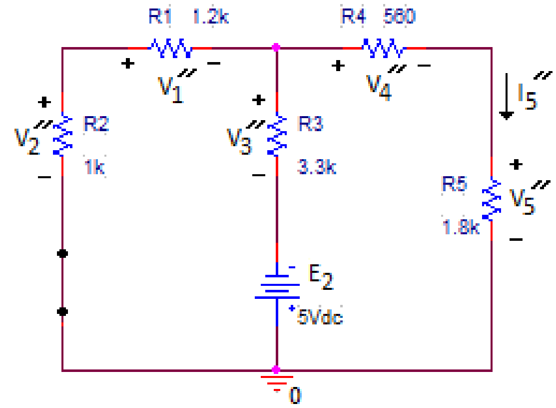

Fig. 1b - Superposition Circuit with E2 Only Active

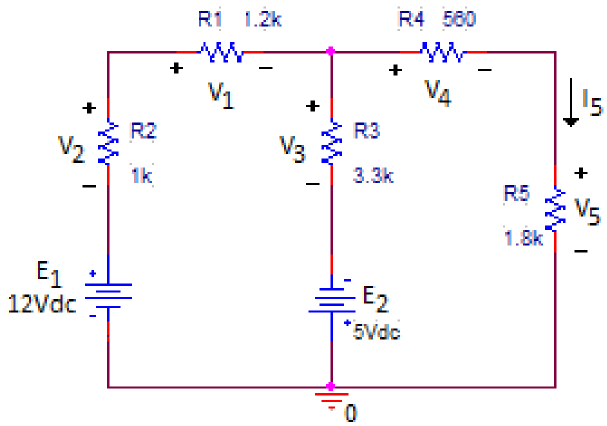

Fig. 1 - Original Circuit for Superposition Analysis

Lab Note 1: Superposition Analysis in the Lab

(NOTE: Refer also to Lab Note 3) When doing superposition analysis in the lab, you make one source active at a time and relax all the other sources in that circuit. Relaxing a voltage source effectively replaces it with a short circuit. To do this safely, we remove the plugs from the voltage source and connect them to each other. <u>We do not short the supply directly</u> as this is potentially dangerous and may damage the equipment. Therefore, we do not say "short the source," instead we "replace the voltage source with a short." Once that is done to all the voltage sources but the one being analyzed, voltages and currents are measured and recorded. This activity is repeated until all the sources are analyzed acting alone. Then, the individual contributions by each source acting alone are <u>algebraically</u> added to get the results equal to those with all the sources acting together or active in the circuit.

Part 2: The Thevenin Equivalent Circuit

1. Build the circuit shown in fig. 2.
2. Carefully measure the open-circuit voltage V_{ab}, This voltage is E_{TH}.
3. Replace the voltage source with a short circuit (DON'T SHORT THE SOURCE DIRECTLY but **<u>replace</u>** it with a short circuit, see Lab Note 2.
4. Use the bench DMM to measure the resistance between terminals a and b, this is R_{TH}.
5. Record the Thevenin Equivalent Voltage (E_{TH}) and Resistance (R_{TH}) in your data table.
6. <u>Save the original circuit of Fig. 2 as it will be used to verify equivalence with the Thevenin Equivalent circuit.</u>
7. Using your values of R_{TH} (use an R-C box) and E_{TH}, build the circuit of Fig. 3.
8. Place a load resistor, R_L = 1kΩ, across both the original circuit terminals a-b and the Thevenin Equivalent Circuit terminals a-b.
9. Measure the voltage across each of the load resistors and record the results. Are they the same? Are they within expected tolerance?
10. Repeat steps 8 and 9 for a load resistance of R_L = 560Ω.
11. Have your work signed off. Answer questions 1 and 2 after lab.

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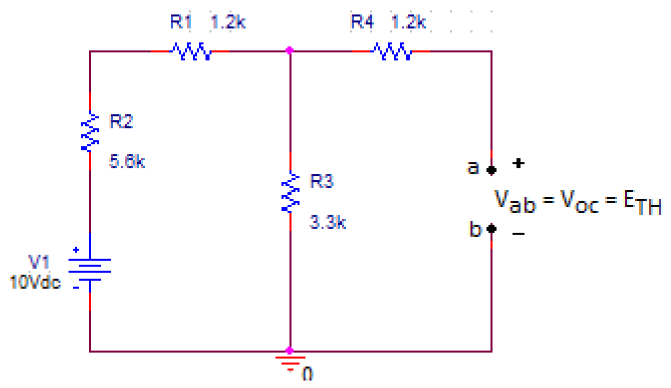

Fig. 2 – Original Circuit for Thevenin Analysis

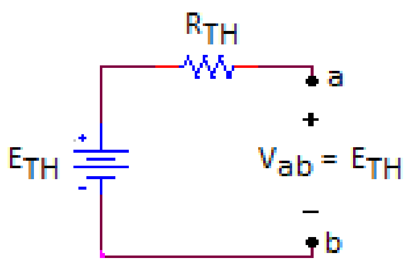

Fig. 3 – Thevenin Equivalent Circuit

Lab Note 2: Thevenin Analysis in the Lab

(NOTE: Refer also to Lab Note 4) Thevenin analysis looks at two terminals of a complex linear circuit, a circuit made up of resistors and sources and reduces that complex circuit to a voltage source in series with a resistor. The two circuits are then equivalent at those two terminals. (see figs. 2 and 3). In the lab, for Fig. 2, we can measure the open circuit voltage at terminals a and b (V_{ab}). This is E_{TH}. Note that E_{TH} will be the same for both Fig 2 and Fig 3 (Equivalent). The Thevenin Equivalent Resistance is the resistance seen at those same terminals with all of the sources in the circuit relaxed (see lab notes 1 and 3). In this case, simply replace V1 with a short circuit and measure the resistance across terminals a and b to record R_{TH}.

