
PART 1
COMPONENTS
DC/C
R-H
D-H

Section One

Components

In Lesson 1, you will be introduced to many common components that are always present in electronics and many of the bits and pieces you will use in the course. It starts out as a jumble. As you use the parts, the confused mass becomes an organized pile.

In Lesson 2, you become acquainted with the two major tools that you will use throughout the course.

In Lesson 3, you will build your first circuit on the solderless breadboard, a platform that allows you to build circuits in a temporary format.

You use your digital multimeter and get voltage measurements when you set up and test your first circuits.

Lesson 1: Inventory of Parts Used in Part I

All components look the same if you don't know what they are. It's like when you first visit a different country. There's a pile of change, just like in Figure L1-01. You have to be introduced to the currency and practice using it, but you become comfortable with it quickly. Now you need to unjumble the pile and become familiar with your electronic components.

Figure L1-01

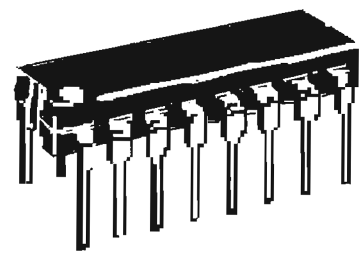

Figure L1-02

Do not remove the small integrated-circuit (IC) chips shown in Figure L1-02 from their antistatic packaging. They are packed in a special antistatic tube or special sponge material.

Semiconductors

These are the electronic components you will be using in Part I. As you identify them, set them aside into small groups.

Diodes

You will need three power diodes as shown in Figures L1-03 and L1-04.

The number on the side reads 1N4005. If the last number is not 5, don't worry. Any diode of this series will do the job.

Figure L1-03

Figure L1-04

Light-Emitting Diodes (LEDs)

Light-emitting diodes are also known as LEDs. You will need three LEDs. An example is illustrated in Figure L1-05.

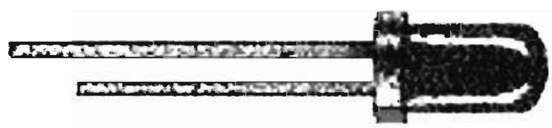

Figure L1-05

They can be any color. The most common colors are red, yellow, or green. The color is unimportant.

Resistors

There should be lots of colorful resistors, nearly all the same size.

Notice that in Figure L1-06 each resistor has four color bands to identify it. If you know the colors of the rainbow, you know how to read resistors.

Figure L1-06

Find these resistors:

1 brown-black-brown-gold 100 Ω

2 yellow-violet-brown-gold 470 Ω

1 brown-black-red-gold 1,000 Ω

1 brown-black-orange-gold 10,000 Ω

1 red-red-orange-gold 22,000 Ω

1 yellow-violet-orange-gold 47,000 Ω

1 brown-black-yellow-gold 100,000 Ω

Capacitors

As you notice in Figure L1-07, the capacitor shown is black and white. The colors of capacitors are different depending on the manufacturer. Then again, all pop cans look alike, but each brand has a different label. Locate four small cans, different in size. Written on each are different values and other mumbo jumbo. Look for the information that specifically lists 1 μF, 10 μF, 100 μF, and 1000 μF.

Figure L1-07

There is another capacitor of a different shape to locate. Figure L1-08 shows the other capacitor used in Part I. Again, it is presented in black and white, because the color will change as the manufacturer changes. It is a 0.1 μF capacitor. It may be marked as any of the following: 0.1 or γ1 or 100 nF.

Figure L1-08

Silicon-Controlled Rectifier (SCR)

The ID number 1607B for the *silicon controlled rectifier* (SCR) is written on the face, as shown in Figure L1-09. This SCR comes in this particular package. Not everything with this shape is an SCR, just as not everything in the shape of a pop can is your favorite flavor.

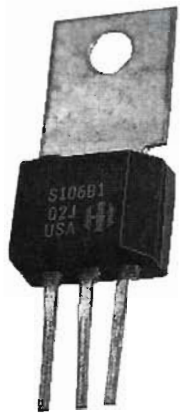

Figure L1-09

Transistors

You need two transistors like that illustrated in Figure L1-10. They are identical except for the numbers 3904 or 3906. All other writing and marks are the manufacturer telling us how great he or she is.

Figure L1-10

Hardware

The solderless breadboard is shown in Figure L1-11.

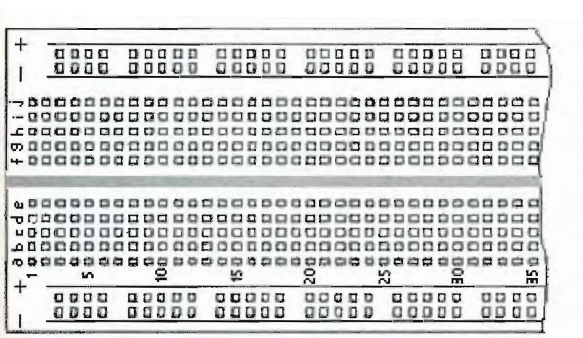

Figure L1-11

Figures L1-12 and L1-13 illustrate two push buttons—they are different, but you can't tell by looking at them. Figure L1-12 is the normally open push button (push to close the contacts), and Figure L1-13 shows the normally closed push button (push to open the contacts).

Figure L1-12

Figure L1-13

You should have lots of 24-gauge solid wire with plastic insulation. There should be plenty of different lengths.

Two battery clips are shown in Figure L1-14.

Figure L1-14

A 9-volt buzzer is shown in Figure L1-15.

Figure L1-15

Two printed circuit boards are premade for your projects: Figure L1-16 is to be used for the night-light project; Figure L1-17 is for your SCR alarm project.

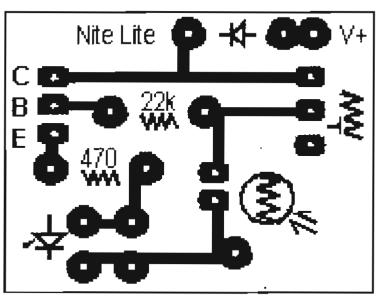

Figure L1-16

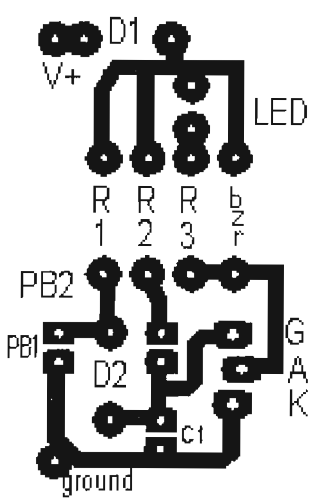

Figure L1-17

Two adjustable resistors are also supplied: The *light-dependent resistor* (LDR) is shown in Figure L1-18 and the potentiometer is shown here in Figure L1-19.

Figure L1-18

Figure L1-19

Lesson 2: Major Equipment

The Solderless Breadboard

When smart people come up with ideas, first they test those ideas. They build a prototype. The easiest way to build prototypes and play with ideas in electronics is on the solderless breadboard, shown here in Figure L2-01.

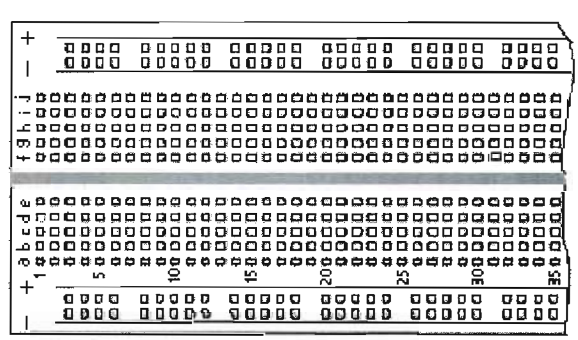

Figure L2-01

The main advantage of the solderless breadboard is the ability to exchange parts easily and quickly.

The top view in Figure L2-01 shows the many pairs of short five-hole rows and a pair of long rows down each side; each of these lines are marked with a strip of paint.

The Digital Multimeter

I recommend the Circuit Test DMR2900 displayed in Figure L2-02.

Figure L2-02

The auto-ranging DMM offers beginners the advantage of being easier to learn.

The second style of DMM is not auto-ranging. This style is easy to use after you become familiar with electronics, but they tend to be confusing for the beginner. A typical dial of a nonautoranging multimeter is confusing, as you can see in Figure L2-03.

I discourage the use of outdated whisker-style multimeters for this course. Figure L2-04 gives an example of what to avoid.

Figure L2-03

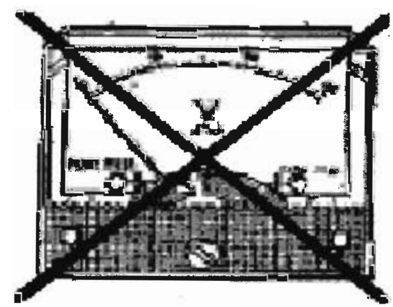

Figure L2-04

Connection Wire

A box of wire provided in the kit is displayed in Figure L2-05.

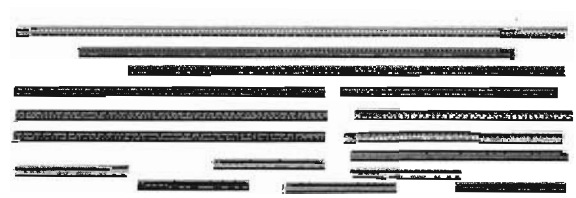

Figure L2-05

These are different lengths convenient for the solderless breadboard. If you need to cut the wire to different lengths, wire clippers will work perfectly. Old scissors work as well.

Set the dial of the DMM to CONTINUITY. This setting is shown in Figure L2-06.

Figure L2-06

Touch the end of both red and black probes to the colored covering. The DMM should be silent and read OL, as in the readout illustrated in Figure L2-07, because the resistance of the insulation prevents any current from passing.

Figure L2-07

Be sure the strip of insulating plastic is removed from both ends of the piece of wire as demonstrated in Figure L2-08. If you don't have a proper wire stripper available, use a knife or your fingernails to cut the insulation. Be careful not to nick the wire inside the insulation.

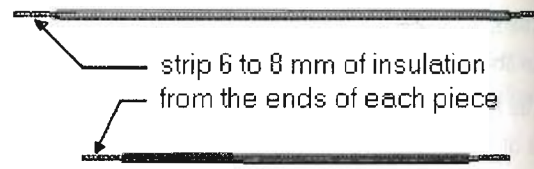

Figure L2-08

Now touch the end of both probes to the exposed wire. The DMM should read "00" and beep, just like the readout in Figure L2-09. The wire is a good conductor, and the DMM shows "continuity," a connected path.

Figure L2-09

Exercise: Mapping the Solderless Breadboard

Strip the end of two pieces of wire far enough to wrap around the DMM probes on one end and enough to insert into the SBB on the other end, as shown in Figure L2-10.

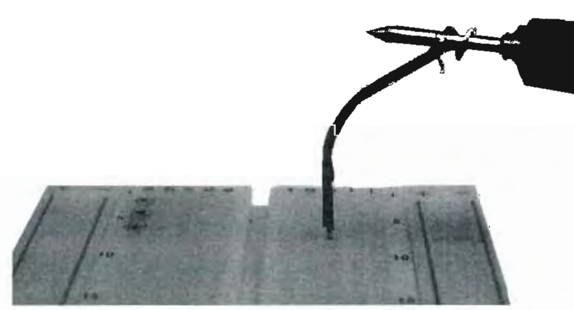

Figure L2-10

1. Set your digital multimeter to continuity. Now refer to Figure L2-11. Notice the letters across the top and the numbers down the side of the solderless breadboard.

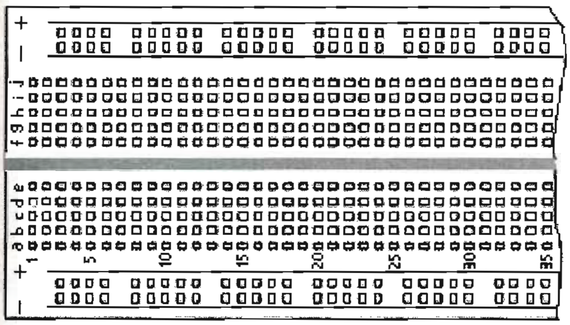

Figure L2-11

2. Probe placement
   a. Place the end of one probe wire into the SBB at point "h3" and mark that on the drawing.
   b. Use the other probe to find three holes connected to the first. The multimeter will indicate the connection.
   c. Draw these connections as solid lines.
3. Base points
   a. Create four more base points at e25, b16, f30, and c8.
   b. Use the other probe to find three holes connected to each of these points.
   c. Again draw these connections as solid lines.
4. Additional base points
   a. Choose two more base points on the outside long, paired lines. These lines are not lettered or numbered but have a stripe of paint along the side. Mark them on the diagram above.
   b. Find three holes connected to each of these points.
   c. Again draw these connections as solid lines.
5. Be sure that you can define the terms prototype, insulator, and conductor.
6. With your multimeter set on continuity, walk around and identify at least five common items that are insulators and five common materials that are conductors.

Lesson 3: Your First Circuit

As you see, the solderless breadboard has a definite layout as shown in Figure L3-01. One strip of the spring metal in the breadboard connects the five holes. You can easily connect five pieces in one strip. The two long rows of holes allow power access along the entire length of the breadboard.

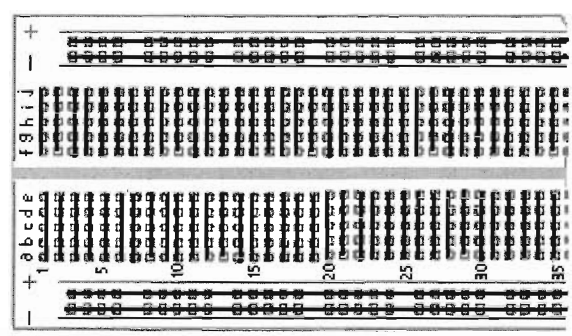

Figure L3-01

Setting Up the Solderless Breadboard

You will have a standard set up for every circuit. The battery clip is connected to one of the first rows of the breadboard, and the diode connects that row to the outer red line. See Figure L3-02.

Figure L3-02

Notice the gray band highlighted in Figure L3-03 on the diode. It faces in the direction that the voltage is pushing.

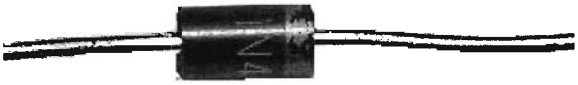

Figure L3-03

The voltage comes through the red wire, through the diode, and then to the power strip on the breadboard.

Why Bother?

This power diode provides protection for each circuit that you build in the following ways:.

- The diode is a one-way street. You can view the animated version of Figure L3-04 at the Web site www.books.mcgraw-hill.com/authors/cutcher.

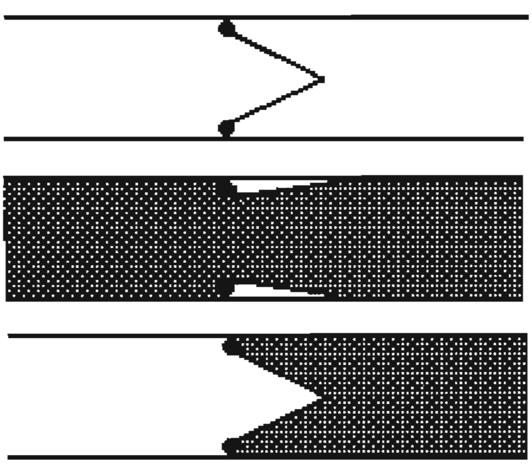

Figure L3-04

- Many electronic components can be damaged or destroyed if the current is pushed through them the wrong way, even for a fraction of a second.
- This standard breadboard setup helps ensure you will always have your battery connected properly.
- If you accidentally touch the battery to the clip backwards, nothing will happen, because the diode will prevent the current from moving.

Breadboarding Your First Circuit

Parts List

D1—Power diode 1n400x

LED1—LED any color

R1—470-ohm resistor

Your LED is a light-emitting diode. That's right, a diode that emits light. It has the same symbol as a diode, but it has a "ray" coming out, as shown here in Figure L3-05.

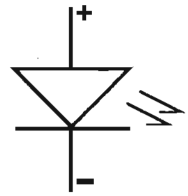

Figure L3-05

Figure L3-06 is a picture of an LED. Never touch your LED directly to your power supply. A burned-out LED looks just like a working LED. Note in the picture how to identify the negative side.

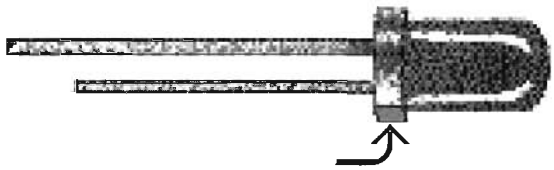

Figure L3-06

- The shorter leg: This is always reliable with new LEDs, but not with ones that you have handled in and out of your breadboard. As you handle the components, the legs can get bent out of shape.
- The flat side on the rim: This is always reliable with round LEDs, but you have to look for it.

Remember, that the LED, as a diode, is a one-way street. It will not work if you put it in backward.

Figure L3-07 shows several resistors. The resistor symbol is illustrated in Figure L3-08. The resistor you need is the 470-ohm yellow-violet-brown-gold.

Figure L3-07

Figure L3-08

Resistance is measured in ohms. The symbol for ohms is the Greek capital letter omega, Ω.

The schematic is shown in Figure L3-09. Set up your breadboard as shown in Figure L3-10. Note that this picture shows the correct connections. The red wire of the battery clip is connected to the power diode that in turn provides voltage to the top of the breadboard. The black wire is connected to the blue line at the bottom of the breadboard.

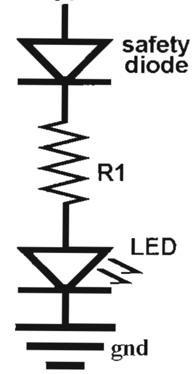

Figure L3-09

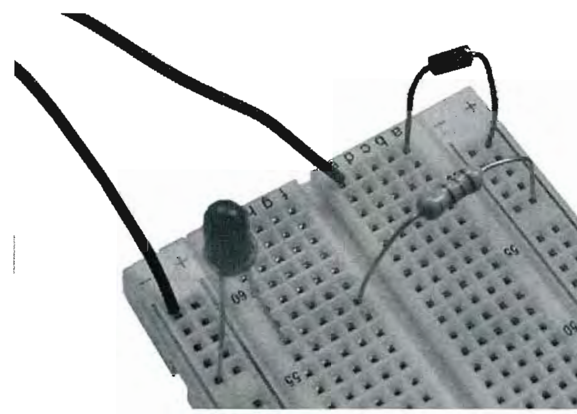

Figure L3-10

A Quick Note

1. Always complete your breadboard before you attach your power to the circuit.
2. Attach your battery only when you are ready to test the circuit.
3. When you have finished testing your circuit, take your battery off.

When you think you've got it, connect the battery and find out.

Exercise: Measuring Voltage on Your First Circuit

Your First Circuit Should Be Working

Figure L3-11 shows what is happening. Like a waterfall, all of the water goes from the top to the bottom. The resistor and LED each use up part of the voltage. Together they use all the voltage. The 470-ohm resistor uses enough voltage to make sure the LED has enough to work, but not so much that would burn it out.

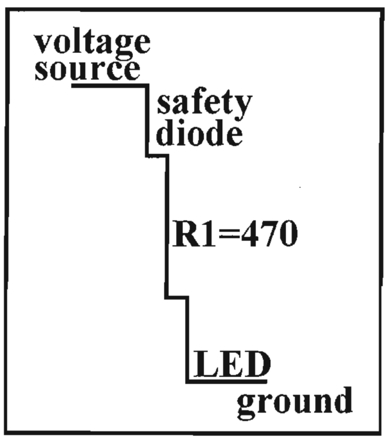

Figure L3-11

Let's look at how the voltage is being used in the circuit

1. Set the DMM to *direct current voltage* (DCV). If you are using a multimeter that is not autoranging, set it to the 10-volt range.
2. Measure the voltage of the 9-volt battery while it is connected to the circuit.
3. Place the red (+) probe at test point A (TP-A) and the black (−) probe at TP-D (ground). The arrows in the schematic shown in Figure L3-12 indicate where to attach the probes. Corresponding test points have been noted in Figure L3-13 as well.
4. Record your working battery voltage. ____V
5. Measure the voltage used between the following points:

   TP-A to TP-B across the safety diode ____V

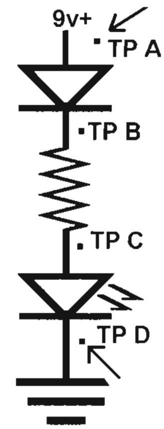

Figure L3-12

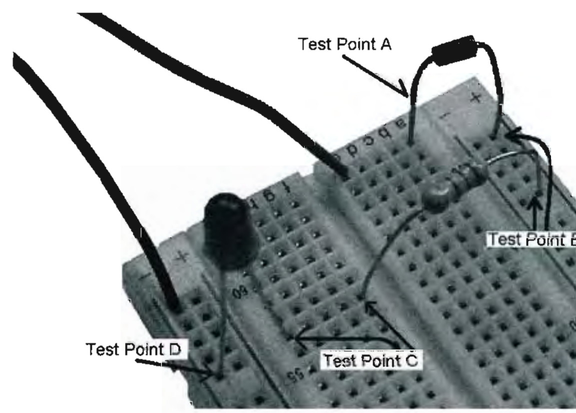

Figure L3-13

   TP-B to TP-C across the 470-ohm resistor ____V

   TP-C to TP-D across the LED ____V

6. Now add the voltages from #5. ____V
7. List working battery voltage (recorded in item 2). ____V
8. Compare the voltage used by all of the parts to the voltage provided by the battery.

