Sierra College MECH-01
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MECH-01
Application 01

1. The goal of this lab will be to
   a. Learn how to use the basic functions of a multi-meter;
   b. Investigate some elementary properties of light emitting diodes (LEDs).
   c. Learn how to solder on a printed circuit (pc) board;.

2. MULTIMETER

   a. The basic multimeter is a formidable instrument when you first look at it. Lots of scales, lots of choices, lots of ways to goof up. But if we break it down into some pretty simple sections it isn't quite so intimidating.

      i. Before we get to the meter itself, we ought to note that one ampere of current is 1000 milli-amperes. One milliampere is 1000 micro-amperes.

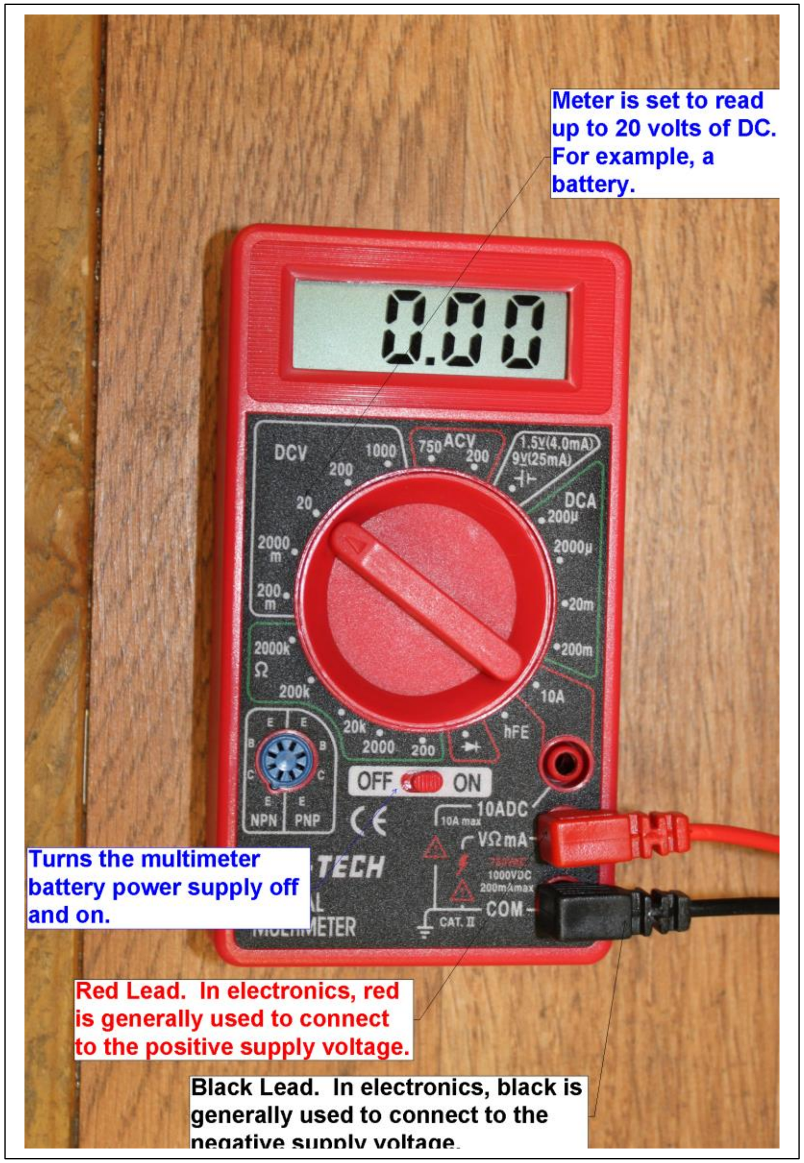
      ii. One volt is 1000 millivolts. One millivolt is 1000 microvolts.

      iii. One thousand ohms is one kilo-ohm, one thousand kilohms is one mega-ohm (megohm).

   b. First of all, the probes (connectors) fit into the lower right corner of the meter. Red to positive, black to negative (ground).

   c. Second, right now this meter is set to measure DC voltage (upper left corner) and in this particular instance it will measure from zero volts to 19.99 volts (the 20 volt scale). You can measure from 199 millivolts (0.199 volts) full scale to 999.99 volts full scale.

   d. If you want to measure DC current (middle right) you can go from 199 microamperes (0.000199 amperes) to 199 milliamperes (0.199 amperes) full scale. If you are working on some really heavy current devices there is a way to measure up to 9.99 amperes if you wish.



e. For resistance, you can measure resistors from 199 ohms full scale to 1.99 million ohms (Megohms) full scale.

f. Forget about the rest of the scales. We can worry about them later.

g. Gather the following parts:

   i. A 9 volt battery.

h. With the voltmeter on the 20 volt scale, measure the battery voltage; red multimeter lead to the terminal on the top of the battery with the (+) marking and the black lead to the other terminal. Record what the battery voltage is.

i. Reverse the leads. Did the multimeter readout change?

j. Switch the multimeter to the 2000 mV scale. Convert 2000 millivolts to volts. Measure the battery on this scale. What did the meter readout do? Why?

   i. Repeat steps h-j above with an AA battery.

k. Can you use what you learned about the meter readout above to tell which is the (+) and which is the (-) terminals of the AA battery?

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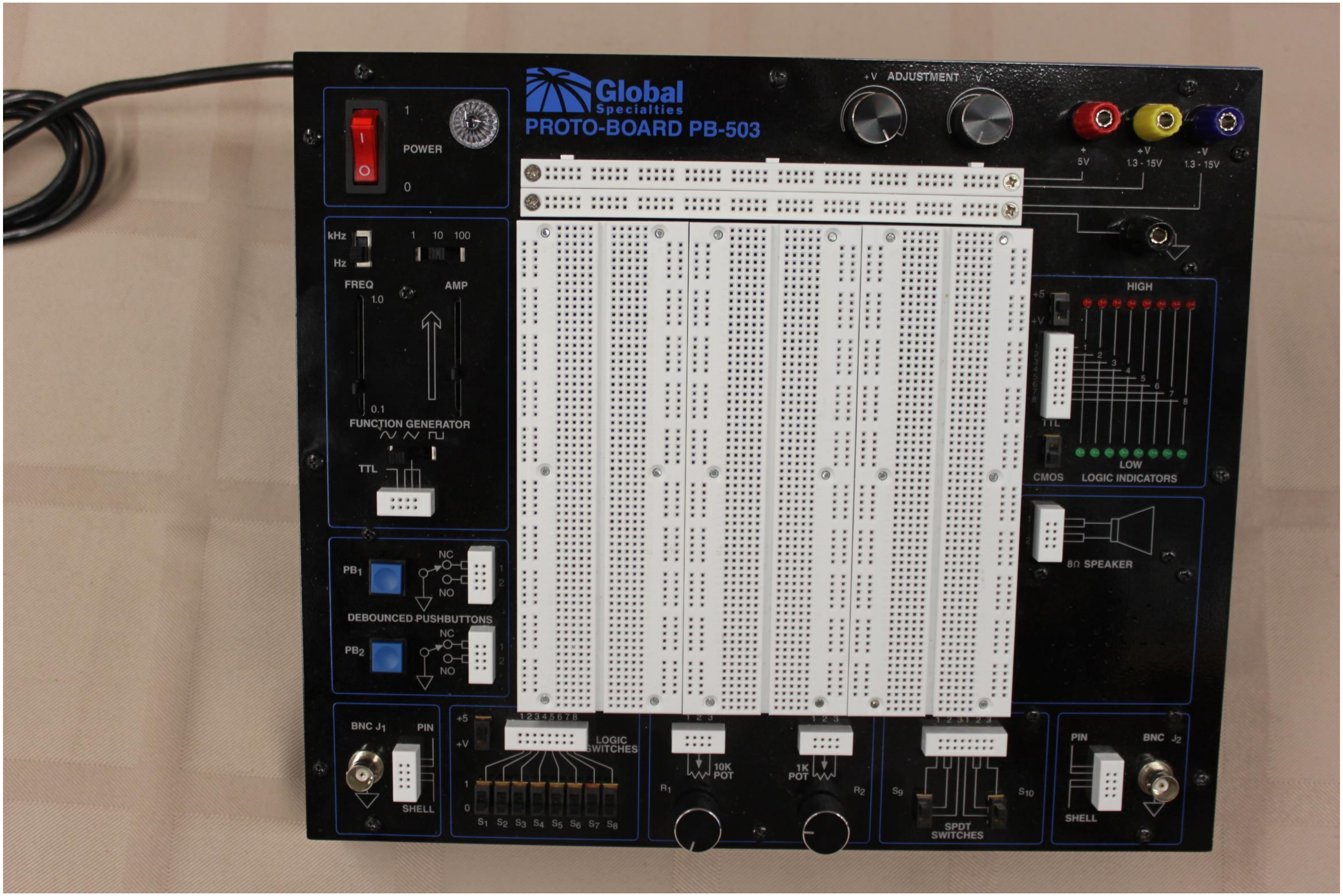
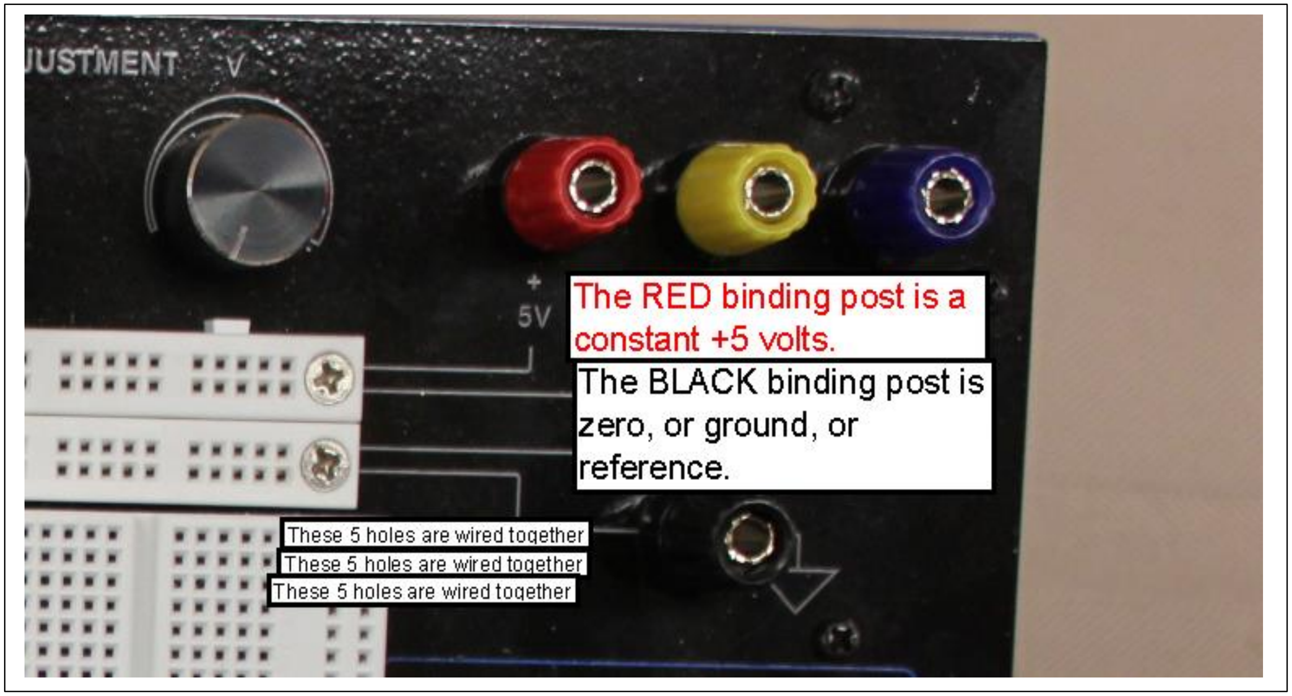
l. Turn the multimeter off for the time being.

