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Lab 1: Resistance, Voltage and Current Measurements

EEE 117 Lab – Section 04: Tuesday, 4:30pm

Abstract:

The objective of this lab is to study the DC measurements of resistance, voltage and current. While also observing that the addition of a Digital Multimeter (DMM) changes a circuits measured value. Kirchhoff's Laws along with Voltage and Current Divisions will also be verified. Students will also be utilizing the oscilloscope to measure the resistance in both 1x and 10x probes, to better understand the impact of internal resistance on circuit readings. Measurements will be taken using a DMM and the oscilloscope; the circuits have already been provided by the lab manual. Fundamental DC analysis will be used in the lab, such as Kirchhoff's Laws, Voltage and Current Division. The measurements collected will verify if the data is accurate, by comparing it with the theoretical values.

Introduction:

When designing a circuit the values given may not always be as accurate as they should be, which can impact the behavior of the circuit. This is why it is important to measure the actual values using a DMM, and then the recorded value can be compared to the theoretical value to get a percent error. A DMM is a tool that can be used to analyze resistance, current, voltage, capacitance, and inductance in a circuit. When a DMM is used to measure values in a circuit there is a minimal impact on the values being recorded. An oscilloscope is a laboratory instrument commonly used to display and analyze the waveforms if electrical signals. The probes of an oscilloscope are used to measure and analyze the behavior of a circuit, the ones being used in this lab have an internal resistance of X1 (1M Ω) and X10 (1M Ω). The probes have a major impact on the measured values recorded in a circuit. Kirchhoff Laws of voltage and current will also be investigated. Kirchhoff Current Law states that the sum of all currents at any node in a circuit equals to zero. While Kirchhoff Voltage Law is the sum of all voltages around any closed path in a circuit equals to zero. The following circuits below will be used to verify Voltage and Current Division, as well as the internal resistance of the probes.

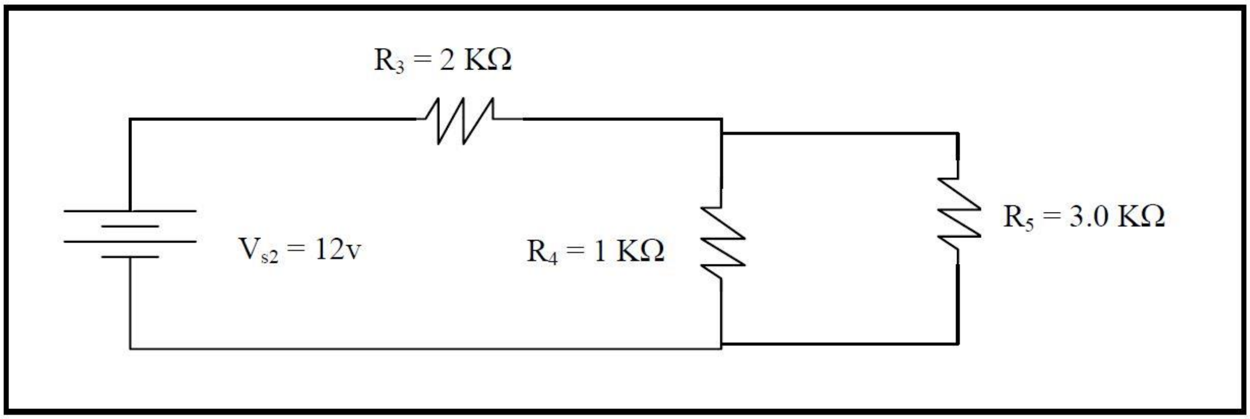

Figure 1. The Voltage Divider Circuit.

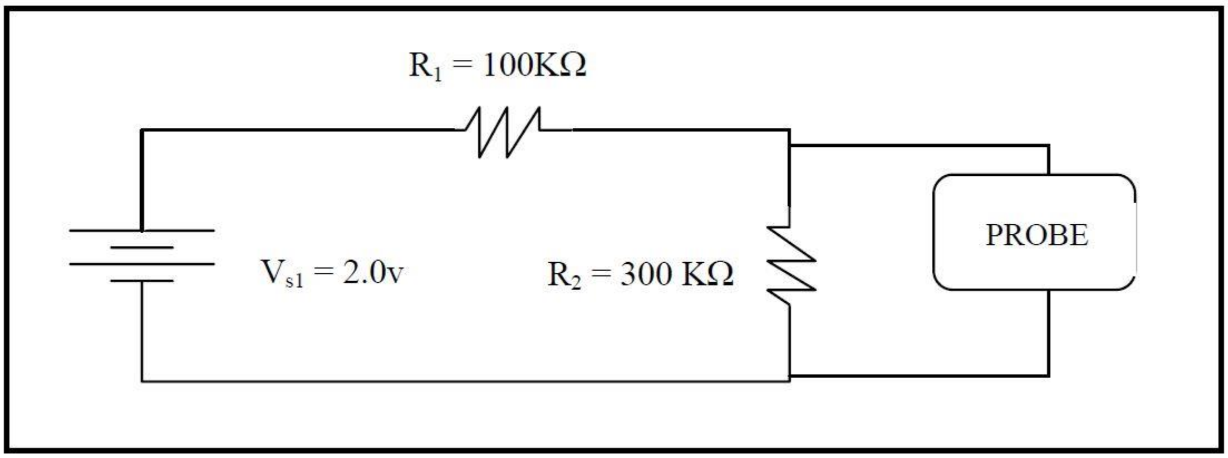

Figure 2. The Probe Connection Circuit.

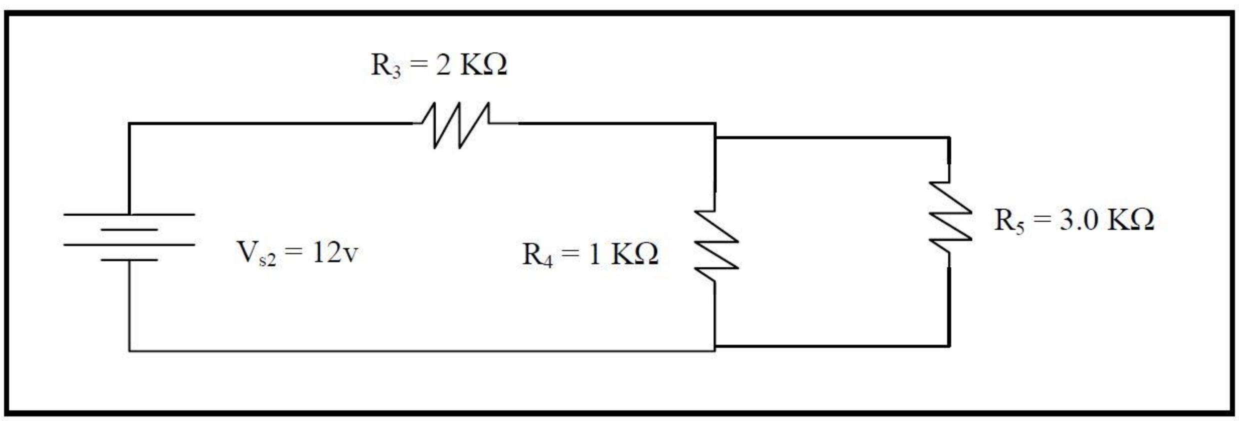

Figure 3. The Current Divider Circuit.

Simulations and Data Collection:

Part one of the lab was focused on resistance measurements, where five resistors whose values consist of 1k Ω, 2k Ω, 3 Ω, 100k Ω, and 300k Ω. Their theoretical values are recorded onto a table. Their actual values are then measured using a DMM, the value is then added to the same table. The percent value is then taken in order to visualize the how a resistor's theoretical value differs from its actual measure value. This portion of the lab also requires students to measure the internal resistance of the probes of the oscilloscope, when turned on and off. At the end there should be a total of nine measurements.

	Theoretical Value	Actual Value	Percent Error
Resistor 1	100,000 Ω	100,600 Ω	0.60%
Resistor 2	300,000 Ω	295,200 Ω	1.60%
Resistor 3	2,000 Ω	1,993.2 Ω	0.34%
Resistor 4	1,000 Ω	999.8 Ω	0.02%
Resistor 5	3,000 Ω	2984 Ω	0.53%
X1 Off	1,000,000 Ω	1,197,000 Ω	19.70%
X1 On	1,000,000 Ω	999,000 Ω	0.10%
X10 Off	10,000,000 Ω	10,180,000 Ω	1.77%
X10 On	10,000,000 Ω	9,978,000 Ω	0.22%

Table 1. Part2: The Resistance Measurements of the Resistors and Probes

In part two the measurements being recorded are from the circuit diagram found in Figure one and two. A 2v DC voltage source is connected in series with two resistors (100k Ω and 300k Ω), this is shown in Figure one. A DMM set to record voltage is connected in series with the resistors to measure the voltage across the circuit, we can call this the unloaded voltage readings. We then will record the loaded voltage readings using the X1 and X10 probe. In order to record these values we will be using the circuit diagram found in Figure two. Where the probe will be added in parallel to the 300k Ω resistor. Make sure the oscilloscope is turned on during this part of the lab. With the voltage readings, the data will be used to verify the internal resistance of the probe by the use of DC analysis and Voltage Division.

