KENNESAW STATE UNIVERSITY **ELECTRICAL & COMPUTER ENGINEERING TECHNOLOGY**

ECET 1101 – Laboratory Exercise #2 **Instrumentation, Ohm's Law, and KVL**

OVERVIEW:

This laboratory introduces Ohm's Law and the instrumentation in measuring voltage and current. The student will take measurements with a Simpson 260-8XPI analog Volt-Ohm-Milliammeter, an Agilent U1242B digital multi-meter (DMM), and an Agilent 34401A bench-top DMM.

INTRODUCTION:

Ohm's Law is a very simple but fundamental equation every student must know very well. Voltage and current in an Ohmic circuit has a linear relationship. V=IxR. The voltage drop across a resistor is related to the current that passes through it. If there is no resistance in the current path, then there will be no voltage drop. The direction of the voltage drop matches the direction of the current. Current flows from the higher potential to the lower potential. So in the diagram below (Figure 2.1), the direction of the current defines the polarity of the voltage across the resistor.

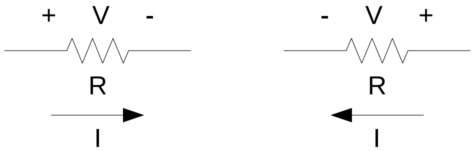

Figure 2.1: Voltage drop and direction of current

The next concept a student must master is the definition of a Node. Many textbook authors define a node at the connection point of two or more circuit elements. For example, if two resistors are connected together using the tie points of a protoboard, the node would be the location where they connect (Figure 2.2).

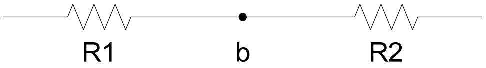

Figure 2.2: Node b at the connection point of two resistors.

However, node **b** is actually all points on the metal connecting both resistors. In Figure 2.3, the resistors are shown on a protoboard. The metal connecting the two resistors is drawn in bold lines. Every point on these wires comprises node **b**.

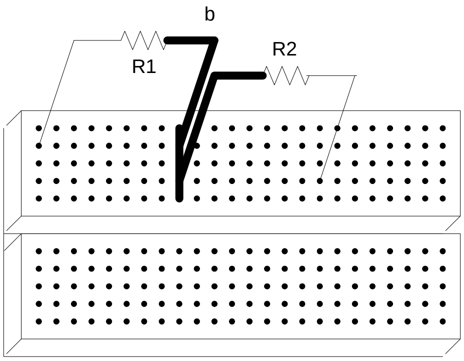

Figure 2.3: The bold lines of the wires represent all points of node b.

Series Circuits

If a voltage was placed across the combination of resistors shown in Figures 2.2 and 2.3, a current would flow from the higher potential to the lower potential (Figure 2.4). The current would be the same value through each resistor but the voltage across each resistor can be different. The resistors form a series circuit. The sum of voltages across each resistor would equal the voltage of the source. Kirchhoff's Voltage Law (KVL) states that the sum of the voltages around a closed loop is zero.

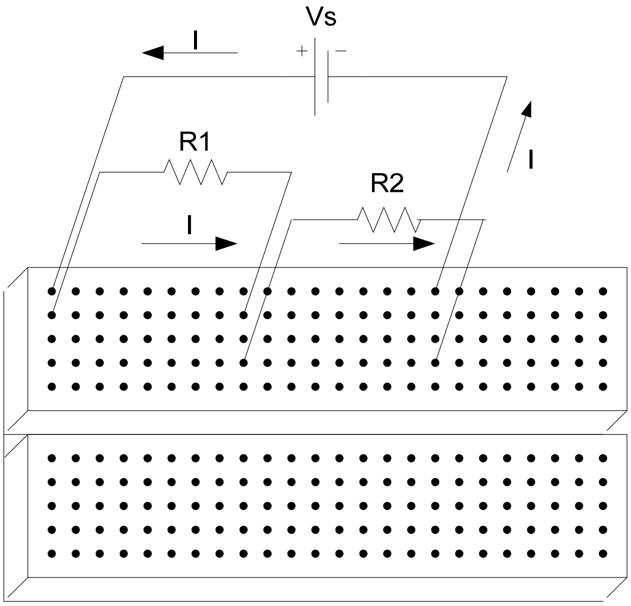

Figure 2.4: Series circuit on a protoboard.

Voltage measurements are simple but care should be taken to place the (+) probe and the (-) probe across the resistor in the correct orientation. In the circuit of Figure 2.5, to measure Vab where should the (+) probe and the (-) probe be placed? In the notation Vab, the first node listed is node **a** so that is where the (+) probe should be placed. The second node is **b** so place the (-) probe there.

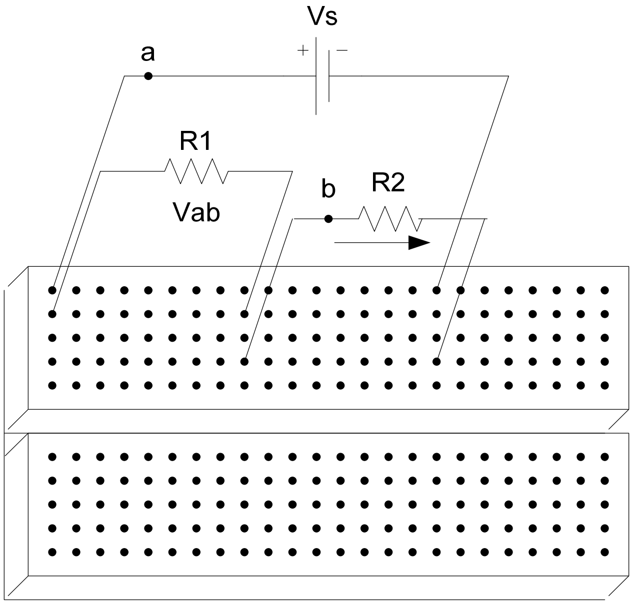

Figure 2.5: Voltage measurement.

Measuring current requires a couple of steps. First, on the meter, make sure to move the (+) probe of the meter to the current terminal usually marked by an **A** (for ampere). Then set the main selector knob to the correct current range. Next, the circuit must be broken at the node where the current is to be measured. Breaking the node allows the current to flow into the (+) probe, then the meter, then out the (-) probe back into the circuit. Figure 2.6 shows how node **b** can be broken so the ammeter can complete the circuit.

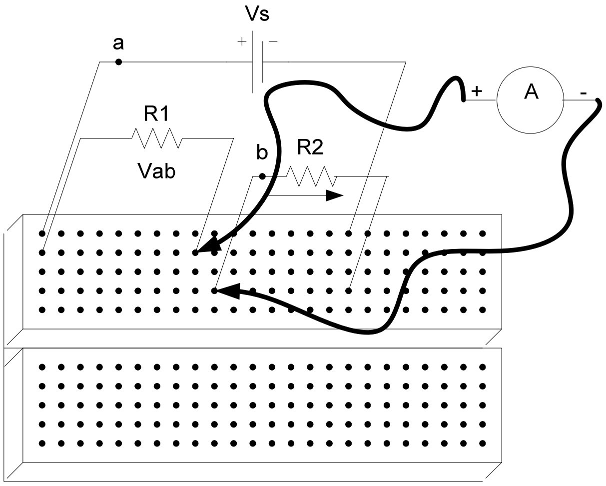

Figure 2.6: Measuring current by breaking the node b (look carefully).

Finally, as a reminder, when asked to compare values, such as A (measured) with B (nominal), the preferred method is:

$$Rd = \frac{A - B}{B} \times 100\%$$

in other words,

$$Rd = \frac{measured - nom}{nom} \times 100\% .$$

Simpson 260-8 Analog Multi-meter

The Simpson 260 analog meter is shown in Figure 2.7. The Simpson meter can be used to measure DC voltage over an extensive range. The sensitivity (S) of the meter is a way of expressing the internal resistance ($R_{internal}$) of the meter for each selector range. The resistance of the meter is equal to the sensitivity multiplied by the full scale voltage (V_{fs}) range.

$$R_{internal} = S \cdot V_{fs}$$

If the meter is set to the 10 V range, the internal resistance of the meter would be:

$$(20{,}000\ \Omega/V)(10V)=200\ k\Omega.$$

Table 2.1: Simpson 260-8XPI Internal Resistance Specifications

Selector	Range	Sensitivity
DC Volts	0-1-2.5-10-25-50-250-500-1000 V	20,000 Ω/V
DC Millivolts	0-250 mV	20,000 Ω/V

To measure DC voltage using the Simpson meter:

1) Connect a black probe lead to the terminal labeled COMMON. Connect a red probe lead to the (+) terminal to the right of common.
2) Turn the left selector knob to +DC.
3) Turn the center main selector knob to the appropriate voltage scale.
4) Place one probe on each side of the resistor while the resistor is held firmly in place on the proto-board. Then read the DC voltage on the bottom of the top black scale.
5) Unlike resistance measurements, it is not necessary to multiply by a scaling factor nor is it necessary to "zero out" the meter.
6) When finished taking measurements, turn the right-hand, range selector switch to the OFF position.

Figure 2.7: Simpson 260-8XPI

To measure DC current using the Simpson meter:

1) Set the function select switch to +DC.
2) Connect a black probe lead to the terminal labeled COMMON.
3) If measuring current in the 0-50 μA range, connect a red probe lead to the +10A/50μA/250mV terminal and set the main selector knob to the 50 μA setting.

   If measuring current in in the 0-1-10-100-500 mA ranges, connect a red probe lead to the positive terminal (+) right and set the main selector knob to the 1 mA, 10mA, 100mA, or 500 mA setting.

   If the expected range of the currents to be measured is unknown, it is safer to start at the higher scales and, if necessary, reduce the scale down to the best range to measure the current.
4) Break the circuit and insert the meter in series with current being measured.

   If the current is larger than the scale, the reset button might pop out. If this occurs, change the main selector knob to a higher current range and push the reset button back in.

Agilent U1242B Digital Multi-meter

The Agilent U1242B digital multi-meter (DMM) is shown in Figure 2.8. The Agilent DMM can measure DC voltage, DC current, AC voltage, AC current, DC resistance, capacitance, conductance, continuity, voltage in dB, frequency in Hz up to 1MHz, duty cycle, and pulse width. The meter has an 11,000 count display which translates to 4 digits.

The Agilent DMM will be used in this laboratory exercise to measure DC voltage. The resolution and accuracy is outlined in Table 2.2 below. The accuracy is the percent of reading plus the number of least significant digits.

Table 2.2: Agilent U1242B Resistance Specifications

Range	Resolution	Accuracy
1000.0 mV	0.1 mV	0.09%+ 5
10.000 V	0.001 V	0.09%+ 2
100.00 V	0.01 V	0.09%+ 2
1000.0 V	0.1 V	0.15%+ 5

To measure DC voltage using the Agilent U1242B:

1) Connect a black probe lead to the black COM terminal and connect a red probe lead to the red V-Ω terminal.
2) Turn the main selector switch clockwise to the V= setting.
3) Place one probe on each side of the resistor. Then read the LCD display and note the units to the right of the numbers.
4) When finished taking measurements, turn the main selector switch to the OFF position.

To measure DC current using the Agilent U1242B:

1) Connect a black probe lead to the black COM terminal and connect a red probe lead to the red μA mA terminal.
2) Turn the main selector knob to either the μA on mA setting.
3) Break the circuit and insert the meter in series with the current being measured.

Figure 2.8: Agilent U1242B

PROCEDURE:

1. Construct the series circuit shown in Figures 2.9 & 2.10 on a protoboard four times using each set of resistors shown in Table 2.3. For example, the first circuit should have three 1 kΩ resistors.
2. Measure the actual resistance of each resistor using either Agilent meter and record the values in Table 2.3.
3. Set the voltage source Vs to 15V and apply it across all four circuits using jumpers wires.
4. Using the Agilent 34401A, measure the voltages Vs, Vab, Vbc, Vcd, and Vbd. Record your data in Table 2.4.
5. Repeat Step 3 using the Agilent U1242B. Record your data in Table 2.5.
6. Repeat Step 3 using the Simpson 260-8. Record your data in Table 2.6.
7. Now break each circuit to measure the current using all three meters. Remember to move the red probe location to the ampere terminal. Record your data in Table 2.7.
8. This completes the measurements needed for the lab. Please check your data before disassembling the circuits.

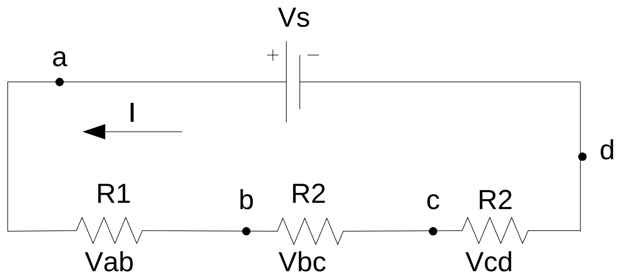

Figure 2.9: Series circuit for voltage measurement.