NOTE: Look at Fig 3 at left. If you were to place a short circuit across terminals a and b, the short circuit current I_{SC} would flow. This current and E_{TH} could be used to calculate R_{TH}…

Do not forget to have your lab work signed off. Work not bearing a signoff from your instructor or lab assistant will not be accepted for grade.

Questions:

1. **After Lab:** Describe how to use the short circuit current detailed in Lab Note 2 above, to calculate R_{TH} in the Thevenin equivalent circuit shown (Fig. 3).

2. **After Lab:** In one or two sentences, describe how Superposition can be used in a Thevenin analysis of a circuit with 2 sources.

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Post Lab Requirements and Lab Notes

After lab and <u>during a time specified by your lab instructor</u>, take the post-lab quiz. You may use your prelab and lab work and data as references.

Submit your completed documentation at the beginning of next week's lab before you take that week's prelab quiz. Your team's submission package will be graded and returned with comments. **Submit ONLY the following 4 pages (stapled together and in the following order):**

1) Your team cover sheet, completely filled in by EACH team member and with instructor signatures, <u>one per team.</u>
2) The schematics and completed data table for Part 1 of the laboratory, properly labeled, including % error calculations, **on one page**, <u>one per team.</u>
3) The schematics and completed data table for Part 2 of the laboratory, properly labeled, including % error calculations, **on one page**, <u>one per team</u>.
4) The answers to questions 1 and 2, answered neatly. The questions should restated (use WORD) and correctly answered **on one page**, <u>one per team.</u>

Lab Note 3: Superposition

Superposition is simple to understand, but complicated to do. The reason is primarily book-keeping. You have to keep track of the voltage and current for each element, for each voltage or current source acting alone and for all the sources acting together. The easiest way to keep all that in order is to assign a voltage ***with a polarity*** to each element of a superposition analysis and then do the same for currents. A current label (I_1, I_2, etc) ***with a direction arrow*** should be assigned to each current. Next, the circuit is re-drawn with all of the sources but one relaxed (a short circuit replaces a voltage source and an open circuit replaces a current source). All the voltage and current labels for that circuit become re-labeled with a prime (i.e. V_1 becomes V_1' and I_3 becomes I_3'). For each redrawn circuit the labels get another prime (I_2, I_2', I_2'', $!_2'''$ etc.) so that when you complete the superposition analysis you can state that, for example, the current I_2 in the circuit with all sources in place is the sum of the I_2 currents resulting from one source at a time ($I_2 = I_2' + I_2'' + !_2'''$). That's why you need a polarity and current direction arrow. When you fix the polarities and current directions in the original circuit, you keep them constant for each redrawn circuit. Some of the voltage polarities and current directions in the different re-drawn circuits will be negative. You won't have to remember which one is an addition or a subtraction (a common mistake) but just algebraically add them up.

Lab Note 4: Thevenin's Theorem

Thevenin postulated that any 2-terminal linear circuit or circuit segment could be replaced by a voltage source in series with a resistor. This theorem is used by engineers to reduce complex linear circuits to simple ones. When analyzing a circuit using Thevenin analysis, one must identify two open terminals (remember equivalence is relative to 2 points in a circuit). If there is an element connecting the terminals, first remove it (when you re-insert that element in the Thevenin equivalent circuit, it will react the same way as it would have if it were replaced in the original circuit) and then continue with the analysis. For 2 circuits to be equivalent, the voltages at these two corresponding terminals must be the same. Therefore the first step is to find the open circuit voltage at the terminals of the original circuit which yields E_{TH}. The Thevenin equivalent resistance is found by calculating (or measuring) the resistance between the two terminals with all sources relaxed (replace voltage sources with short circuits, and current sources with open circuits). The combination of the Thevenin equivalent voltage in series with the Thevenin equivalent resistance creates a circuit that is equivalent at the two terminal to the original circuit at its two terminals hence a "load" placed across the two terminals of either circuit will experience the same voltage and current.

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Team Name and Lab Section:...

Team Members Present (printed)

First Name, Last Name	Role This Lab	RIT Program

TEAM LABORATORY GRADE

(All work complete, legible and properly organized. Schematics and data tables included, accurate, properly annotated and titled. Q1 and Q2 restated and answered accurately and clearly. Both signoffs in place, no missing or extraneous information.)

Instructor Signature, Superposition _____	**/15**
Schematic/Data Table	**/10**
Instructor Signature, Thevenin _____	**/15**
Schematic/Data Table	**/10**
Questions (restated, accurate and thoughtful answers)	**/10**

Final Team Grade............................... **/60**

Instructor comments: