Experiment 1 - LED Flashlight & Digital Multimeter

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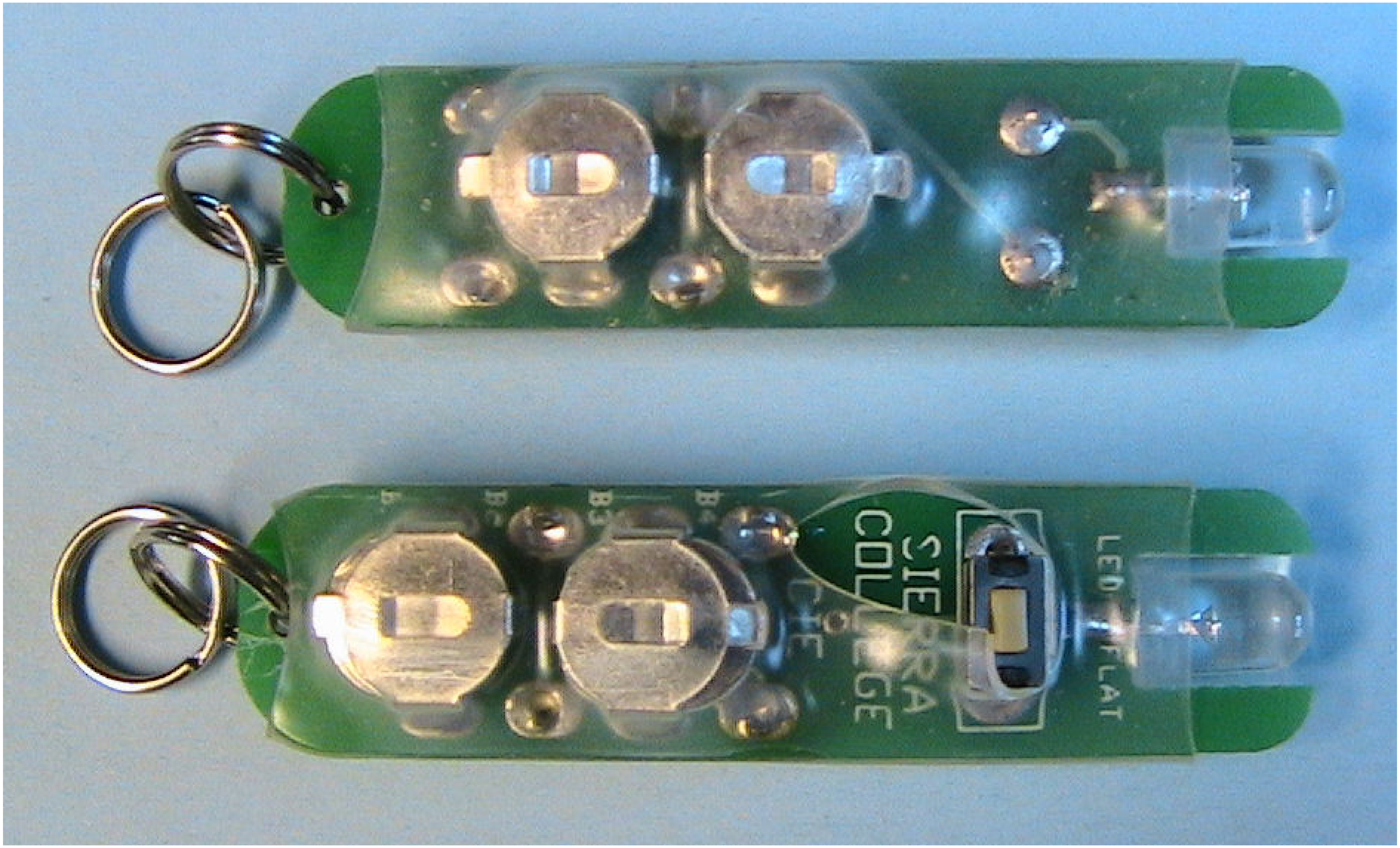
A. LED Flashlight



