LABORATORY #1
Circuits Review

Part 1: Resistive Circuits, Linear Scale Ohmmeter

Purpose

The goals of this laboratory are to verify Ohm's Law, Kirchhoff's Voltage Law, and Kirchhoff's Current Law. In addition, the operational ranges for voltages and currents as related to component tolerances will be explored.

Theoretical Background

Ohm's Law

Ohm's Law states that the voltage across a linear resistor is directly proportional to the current flowing through the resistor. Mathematically, the voltage, current, and resistance are related by

$$V = I*R$$

Kirchhoff's Voltage Law (KVL)

Kirchhoff's Voltage Law states the algebraic sum of the voltages around any closed path or loop in a circuit must be equal to zero. That is for the circuit below:

$$V_s = V_1 + V_2$$

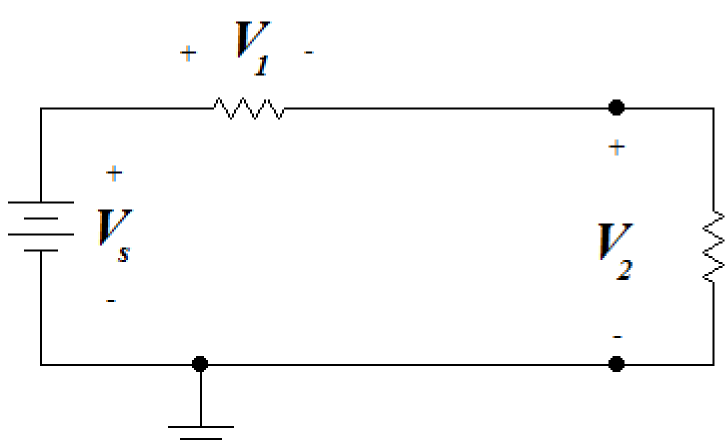

Figure 1.1

Kirchhoff's Current Law (KCL)

Kirchhoff's Current Law states that the algebraic sum of the currents entering a node must be equal to the algebraic sum of the currents leaving the node.
Mathematically:

$$I_1 = I_2 + I_3$$

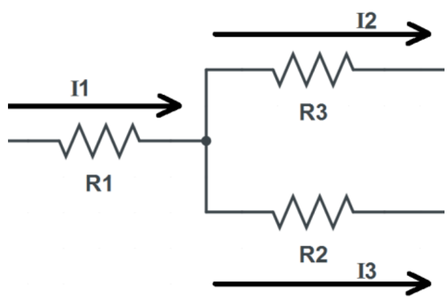

Figure 1.2

Theoretical Analysis

Referring to Figure 1.3, calculate the circuit's Branch Voltages, Branch Currents, Node Voltages, and Loop Currents with the following assumptions. (Note: Mesh Analysis may be useful here.)

1. First assume all the resistors are exact (i.e. a 10 ohm resistor is exactly 10 ohms).
2. Then assume all resistors are 10% above the exact values.
3. Then assume all resistors are 10% below the exact values.

Record all your data in tabular format similar to Table 1.1. Let the exact values of source voltage and resistors be defined by the following values:

Vs = 5.0V

$R_1 = R_2 = R_3 = 100$

$R_4 = R_5 = 1$ K

$R_6 = R_7 = 2.2$ K

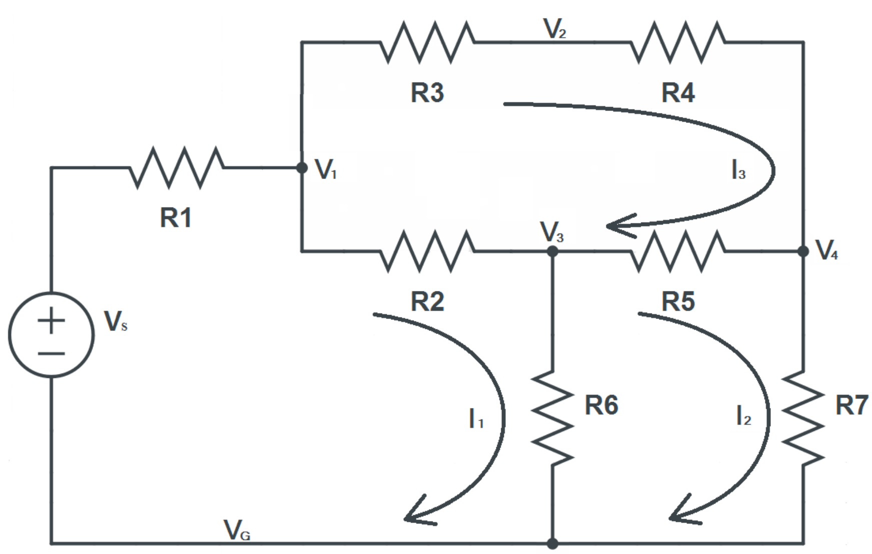

Figure 1.3

Simulation

Build the circuit Figure 1.3 using the Electronics Workbench. Then place virtual Volt and Ammeters in the circuit to find all required voltages and currents that you found in the theoretical analysis section. Print out the schematic showing all the readings before moving on to the next section.

Laboratory Procedure

Part A

Using the Analog/Digital trainer, build the circuit and re-measure all Branch Voltages, Branch Currents, Node Voltages, and Loop Currents using a digital multimeter.

Record all the specified measurements in a table similar to Table 1.1.

TABLE 1.1

Branch Voltages	**Branch Currents**	**Node Voltages**	**Loop Currents**
V_{R1} =	i_{R1} =	V_1 =	I_1 =
V_{R2} =	i_{R2} =	V_2 =	I_2 =
V_{R3} =	i_{R3} =	V_3 =	I_3 =
V_{R4} =	i_{R4} =	V_4 =	
V_{R5} =	i_{R5} =		
V_{R6} =	i_{R6} =		
V_{R7} =	i_{R7} =		

1. Verify each of the following using your experimental results. Account for component tolerances in the calculations if necessary.

   a. Ohm’s Law
   b. Kirchhoff's Voltage Law
   c. Kirchhoff's Current Law

2. Compare your experimental results for voltages and currents with the results from a theoretical analysis. Do your experimental values fall within operational ranges? Explain in detail.

Part B

Build the circuit shown in Figure 1.4.

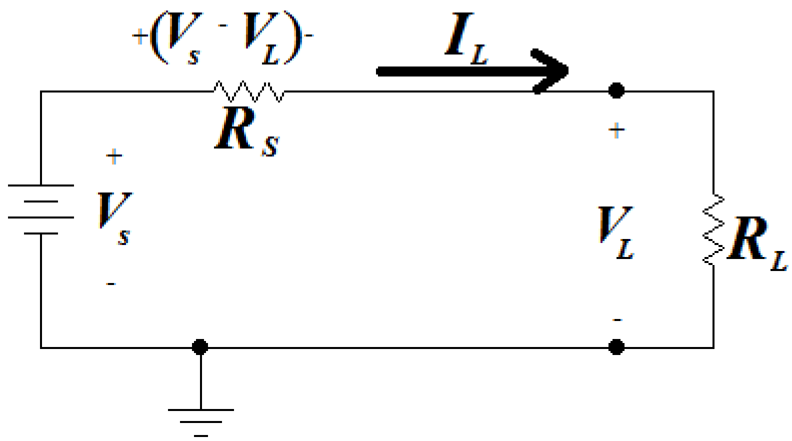

Figure 1.4

Set your source voltage and resistance values as follows; let $\mathbf{V_s}$ = 5.0 Volts and $\mathbf{R_s}$ = 100 . It does not matter if these values are exact as long as they remain consistent throughout the experiment.

1. Measure and record the values of load voltages and currents for various values of R_L (load resistance) as specified in Table 1.2. Use a variable resistor to vary the load resistance.

Table 1.2

R_L (Ohms)	V_L (V)	I_L (mA)
10		
20		
40		

70		
100		
150		
200		
300		
500		
1000		

1. Using your data and a spreadsheet program plot V_L vs. I_L. Determine and report the values of x and y intercepts, and the slope of the line.

Part 2: Norton and Thevenin Equivalent Circuits

Purpose

The goals of this laboratory are to demonstrate the equivalence between a multiple resistive network and its' Thevenin or Norton equivalent circuits. The concepts of load line and maximum power transfer will also be introduced.

Theoretical Background

Thevenin and Norton's Theorems can be employed at any load terminal. The advantage of applying these theorems is that a complex circuit can easily be reduced to a simpler one. This is very effective in simplifying the process of determining the current, voltage and power at the load.

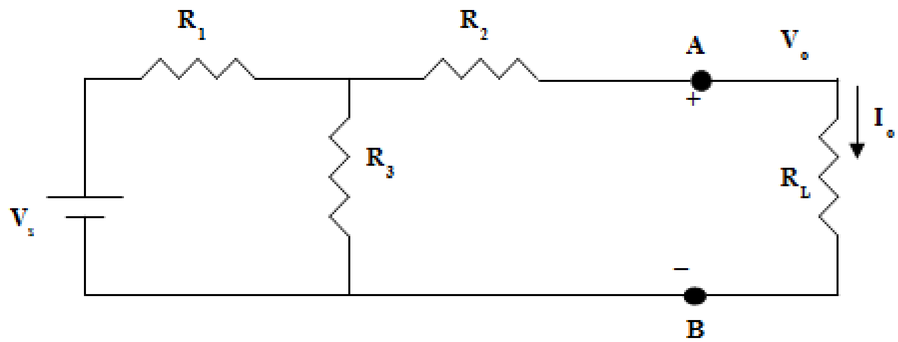

Figure 1.5

Thevenin Theorem

Thevenin's theorem states that an entire network can be replaced, exclusive of the load, by an equivalent circuit that contains only two components. They consist of an independent voltage source in series with a resistor in such a way that the current-voltage relationship at the load remains unchanged.

