Experiment 15
Resistors and Voltage Drops

Parts Bin

Assembled PCB with breadboard

Three resistors with brown, black, and orange bands

Tool Box

Wiring kit

DMM

Using the water analogy to continue to explain how electricity works, you should realize that water does not travel in a pipe effortlessly. The pipe subtly impedes the passage of the water running through it. If you were to measure the pressure at the inlet of a pipe and the exit, you would find that the restriction of the motion of water would cause a pressure drop.

This pressure drop is caused by the friction that the water experiences moving through the pipe. *Friction* is a force that resists motion, converting the energy of the moving water into heat. The first law of thermodynamics states that energy can neither be created nor destroyed; if some is lost in the pipe, then it must be converted into some other form. When energy is lost, it is almost always converted into heat.

When we are dealing with electricity, we assume that conductors are perfect, that they offer no friction (called *resistance*) to electricity moving through them. This is actually not true; except for materials called superconductors, everything will resist the movement of electricity through them. Conductors typically have a very low level of resistance, which is why the approximation of them being perfect is made.

In many electrical circuits, electrical energy has to be changed to be more suitable. The most common component for doing this is called a *resistor*, and different parts are available, offering different amounts of resistance to electricity. The units of resistance are ohms and are given the Ω symbol. Resistors themselves are quite small physically, so their values are indicated on them by a series of colored bands.

The bands specify the resistance using the following formula and are defined in Table 3-2.

Table 3-2 Resistor band color coding

Color	*Band Color Value*	*Tolerance*
Black	0	N/A
Brown	1	1%
Red	2	2%
Orange	3	N/A
Yellow	4	N/A
Green	5	0.5%
Blue	6	0.25%
Violet	7	0.1%
Gray	8	0.05%
White	9	N/A
Gold	N/A	5%
Silver	N/A	10%

$$\text{Resistance} = ((\text{Band 1 Color Value} \times 10) + (\text{Band 2 Color Value})) \times 10^{\text{Band 3 Color Value}} \text{ Ohms}$$

Using the formula and the color chart, you can calculate the resistors used in this experiment to be

$$\text{Resistance} = ((\text{Brown} \times 10) + \text{Black}) \times 10^{\text{Orange}} \text{ Ohms}$$

$$= (10 + 0) \times 10^{3} \text{ Ohms}$$

$$= 10{,}000 \text{ Ohms}$$

Most resistors offer 5 percent tolerance and this is more than acceptable for the circuits presented in this book and the ones that you will work with. In practical terms, you will find that most resistors have a tolerance of 1 percent or less—they are specified as being 5 percent as the absolute worst case by the manufacturer.

To demonstrate the operation in an electrical circuit and how it affects the electrical pressure or voltage, build the circuit shown in Figure 3-16 and measure the voltage across the resistors. In your first test, set your DMM to "Voltage" (the 0- to 20- volt range) and place the black probe at the negative or Vss voltage and place the red probe at the four points noted in Figure 3-16 and record the voltages.

When you have recorded the voltages, you would have found that the voltages changed evenly from zero to the applied battery voltage at each resistor step. This is analogous to measuring the pressure of water as it travels down a pipe. Each resistor behaves similarly to a length of pipe in which the water pressure drops. Just as the pressure reduction in a length of pipe is called a *drop*, the voltage reduction through each resistor is called a *voltage drop*. You should notice that none of the voltages measured in Figure 3-16 is greater than the applied battery voltage; they are either less than or equal to the battery's voltage.

The voltages being less than or equal to the applied voltage should not be a surprise—especially considering the comments I made at the start of this experiment. If the voltage increased, then the energy of the electricity would have increased, which should be impossible due to the first law of thermodynamics.

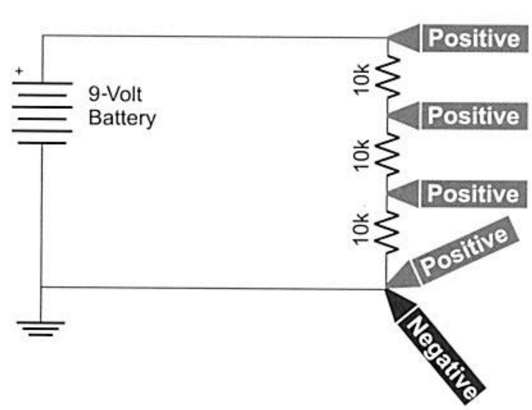

Figure 3-16 *Measuring voltages in a circuit relative to ground*

For the energy to increase, an energy source, such as a battery, would have to be inserted into the circuit.

To further investigate the behavior of voltage in a circuit with resistors, measure the voltage across each resistor using the DMM probes as shown in Figure 3-17. You should find that the voltage across each resistor is approximately the same and is one-third the voltage applied by the battery. In doing this, you are measuring the voltage across each resistor.

Finally, measure the voltage across two resistors as I have shown in Figure 3-18. This voltage should be two-thirds of the total voltage applied to the circuit. As I will explain later in this section, the voltage across a resistance is proportional to its fraction in the total circuit. These two resistors have two-thirds of the resistance in the circuit, so it should make sense that they have two-thirds of the voltage drop in the circuit.

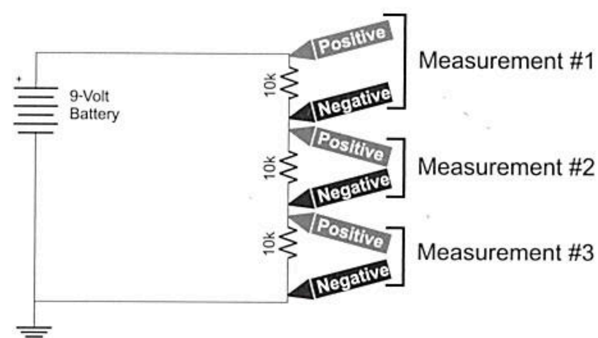

Figure 3-17 *Measuring voltage drops across individual resistors*

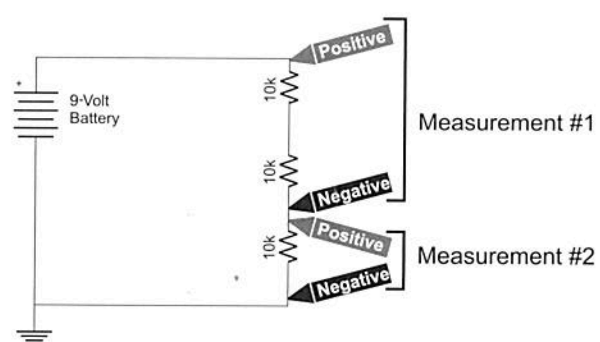

Figure 3-18 *Measuring voltage drops across multiple resistors*