

The Art of Electrical Measurements

Purpose: Introduce fundamental electrical test and measurement tools and the art of making electrical measurements.

Equipment Required

- 1 – Digital Multimeter
- 1 - Variable DC Power Supply
- 1 - Protoboard
- 2 – 10k Ω , 1/4 W Carbon Film Resistors
- 1 – 510k Ω , 1/4W Carbon Film Resistor

Prelab

Before coming to lab prepare your new lab journal by leaving a couple of blank pages at the beginning of your book for a table of contents and then sequentially number all of the pages.

Procedure

1. The Multimeter

The multimeter is a basic circuits laboratory tool used to measure the two premier signal variables *current* (in amperes, A) and *voltage* (in volts, V) as well as an important element parameter *resistance* (in ohms, Ω). They often have additional capability that is generally some special application of these basic measurements. There are two common types of multimeters, digital (DMM) and analog (AMM). Although we will be using a DMM for this exercise, much of the following discussion applies to both types.

The multimeter (or meter for short) is connected to the circuit-under-test via two *leads* (or *probes*). The leads usually have a male banana connection on one end, which plugs into the meter. The other end can have either a "grabber" type connection such as an alligator clip, or a bare metal tip much like the point of a pencil. The meter leads are normally color-coded, one red and one black. It is standard practice to connect the black lead to the negative (or low) jack on the meter, and the red lead to the positive jack.

Some form of selector on the meter determines the signal variable being measured. The measured value indicated by the DMM may not be completely qualified on the display, that is, the position of the selector, or range, may have to be known to determine the actual value indicated by the meter. Fortunately, the meters used in this lab are completely "autoranging", that is, the display shows both the value and the units (e.g. k Ω or M Ω .)

In this course we'll use widely accepted vernacular to describe the three standard functions on AMMs and DMMs. *Ohmmeter* identifies an instrument used to measure resistance. *Ammeter* and *voltmeter*, as you probably suspect, describe instruments used to measure current and voltage. We'll often use these terms to describe a DMM that is set to the specific function described by the term.

2. The Protoboard

A protoboard (Fig. 1) is a tool used for constructing and testing (or breadboarding) a circuit. Don't let the size fool you. Even small protoboards can accommodate surprisingly large and complex circuits.

The protoboard has two or more white plastic strips with lots of holes in them. The thin strips usually have two columns and many rows of holes. As shown in Fig. 1, these thin strips conduct in the long direction, along the columns. Therefore, any wire inserted in column 1 will share a common node with any other wire inserted in column 1 no matter which row you select. The same is true for column 2. However, columns 1 and 2 are not connected together. These thin strips are usually reserved for signals that will be used in several places in your circuit, such as the $\pm V_{DC}$ delivered by the power supply.

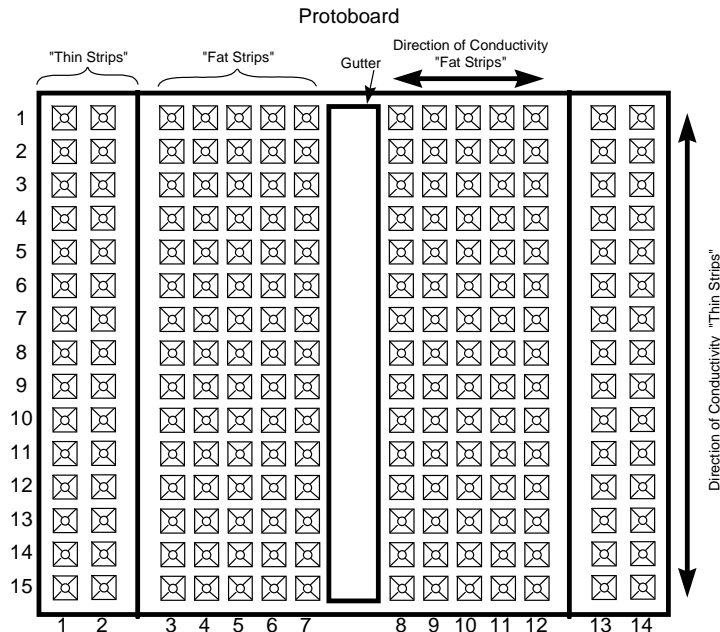


Figure 1

The fat strips conduct in the horizontal direction. There are five holes on one side of the gutter, which are all connected together, and five more on the other side that are connected together. The two rows of five do not conduct across the gutter, and thus are *isolated*. The columns in the "fat strip" section do not conduct from one row to the next. Thus, a wire inserted in row 4 of a fat strip will share a node with any other wire inserted in row 4 regardless of the column it is in. This wire does not share a node with a wire inserted in row 3 or row 5. Stated another way, each row on one side of the gutter represents a different node than any other row. Because these fat strips conduct along the row, if you wish to connect row 4 to row 13 you must insert one end of a wire in any hole in row 4 and the other end in any hole in row 13. It is this area, the fat strips with

five holes on each side of the gutter, which is used for most of the individual components that comprise your circuit.

Jumper wires used on the protoboard should be stripped 22 gauge solid copper. Smaller wires are difficult to insert into the nodes on the protoboard. Larger wires can damage the spring action of the metal contacts inside the protoboard.

Most protoboards also have two or more *posts*. Posts simplify the connection between the power supply, where a banana connector is preferred, and the protoboard, where stripped 22 gauge solid copper wire is required. While any post could be used for any external connection, black is usually reserved for *reference* or ground, while a red post is typically used for $+V_{DC}$, or the "hot" lead. Following this convention consistently can speed up the inevitable process of troubleshooting your circuits.

Generally the posts are built so that they can accommodate a wire underneath the Banana socket so that a connection to the protoboard can be easily made.

- a) Attach wires from both a black and a red post to a different column on a thin strip on the protoboard. Don't let the insulation on the end of the wire that is inserted into the post get under the threaded cap; it might not create a good connection.
- b) Make sure that the power supply is off. Use a Banana-to-Banana patch cable to connect the ground from your power supply to the black post. Connect the positive voltage side of the power supply to a red post.
- c) Place a jumper wire into each of the thin strips and make a connection over to a node on the fat strip portion of the protoboard.

3. Measuring voltage

- a) Turn on the power supply, set it to some voltage greater than zero and measure the voltage directly at the output of the power supply and again at a point electrically as far from the power supply as possible. If all is well, these voltages will be the same, indicating a complete connection has been made.
- b) Turn the power supply voltage down as far as possible. Measure and record the output voltage. Now measure and record the maximum voltage that the supply can produce.
- c) Turn off the power supply.

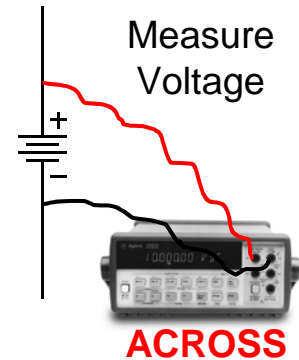


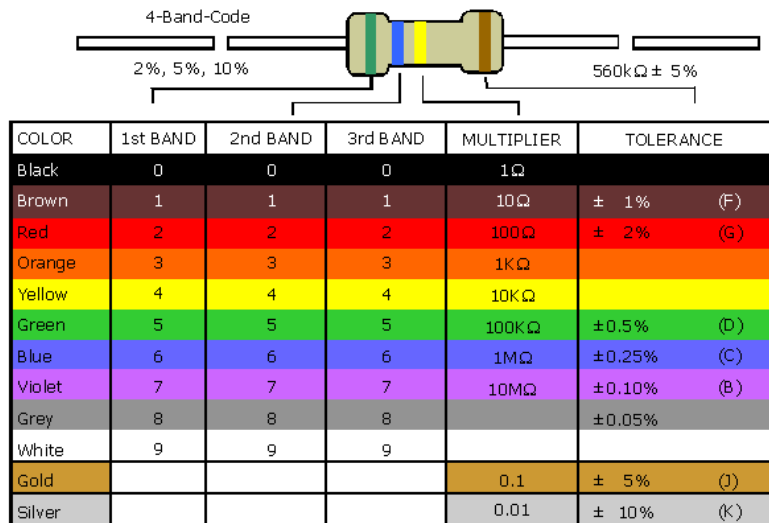
Figure 2

4. Measuring resistance

The standard resistance color code (as shown¹) provides a method of determining the value of a resistor without direct measurement. These markings, however, indicate only the nominal value. The actual value will most likely fall with the tolerance range of that indicated value.

To determine the actual value, a measurement must be made. Resistance measurements are accomplished by switching the DMM to the Ω scale. Later in the

course we'll discuss in detail what happens when resistors are in series or parallel with each other. For the moment, suffice it to say that resistors must be isolated from other



Electronix Express / RSR
<http://www.elexp.com>

1-800-972-2225
 In NJ 732-381-8020

Figure 3

¹ http://www.elexp.com/t_resist.htm, Accessed 8/23/03

parts of the circuit for accurate resistance measurements to be made. In this part, we'll use the resistance of your body to induce measurement errors.