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.**

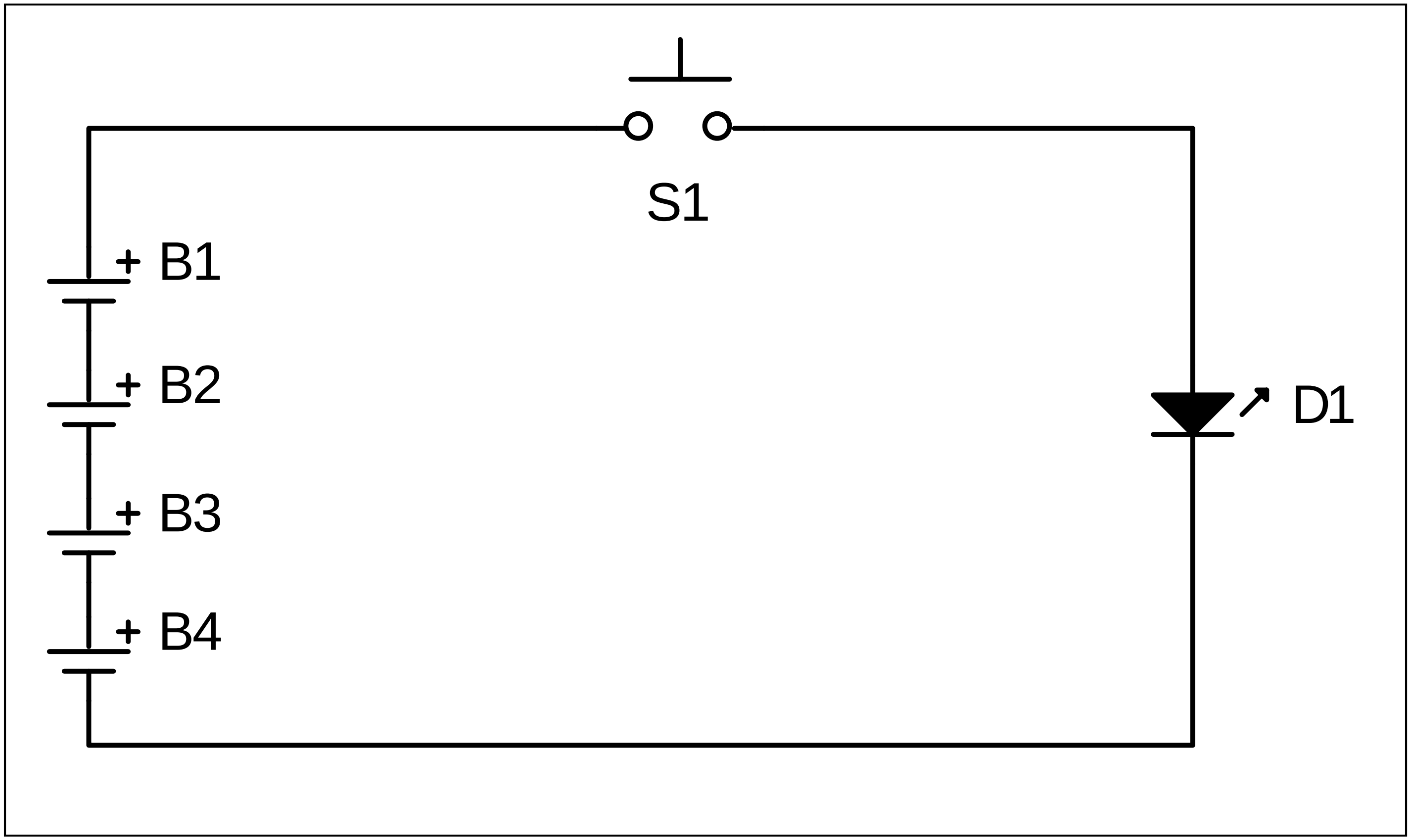
The SOURCE is the device(s) that supply electrons to do the work. In this case it is four small "wristwatch" size batteries connected in *series* (head-to-tail). Note that the plus terminal of B2 is connected to the minus terminal of B1 and so forth. Each cell has a 1.5 volt output and ***cells in series 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.

Digital Multimeter

1. A digital multimeter measures (at a minimum) voltage - volts, current -amperes, and resistance - ohms. It generally will measure a few more things that we don't really care about right now. It looks something like this:

2. The multimeter as shown will measure VOLTAGE with the switch in the DCV (direct current - voltage) with a full scale reading of twenty (20) volts. It has full-scale capability of 200 millivolts (0.2 volts) to 1000 volts.

a. 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:

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 -):

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).