3. The Mean Evil Machine



a. The title "Mean Evil Machine" was coined by one of my students nearly twenty years ago when he could NOT figure out all the knobs and switches on "The Trainer" (the "official" title).



b. We will be using just one little tiny corner of the trainer, so let's not worry about all of the other stuff on the machine that will just confuse us.

c. Turn the trainer on by pushing the "power" switch in the upper right hand corner on and notice that the red light in the switch comes on.

d. . Take your multimeter and prove to yourself that the voltage between the red binding post and the black binding post is between 4.9 and 5.1 volts.

Twist the red plastic knob on top of the +5 volt binding post about 5 or 6 turns.

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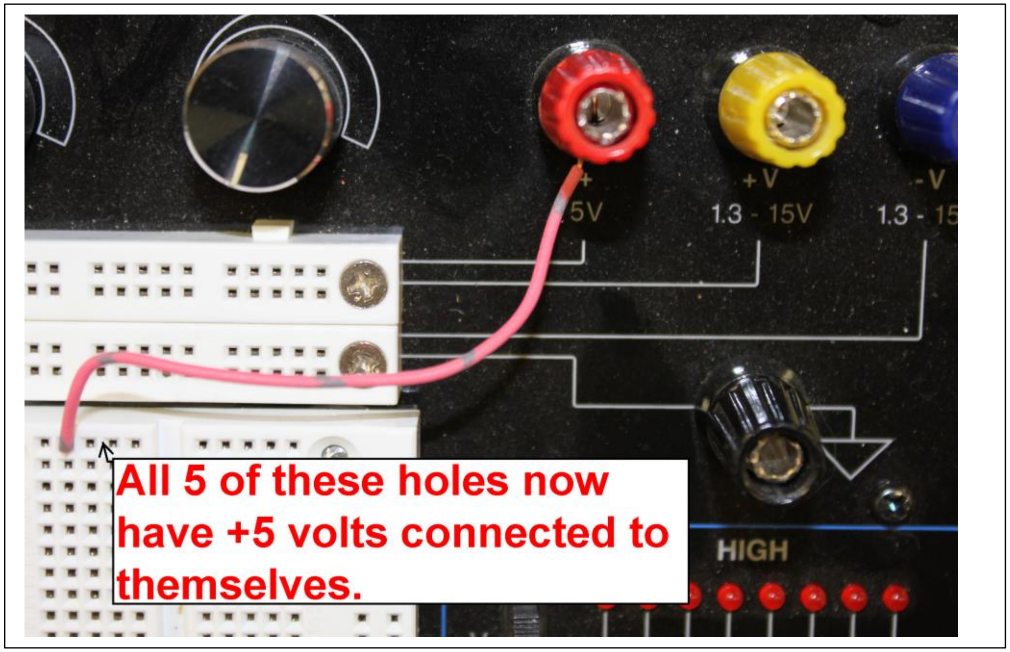
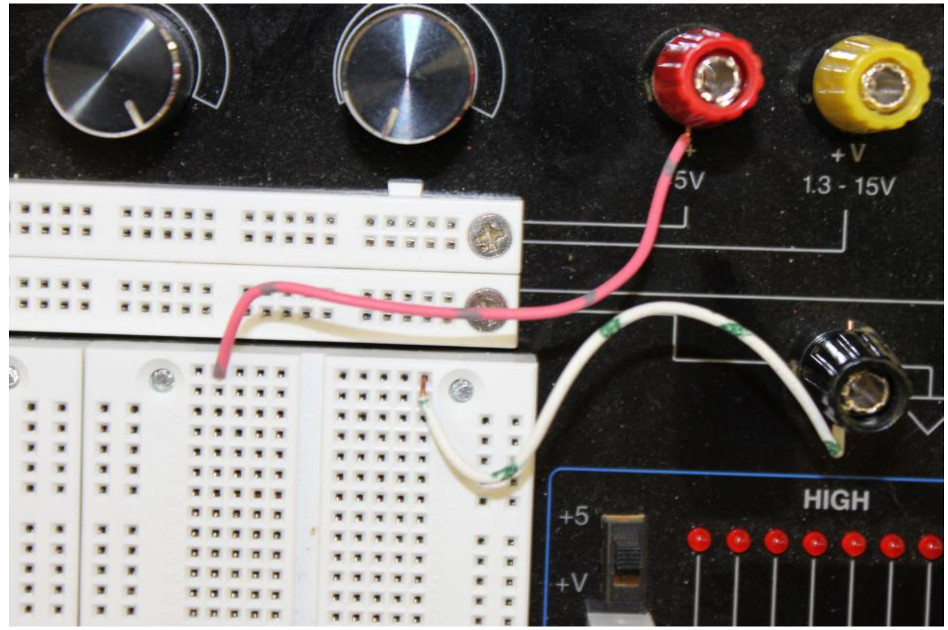


e. Take a jumper wire (any color) insert it into the bottom of the +5 volt binding post and fasten the red knob to hold it firmly to the post (there is a wire hole in the bottom of the post).

f. . Insert the free end of the wire into any one of the 5 holes as shown. Take the voltmeter and another wire and prove to yourself that there is +_5 volts between the black ground post and any of the other 5 holes in that row. Test a few other holes in other rows to prove to yourself that none of the other holes are connected to these 5 holes.

g. Similarly, connect a different color wire from the black ground binding post to a hole in the row of 5 directly across from the +5 volt row.

h. MOMENTARILY connect a wire from the +5 volt row to the ground row. Did the white light in the upper left corner of the trainer llight up? This is an indication of a SHORT CIRCUIT drawing EXCESSIVE CURRENT from the internal +5 volt power supply. Check that light from time to time when you are building circuits later this semester to be sure you didn't inadvertently create a short circuit.

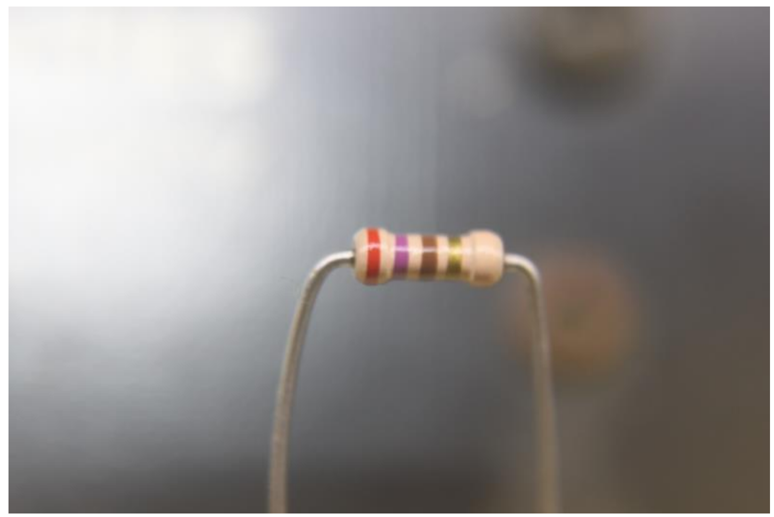


4. RESISTORS

a. A resistor is an electronic component that sets a known current into a circuit. Georg Ohm told us a couple of hundred years ago that the ratio of voltage to current was resistance. In mathematical terms, R (resistance in ohms) is equal to E (electromotive force, or voltage) divided by I (current in amperes. In algebra form, R = E / I.. By a little algebra E = I * R and I = E / R. (By the way, this is about the most complex math in this entire course.)

b. This is a resistor. It is about the size of three grains of rice laid end to end. It is FAR too small to print the value, so we use what is called the Resistor Color Code. You read a resistor from the colors TO the gold band. Here is the code: Black 0, Brown1, Red, 2, Orange 3, Yellow 4, Green 5, Blue 6, Violet 7, Gray 8, White 9. Gold indicates a tolerance from the marked value of +/- 5%/..

c. Let's read this resistor. First band is red, that's 2. Second band is violet, that's 7. Third band is brown, that is the number of zeroes to add, and that is 1 zero. That's a 270 ohm resistor plus or minus 14 ohms. That means that the resistor can read from 256 to 284 ohms to be within the allowable tolerance.



d. Turn the multimeter on. Turn the center dial to the Greek letter Ω (Omega).

e. Connect the 270 ohm resistor across the red and black leads. See later note about how to hold the resistor.

f. Determine that the resistor is within the tolerances we just calculated. Plus or minus 14 ohms. Obviously this resistor has an error of one ohm. That is WELL within the allowable tolerance.

g. Move the center dial to 200 ohms full scale. What does the meter read? It should show that the resistance is over the maximum reading of this scale (199 ohms).

h. Move the center dial to 20K (20,000 ohms). What does the meter read (and the value will be in kilohms. Note that the accuracy of the reading has decreased.

5. CURRENT

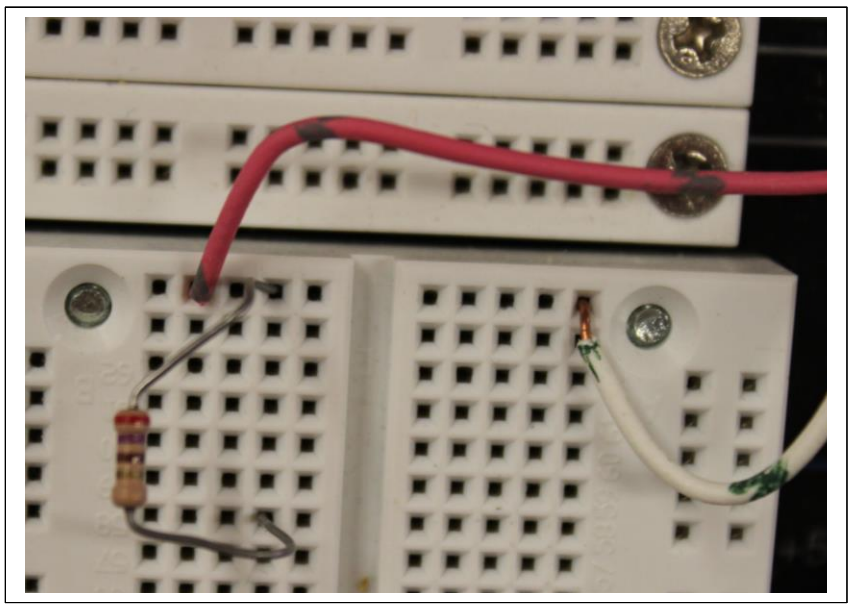
a. Current is measured in Amperes. In electronics, one-one thousandth of an ampere is a milliampere (i.e. 1000 mA equals one Amp). We rarely measure in Amps; milliamps are the stock in trade of an electronic project.

b. Connect one end of the 270 ohm resistor to one of the open pins on the +5 volt row. Connect the other end to any of the open 5-pin rows.

c. We are about to connect a milliammeter (milliamperes of current) to see if Ohm was correct. The current in a 5 volt circuit that a 270 ohm resistor sets should be about 18 milliamperes. Give or take a milliampere or two because of the resistor's tolerance.

d. Turn the red selector knob to the 20m DCA (Direct Current Amperes) ...Connect the red multimeter lead to the free end of the 270 ohm resistor.

e. Put a wire (no particular color) into one of the free holes of the black (ground) line of holes (the white wire in this image. Read the current. How does it compare to your predicted current?



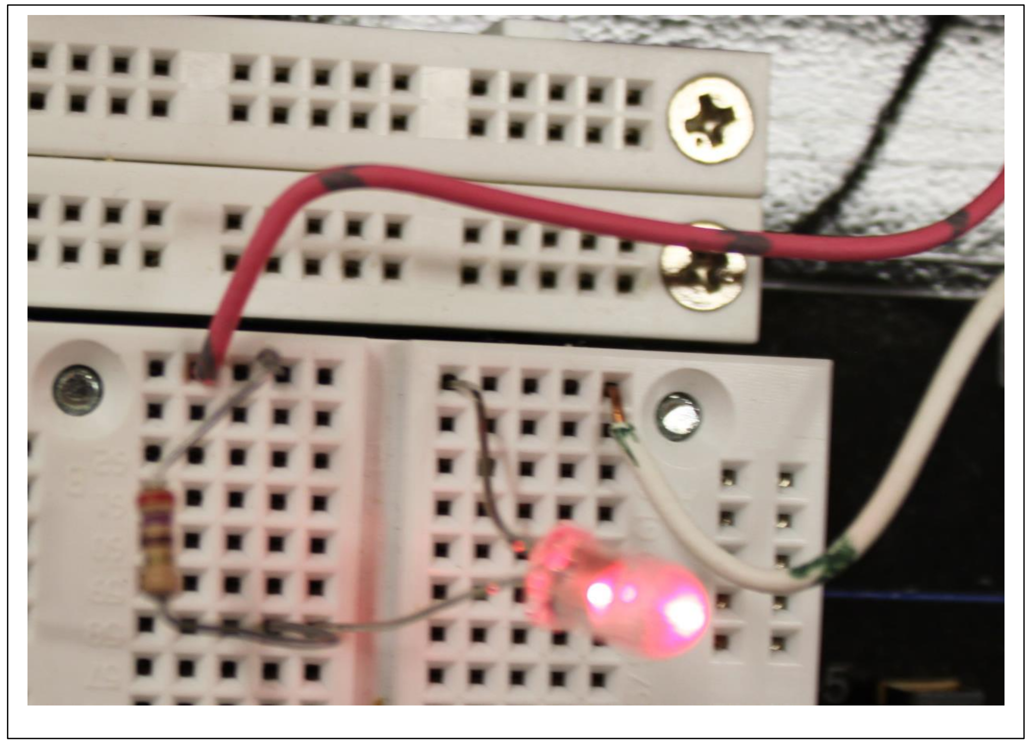
6. Light Emitting Diodes

a. As we learned in the Theory of Lesson #1, a light emitting diode (LED) is a device that when current is passed through it, emits visible light (or invisible in the case of the infrared and ultraviolet LEDs). We will do a thorough investigation of LEDs in a future lesson but for right now, let's just presume that what I said is true … pass current through an LED and it will light up.

b. We are going to light this LED with the 270Ω resistor providing the current-set, as applying a full 5 volts to the LED will **way** over exceed its ratings and (if it were heavier) would make it an excellent doorstop. The resistor sets the current through the LED within the limits of the LED.

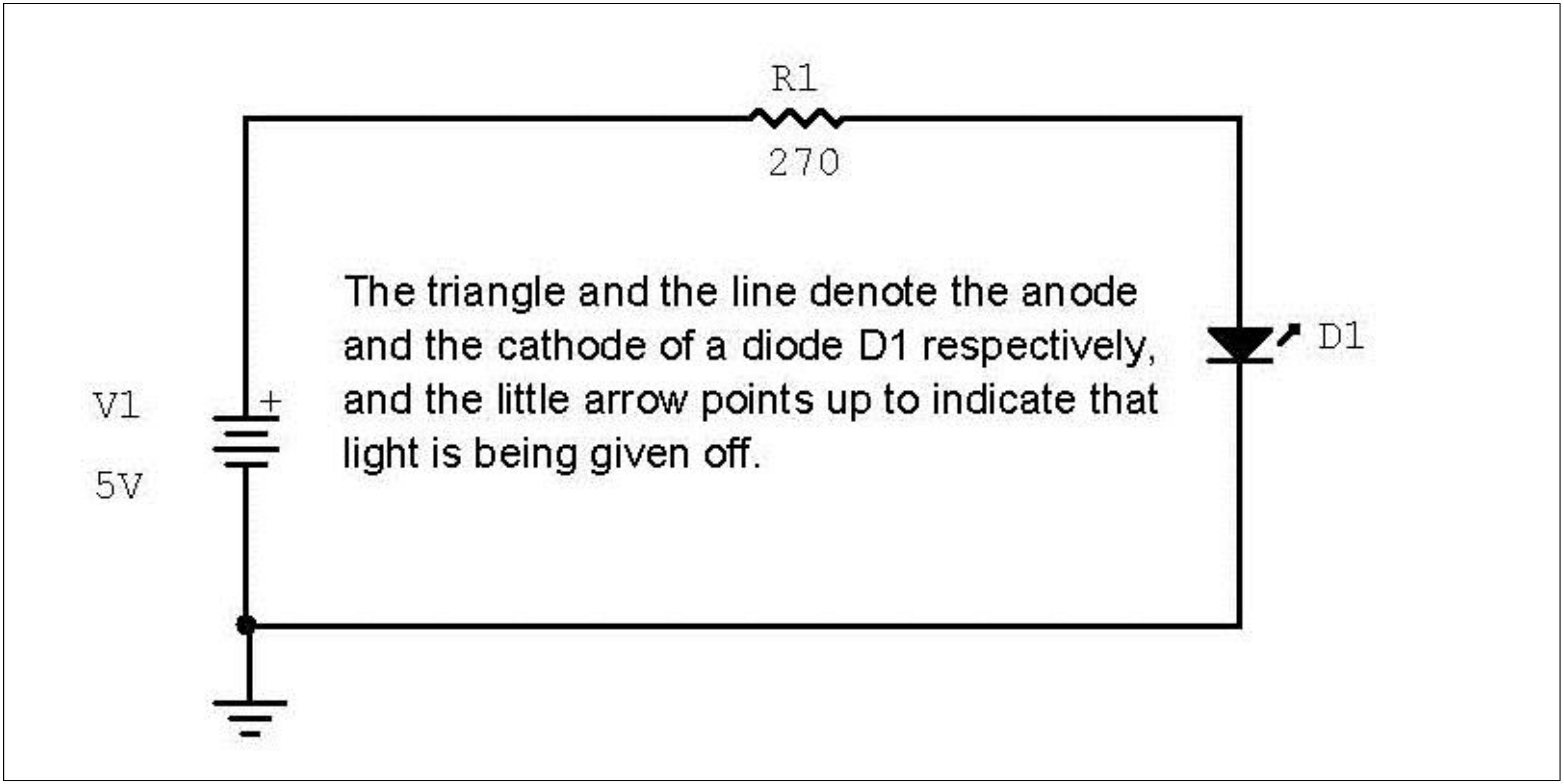
c. The LED has two terminal leads, the "anode" and the "cathode". The anode must be connected to the most positive part of the circuit and the cathode to them most negative for current to flow. The CATHODE is the lead on the "flat" side of the skirt.

d. Connect the ANODE side of the LED to the free end of the 270 ohm resistor. Connect the CATHODE side of the LED to the white wire (ground, negative) set of holes on the trainer.



e. Measure the voltage drop across the 270 ohm resistor. Calculate the current through the resistor (which is the same current through the LED) by the formula I = E / R. You should get something around 10 milliamperes.

f. Uh, oh. Here comes something new. On the next page is the SCHEMATIC DIAGRAM of what you just did.. A SCHEMATIC is a representation of the parts we all put together with symbols replacing the actual physical representation of the components.


R1
270
The triangle and the line denote the anode and the cathode of a diode D1 respectively, and the little arrow points up to indicate that light is being given off.
D1
V1
+
5V

7. Soldering and unsoldering.

   a. Soldering is done with a wire alloy of 60% tin and 40% lead combined with a core in the wire of rosin (pine tree sap) that acts as a board cleaner or detergent to remove any oxide from the parts being soldered together. Note that if the parts are dirty or greasy, the rosin will NOT clean them and the resultant joint will not be usable.

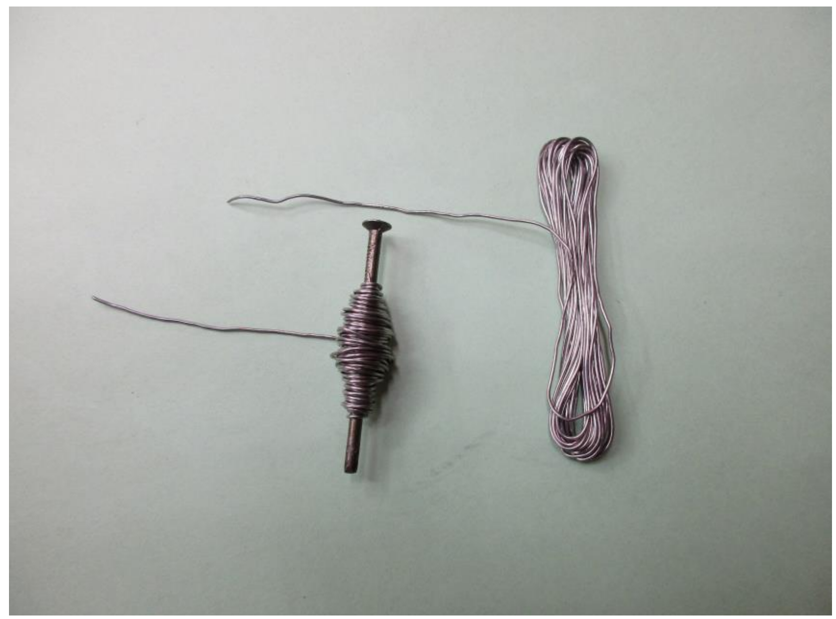
   b. Solder itself is very soft and pliable. It flexes and is generally difficult to work with in long strands.

   c. . Here is a good video on soldering: **https://www.youtube.com/watch?v=Qps9woUGkvI&spfreload=10**

TIP OF THE DAY

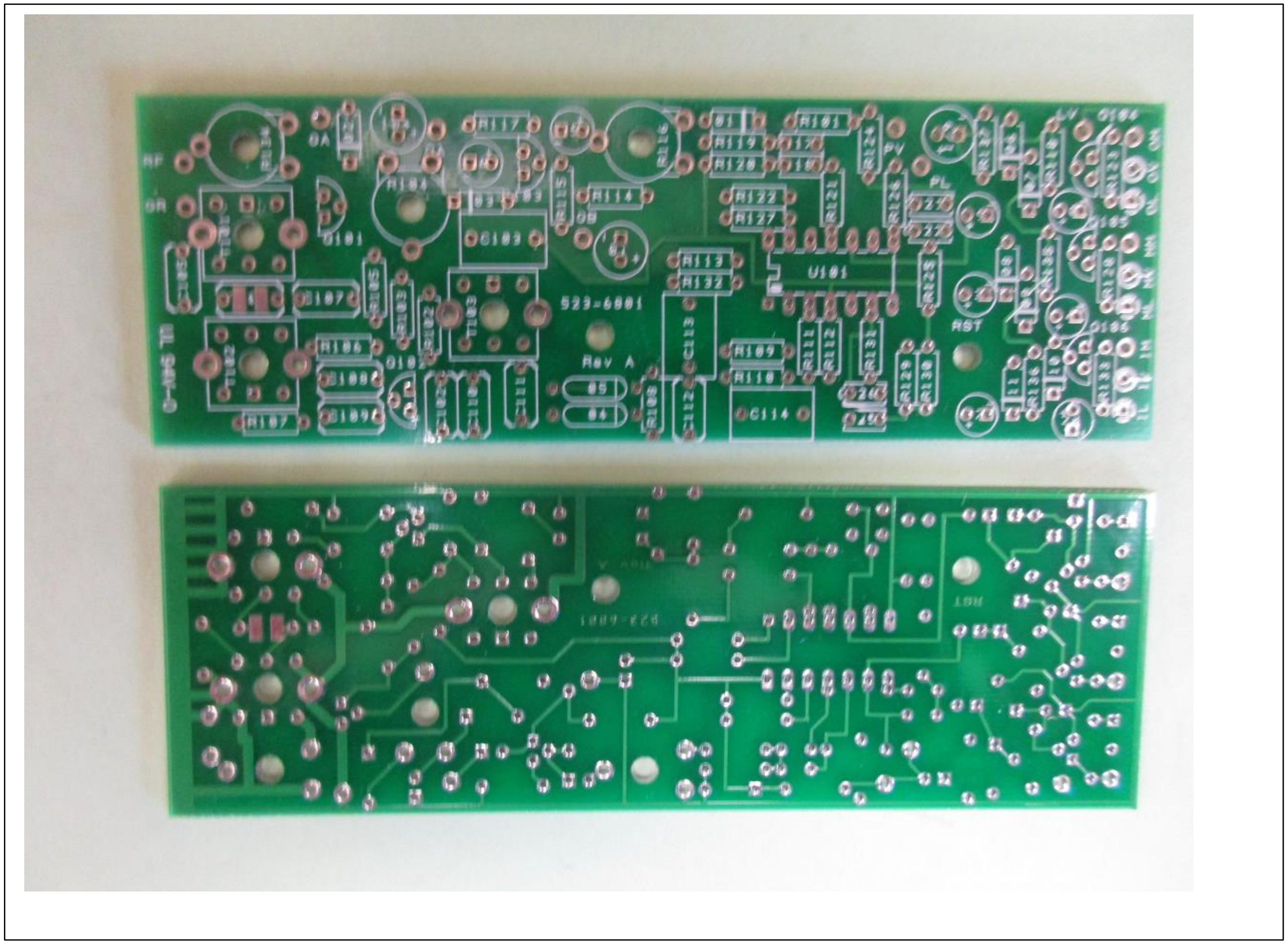
   d. If you wind a "hank" of solder onto a framing nail, it becomes a lot easier to work with. Grind the tip of the nail off to keep from scratching the table (or yourself) while working with it. **(When using the grinder in the machine shop, EVERYBODY in the machine shop must wear safety glasses.)**

   e. The soldering iron itself runs at temperatures from 400°F (200°C) to 800°F (400°C). In general, unless there is a reason to use another temperature, start off in the middle at 600°F (300°C).

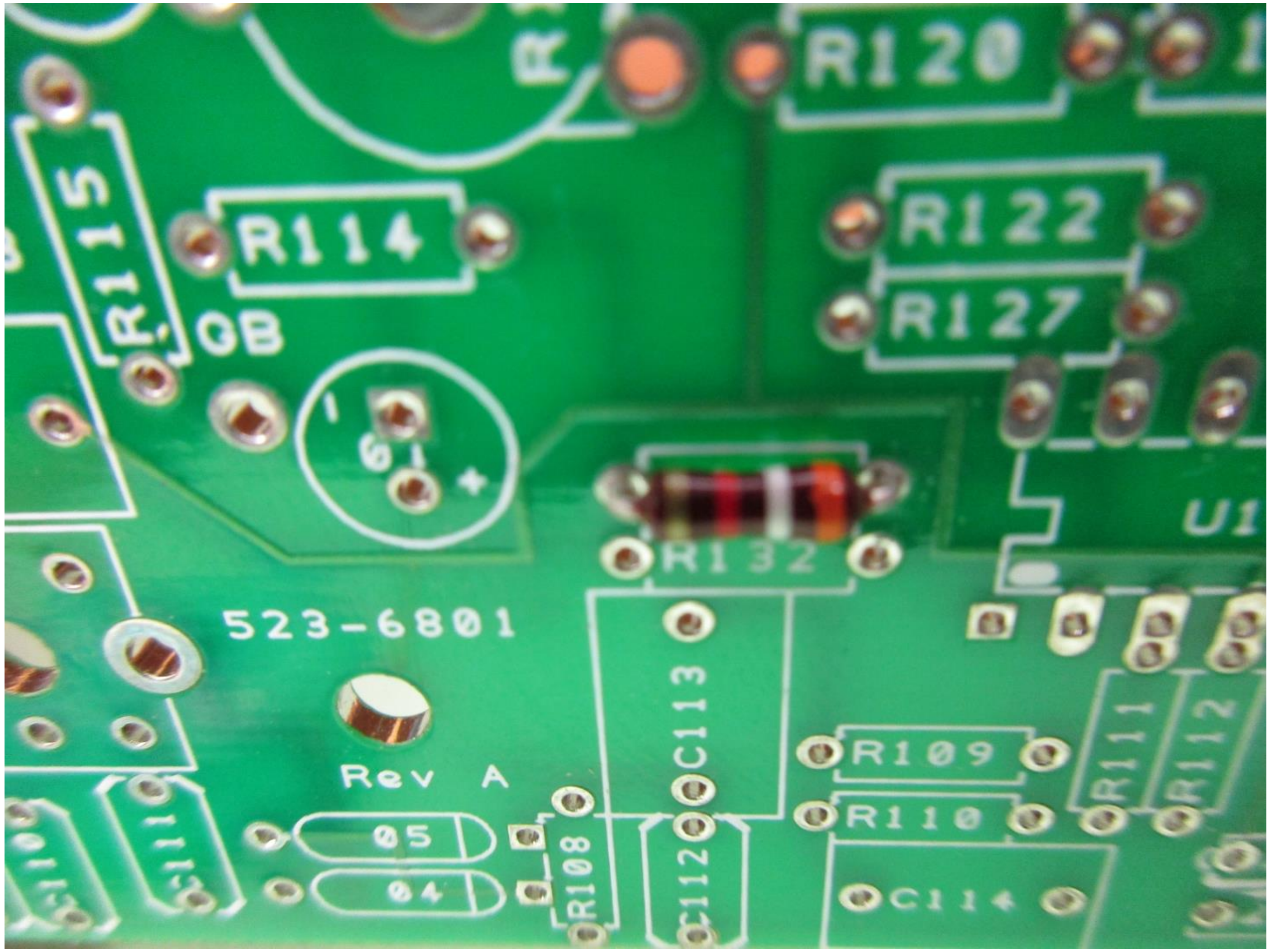


f. The tip of the soldering iron needs to be bright and shiny. To prepare the tip, first wipe the tip on the wiping pad or sponge to get rid of any soldering oxides or burned flux. The wiping pad (brass or copper wool) is used dry, while the sponge type needs to be DAMP (*NOT* soaking wet). Then melt a very small amount of solder onto the tip and wipe it again.

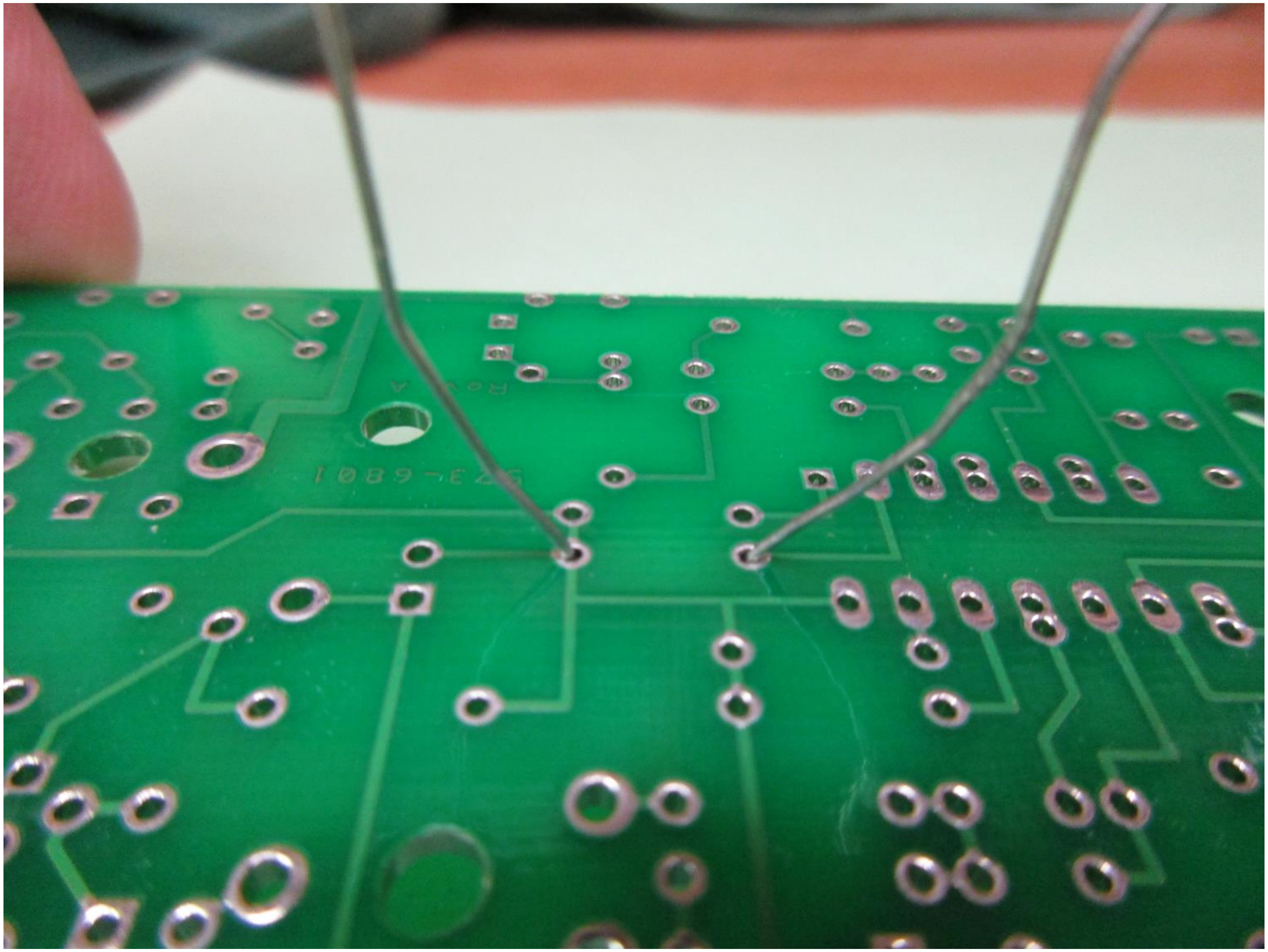
g. PC Boards generally have two sides. There is a side with white ink and shapes with the part number inside of the shape. We call this side the "component" side. The other side of the board has small silver-colored holes where the part is soldered onto the board. We call this side the "trace" side. The silver-colored holes are actually copper holes with solder plating on the copper, ready to have components soldered onto the holes. We call this "through hole" type boards, as opposed to "surface mount" where the part is soldered to the copper trace without a hole. We will see surface mount much later in the semester, but not now.



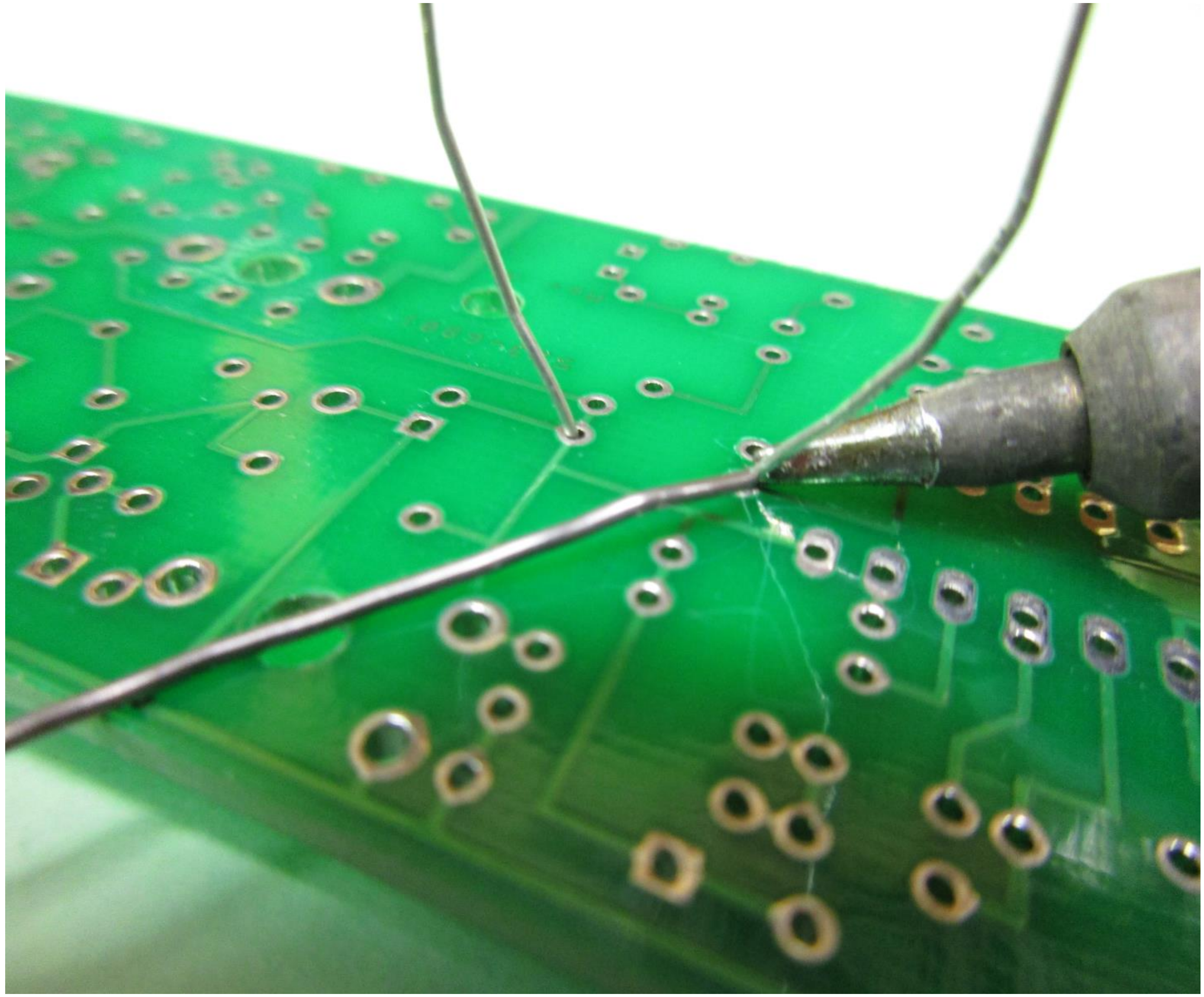
h. he idea is to mount the component on the COMPONENT side of the board with minimum spacing between the component and the board, with the component wires going through the holes provided.