	Actual Voltage	Measured Voltage	Percent Error
Voltage	2V	1.998V	0.1%
Resistor1 (100k Ω)	0.5V	0.505V	1%
Resistor 2 (300k Ω)	1.5V	1.481V	1.27%

Table 2. Part 2A: The Unloaded Voltage Readings

	Measured Voltage
Voltage	1.998V
Resistor 1 (100k Ω)	0.608V
Resistor 2 (300k Ω)	1.378V

Table 3. Part 2B: The Loaded Voltage Readings from X1 Probe

	Measured Voltage
Voltage	1.998V
Resistor 1 (100k Ω)	0.515V
Resistor 2 (300k Ω)	1.469V

Table 4. Part 2C: The Loaded Voltage Reading from X10 Probe

The last part of this lab consists of measuring current through a circuit, the diagram can be found in Figure three. Students are to increase the DC voltage from 2V to 12V, and connect two resistors (2k Ω and 1k Ω) in series and a third resistor (3k Ω) with the 1k Ω resistor. The current will be recorded using a DMM set to read the current in the circuit. The values collected will be used verify Kirchhoff Current Law. Current Division may also be used to analyze the current across each resistor, within the range of the expected value.

	Actual Current	Measured Current	Percent Error
Voltage	12V	12V	0%
Resistor 1 (2k Ω)	4.36mA	4.369mA	0.21%
Resistor 2 (1k Ω)	3.27mA	3.271mA	0.03%
Resistor 3 (3k Ω)	1.09mA	1.097mA	0.64%

Table 5. Part 3: Current Measurements

Results and Calculations:

In table 1, we are able to see how accurate the resistors theoretical values are when compared to the measured values. With having both theoretical and measure values, we can calculate the percent error. We can also see for the probe measurements taken both on and off, and how close it is to the given value. When doing the oscilloscope probe at X1 and it being turned off the percent error is rather high. However with the X10 probe when turned off the percent error is not as high, the theoretical and measured value is relatively close.

In table 2 we can see the theoretical voltage across each resistor and the measure voltage found using the DMM. Since current is the same throughout the entire circuit we can use Voltage Division to verify the voltages across each resistor.

$$\mathbf{V_{R1} = V_s * (R1 / (R1 + R2))}$$

We can also use the values found in table 2 to verify if Kirchhoff Voltage Law hold true. In order to do this we sum up all the voltages in the closed loop and see if it equals to zero.

$$\mathbf{V_s + V_{R1} + V_{R2} = 0}$$

Following Kirchhoff Voltage Law, the voltage measurements of each resistor add up relatively close to the measure voltage of V, with a percent error of 0.1%. The measurements recorded in table 3, we can see the impact of internal resistance of the X1 probe. When compared to the measurements recorded using the X10 probe, as seen in table 4. We can see that the values in table 4 are much closer to those recorded in table 2.

In table 5 we have the measurements of how much current is passing through each resistor. We can use current division to help verify if the current across each resistor is within the range of expected value.

$$\mathbf{I_n = I_{total} * (R_{total} / R_n)}$$

By using Current Division we can verify if Kirchhoff Current Law holds true. The law states that all current entering and exiting a node must be equal to zero.

$$\mathbf{I_s + I_{R1} + I_{R2} + I_{R3} = 0}$$

In table 5 we can see that current across each resistor is relatively close to its theoretical value. Having the percent error be below 1% for all three resistors.

Conclusion:

In this experiment, most of the measurements taken were significantly close to each other. With the exception of the X1 probe, which had the highest percent error. Now knowing this I would suggest choosing the X10 probe if I wanted to disturb the circuit as little as possible. Overall Kirchhoff Laws were verified, and this was proven using Voltage and Current Division. The color code values of the resistors when compared to the measured values are close to one another. As for the measured input voltage, it almost matched perfectly to the source digital display. At the end of the experiment I learned that is it important to measure the elements being used in a circuit design because the measuring instruments that are used can disturb the readings of the circuit.