# Laboratory Session: Week 1: Multimeters and Power Supplies

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## Multi-Meter Measurements

1. Pick 6 resistors with different color codes. If your resistors have 5 bands, consider only the first four bands. Measure their values with your DMM. Compare their stated values and tolerances (color code) with your measured multimeter results.

| Resistor # | Marked | DMM Measured | % Tolerance | % Deviation from marked |
|---|---|---|---|---|
| $R_1$ | 33K Ω | 32K75 Ω | 5% | 0.7% |
| $R_2$ | 3K3 Ω | 3K23 Ω | 5% | 2% |
| $R_3$ | 2K2 Ω | 2K15 Ω | 5% | 2.3% |
| $R_4$ | 1K Ω | 0K99 Ω | 5% | 1% |
| $R_5$ | 330 Ω | 325 Ω | 5% | 1.5% |
| $R_6$ | 22K Ω | 24K6 Ω | 10% | 10.57% |

Is the % Deviation greater or less than the indicated tolerance?

Answer: Except for $R_6$, the deviation falls below the indicated tolerance.

2. If you look at a standard list of 20% resistors available, you will see 1000 ohms and 1500 ohms but not 1200 ohms. Why? If you look at 5% resistors, would the results be different? Why? [A listing of resistor values can be found on the wall of the laboratory.] Hint: Think about what tolerance means and how it differs from measurement error.

Answer: Because of the 20% tolerance, the 1K Ω and 1K5 Ω resistors cover an interval $1 \pm 0.2$ K Ω and $1.5 \pm 0.3$ K Ω, respectively. By the interval, the 1K2 resistor is covered by both 1K Ω and 1K5 Ω. Hence, a 1K2 Ω resistor is unnecessary for 20% tolerance. However, for 5% tolerance, a 1K2 Ω is necessary because the 1K Ω and 1K5 Ω resistors will only cover $1 \pm 0.05$ K Ω and $1.5 \pm 0.075$ K Ω, respectively. Based on these intervals, the 1K2 Ω is not covered and is, therefore, necessary.

3. Pick two resistors that are approximately two orders of magnitude different, i.e. 1,000 Ω and 100,000 Ω, or 22 Ω and 2,200 (See Figures 1-2, 1-3, and 1-4.)

   a. Measure them carefully. Note their actual values rather than the color code indicated value.

| Resistor # | Color Code Value | Measured Value |
|---|---|---|
| $R_1$ | 22K Ω | 24K6 Ω |
| $R_2$ | 22 Ω | 22.4 Ω |

   b. Measure them in series and parallel connections.

| | |
|---|---|
| $R_{Series}$ | 24K6 Ω |
| $R_{Parallel}$ | 22.5 Ω |

   c. Compare your measurements with the calculated values. Your calculated values should be calculated using the individually measured values from part a. Note: in series, the larger value dominates the measurement.

| | Calculated | Measured | % Difference |
|---|---|---|---|
| Series | 24K622 Ω | 24K6 Ω | 0.089% |
| Parallel | 21.98 Ω | 22.5 Ω | 2.3% |

   d. In the parallel connection, which resistor dominates and why?
   e. In the series connection, which resistor dominates and why?

<u>Answer</u>: In parallel, the resistor with the lower resistance dominates because current flows easier through low resistance. Quantitatively, $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_{tot} \approx R_2$ since $R_2 < R_1$. In series, greater resistance dominates because current must flow through both resistors. Quantitatively, $R_{tot} = R_1 + R_2 \Rightarrow R_{tot} \approx R_1$ since $R_1 > R_2$.

## Measuring Internal Resistance of a Power Supply

DMM Readings

| | |
|---|---|
| Unloaded Voltage | 6.041 V |
| Loaded Voltage | 6.038 V |
| Voltage Shift | 0.003 V |
| Calculated internal resistance | $6.038 = 6.041\left(\frac{5}{5+R}\right) \Rightarrow R = 0.0025\ \Omega$ |

## Unloaded and Loaded Voltage Dividers

Unloaded and Loaded Voltage Dividers

2. Measure $V_{out}$ at the red and black dots. Record the value here <u>3.019</u> V
4. Measure the new $V_{out}$ as in Step 2. Record the value here: <u>2.621</u> V

| | Unloaded Voltage Divider | Loaded Voltage Divider |
|---|---|---|
| $V_{out}$ | 3.019 V | 2.621 V |
| $V_{upper1K}$ | 2.981 V | 3.379 V |
| $I_{total}$ | 3.000 mA | 3.396 mA |

How does the increase in total current affect the $V_{out}$ of the loaded voltage divider circuit?

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| <u>Answer</u>: The increase in total current decreased the output voltage. |

## Validation of Kirchhoff's Laws

| Unconnected F | |
|---|---|
| Measurement | Value |
| A | 4.993 V |
| B | -1.649 V |
| C | -1.672 V |
| D | -1.672 V |
| E | 0 V |
| F | 1.672 V |
| G | 0 V |

3. Add measurements A through D. Put your answer here: 0 V
4. Add measurements C, E, F, and G. Put your answer here: 0 V

| Connected F | |
|---|---|
| Measurement | Value |
| A | 4.993 V |
| B | -1.758 V |
| C | -1.452 V |
| D | -1.783 V |
| E | 0.731 V |
| F | 1.672 V |
| G | 0.72 V |

7. Using Ohm's Law, calculate the ABSOLUTE VALUE of the current through resistors B, C, and G (answers in "CURRENT" column in the table below). Also, using the Passive Sign Convention, determine whether the current through each resistor is entering or leaving the B-C-G node connecting the three resistors.

| Resistor | Current | Leave/Enter |
|---|---|---|
| B | 1.758 mA | Enter |
| C | 1.452 mA | Leave |
| G | 0.327 mA | Leave |

8. Using [a] the Passive Sign Convention rule** (see footnote) and [b] the NVA convention that currents leaving the node are positive, attach the + or – sign to the currents and **add them up to see if KCL holds**. NVA rule: currents leaving the node are marked +; currents entering the node are marked −.

9. Put your sum here: 0.021 mA

| |
|---|
| KCL states that the sum of currents flowing through, into and out of, a node is equivalent to 0. Likewise, KVL states that the sum of the electrical potential differences around the loops is equivalent to 0. Although the sum of the current flow is not exactly 0, the deviation is negligible and can be attributed to the experiment materials being non-ideal. Hence, by the results from step 3, 4, and 9, my group has validated Kirchhoff's Laws. |