The voltages added together should be approximately the same as the voltage provided by the battery. It may be only a few hundredths of a volt difference.

Lesson 3 - Your First Circuit

Section Two

Resist If You Must

Lesson 4: Reading Resistors

If you know the colors of the rainbow, you know how to read resistors (Table L4-1).

Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White

The gold bands are always read last. They indicate that the resistor's value is accurate to within 5%.

Table L4-1 Resistor band designations

Color Band	*First Band: Value*	*Second Band: Value*	*Third Band: Number of Zeros*	*Units*
Black	0	0	No zeros	Tens ##
Brown	1	1	One zero "0"	Hundreds ##0
Red	2	2	Two zeros "00"	Thousands (k) #,#00
Orange	3	3	Three zeros "000"	Ten thousands (k) ##,000
Yellow	4	4	Four zeros "0,000"	Hundred thousands (k) ##0,000
Green	5	5	Five zeros "00,000"	Millions (M) #,#00,000
Blue	6	6	Six zeros "000,000"	Ten millions (M) ##,000,000
Violet	7	7	Not available	
Gray	8	8	Not available	
White	9	9	Not available	

When using the digital multimeter to measure resistance, set the dial to Ω. Notice the two points of detail shown in Figure L4-1.

Figure L4-1

The first point is that when the dial is set directly to the Ω symbol to measure resistance, it also appears on the readout. Secondly, notice the M next to the Ω symbol. That means the resistor being measured is 0.463 MΩ. That is 0.463 million ohms, or 463,000 ohms. When it is there, *never* ignore that extra letter.

As you use resistors, you quickly become familiar with them. The third band is the most important marker. It tells you the range in a power of 10. In a pinch, you could substitute any resistor of nearly the same value. For example, a substitution of a red-red-orange could be made for a brown-black-orange resistor. But a substitution of a red-red-orange by a red-red-yellow would create more problems than it would solve. Using a completely wrong value of resistor can mess things up.

Exercise: Reading Resistors If you have an auto-ranging multimeter, set the DMM to measure Resistance. If you do not have an auto ranging DMM, you have to work harder because the resistors come in different ranges. You have to set the range on your DMM to match the range of the resistor. That means that you should have an idea of how to read resistor values before you can measure those values using a DMM that is not auto ranging. An auto ranging DMM really does make it much easier.

Your skin will conduct electricity, and if you have contact with both sides of the resistor, the DMM will be measuring your resistance mixed with the resistor's. This will give an inaccurate value.

Proper Method to Measure Resistor's Value Figure L4-2 shows how to measure a resistor. Place one end of the resistor into your solderless breadboard and hold the probe tightly against it, but not touching the metal. You can press the other probe against the top of the resistor with your other finger.

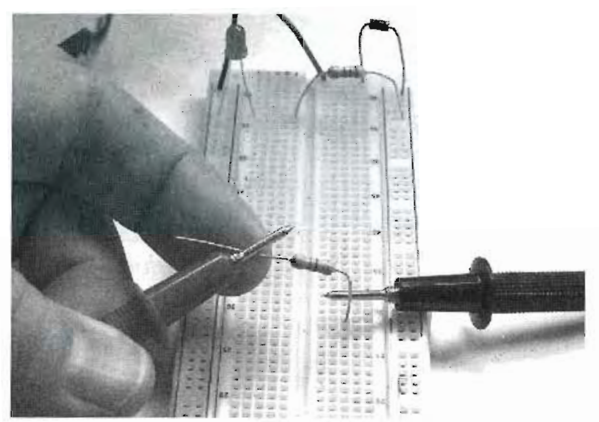

Figure L4-2

1. Some of the resistors you will need to be able to identify, because you use them soon, are listed in Table L4-2.

Table L4-2 Resistors needed

First Band: Value	*Second Band: Value*	*Third Band: Number of Zeros*	*Resistor Value*	*DMM Value*
Brown 1	Black 0	Brown 0	100 Ω	_______ Ω
 4	Violet 7	Brown 0	470 Ω	_______ Ω
Brown ____	Black ____	Red 00	1,000 Ω	_______ Ω
Brown ____	Black ____	Orange 000	10 kΩ 10,000Ω	_______ Ω
Red ____	Red ____	Orange ____	22 kΩ 22,000 Ω	_______ Ω
Brown ____	Black ____	Yellow ____	100 kΩ 100,000	_______ Ω

2. Don't be surprised if the resistor value is not exactly right. These resistors have a maximum error of 5%. That means that the 100-ohm resistor can be as much as 105 ohms or as little as 95 ohms. Plus or minus 5 ohms isn't too bad. What is 5% of 1,000,000?

   What is the maximum you would expect to see on the 1,000-ohm resistor? _____ Ω

   What is the minimum you would expect to see on the same 1-kilo-ohm resistor? ____ Ω

3. Measure your skin's resistance by holding a probe in each hand. It will bounce around, but try to take an average. ______ Ω

   Did you know that this can be used as a crude lie detector? A person sweats when they get anxious. Have a friend hold the probes. Then ask them an embarrassing question. Watch the resistance go down for a moment.

4. Write each of these values as a number with no abbreviations.

   10 kΩ = ________ Ω

   1 kΩ = ________ Ω

   .47 kΩ = ________ Ω

   47 kΩ = ________ Ω

Lesson 5: The Effect Resistors Have on a Circuit

Let's go back to the breadboard and see how different resistors affect a simple circuit. The resistors and the LEDs are both loads. The resistor uses most of the voltage, leaving just enough for the LED to work. The LEDs need about 2 volts.

What would happen if you changed resistors on the circuit you just built, shown in Figure L5-1?

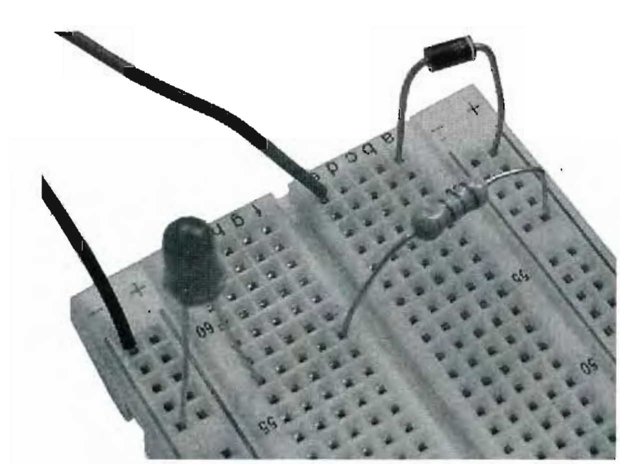

Figure L5-1

You measured the voltage used across the resistor from TP-B to TP-C and measured the voltage used across the LED from TP-C to TP-D.

Figure L5-2 is the schematic of the circuit.

Figure L5-3 shows a waterfall. A waterfall analogy explains how voltage is used up in this circuit. The water falls over the edge. Some of the force is used up by the first load, the safety diode. More of the voltage is then used by the second load, the resistor. The remaining voltage is used by the LED.

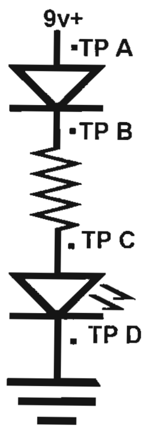

Figure L5-2

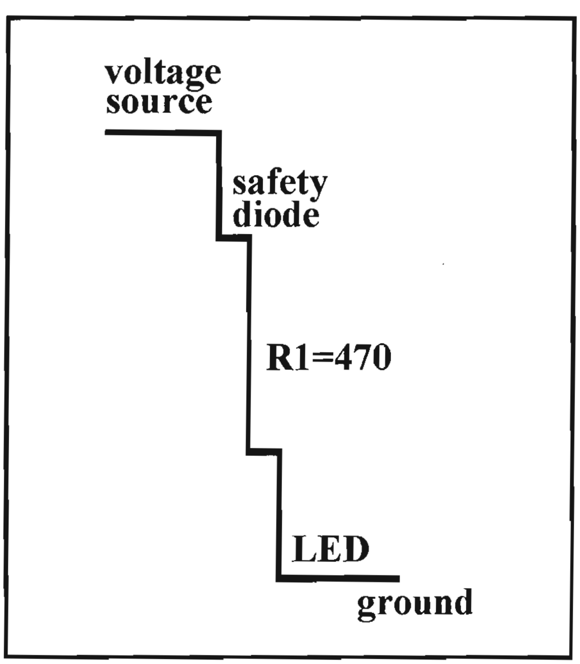

Figure L5-3

This "waterfall" shows how the voltage is used by a 470-ohm resistor. If the resistor wasn't there, the LED would be hit with the electrical pressure of more than 8 volts. It would burn out. The waterfall analogy helps you visualize how voltage is used in a circuit.

Remember, all the water over the top goes to the bottom, and all of the voltage is used between source and ground. Each ledge uses some of the force of the falling water. Each component uses part of the voltage.

What happens if there is more resistance? More of the voltage is used to push the current through that part of the circuit, leaving less to power the LED.

This is represented visually in Figure L5-4.

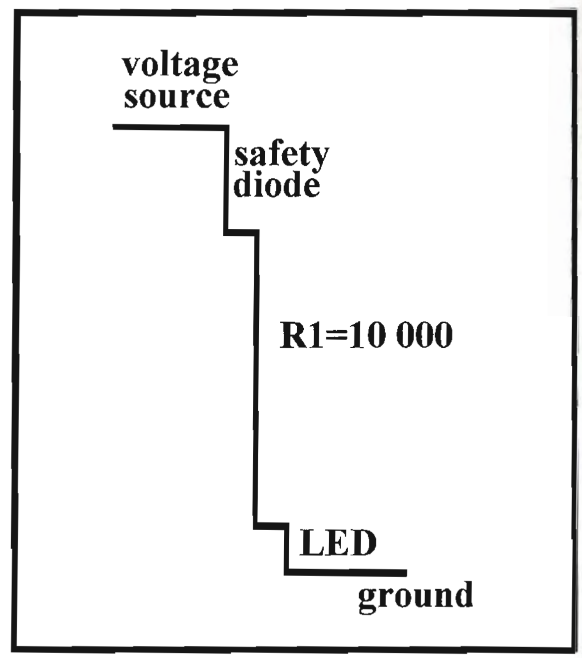

Figure L5-4

Exercise: The Effect Resistors Have on a Circuit

Your setup should look like Figure L5-5. Have your resistors arranged from lowest to highest value as presented in Table L5-1.