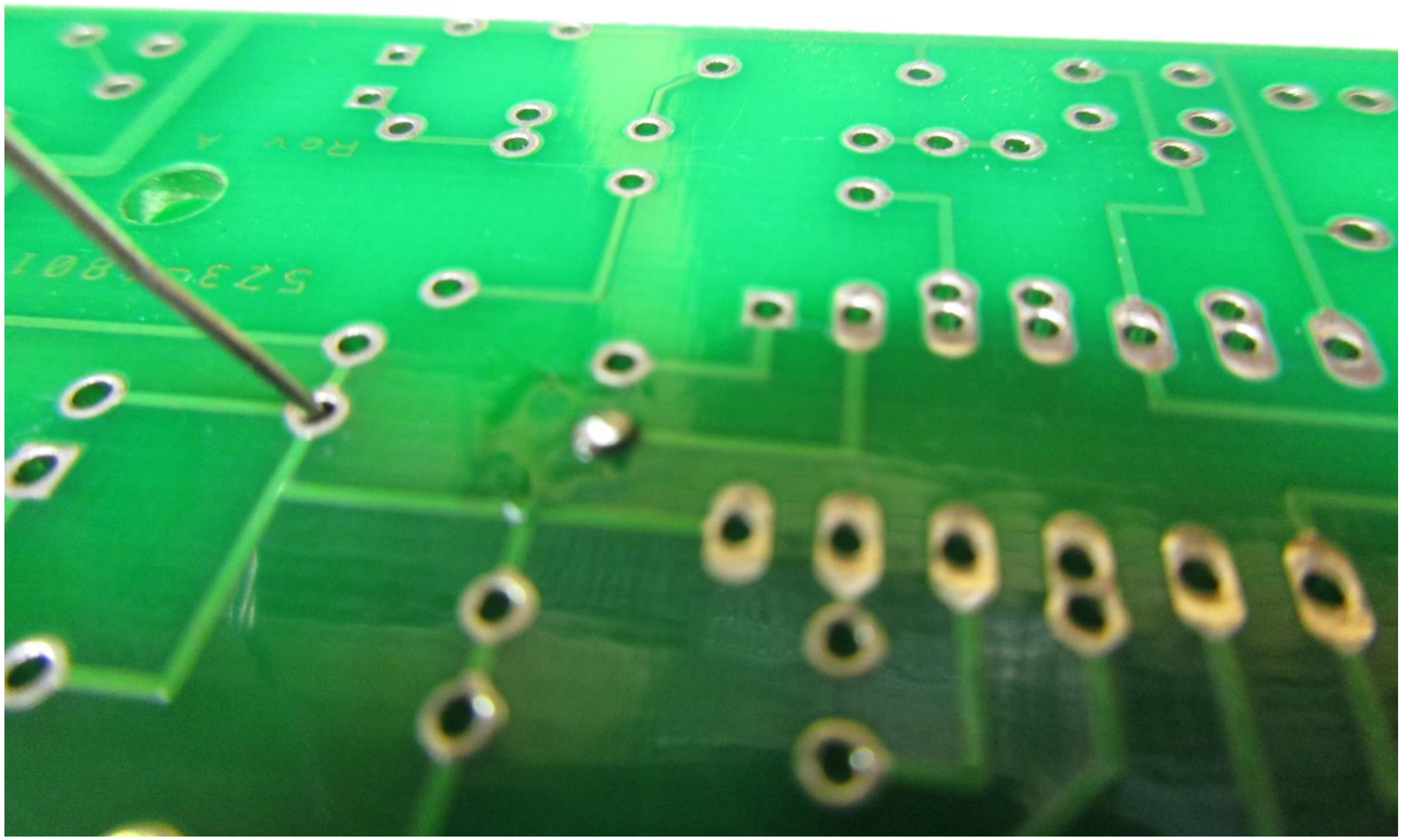
i. Component leads go through the holes in the board and are bent out at a 45° angle to keep the part from falling out of the board.



j. The hot soldering iron tip is brought in from one side of the joint, the solder is brought in from the other, and THE JOINT IS HEATED so that the solder melts onto the joint, not the iron.



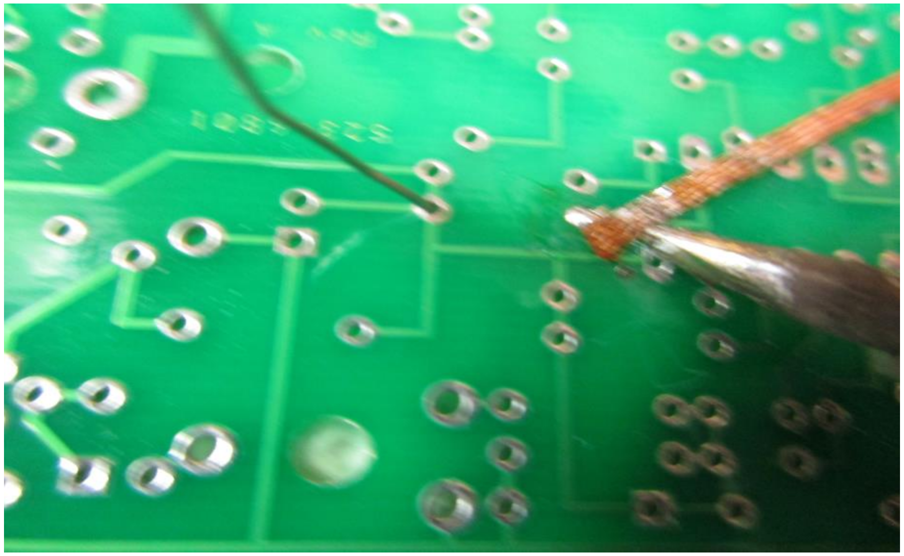
k. A nice round joint of solder is inspected, the excess lead cut off, and you move on to the next joint.

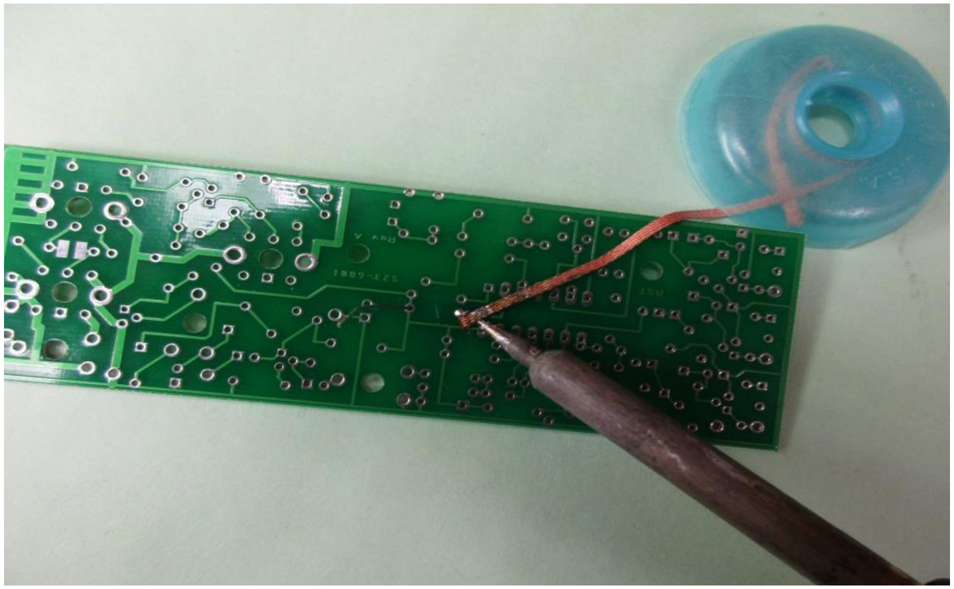


l. OOPS, you put the wrong part into the holes. Not to worry. Desoldering braid to the rescue. Desoldering braid is just copper braid soaked in flux. The solder on the joint is MUCH happier to wick up into the braid than stay on the joint.

It sounds easy. It isn't. Generally, two people have to be in on the operation. One to wick off the old solder and keep the joint molten and the other one to pull on the part to get it out of the hole.

m. EXERCISE: Take an old surplus PC board. Solder one junk part on the board. Have your lab partner remove it. Have your lab partner solder a junk part on the board. Remove it.





Project 1 - LED Flashlight

A. LED Flashlight

The LED flashlight is what we call a "complete circuit". It has the four basic elements found in all electronic circuits -- **Source, Load, Conductors, Control.**

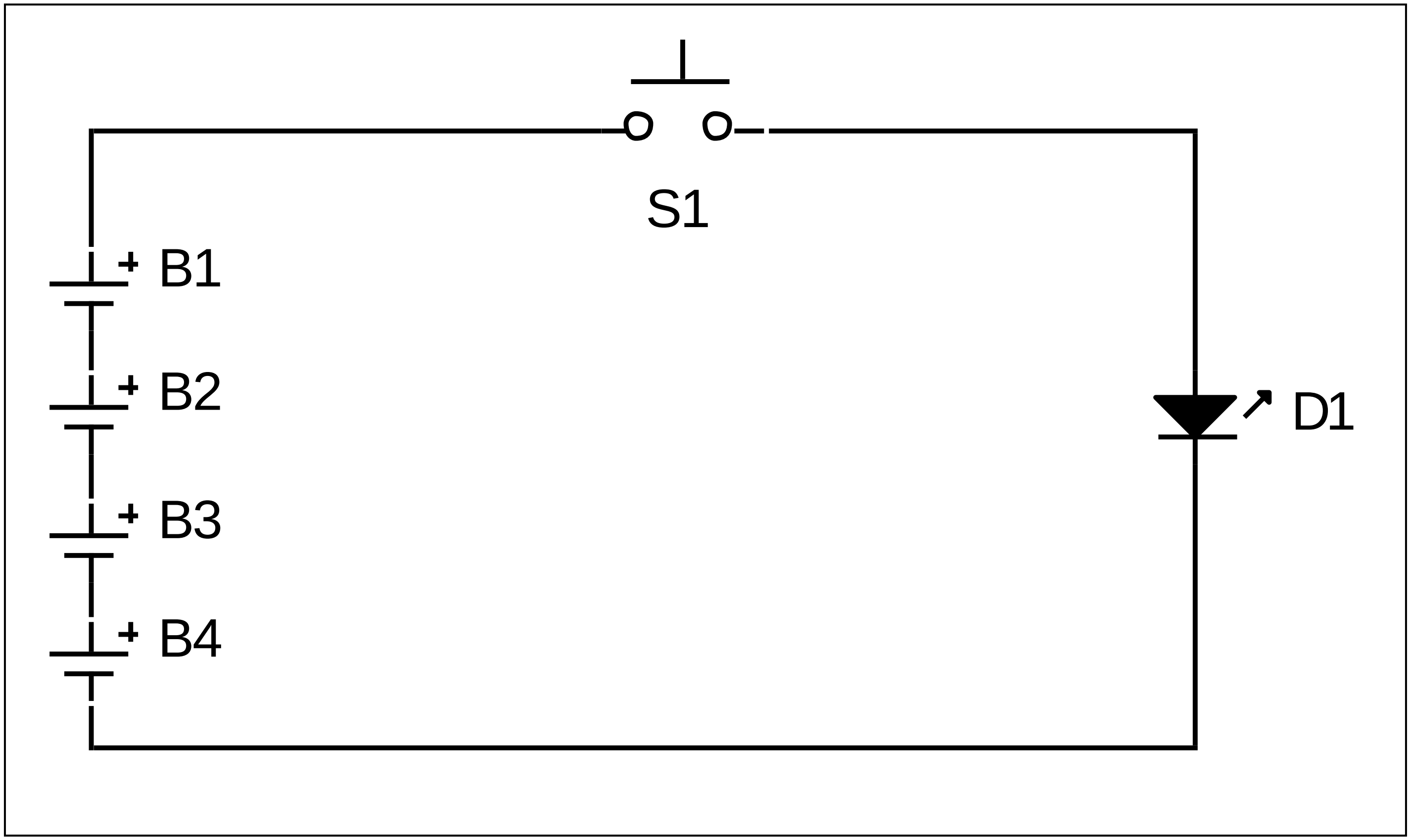
The SOURCE is the device(s) that supply electrons to do the work. In this case it is four small "wristwatch" size batteries connected in *series* (head-to-tail). Note that the plus terminal of B2 is connected to the minus terminal of B1 and so forth. Each cell has a 1.5 volt output and ***cells in series add voltage.*** Thus the voltage that you would measure from the (+) plus terminal of B1 to the (-) negative terminal of B4 would be 6 volts (1.5 plus 1.5 plus 1.5 plus 1.5).