Method for finding a Thevenin's equivalent circuit.

Refer to Figure 1.5

1. Disconnect the load $\mathbf{R_L}$ to open the terminal **A-B.** Find the Voltage at the terminal. This is called open circuit voltage V_{oc}. V_{oc} is the independent voltage source for the Thevenin's equivalent circuit.
2. Next, short-circuit the terminal **A-B** by adding a wire.
3. Find the current at the terminal. This is called short circuit current I_{sc}.
4. Calculate the Thevenin equivalent resistance R_{Th}, where $R_{Th} = V_{oc}/I_{sc}$.
5. Draw the Thevenin equivalent circuit using V_{oc} in series with R_{Th}, as demonstrated in Figure 1.6.

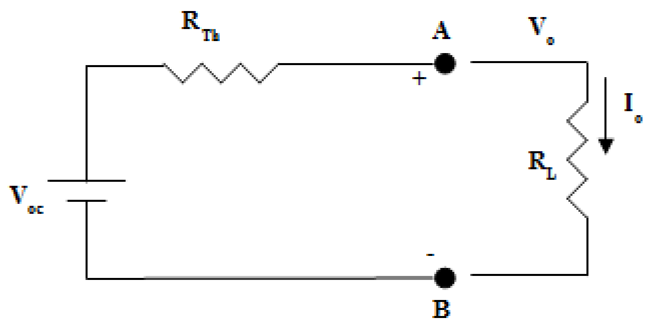

Figure 1.6

Norton's Theorem

Norton's theorem is similar to Thevenin's theorem with the exception that the equivalent circuit is an independent current source in parallel with a resistor.

Method for finding a Norton equivalent circuit (Refer to Figure 1.5)**:**

1. To begin use the same steps 1-4 that you applied in the Thevenin method. But, you will draw the Norton's equivalent circuit using I_{sc} in parallel with R_{Th}. (See Figure 1.7)

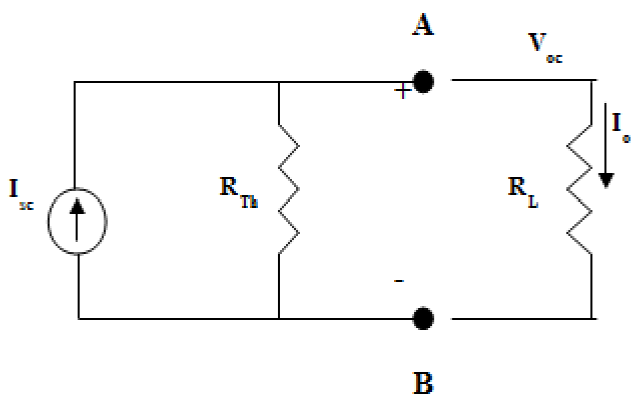

Figure 1.7

Maximum power transfer to the load

Once you have simplified circuit using Thevenin's Theorem, you can easily find the voltage and the current at the load. One of the main applications of this technique is to find the maximum power transfer to the load. Referring to figure 1.6:

$P_L=V_oI_o$ or $= I_o^2R_L$

For max condition $R_L=R_{Th}$

So $P_{max}=V_{oc}^2/(4R_{Th})$ Watt

Theoretical Analysis

Referring back to Figure 1.5

Let V_s = 5.0 V, $R_1 = R_2 = R_3$ = 1K Ohm.

1. Disconnect R_L so that the terminal A-B is open. Calculate the open circuit voltage V_{oc}.

2. Short-circuit the terminal A-B. Calculate the short circuit current I_{sc}.
    a. Calculate Thevenin's equivalent resistance R_{Th}. Recall $R_{Th} = V_{oc}/I_{sc}$. (You can also find R_{Th} by short circuiting V_s and calculating resistance between terminal A-B.). What is the R_L for maximum power transfer to the load? Find P_{max}?
    b. Repeat step 4 using the Norton equivalent circuit.
    c. Draw the Thevenin and Norton's equivalent circuits. Clearly mark all the values (use values from steps a-c) with correct polarity.

Simulation

Draw the circuit in Figure 1.5 using Electronics Workbench. Repeat steps 1 and 2 (a, b, c) of Theoretical Analysis using virtual Amperage & Volt meters to determine the currents and voltages. Print out your schematic diagram before moving on to the next section.

Laboratory Procedure

1. Build a circuit as shown in the Figure 1.5. Letting: V_s = 5.0 V, $R_1 = R_2 = R_3$ = 1K Ohm.
2. Measure V_{oc}, I_{sc}, and calculate R_{Th} at the terminal A-B. Draw Thevenin and Norton's equivalent circuit.
3. Build a circuit using your Thevenin's equivalent circuit from step 2, then chose RL= 1000, 1500, 2000 Ω and calculate the P_L for these cases and discuss your results.