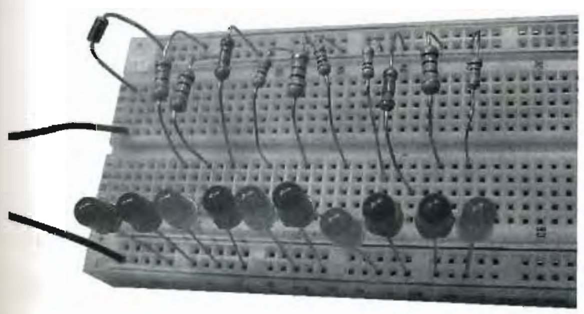

Figure L5-5

Table L5-1 Exercise sheet

Resistor Value	*Total Voltage Available*	*Voltage Drop Across Resistor*	*Voltage Drop Across the LED*	*LED Brightness (compared to 470 Ω)*
100 Ω	____V	____V	____V	________
470 Ω	____V	____V	____V	**Normal**
2,200 Ω	____V	____V	____V	________
10,000 Ω	____V	____V	____V	________
47,000 Ω	____V	____V	____V	________
220,000 Ω	____V	____V	____V	________

Lesson 6: The Potentiometer

Not all resistors are "fixed" like the small color-banded ones that you've already been introduced to. A common variable resistor is the potentiometer, pictured in Figure L6-1.

This useful device is often simply referred to as a pot. A smaller version is also shown. These are called *trim pots*. You have often used potentiometers as volume controls. The maximum resistance value is usually stamped onto the metal case.

Figure L6-1

Figure L6-2 shows a picture of a potentiometer taken apart. The potentiometer works because the sweep arm moves across the carbon ring and connects that to the center. The leg on the left is referred to as A, the center leg as C (center), and the right leg as B.

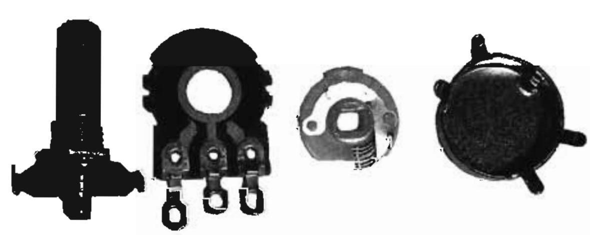

Figure L6-2

The carbon ring shown in Figure L6-3 is the heart of the potentiometer. It is made of carbon mixed with clay. Clay is an insulator. Carbon is the conductor.

The action of the potentiometer is the sweep arm (copper on white plastic) moving across the carbon ring (Figure L6-4). The sweep arm allows the current to move between A and C as its position changes. The resistance between A and C also changes with distance.

Figure L6-3

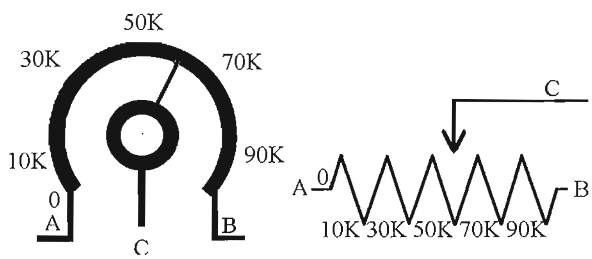

Figure L6-4

The distance between A and B is always the same, so the resistance between A and B is always the same. The value for this demonstration potentiometer is 100,000 ohm. The 100-kilo-ohm value means the set value between legs A and B is 100 kilo-ohm. Ideally, the minimum between A and C is 0 ohm (directly connected), and the maximum between A and C should be 100 kilo-ohm.

The ratio between carbon and clay determines how easily electrons pass through the a resistor. More clay mixed in leaves less carbon. The less carbon means less conducting material. That creates higher resistance.

The carbon in the ring is similar to the carbon in a pencil. The pencil lead is also made of a mixture of carbon and clay. Carbon is the conductor. Clay is the insulator.

Soft pencils have less clay, and more carbon. A mark by a soft pencil will have less resistance.

Hard pencils have lead that contains more clay and less carbon. These provide higher resistance.

Exercise: The Potentiometer

1. Use a No. 2 soft pencil to draw a thick line on this piece of paper as demonstrated in Figure L6-5. A harder pencil has too much clay and will not give good results.

Figure L6-5

2. Set your multimeter to measure resistance Ω. If it is not auto ranging, set it to maximum resistance.
3. Just as it is shown in Figure L6-6, press the probes down hard against the pencil trace about an inch apart. Be sure that you don't touch the tips of the probe. You want to measure the resistance of the pencil trace, not the resistance of your body.

Figure L6-6

   a. Now record the resistance from the multimeter. ________ Ω If the DMM says the resistance is out of range, move the probes together until you get a reading.
   b. Move the probes closer together; then further apart. Write down what you observe.

4. Use the 100-kilo-ohm potentiometer. Record your results.

   a. Measure the resistance between the two outer legs A and B. ______ Ω

   b. Adjust the knob and check the resistance between A and B again. ______ Ω

   c. Adjust the knob about 1/2 way. Measure the resistance between the left and middle leg—A and C. ______ Ω

   d. Turn the knob a bit and check again. Note any change. ______ Ω

Explain what is happening, relating that to the carbon ring shown in Figure L6-3.

____

____

Breadboarding the Circuit

Note the similarities of the schematic shown in Figure L6-7 and the picture of the circuit displayed in Figure L6-8.

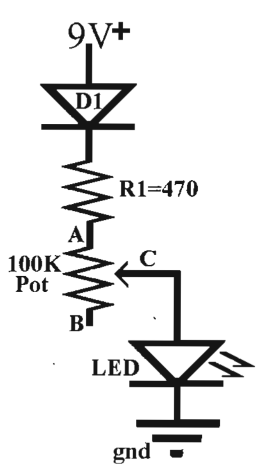

Figure L6-7

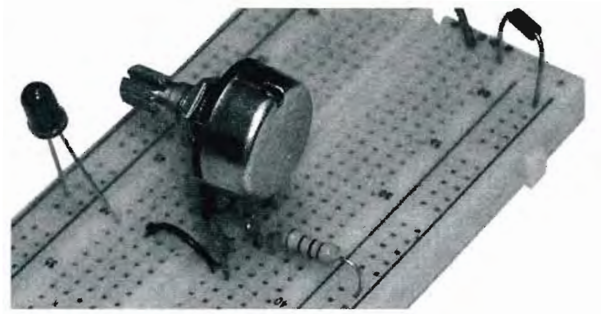

Figure L6-8

5. Make sure that you have the battery hooked up properly through the power diode placed properly as noted on the schematic.