The LOAD is the device that is intended to do some useful function. In this case it is the Light Emitting Diode D1. D1 is a WHITE LED that is really a blue LED with white phosphor painted over the top of the diode. The LED will draw about 70 milliamperes from a 6 volt source.

The CONDUCTORS are the tin coated copper traces on the fiberglass PC board. Copper is the SECOND best conductor known (silver is the best). However, copper corrodes (why?) in air to form a greenish-blue copper sulfate (looks pretty on roofs but doesn't work worth a darn for electronics). We coat the copper with tin which will not corrode.

The CONTROL is the device that connects the source to the load through the conductors. In this case it is pushbutton switch S1.

A switch (in general) is nothing more than two CONDUCTORS that may be pressed together to *make* a completed circuit (on) or separated to *break* an incomplete circuit (off).



Assembly

1. Check your kit to be sure that you have all the parts listed. If you are missing parts, ask for help. As a matter of fact, if you have ANY doubts at all about any of these steps please don't hesitate to ask for help. **CIRCLE ☺ EACH STEP AS YOU COMPLETE IT!!**

☑	Reference Designator	Part Value	Description
	B1-B4	1.5 volt alkaline button cell	Small round watch size battery (quantity 4)
	D1	White LED	Water clear plastic domed top with two wire leads
	S1	SPST Normally open switch	Rectangular boxcar shaped object with a white button on top and two leads coming down the long ends of the box.
		Printed circuit board	Predominantly green flat rectangular board with a rectangular cutout at one end and a drilled centered hole at the other end.
		AG3 battery holder	Round metal clip with a rectangular cutout on the top, a tab coming out one side of the round section and a bent DOWN tab coming out the other side of the round section, and two solder tabs coming out of the bottom of the clip.
		Heat shrink sleeving	Clear plastic tubing about 2" long and ¾" in diameter
		Split ring, 9 mm	Round "key ring" for attachment to … a key ring

2. Examine the PC board. One side has white lettering and we will call this the "component" side. We will call the other side the "bottom" or back side. On both the component and the bottom side there is a fairly large round "pad" or metal trace in the general location of B1, B2, B3, and B4. Use a pencil eraser VERY LIGHTLY to remove any contamination from these round pads. Clean the board with alcohol and a paper towel when you are through erasing the contamination.

3. Inside of the rectangular cutout on the top of each battery holder there is a small metal tab. Press this tab EVER SO SLIGHTLY down so that the battery will make good contact with the clip. About one metal thickness of depression is enough.

4. Solder the four battery clips to the board at B1-B4 **one at a time**. There will be two battery clips on the component side of the board and two clips on the bottom side of the board. Please note:

a. Note that both metal tabs extending OUT from the circular section of the clip face towards the OUTside of the board, and both metal tabs extending DOWN from the circular section of the clip face INWARD towards each other. If one clip touches the other clip, you have the clips in backwards.

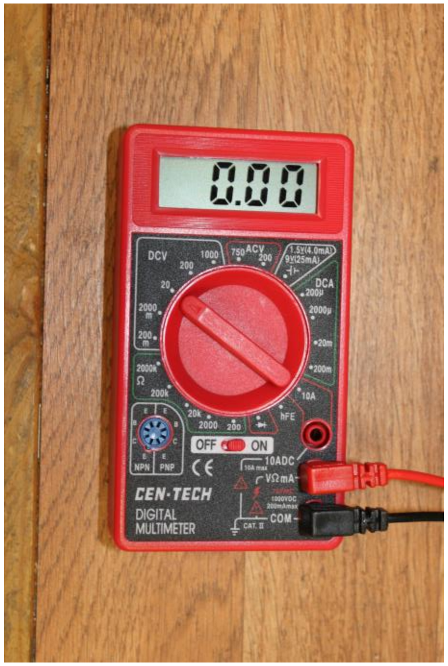
b. Put a battery clip into the holes on the board, turn the board over, and have another student lightly press down on the PC board while you solder the leads to the backside of the board. The clips have to be soldered so that they are as close to the board as possible AND the leads of the clip have to extend THROUGH the hole so that they can be soldered on the BACKSIDE of the board. It may help to slightly straighten out the leads instead of being bent at a right angle.

5. Insert the switch onto the component side of the board and press the switch into the holes in the board as far down as the switch will go. Keep pressure on the switch while you solder it in place.

6. Stop here and have the instructor or lab tech inspect your work.

7. Cut (using diagonal wirecutters, colloquially called dikes) the leads of the LED so that 0.1" (100 mils) of the lead is left on the LED. This should be JUST BARELY on the LED side of the little "square" part of the wire lead. For reference, the pc board is about 50 mils thick. Bend the leads on the LED very slightly towards each other.

8. Note that there is a "flat" spot on the skirt of the LED plastic case. This flat is generally (but not always) the cathode of the diode. Insert the LED into the rectangular cutout on one end of the pc board with the flat (cathode) on the COMPONENT side of the board. Push the LED into position so that the bottom of the plastic case touches the pc board and the leads are on the small square solder pads. Solder the leads to the pads.



9. You have four batteries supplied to you for the flashlight. Take each one of them and measure their voltage. You do this by taking the end of the BLACK lead with the pointed probe and putting the point in the middle of the ROUNDED side of the battery and the RED lead pointed probe in the middle of the FLAT side of the battery. (It helps to have your lab partner hold the battery while you make the measurement. Record the battery voltage here:

a. Battery 1 ______ Battery 2 ______ Battery 3 _____ Battery 4 ______

b. Now REVERSE the probes (black to flat side of battery, red to rounded side of battery) and take the measurement again. Be careful to note the difference in the sign of the voltage (+ or -):

c. Battery 1 ______ Battery 2 _______ Battery 3 _____ Battery 4 ________

Question -- did the measurements CORRELATE? That is, except for sign was the voltage of each battery the same (out to ± 1 digit in the rightmost decimal place).

e.. Now switch the range of the meter to 2000m (2000 millivolts which is also 2 volts) and remeasure the batteries. You got another decimal place worth of accuracy, but did the decimal places you originally had change at all?

Battery 1 ____________ Battery 2 _____________ Battery 3 _____________ Battery 4 _____________

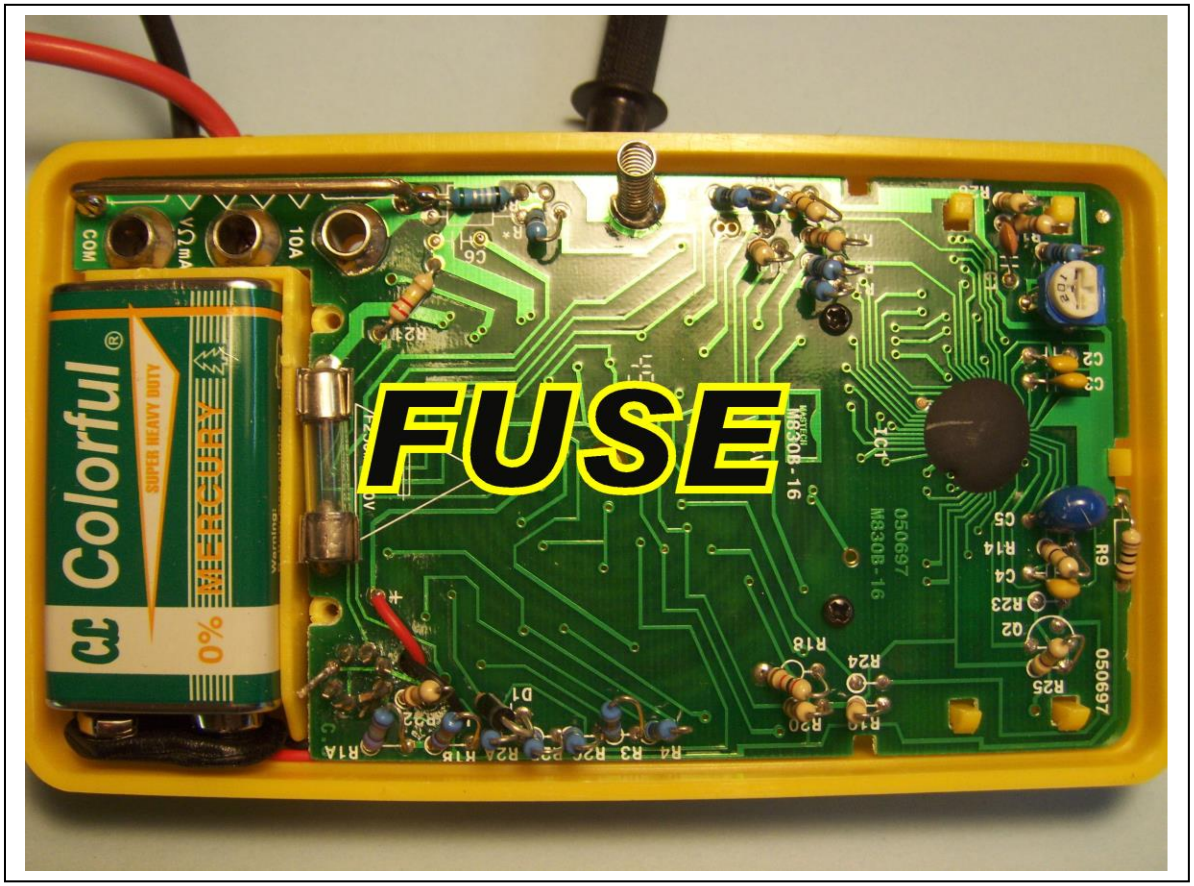
9. Insert all four batteries into their holders. Do not use a great force to insert them; if they don't fit in fairly easily, ask for help. Note that the small "button" part of the battery faces the PC board. There may or may not be a plus (+) sign on the side of the battery that touches the battery clip.

10. Test the flashlight by pushing on the switch button. If the flashlight doesn't light, or is noticeably dimmer than other flashlights, ask for help (it is generally a battery in backwards).

11. Every now and again (and I don't encourage it) you will forget to switch from current to voltage when taking a reading. It happens. It happens to me as well as you. I've done my share of fuse-popping over the years and it is no shame to admit it.