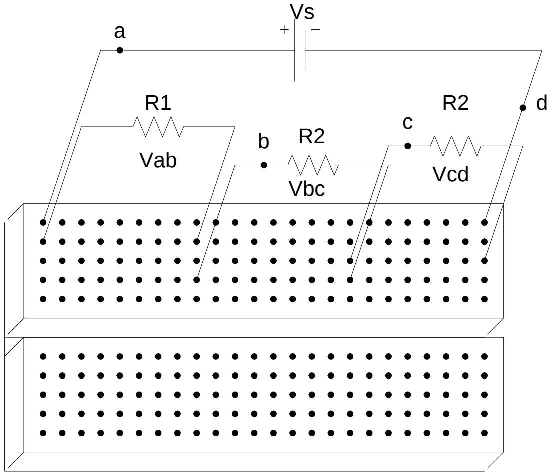

Figure 2.10: Series circuit for voltage measurements.
(Replicate the circuit two times using the values shown in Table 3).

DATA:

Table 2.3: Measured Resistor Values for Each Circuit Using Either Agilent Meter

	R1 Nominal	R2 Nominal	R3 Nominal	R1 Measured	R2 Measured	R3 Measured
Circuit 1	**1 kΩ**	**1 kΩ**	**1 kΩ**			
Circuit 2	**10 kΩ**	**10 kΩ**	**10 kΩ**			
Circuit 3	**100 kΩ**	**100 kΩ**	**100 kΩ**			
Circuit 4	**1 MΩ**	**1 MΩ**	**1 MΩ**			

Table 2.4: Agilent 34401A Voltage Measurements

	Vs Measured	Vab Measured	Vbc Measured	Vcd Measured	Vbd Measured
Circuit 1					
Circuit 2					
Circuit 3					
Circuit 4					

Table 2.5: Agilent U1242B Voltage Measurements

	Vs Measured	Vab Measured	Vbc Measured	Vcd Measured	Vbd Measured
Circuit 1					
Circuit 2					
Circuit 3					
Circuit 4					

Table 2.6: Simpson 260-8 Voltage Measurements

	Vs Measured	Vab Measured	Vbc Measured	Vcd Measured	Vbd Measured
Circuit 1					
Circuit 2					
Circuit 3					
Circuit 4					

Table 2.7: Current Measurement Using All Three Meters

	Agilent 34401A Measured I	Agilent U1242B Measured I	Simpson 260-8 Measured I
Circuit 1			
Circuit 2			
Circuit 3			
Circuit 4			

RESULTS:

Calculate the relative difference of the voltage and current measurements using each meter compared to the expected values.

Table 2.8: Circuit 1 (1 Ω) Relative Difference

Circuit 1 Nominal	Measured 34401A	Rd (%) 34401A	Measured U1242B	Rd (%) U1242B	Measured Simpson	Rd (%) Simpson
Vab=5V						
Vbc=5V						
Vcd=5V						
Vbd=10V						
I=5 mA						

Table 2.9: Circuit 2 (10 kΩ) Relative Difference

Circuit 2 Nominal	Measured 34401A	Rd (%) 34401A	Measured U1242B	Rd (%) U1242B	Measured Simpson	Rd (%) Simpson
Vab=12.5V						
Vbc=1.25V						
Vcd=1.25V						
Vbd=2.5V						
I=0.125 mA						

Table 2.10: Circuit 3 (100 kΩ) Relative Difference

Circuit 1 Nominal	**Measured 34401A**	**Rd (%) 34401A**	**Measured U1242B**	**Rd (%) U1242B**	**Measured Simpson**	**Rd (%) Simpson**
Vab=5V						
Vbc=5V						
Vcd=5V						
Vbd=10V						
I=5 mA						

Table 2.11: Circuit 4 (1 MΩ) Relative Difference

Circuit 1 Nominal	**Measured 34401A**	**Rd (%) 34401A**	**Measured U1242B**	**Rd (%) U1242B**	**Measured Simpson**	**Rd (%) Simpson**
Vab=5V						
Vbc=5V						
Vcd=5V						
Vbd=10V						
I=5 mA						

CONCLUSION:

Qualitatively compare the measurement accuracy of the Simpson 260 compared to the Agilent U1242B for each circuit and explain how meter sensitivity affects the voltage measurements.

Name:____________________________ Approved by:___________________ Date: ___________