6. As you turn the shaft of the potentiometer, the LED should brighten and dim. Explain what is happening.

____

____

7. Why is there a 470-ohm fixed resistor in this circuit?______________________________

Lesson 7: Light-Dependent Resistors

Another variable resistor is the *light-dependent resistor* (LDR). The LDR changes its ability to conduct electrons with the change of light.
It is commonly used to turn equipment on automatically as night falls. Some cars use it as the input to the switch that turns on headlights as conditions change, even as they drive through a tunnel. The symbol for the LDR is shown here in Figure L7-1.

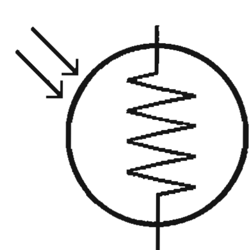

Figure L7-1

There is no room to place a value on most LDRs. They are ordered and supplied in specific values. An easy way to measure the maximum resistance is to measure it in darkness.

Insert the LDR onto the breadboard so the legs are not connected, as shown here in Figure L7-2. Measure the resistance using your DMM. The read-out may be jumping around because LDRs are sensitive.

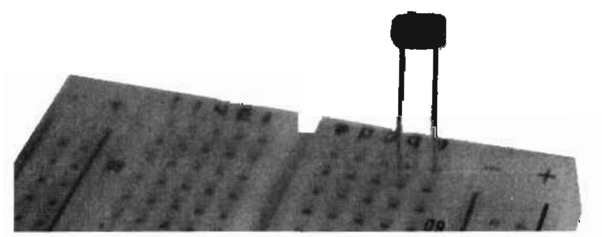

Figure L7-2

Look at Figure L7-3. Place lid of a black pen over the LDR and measure the resistance again.

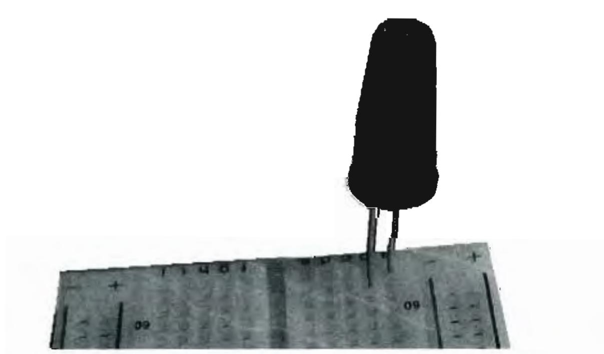

Figure L7-3

Breadboard the Circuit in Table L7-1

Table L7-1 Example circuit

Parts List	
D1	Power diode
LDR	1 MΩ dark
LED	5 mm round

Note the similarities of the schematic in Figure L7-4 and the breadboard layout in Figure L7-5.

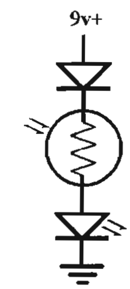

Figure L7-4

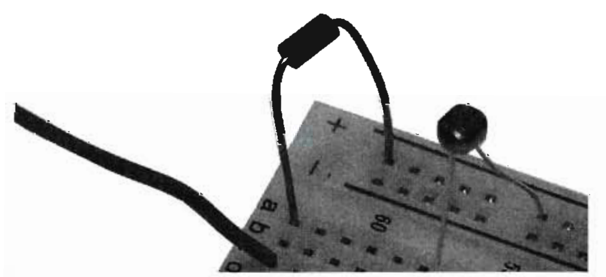

Figure L7-5

What to Expect

1. Attach the battery and note the brightness of the LED. It should be fairly bright.
2. Place the lid of the pen over the LDR again. The LED should dim to nearly nothing.
3. Consider this. What is the relationship between the amount of light on the LDR and the LDR's resistance?

Exercise: Light-Dependent Resistors

1. Disconnect the power supply. Measure and record the resistance of the LDR in the light. It may be necessary to take a rough average because it will be jumping around wildly.
2. Place a dark black pen lid over the LED and measure the resistance again. Remember that your fingers can affect the read out.

3. Attach the power supply and note the brightness of the LED. Place the lid of the pen over the LDR again. State the relationship between the amount of light on the LDR and the resistance of the LDR.

4. Note the minimum resistance that occurs on the LDR in the light. Why is the 470-ohm resistor not used in this circuit?

5. Consider the "waterfall" diagrams presented in Figure L7-6. From brightest to darkest conditions, what would be the best order of these diagrams regarding the LDR's effect on the brightness of the LED?

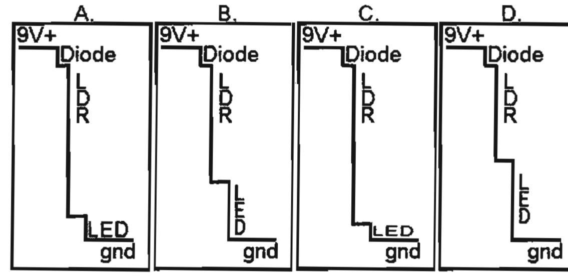

Figure L7-6