What IS shame is to know that you did it and put the meter back into the stock box knowing that the next person will find a dead meter. That's majorly uncool. **If your meter has digits displayed but refuses to show voltage and/or current, the odds are nearly 100% that the fuse is blown.**

A blown fuse will GENERALLY have a white coating of vaporized element, but not always. If you think you have a blown fuse, call the instructor over and they will measure the fuse and determine good or bad. Here is where the fuse is (you will have to take out the two phillips head screws in the recessed holes to get the back off the meter):



11. Put the multimeter into the 200m (200 milliamperes full scale) on the DCA side of the multimeter

12. Measure the current being drawn from the flashlight by putting one lead (it doesn't matter which one) to the solder joint on one side of the switch and the other lead to the solder joint on the other side of the switch. The LED should light and the current should be somewhere around 70 mA.

13. Slide the shrink sleeving over the assembled flashlight so that it covers the battery clips on one end and at least the leads of the LED on the other end. Mark where the switch button is with a pen or pencil.

14. Remove the shrink sleeving and make a cut on your pencil line about 0.25" long going in the long direction of the switch body (this will be a cutout for the switch). Use a hobby (exacto) knife to make the cut. For reference, the switch body is about 0.25" long.

15. Place the shrink sleeving back onto the assembled flashlight with the cut line directly over the switch. Use a heat gun to shrink the sleeving onto the flashlight. The switch body should fit into the cutout in the sleeving. This sleeving insulates the entire flashlight from short circuits (like metal keys in your pocket).

16. Place the two split-rings "in series" through the hole in the end of the board. Test the flashlight one more time.

TROUBLESHOOTING

Things do not always go according to plan. In general, the odds of a circuit working "first time" go as 1/n, where n is the number of components in the assembly. In this LED flashlight case we have four batteries, one switch, and one LED. The odds of this circuit working is therefore about 1 chance in 6, or a probability of 17% that it will work just as you assembled it.

You can cut down on these odds by being very careful during assembly, by doing an optical inspection prior to soldering, and by reading the instructions twice before assembling the parts.

To troubleshoot the flashlight, we will define 6 test points on the board, TP0 through TP5. We will use a digital voltmeter to find out where the circuit is not being complete.

First, solder a short bare wire to TP0 (the cathode of the LED). We will call this the "common" point and we will measure all voltages with respect to this common point. Each battery will add "about" 1.6 volts to the series string of batteries B1 through B4. We say "about" because we really don't care if it is 1.5 or 1.7, what we are really looking for is a break in the circuit where the voltage goes to "about" zero. Again, we don't care if it is 0.1 volts or zero, what we care about is that it is a drop from the prior test point. This points to either a break in the circuit (if it goes to zero) or a reversed battery (if the voltage DROPS from one test point to another).

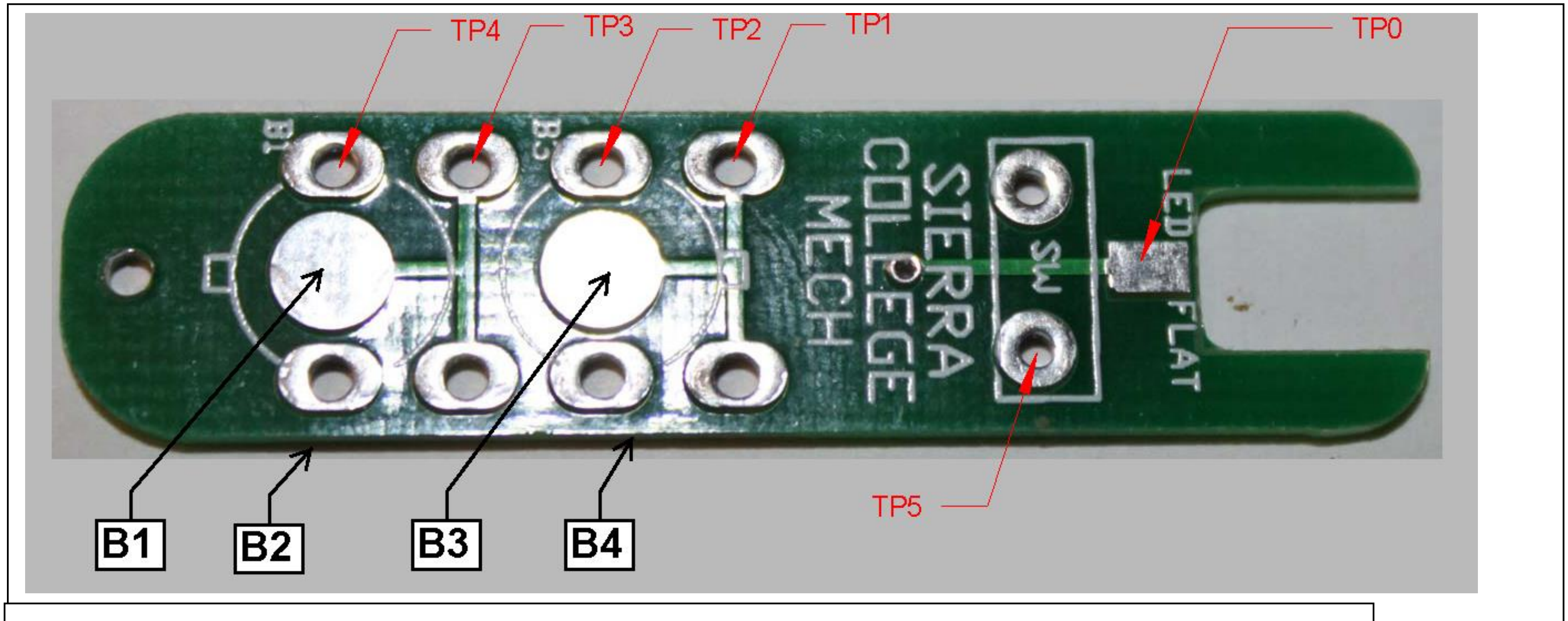
With respect to TP0, here are what the test point voltages should be:

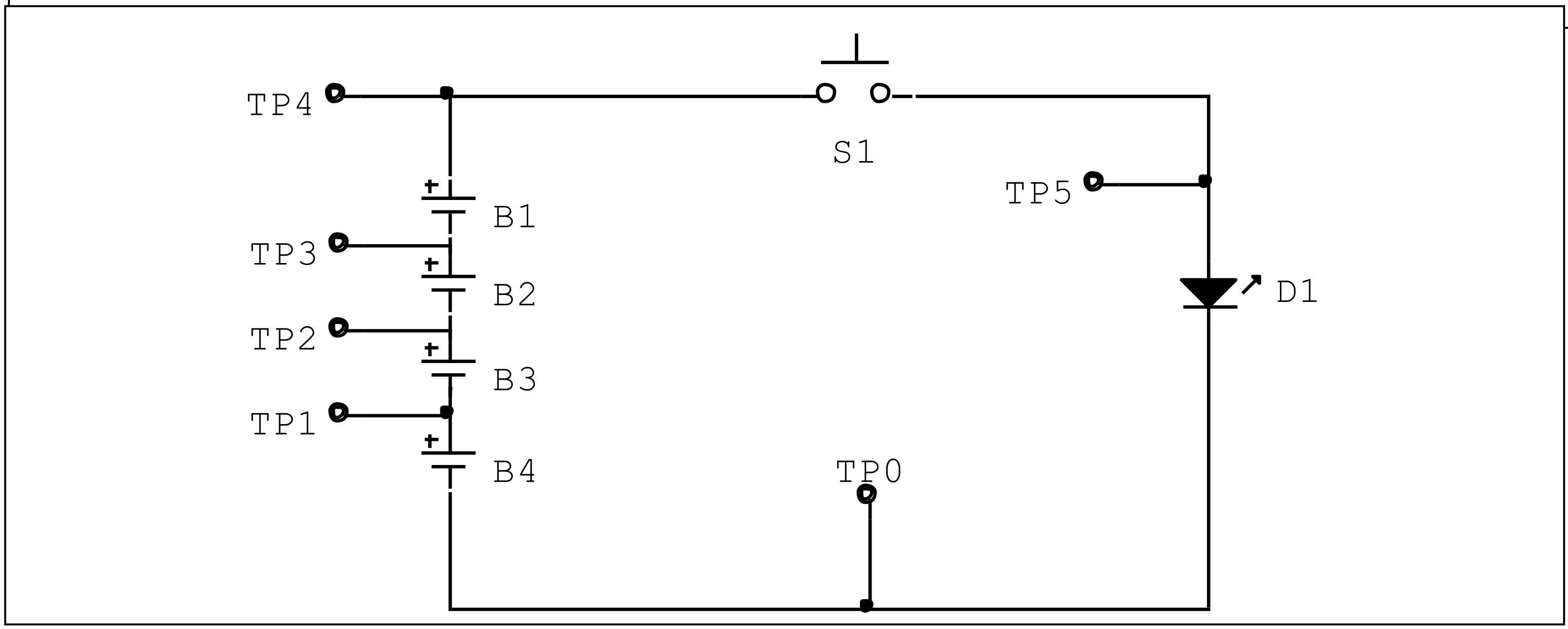
TP1	TP2	TP3	TP4	TP5
Switch open	Switch open	Switch open	Switch open	Switch closed & lamp lit
1.6 volts	3.2 volts	4.8	6.4	3.6

There are many techniques for troubleshooting, but the one I find most efficient is called the "binary" technique. You split the circuit into halves. You test right at the half point for the correct voltage. For example, in this simple circuit I'd go straight to TP3. If the voltage at that point is "about" good, then we know that TP1 and TP2 are going to be good also. Then to TP4 to split in half again, midway between TP3 and TP5. Then all that is left is TP5.

For example, if TP3 is "good" and TP4 is zero, then we can most assuredly say that battery B1 is either dead (not likely) or the battery clip holding B1 was not properly soldered. A little poking and prodding around B1 should reveal why this battery is the problem.

What I do NOT recommend is jumping around randomly to test points without thinking about what the reading means. This will double or triple your troubleshooting time, and the boss is not generally pleased when you take twice to three times as long to fix a problem as the other technicians.


TP4
TP3
TP2
TP1
TP0
B1
B3
SIERRA
COLLEGE
MECH
SW
LED
FLAT
TP5
B1
B2
B3
B4


TP4
S1
TP5
B1
TP3
B2
D1
TP2
B3
TP1
B4
TP0