Abstract

This experiment introduces a few basic electrical circuit components and measurements that will be used throughout this course: batteries, bench power supplies, resistors, and digital multimeters (DMMs). Although this experiment is not too complicated, keep in mind that the entire field of electrical engineering is built on a few key concepts, including the details you will start to learn this week.

After completing this experiment you should:

(1) Be able to determine the resistance and tolerance of resistors using the standard color chart,
(2) Be able to assemble series and parallel resistor circuits on your protoboard and measure the total resistance of these circuits using a DMM,
(3) Be able to calculate the percent difference between a resistor’s nominal value and its measured value,
(4) Be able to use the DMM to make a DC voltage measurement,
(5) Be able to use the bench power supply to generate a desired DC voltage and verify its value using a DMM.

Introduction and Theory

In order to do anything useful with electricity, we need to create an electrical circuit. A circuit is a conducting path made up of one or more electrical power sources, some electrical components, and interconnecting wires. Electrical charge can move from place to place in the circuit, and this movement of charge is known as an electrical current. A circuit has to be in the form of a loop since the electrical current exiting the power source must exactly balance the electrical current returning to the power source.

The dry cell battery is a well-known example of an electrical power source. The battery contains a carefully chosen combination of chemical compounds. The chemical reaction releases energy from the chemical bonds, and also creates an excess of electrical charge that can travel through the circuit as a current. A battery produces direct current (DC), since the chemical reaction in the battery causes current to flow in only one direction through the circuit. The measurement unit for electrical current is called the ampere, or simply the amp, and is abbreviated with a capital-A.

The electrical potential, or voltage, of a battery indicates how much energy is available to move the electrical charge through the circuit. However, the voltage alone does not tell us how much electrical power the battery has, since no matter what the voltage, there must also be enough electrical charge available to make a sustained current. The measurement unit for electrical voltage is called the volt, abbreviated with a capital-V. Even though the abbreviation DC means direct current, electrical engineers often use the abbreviation “DC” even when talking about a constant voltage. Thus, we often say that an AA-size battery has 1.5 “volts DC,” even though this might seem confusing usage.

In the laboratory it is often convenient to use an adjustable voltage source that is powered by a wall outlet. The bench DC power supply will serve this purpose. The bench supply converts the AC (alternating current) provided by the power company into a DC voltage that can be adjusted with knob or dial.
Resistors are commonly used in electronic circuits, along with other components such as capacitors, inductors, and active devices such as transistors and integrated circuits (commonly called ICs). Electrical resistance is measured in the units of ohms, indicated by the Greek letter Omega (Ω). Resistors may be connected in series and/or parallel for many reasons, such as to reduce a voltage to a convenient value (as in a voltage divider) or to provide a value different from one that is commercially available. You therefore need to be able to find the effective resistance of various combinations of individual elements.

Resistors have a nominal value indicated by colored bands or other labeling. Refer to a color-code chart to interpret the nominal value indicated by the colored bands. The actual (measured) resistance will vary from the nominal value due to subtle mechanical and chemical differences that occur during manufacturing. The manufacturer specifies the maximum deviation from the nominal value as a ±percentage. This range of deviation is called the tolerance of the resistor family. Typical tolerance values are ±1%, ±5%, or ±10%. Some resistors in your lab kit are 5%, which is indicated by a fourth band that is gold in color. We will observe the variation in measured resistance values for the class and prepare a histogram of the measured values.

For example, a 1 kΩ ± 5% resistor \([10 \times 10^3]\) is labeled BROWN:BLACK:RED:GOLD, a 220Ω ± 10 % resistor is labeled RED:RED:BROWN:SILVER, and a 1Ω ± 5% resistor must be represented as \([10 \times 10^{-1}]\), or BROWN:BLACK:GOLD:GOLD.

Note that some resistors have a 1% tolerance rating, and this requires an extra digit of precision. One percent tolerance resistors usually have a light blue colored body, and five stripes (ABCDE) interpreted as \(ABC \times 10^D \pm\text{tolerance (E)}\), where the E band is brown in color for a 1% resistor.

This week you will work with one of the basic pieces of electrical test gear: the digital multimeter, or DMM. The DMM is used to measure current, voltage, and resistance. The DMM can be used to make the DC measurements needed this week, and it is also able to perform AC measurements.
**Equipment**

Your circuit prototype board, your lab kit (containing resistors, resistor color code chart, and alligator clips), and the bench power supply, multimeter, AA-size battery, and banana cables furnished in the lab.

**Procedures**

**P1.** → Using the resistor color code chart, you and your partner should each select the following resistors from your lab kit: two 10 kΩ (10,000 Ω), one 1 kΩ (1,000 Ω), and one 470 Ω.

→ Fill out the table below for the resistors selected from both your lab kit and your partner’s lab kit. You will record:

- the sequence of color bands and the nominal resistance value this represents
- the measured value of each resistor,
- the percent difference between the nominal value and the measured value

The percentage difference between the nominal value (indicated by the color code) and the measured value is calculated using the equation:

\[
\text{Percent difference} = \frac{\text{measured value} - \text{nominal value}}{\text{nominal value}} \times 100\%
\]

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<th>No.</th>
<th>Color bands on the resistor (Use three letter abbreviations for color names, e.g. Blk for black, Blu for blue)</th>
<th>Nominal Resistance (Value calculated from color codes; in ohms)</th>
<th>Measured resistance using multimeter (Be sure that the decimal point and units are correct)</th>
<th>Percent difference, measured value relative to color code value, in percentage</th>
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**P2.** → Select a 1 kΩ resistor and a 470 Ω resistor. Using your prototype board, connect these two resistors in **parallel** and then measure the combination resistance using the multimeter.

R₁ nominal value: ____________  R₂ nominal value: ____________

R₁ measured value: ____________  R₂ measured value: ____________

Resistance of parallel combination **calculated** using nominal values: ____________

**Measured** resistance of parallel combination: ____________
Give the mathematical formula you used to calculate the parallel combination resistance.

Given two resistors connected in parallel, what can we say about the equivalent resistance of the combination in relation to the values of the individual resistors?

**P3.** → Next, connect the same two resistors in *series* and then measure the combination resistance using the multimeter.

Resistance of series combination *calculated using nominal* values: __________

Measured resistance of series combination: __________

Give the mathematical formula you used to calculate the series combination resistance.

Given two resistors connected in series, what can we say about the equivalent resistance of the combination in relation to the values of the individual resistors?

**P4.** → Use the DMM to measure the DC voltage of an AA-size battery. Is it exactly equal to 1.5 volts DC? Why might it be different?

**P5.** → Set the DC Bench supply to produce 8 volts between the red and black terminals of the “A” supply. Use the DMM to monitor the voltage while you adjust the supply knob. Demonstrate for your instructor or lab TA that you can adjust the supply to any specified voltage between 2 volts and 15 volts.

*Instructor/TA initials* __________