Homemade LED Flashlights from PVC Plumbing Parts

By Dave Strenski

I first became interested in LED flashlights when I read an article in HomePower Magazine (See www.homepower.com) in which the author explained how he converted a Mini-mag light into an LED flashlight. He bought a white LED from Radio Shack and the new "bulb" made the flashlight last longer and, more importantly, improved durability. LEDs simply do not break (no glass nor filament), are typically rated for tens of thousands of hours, and just slip a little power. My interest peaked further when I read an article in Technology Review about the invention of white LEDs and their superiority to incandescent and fluorescent lights. (See www.technologyreview.com/article/talbot0503.asp)

I started looking around for LED flashlights for sale. I found a catalog that offered several styles of LED flashlights that looked great, but the cheapest was a 2-LED light for $30 on up to a 19-bulb version for $150. These are out of my price range, so I decided to build one. I gave my first flashlight to my spouse for Mother's Day. Our six-year-old daughter loved it because it was made using red LEDs, which happen to be cheaper and brighter than white ones. She called it our "love flashlight." I was completely hooked after I discovered that after leaving it on overnight, the LEDs were as bright as new in the morning. Advertisements for retail LED flashlights claim about 50 hours of full brightness and another 100 hours of usable light, all with 2 AA batteries. I am using C batteries, so my flashlight should last a long time. I had so much fun building the first one that I have continued making them and giving them away. I am also improving the design and looking for cheaper sources for different color LEDs, flashlight bodies, and types of switches.

Building the Flashlight Body

My goal was to build a flashlight from scratch for around $15.00. The biggest question was what type of body to use. The thought of converting a standard flashlight came to mind, but then one day out in the garage, I discovered that a C battery fits perfectly into a standard 1" (25.4mm), schedule 40, PVC water pipe, and it would do for the main portion of the body. The next day I was at my neighborhood Congdon's Ace Hardware store. Playing with the fittings in the bins, I figured out that a 1" (25.4mm) PVC cap easily closes off the battery end, and a 1" (25.4mm) couple link can be used for the torch end, giving the flashlight a base cost of about $1.00. PVC piping is easy to build with because it fits together tightly without glue. If you rough up the surface with a light sanding, the fit is even tighter.

The next thing to figure out was how to snugly house the batteries in the PVC pipe. I cut a small ¼" (6.4mm) piece off the pipe and cut a small section out of that piece, making a chunk of PVC in the shape of a "C". I then placed a small amount of glue about 2" (50.8mm) down one end of the pipe and compress the "C" and slide it down within the pipe. Once the glue dries, this makes a battery stop for the top (positive) end.

With the location of the top end of the batteries now fixed, I cut a hole in the side of the pipe for the flashlight switch. Being a scavenger, I had plenty of old switches to choose from. The only requirement is that the body of the switch must fit within the PVC pipe. For another flashlight I bought an appliance switch from Congdon's, which looks and works great, but cost about $5.00. Radio Shack sells a wide variety of switches that will work in the $2.00 to $4.00 range. If the switch body is rectangular, you'll need to drill a series of holes and use a sharp knife to cut the appropriate hole. When cut correctly most switches will simply snap in, but if the hole is too large you might have to glue the switch to the PVC pipe.

For my first flashlight I tried to epoxy a spring to the base cap that would hold my electrical connection on the negative side of the battery. I also placed a piece of metal between the positive end of the batteries and the battery stop. This worked, but I had trouble finding the right spring and maintaining a good contact. I was also trying to keep the cost as low as possible. Then the thought came to me that if the batteries last a long time because the LED consume such little power, why not solder the wires directly to the batteries. The design is now cheaper, no springs or metal pieces, and more reliable.

The length of the pipe will vary depending on what type of LEDs you use. Each battery has a nominal voltage of 1.5 volts. For LEDs needing 3 volts or less, the pipe is trimmed to hold two batteries. For LEDs that need more then 3.0 volts, you will need to have three batteries, 4.5 volts.

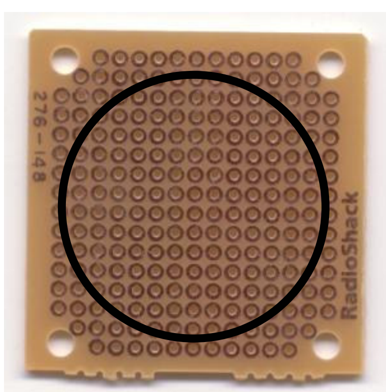
With the battery stop in place, solder a long wire to the negative end of one battery and a long wire to the positive end of another battery. Now depending on whether you have a 2 or 3-battery design, solder short wires between each of the batteries connecting them all together. For wire I used some scavenged solid telephone wire. You only need about 12 inches (300mm) of it. With the batteries soldered together, feed both the negative and positive wires into the bottom of the pipe and push the batteries in till they hit the stop. Now you can cut the pipe so that it is flush with the bottom of the last battery. Push on the PVC cap and the back end of the body is complete. If you have a voltmeter it is a good idea to measure the voltage across the wires to make sure everything is connected and working.

The next step is to install the switch. Leave the positive wire long, for when you have to replace the batteries and fish it out the hole for the switch and soldered it to one post of the switch. Next solder about four inches (100mm) of wire on the other post of the switch. Install the switch into the pipe using glue if necessary. When installing the switch, make sure that "ON" is forward and "OFF" is backwards. Again, if you have a voltmeter, check that everything is working.

The Torch End of the Flashlight

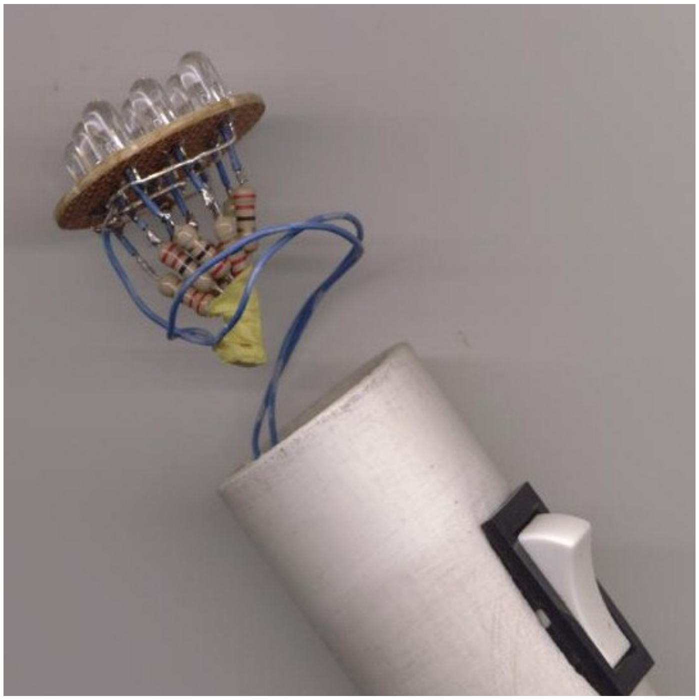
Start by cutting a small piece of circuit board to just fit inside the couple link against the stop. I start by placing the couple link on the circuit board and use a pencil to trace a line on the board. Then use some side cutters or nippers to clip the board close to the shape. Next I use a file or a power sander to shape the board so it fits tightly into the couple link.

As you can see in the photos for this flashlight I used nine LEDs for the flashlight, arranged in a 3 by 3 grid. LEDs have a positive and a negative end so I position all the LEDs in the same direction on the circuit board and soldered the LEDs to the copper rings using a fine tipped soldering iron. With all the LEDs soldered in place, move the leads so they can be soldered together, keeping all the negative ends down close to the board and all the positive leads up in the air. I then solder the appropriate resistor, discussed below, to all the positive ends of the LEDS and then tie all those together and solder it to the wire leading from the switch. To make sure I don't have electrical shorts I slipped some insulation off the phone wire and onto the LED positive leads.

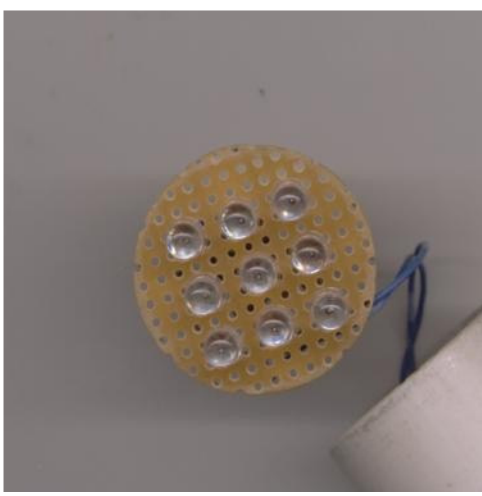
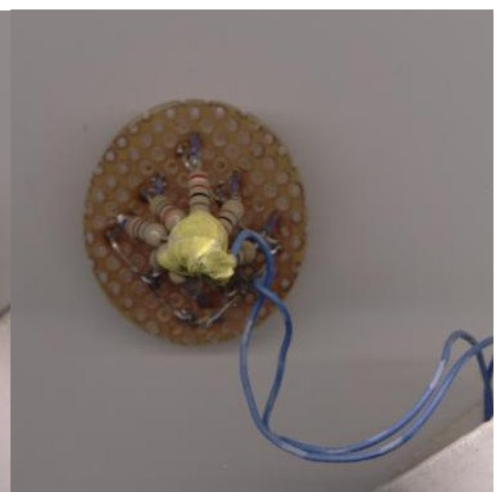


Circuit Board

LED



Carefully stuff the excess wire into the top of the pipe and press the circuit board with LEDs onto the top of the pipe. Slide the couple link on top of the pipe and the flashlight is functionally ready for use. When the switch is turned on, the 3.0 volts (2 batteries) or 4.5 volts (3 batteries) passes through the switch and is sent in parallel to all the LEDs. The resistor on each LED knocks the voltage down from the battery to the appropriate voltage needed for the LED.