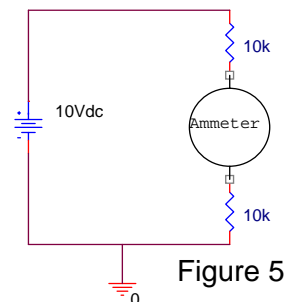
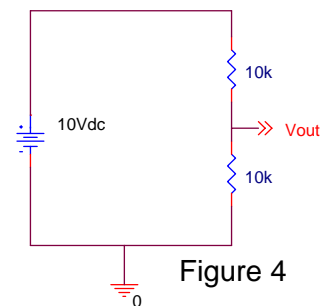
- With the meter set to measure Ω , pinch one probe tip in your left hand and the other probe tip in your right. Measure and record in your journal the minimum resistance you can produce this way. Can you offer any ideas on how to reduce this resistance?
- Use the resistor color code to locate the 510k Ω resistor. Measure the resistance of this resistor by pinching one probe tip to one lead of the resistor with your left hand and pinching the other probe tip to the opposite lead on the resistor with your right. Record this measured resistance in your journal.
- Now re-measure and record the actual resistance of the 510k Ω resistor without touching the probe tips. One way to do this is to put the legs of the resistor into different nodes on your protoboard and then press the probe tips against the legs of the resistor with your hands, touching only the plastic body of the probes.
- Compute the allowable error of the resistor from the tolerance band on the body of the resistor. Does the measured actual value of the resistor fall within the allowable tolerance for this device?
- In part b) of this section, you were instructed to measure the resistance using poor technique. Most likely the measured resistance in part b) was less than that measured in part c). In your journal briefly describe any theories you might have that would explain this behavior.

5. Measuring current

Measuring current in a circuit presents special challenges because it requires that the circuit be modified to accomplish the task. To measure current the meter must be wired in to the circuit so that the circuit current flows through the meter. This creates additional risks, in that the meter must be able to handle the current that is flowing in the circuit, or it will be damaged. In practice we generally attempt to avoid measuring current directly.

The DMMs used in this lab are “fused” on current, which means that if you make a mistake that draws too much current, the fuse will open up and the meter will no longer measure current. These \$5 fuses blow when small numbers of amps flow through the meter.

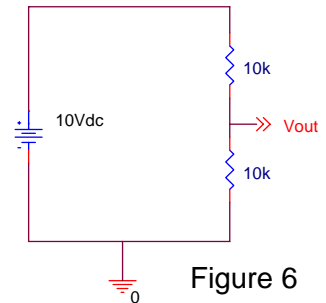
Be careful to ensure that you do not hook the ammeter directly to the power supply!



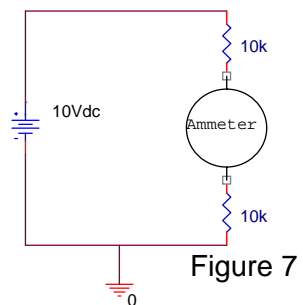
We'll soon be discussing at length the premier law for electronics, Ohm's Law. Today we'll use it to help us figure out how the ammeter works.

$v = ir$ Ohm's Law

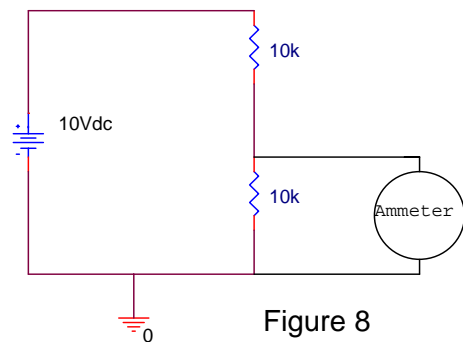
- a) For the circuit to the right we can use Ohm's Law to calculate the expected current. The two $10k\Omega$ resistors in series add so that the total circuit resistance is equivalent to $20k\Omega$. In your journal, use Ohm's Law and the total circuit resistance to compute the expected current in this circuit.



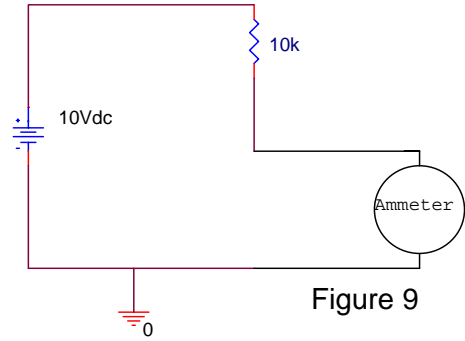
- b) Connect the ammeter as show in Figure 7. Record the results and in your journal comment about whether or not Ohm's Law correctly predicted the current in this circuit.



- c) Connect the ammeter as show in Figure 8. Record the measured current in your lab journal.



- d) Connect the ammeter as show in Figure 9. Record the results in your journal.



- e) Using Ohm's Law, compute the resistance required to produce the measured current in parts c) and d) of this section. You probably found that the measured current in the circuits of figures 8 and 9 was about twice that of the measured current in the circuit of Figure 7. Can you explain why this happened?

6. Conclusion

In your journal, predict the current that would be measured in each of the following circuits:

