

# Mount LEDs in an El Cheapo Headlamp

A widely available, inexpensive headlamp makes a fine, waterproof housing for a homemade LED array.

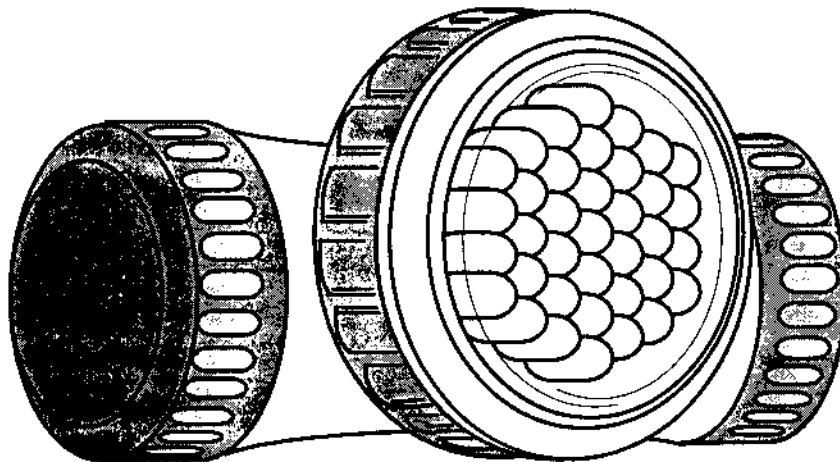


Figure 1: An array of 37 LEDs in an El Cheapo headlamp body.

So, you've made a high-tech lamp by soldering a bunch of white-light LEDs onto a circuit board. In fact, when you touch the dangling wires to a couple of batteries, they light up. Congratulations. You've decided that you've admired your work long enough and you're tired of its looking like a science project. It's time to convert it to real caving gear. Here goes.

We're talking here about a headlamp housing. An LED array will fit into any number of existing headlamp bodies used by cavers. If you can remove the reflector surrounding the existing bulb, you can probably fit an array of LEDs into it. This article describes the conversion process for one of those inexpensive, waterproof headlamps available at discount stores.\*

Off the shelf the headlamp is designed to use 4-AA batteries. It has a rotary switch on the right side of the unit. The headlamp can be positioned vertically by rotating the body up or down on its base. It clicks firmly into place (a bit too firmly). It is supplied with a headband made of either rubber (Eveready brand) or elastic (Wal-Mart brand). The battery compartment and the screw-on lens are both sealed with O-rings, making the unit, indeed, waterproof.\*\*

Since this headlamp is available for less than \$10 and since it comes in a couple incarnations under different aliases, it will be referred to in this article as the El Cheapo headlamp.

An array of 37 LEDs is just the right size to fit nicely into an El Cheapo headlamp. Of course, your array may have a different number. With very little effort, the headlamp can be modified to power the LEDs on 3-AA batteries. Use of the built-in switch is maintained. If your LED array has circuitry which divides the LEDs into groups as described in the article, *Build a High-Tech Cave Light*, then a switch can be added to control three brightness settings. Finally, if you decide that three AA batteries don't last long enough for your caving needs, an external battery pack can be added when desired.

Let's get to work.

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\* Energizer Brand made by Eveready (yellow body, about \$10 at Home Depot, including 4 alkaline batteries) and Wal-Mart (black body, about \$7.50, no batteries).

\*\* The Eveready light boasts an "Adjustable Beam" prominently on the front of the packaging. However, if you screw the lens piece to move the reflector and adjust the beam, the O-ring seal is broken. To its credit, the front of the package does not say "waterproof". However, the back of the package does, though it makes no claims to an adjustable beam. So, the light is *either* waterproof *or* has an adjustable beam, depending on whether you read the front (marketing) or back (engineering) part of the package.

## Installing the LED Array

Before soldering the LEDs, you cut off the corners of your circuit board, right? The board has a diameter of 1-5/8 inches or less so it fits inside the El Cheapo headlamp, right? If not, be careful at this point making a cut, especially if your board contains a large number of LEDs that extend close to the edge of the circle. Circuit board material is somewhat brittle. Boards can be *trimmed* by chipping away small chunks of material with strong scissors or preferably with metal snips. At this point it might be safer to use a fine-toothed hacksaw or, if you have access to a Dremel tool, one of those cutting disks.

Now for the headlamp. Unscrew the lens from the front of the unit. Remove the reflector from the lens. Shake it. The reflector can be discarded or put into the same drawer as that decoder ring you got in Cracker Jacks. With the lens removed two, small, Phillips-head screws will be exposed. Remove them along with that weird-shaped plastic piece that falls out when you do. There should also be a tiny, black cylinder that almost rolls off the table.

This cylinder is a hydrogen gas absorber. As alkaline batteries are used, hydrogen gas is released. Since the headlamp is sealed, the hydrogen does not escape but, rather, mixes with the oxygen from the air inside the headlamp. There is a chance that closing the switch, also inside the headlamp, will produce a spark that can ignite this mixture and cause an explosion. If you choose not to reinstall the hydrogen absorber and your headlamp explodes, I want to hear the story.

All of this disassembly will expose two metal tabs uncomfortably far inside the body of the headlamp.

Now for the hard part. The two leads from the circuit board must be soldered to these two tabs. (If you have four leads from the circuit board and are installing a switch to control three brightness levels, the connections are a bit more complicated and are described in a later section. But for now, read on.) Before soldering, a reasonably strong mechanical connection must be made. Wrap each bare wire around a tab. Better still, drill a small hole in each tab for the wire to go through. There's room for a 1/16 inch hole. Solder to make a good electrical connection.

Here's a hint. If you find it difficult to work with the tabs so far inside the headlamp, you can remove the piece of plastic holding them. The whole thing will slide out the battery opening. You'll have to remove the this-side-up battery stickers, but then it just slides out.

Yes, it matters which wire goes where. Unlike light bulbs, LEDs allow electricity to flow through them in only one direction. The top tab is positive and must ultimately connect to the long lead or non-flat side of your LEDs.

This brings us to the issue of polarity. Batteries must be inserted into the headlamp pointing the right direction if they are to work with LEDs. The stickers inside the battery compartment show you what's up. Surprisingly, the El Cheapo headlamp is so well designed that it has polarity protection. If you insert a battery backwards, the butt end won't make contact because it has no nipple to extend to the conductor. This is so even though the headlamp is designed for a tungsten light bulb which couldn't care less which direction electricity flows through it. The El Cheapo seems predestined for conversion to a congregation of LEDs. (And you no longer believe in magic.)

With the connecting wires soldered to the tabs, fit the circuit board into the headlamp body. (LED side out, you knew that, right?) Just set it in. The wires will tend to push the unit out against the lens. Or add a little piece of foam rubber behind the circuit board to act as a spring. When I soldered the connecting wires to my circuit board I positioned them flat and all pointing counter-clockwise. That way the several inches of wire coils neatly into the headlamp body as I rotate it a bit. Screw the lens down tight to seal the O-ring.

## An Inexpensive Voltage Converter

Next the headlamp must be modified from its 4-cell, 6 volt design to a 3-cell, 4.5 volt incarnation.\*\*\* This is easier than it sounds. We simply need a dummy battery that conducts electricity but provides no

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\*\*\* Actually, 4.5 volts is way too much voltage for the LEDs, says the manufacturer. They are rated at 3.6 volts, with a maximum of 4.0 volts before being damaged. Cavers generally ignore this advice because they find that three alkaline cells work just fine. Purists may want to use NiCads at 1.25 volts or Nickel-Metal Hydride cells at 1.2 volts, giving 3.75 and 3.6 volts respectively for three cells. The problem is that they don't last nearly as long as alkalines. This is especially true for those cavers who don't change batteries even though their light has dimmed considerably, which is *most* cavers. Alkaline cell voltage drops gradually and lulls us into thinking that we can still see.

electrical push. Here is the nifty part. At the hardware store there are cylindrical, 250 volt fuses that are the same diameter and the same length as a AA battery! They cost fifty-nine cents. (And you no longer believe in magic.) Insert three AA batteries and this fuse into the headlamp and *voila*, a 4.5 volt system. Almost.

Unfortunately, the fuse has no nipple, like the positive end of a battery does. That wouldn't normally be a problem, but the El Cheapo headlamp is so well designed that it has polarity protection. If you insert a non-nippled object into the battery compartment, it won't make contact. Look inside the headlamp and you will see a couple of plastic tabs that contact the shoulder of the battery in the two positive-end-down battery compartments. (Don't feel bad if you have trouble seeing them. I spent an hour trouble-shooting other areas before discovering the problem.) In addition, the battery cover has polarity protection on two of the contact springs on the Eveready, but not the Wal-Mart, headlamp. They are easier to see.

How do we solve the no-nipple problem? The simplest solution is augmentation. Drop a little wad of aluminum foil into the bottom of the dummy battery compartment. This will work fine until you lose the foil while changing batteries deep in a cave somewhere. A gum wrapper is a field repair possibility. A more elegant solution is to melt a glob of solder onto one end of the fuse to form a nipple. An alternative to the fuse would be a short length of dowel wrapped in aluminum foil with one end bunched and poached out to form an integral nipple.

I should make one more point at this time. If you plan to modify the headlamp to accept an external battery pack, the fuse-style dummy battery won't work. Some of the space in the extra battery compartment will be filled with wire and screw heads, so a thinner diameter dummy battery is needed.

Put three batteries and the dummy into the battery compartments. Screw the lid down tight to seal the O-ring. You're done. The switch should turn the LEDs on and off.

Admire your work a while, then go caving.

### Adding a Switch to Access Three Brightness Levels

An earlier article describes a circuit that divides an array of 37 LEDs into three separate groups. (See *Make a High-Tech Caving Light*.) The advantage of having independent control over a large group of LEDs is twofold. Battery life can be conserved by using fewer LEDs when less light is needed. Also, battery life can be extended by turning on more, dim LEDs, at a time when fewer, dim LEDs would require battery replacement.

Here's how it works. The circuit described has a group of 6, a group of 10, and a group of 21 LEDs, for a total of 37. These can be wired so that a single switch selects 6, 16, or 37 LEDs. Each of the two steps provides about two-and-a-half times the brightness of the lower setting. The switch that makes this possible is a double-pole, double-throw, (DPDT), center-off switch. (Radio Shack part # 275-620) It is really four switches in one. In its center position all switches are open. This is the *low* setting with only 6 LEDs powered up. The power switch is the headlamp's own, independent, on/off switch. Push the DPDT switch to the right and two switches are closed. We actually need only one of them to power up 10 more LEDs for the *medium* setting. Push the DPDT switch to the left and two separate switches are closed. One of them powers up 21 LEDs, and the other powers up the

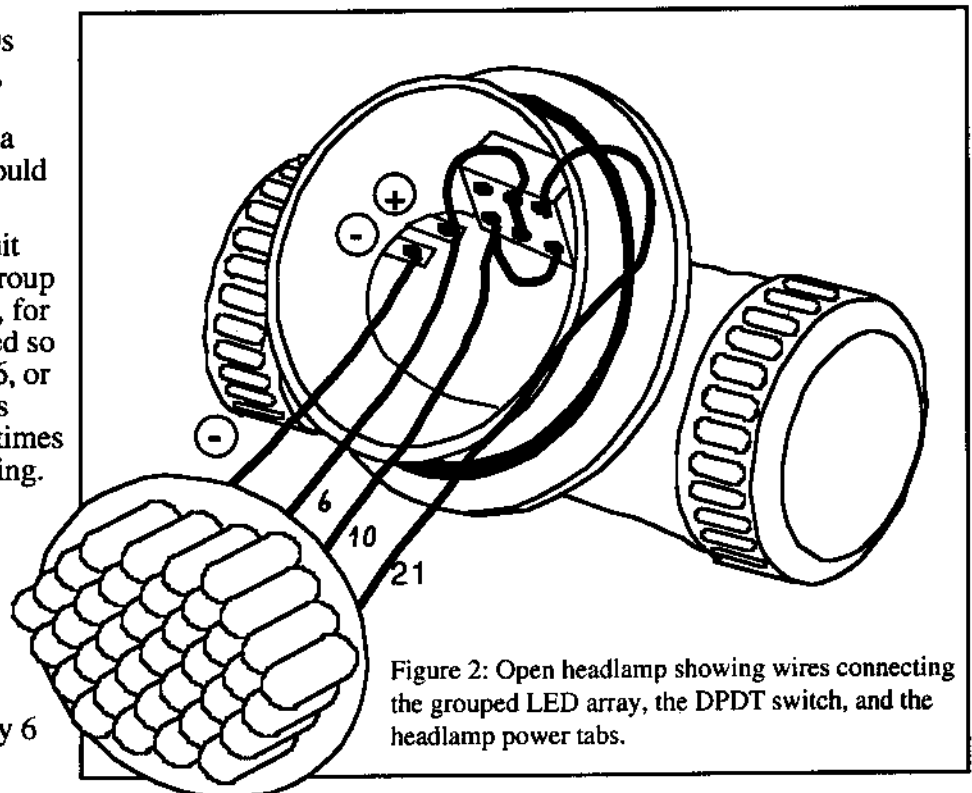


Figure 2: Open headlamp showing wires connecting the grouped LED array, the DPDT switch, and the headlamp power tabs.

same 10 LEDs as the previous position, for *high*.

Figure 2 shows how to make the connections among the power tabs on the El Cheapo headlamp, the grouped LED array, and the DPDT switch. The switch is shown mounted in the body of the headlamp with its toggle extending out the top, but hidden in the illustration. Notice the six tabs on the bottom of the switch. They have holes for inserting the connecting wires before soldering. Notice that a short piece of wire must be soldered to connect the two center tabs. The solder connections are a little easier to make before the switch is mounted in the headlamp, but not much. Just be careful not to hold the soldering iron too close to the meltable plastic lip while concentrating on the switch.

Be careful to select the correct wires from the LED array. The negative wire is the one which connects to all of the LEDs. There are three positive wires. The one on

bottom (or top) connects to 6 LEDs. The one on the other end connects to 10 LEDs. The one in the middle connects to 21 LEDs. Figure 3 shows the complete wiring diagram, but it's a little less intuitive than Figure 2.

Oh, yes, mounting the switch in the headlamp. You must drill a hole in the cone part of the body which held the reflector, not the cylinder part which holds the batteries. The hole is centered 1/4 inch from the seam between the cone and cylinder parts. (The hole is not 1/4 inch away; its *center* is 1/4 inch away.) The hole itself is 1/4 inch in diameter, or 15/64 inch if you have a more complete set of drill

bits. There's not a whole lot of extra room here, especially if your LED leads are cut a little long.

Insert the toggle through the hole, with only that tabbed washer left on the switch. It keeps the toggle from sticking out too far. Use one of the two nuts to hold the switch firmly in the headlamp body. Put the other nut the same place you put the reflector.

Now for another nifty part. (It's not often you get two *nifties* in one article.) Radio Shack makes a neat, little switch-condom to keep this whole mechanism waterproof! Radio Shack calls it a rubber cap (part #275-1596). It screws down over the toggle onto the same threads that hold the nut you just installed. In fact, it is designed to replace that nut. The only problem is that it is also designed to seal against a flat surface, which the headlamp is not. (It has its own, tiny built-in O-ring.) We can solve this problem with a little caver engineering. Place a larger O-ring around the installed nut (3/8 inch inside diameter x 9/16 inch thick), then screw the rubber cap down firmly against the O-ring. *Viola*, we're practicing safe switch.

## Adding an External Battery Pack

(Under construction)

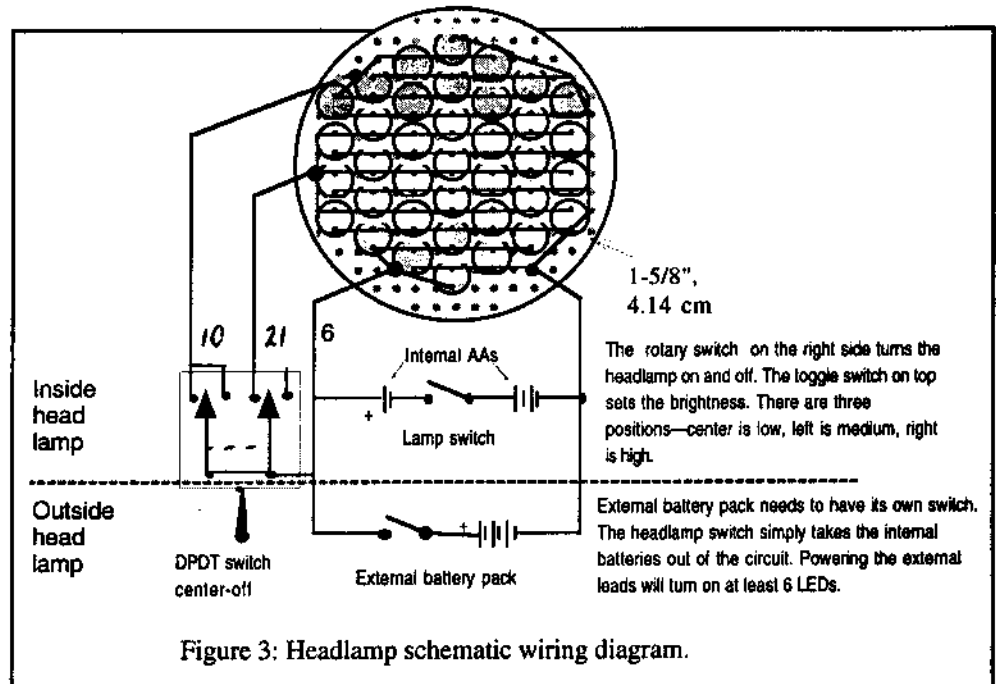


Figure 3: Headlamp schematic wiring diagram.

# Parts List

<i>Item/Purpose</i>	<i>Comment</i>	<i>Radio Shack #</i>	<i>Price</i>
<b>For making an LED array:</b>			
LEDs, white-light: To pierce the darkness.	Radio Shack has just added white-light LEDs to their 2001 catalog. For \$4.99 you can be the proud owner of one!	(276-320)	1.60 (plus .06 shipping) from Robin
Assorted LEDs: For soldering practice.	If you're going to fry some LEDs while learning to solder, fry these.	276-1622	2.29 / Pkg. of 20
Circuit board, perforated: To hold everything together.	Radio Shack's "Dual mini board" is perfect it—snaps apart in the middle to make two 1-3/4" squares.	276-148	1.49 each
Wire, solid, uninsulated: For connecting LED leads on circuit board.	Radio Shack has "Pretinned solid bus wire" or just strip the insulation off some solid wire	278-1341	1.79 / 50 feet
Wire, stranded, insulated: For connecting printed circuit board to batteries and switch.	22 gauge (or 20, thicker) is about right. You have some wire somewhere, don't you?	278-1218	3.99 / 90 feet
Solder, rosin core: For electrical connections.	You want the thin-wire type	64-017	1.19 / 0.5 oz.
Tape or Superglue: To hold LEDs in place before soldering.	If you figure out something better, let me know.		
<b>For mounting array in headlamp:</b>			
Headlamp, 4-AA, one-piece with headband.	Eveready sells a yellow version available at Home Depot; Wal-Mart's model comes in basic black.		Eveready \$10 with batteries, Wal-Mart \$7.50 without.
Fuse, Buss, 250v: Serves as a dummy battery.	This fuse is the same size as a AA-battery! Placed into the headlamp, it converts it from 6 to 4.5 volts.	Hardware store	0.59 for the 10 amp version (which ought to be enough).
<b>For accessing brightness settings of grouped LEDs:</b>			
Toggle Switch, sub-mini, center-off, DPDT: For controlling three brightness settings (optional).	Allows an LED array wired in three groups to have three brightness settings.	275-620	4.79 each
Rubber Cap: A waterproof cover for the switch above.	For safe switch.	275-1596	1.49 / Pkg. of 2
O-Ring: 3/8" inside diameter x 9/16" thickness: For use with switch.	Allows the switch cover to make a watertight seal with the curved surface of the headlamp.	Hardware store	about 0.30
<b>For connecting an external battery pack to headlamp:</b>			
Screw, pan-head, stainless steel; 8/32" x 5/8"	To make an electrical terminal on top of headlamp.	Hardware store	2 @ 0.20
Nut, hex, stainless steel; 8/32"	To make an electrical terminal.	Hardware store	2 @ 0.08
Washer, #8, stainless steel	To make an electrical terminal.	Hardware store	2 @ 0.08
Washer, lock, #8, stainless steel	To make an electrical terminal.	Hardware store	2 @ 0.08
Knurled Nut, brass, 8/32" (or stainless steel wing nut)	To make an electrical terminal on top of headlamp.	Hardware store	2 @ 0.35 (or 2 @ 0.65)
Epoxy or silicone seal	To seal electrical terminal.	Hardware store	about 2.00