c. 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 ___________

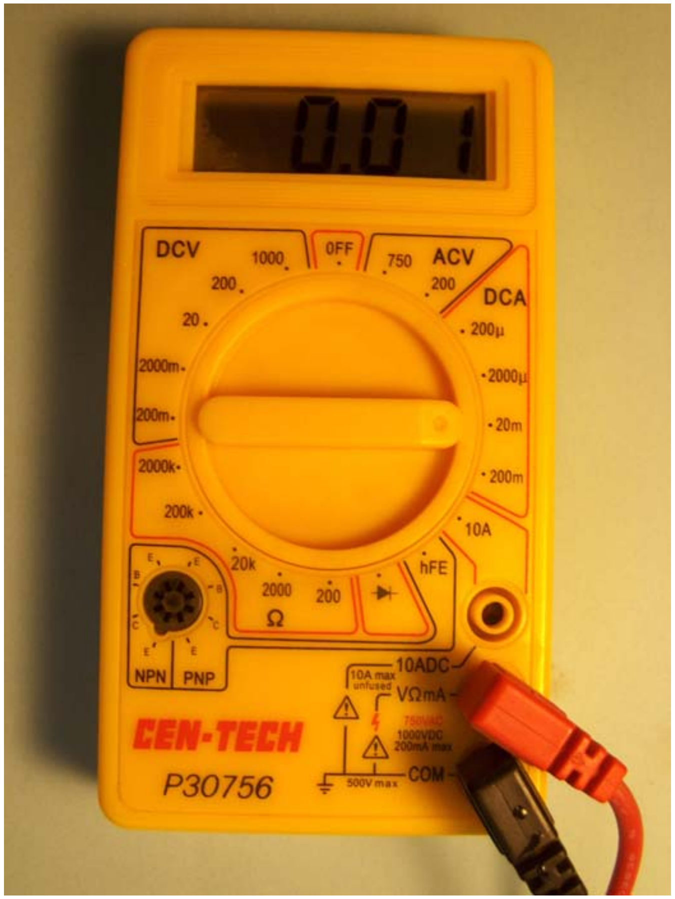
(multimeter continued on the next page)

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)..

(multimeter … continued)

3. The multimeter will measure CURRENT (amperes) in the DCA position of the range switch. In the DCA mode the meter will look like this:



4. The multimeter will measure current from 200 microamperes (0.000002 amperes) to 200 milliamperes (0.002 amperes). A separate unprotected range of up to ten AMPERES is available at the connector just above the red lead. As shown, the multimeter will measure current up to 20 milliamperes (abbreviated mA) full scale.

a. Put the multimeter into the 200 mA full scale position. Without pressing the switch, measure the current drawn by the LED by measuring current ACROSS the open switch. Record your measurement here (did the LED light?):

Current ___________________ ________________ (microamperes, milliamperes, or amperes?)

b. If the current is less than 20 milliamperes, switch the multimeter to the 20 mA scale and retake the measurement above:

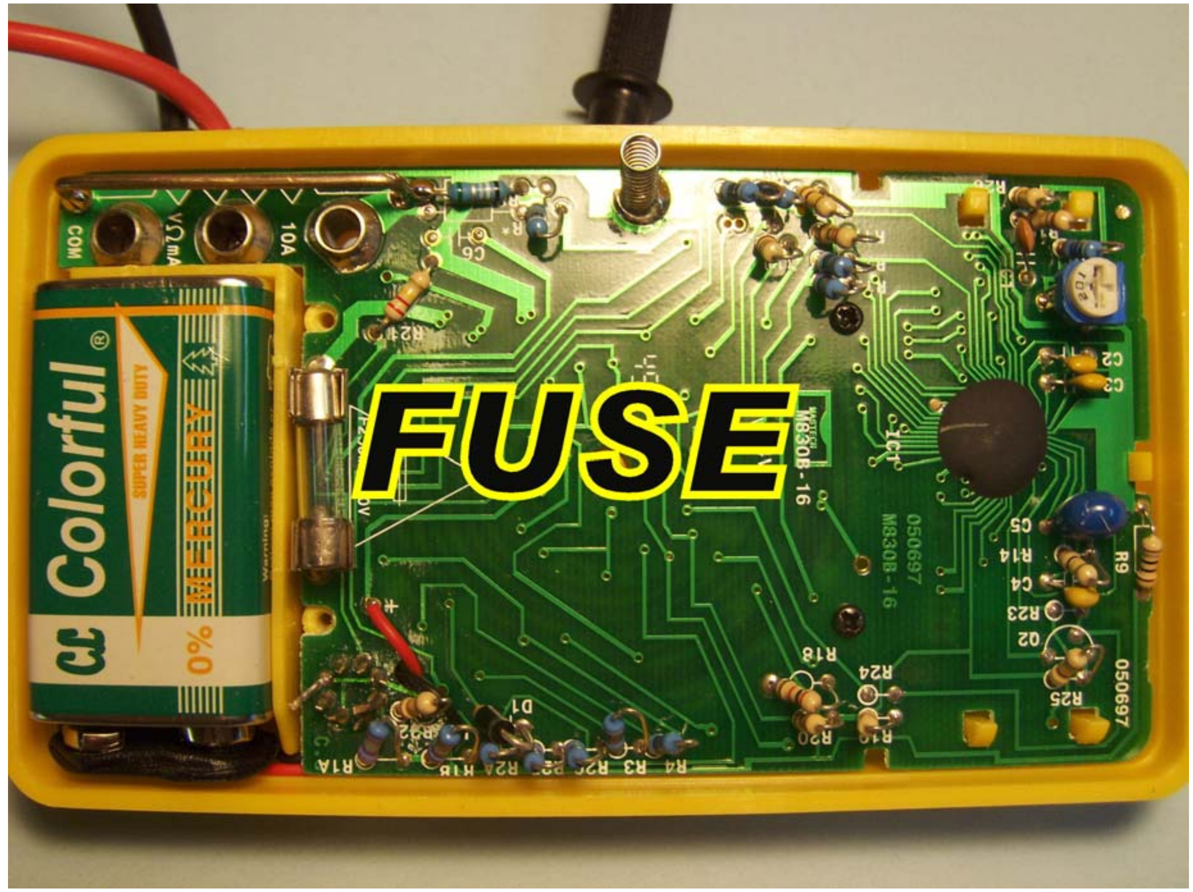
Current ___________________ ________________ (microamperes, milliamperes, or amperes?)

c. Put the multimeter back into the DCV position, 20 volts full scale. With your lab partner pressing the switch, record the voltage across the LED when lit. This is called the "LED operating voltage".

Voltage ___________________ ________________ (microvolts, millivolts, or volts.)

5. 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):



6. ***Turn the meter "OFF"***.

11. 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.

12. 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.

13. 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).

14. 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).

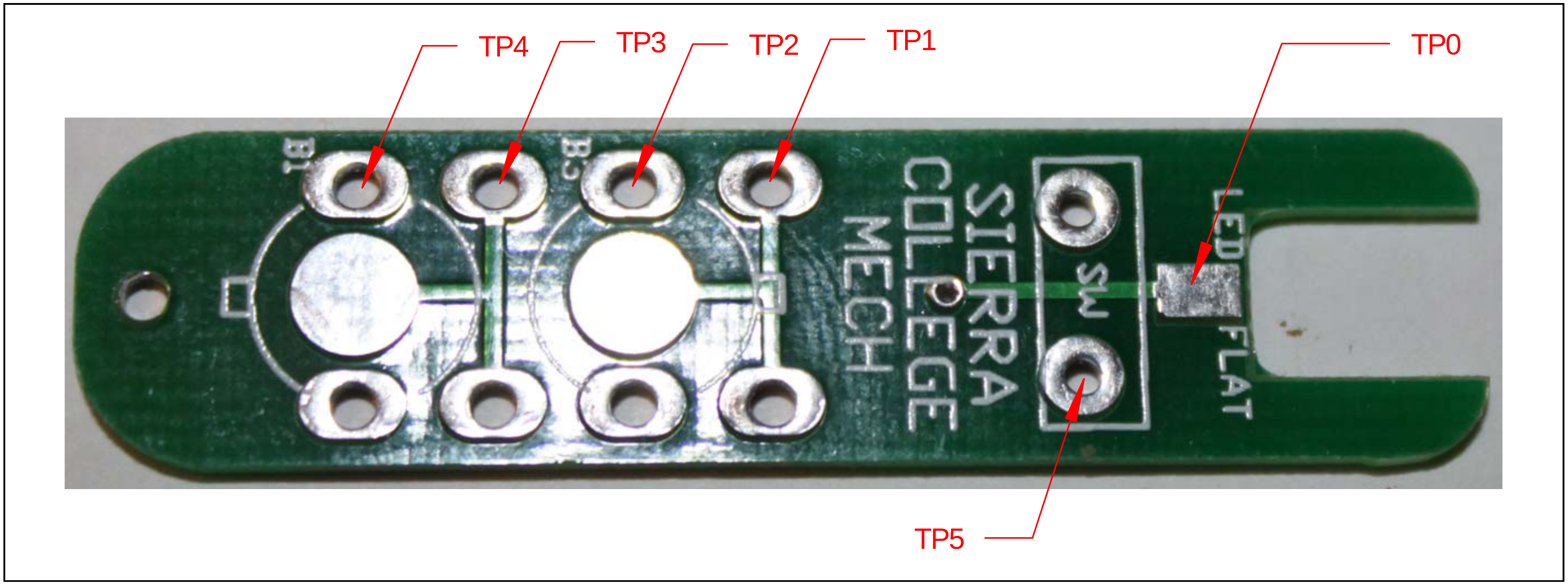
With respect to TP0, here are what the test point voltages should be:

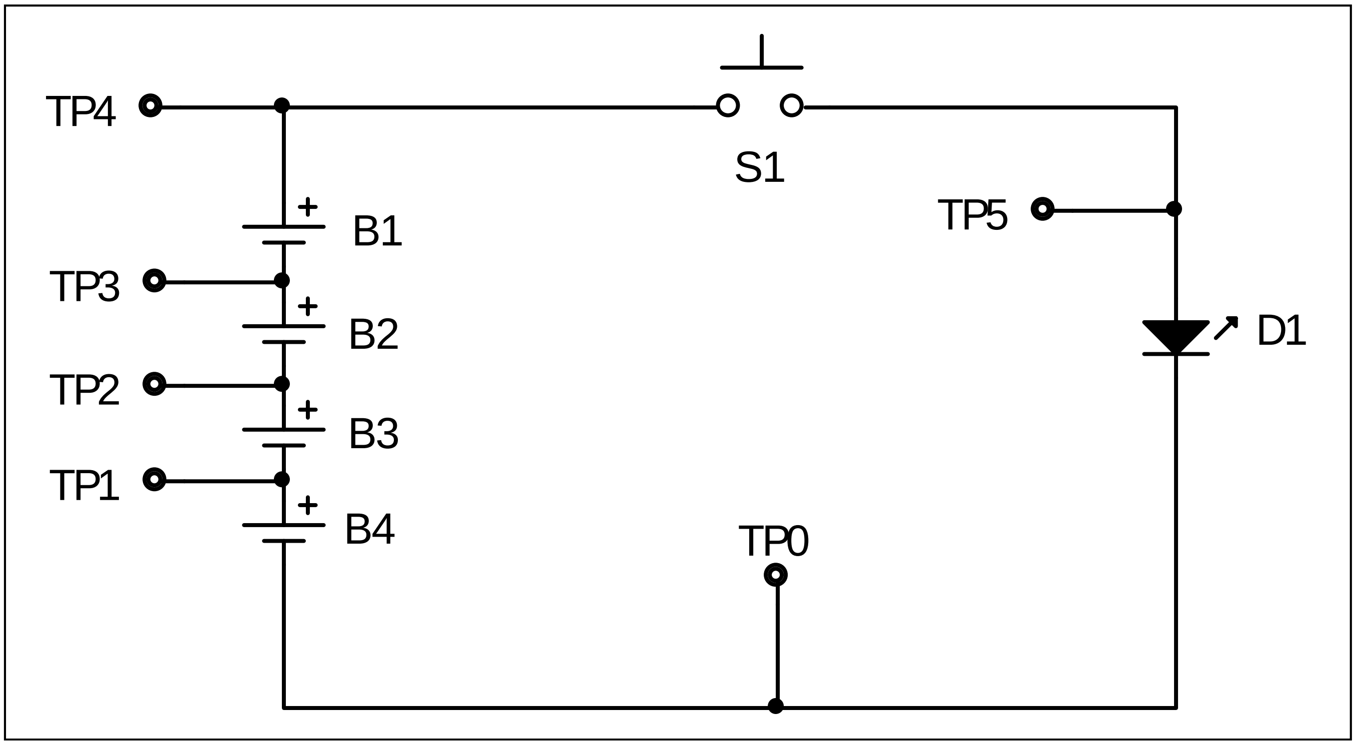
TP1	TP2	TP3	TP4	TP5
Switch open	Switch open	Switch open	Switch open	Switch closed & lamp lit
1.6 volts	3.2 volts	4.8	6.4	3.6

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
TP5
SIERRA
COLLEGE
MECH
SW
LED
FLAT


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