Electronics 101

To select what size of resistor to use, we need to review the equation V=IR, or voltage is equal to current times resistance. If I consider the white LED flashlight design, it uses 3 batteries as the supply voltage, which equals a total of 4.5 volts. The LEDs themselves need only 3.4 volts, and if supplied the full 4.5 volts the LEDs would burn out. Subtracting the LEDs voltage from the supply voltage yields 1.1 volts (4.5v – 3.4v = 1.1v). This means we need a 1.1 voltage drop across the resistor. Using the equation V=IR, and the current draw on the LEDs, 30 milliamps, we can figure the size of the resistor. (1.1volts = 0.03 amps * R ohms) So the resistor needs to be 36.7 ohms. (1.1v / 0.03 amps = 36.7 ohms) The closest resistor I could find was a 33-Ohm resistor, and that is what I used in the white flashlight design.

If we now consider the red flashlight design, the supply voltage is 2 batteries or 3.0 volts. The red LEDs require a voltage of 2.1 volts and have a current draw of 50 milliamps. So the resistors needed for this flashlight design is (3.0v – 2.1v) / 0.50 amps = 18.0 ohms. The closest resistor I could find was 22 Ohms, and that is what I used for the red flashlight.

Buying Parts

Below I show the complete parts list for both the red and white flashlights. When you go to SuperBrightLED.com you'll notice that there is a price drop if you purchase 10 or more LEDs, so I went ahead and bought 10 and use the extra LED for testing. Similarly, Radio Shack only sells resistors in packets of 5, so you'll have to purchase 10 resistors. There are many sources for LEDs and resistors like DigiKey and others. Radio Shack tends to be expensive, but it's a tradeoff between convenience and shipping costs.

Styling

Once the flashlight was assembled I cleaned the PVC with PVC solvent, removing the manufacturer's lettering and any remaining adhesive from price tags, etc. If you wanted to make it look less like a plumbing pipe, you can round and/or taper the cap or couple link. I've also thought about attaching an eyehook on one end for a strap. You can also paint the PVC with an appropriate paint.

Future Projects

I am continuing to work on new variations of the flashlight. Next on my list is to try and pack even more LEDs on the circuit board. I'd also like to try and make some flashlight with different color LEDs. I've also found some cheap plastic flashlight that I'd like to retro fit for LEDs. The difficulty is that they typically only hold 2 batteries and the white LEDs need more then 3 volts. I've looked at DC/DC inverters, but haven't found one that can handle the current that are cheap enough.

Table 1: Retail LED flashlight source

CC Trek Light, Item AWL, $29.95, 2 White LED, 3 AA batteries, 50 hours full power, 100 hours of useful light, bulb life 60,000 hours

CC Expedition, Item EBK, $59.95, 7 White LED, 3 C batteries, 40 hours full power, hundreds of hours of useful power. Diver version for $69.95, rated at 1000 feet.

CC Expedition 1400, Item 4BK, $119.95, 14 White LED, 3 C batteries, 20 hours full power and another 20 of usable light

CC Expedition 1900, Item 9BK, $149.95, 19 White LED, 3 C batteries, 10 hours full power and 10 hours of useful light.

Table 2: Red flashlight parts list

Quantity	Part	Part Number	Unit Cost	Cost
9	Red LEDs	SuperBrightLED RL5-R12008	$0.56	$5.60
2	C batteries	Congdon's ACE Hardware	$1.50	$3.00
1	Switch SPST	Salvaged or Radio Shack	$3.00	$3.00
1	Mini circuit board, 2/pack	Radio Shack 276-148	$1.80	$0.90
12"	1" PVC Pipe	Congdon's ACE Hardware	$0.15	$0.15
1	1" PVC Cap	Congdon's ACE Hardware	$0.50	$0.50
1	1" PVC Couple Link	Congdon's ACE Hardware	$0.80	$0.80
9	22 Ohm resistors	Radio Shack 271-1103	$0.20	$1.80
Misc	Solder, glue, wire		$0.00	$0.00
			Total	$15.75

Table 3: White flashlight parts list

Quantity	Part	Part Number	Unit Cost	Cost
9	White LEDs	SuperBrightLED RL5-W10015	$1.35	$12.15
3	C battery	Congdon's ACE Hardware	$1.50	$4.50
1	Switch SPST	Salvaged or Radio Shack	$3.00	$3.00
1	Mini circuit board, 2/pack	Radio Shack 276-148	$1.80	$0.90
12"	1" PVC Pipe	Congdon's ACE Hardware	$0.15	$0.15
1	1" PVC Cap	Congdon's ACE Hardware	$0.50	$0.50
1	1" PVC Couple Link	Congdon's ACE Hardware	$0.80	$0.80
9	33 Ohm resistors	Radio Shack 271-1104	$0.20	$1.80
Misc	Solder, glue, wire		$0.00	$0.00
			Total	$23.80

Reference:

Congdon's Ace Hardware
111 Pearl Street
Ypsilanti, Michigan 48197
734-482-2545

C. Crane Company, Radio, Light & Science
www.ccrane.com
800-522-8863

Radio Shack, www.radioshack.com
2738 Washtenaw Avenue
Ypsilanti, Michigan 48197
734-434-1198

SuperBrightLED
www.superbrightled.com