LED Caving Lamp Development & Use

by Pete Shifflett 21467RL(FE) Pete@The-Cavern.com

There will be many different uses for LED lighting by cavers. Station markers, emergency flashlights and instrument illuminators are just a few applications that LEDs have commonly been used for over the years. Now, recent advances in solid-state LED/phosphor technologies has made primary LED caving lamps a practical and decidedly advantageous alternative to incandescent lamps. There can be little doubt that LED technology will soon be the preferred lighting choice among the majority of cavers. Over the past couple of years I've built ten such white LED lamps designed specifically for use by cavers on long remote caving expeditions. This is a description of these lamps.

Development and use

In designing a primary LED caving lamp, at least all of the following factors need to be considered:
* Battery weight and volume
* Battery electrical characteristics
* LED efficiency
* LED lifetime
* Power converter efficiency
* Robustness

For caving that involves long continuous underground use (weeks or more at a time) in very remote areas, it's best to try to optimize Burntime*Brightness/Weight. This dictates the use of lithium batteries, high converter efficiency, and high LED efficiency. Typically, the weight penalty of bringing a backup primary lamp cannot be tolerated, so the lamp had better be bomb proof.

One of the design requirements for my white LED lamp was that power would be supplied from a single lithium D-cell or by two alkaline D-cells. This meant that I was forced to use an efficient boost current regulator. I also decided to run the LEDs (lamp at full power) at about 13.3mA instead of the usual 20mA. This provides for good LED efficiency, very long LED lifetime and means that I draw only about 1.2 Watts from the batteries (25LEDs x 0.0133Amp x 3.4Volt / 0.92 efficiency). Pairs of alkaline D-cells are quite happy at this power drain and will gladly produce full power for 17 or 18 hours continuously. They become increasingly unhappy if you try to run them at substantially higher drain. The neat thing about LEDs is that they become more efficient at lower currents so there is only a small decrease in brightness when running them at somewhat reduced current levels. Overdriving fewer numbers of LEDs at higher currents is a loosing game.

Details

My LED lamp uses an array of 25 white Nichia LEDs. I use a very efficient step-up switcher (Maxim MAX1703) powered by anything from about 1 to 3 Volts or so. I prefer to use either a pair of alkaline Ds or a single lithium D, which I mount on the back of my helmet. I include a 0.1W current sense resistor and an op-amp in the circuit in order to convert the MAX1703 into a constant current regulator. By selecting op-amp gain I can run my lamp at full current (333mA), half current (167mA), or 1/10 current (33mA). Since I drive the LED array in parallel, and because NICHIA LED forward voltages vary quite a bit, I decided to use a small ballast resistor (~10W) for each LED. I measure the forward voltage of each LED using a 13.3mA current source. Then I calculate the appropriate resistor values that will perfectly

(Continued on page 22)

(Continued from page 21)
balance the current through the array. On the other hand, if you have a large batch of LEDs to choose from you can usually select 25 of them that have about the same forward voltage. In this case, you can eliminate the ballast resistors altogether and recover about 4% lamp efficiency.I designed a circular two-sided circuit board with the LED array, the SMT inductor, and a few caps on one side, and all other SMT parts on the other. I wasn't happy with any of the commercial lamp housings so I machined my own housing from 6061 aluminum alloy tubing 2.25" OD, 1.75" ID, 1.30" long. The circuit board is inserted from one side where it rests upon a step. The other side of the tube also has a recessed step on which is epoxied a 1/8" thick, 2" diameter borosilicate window. The window is recessed into the housing by about 1/4" in order to reduce chances of breakage.

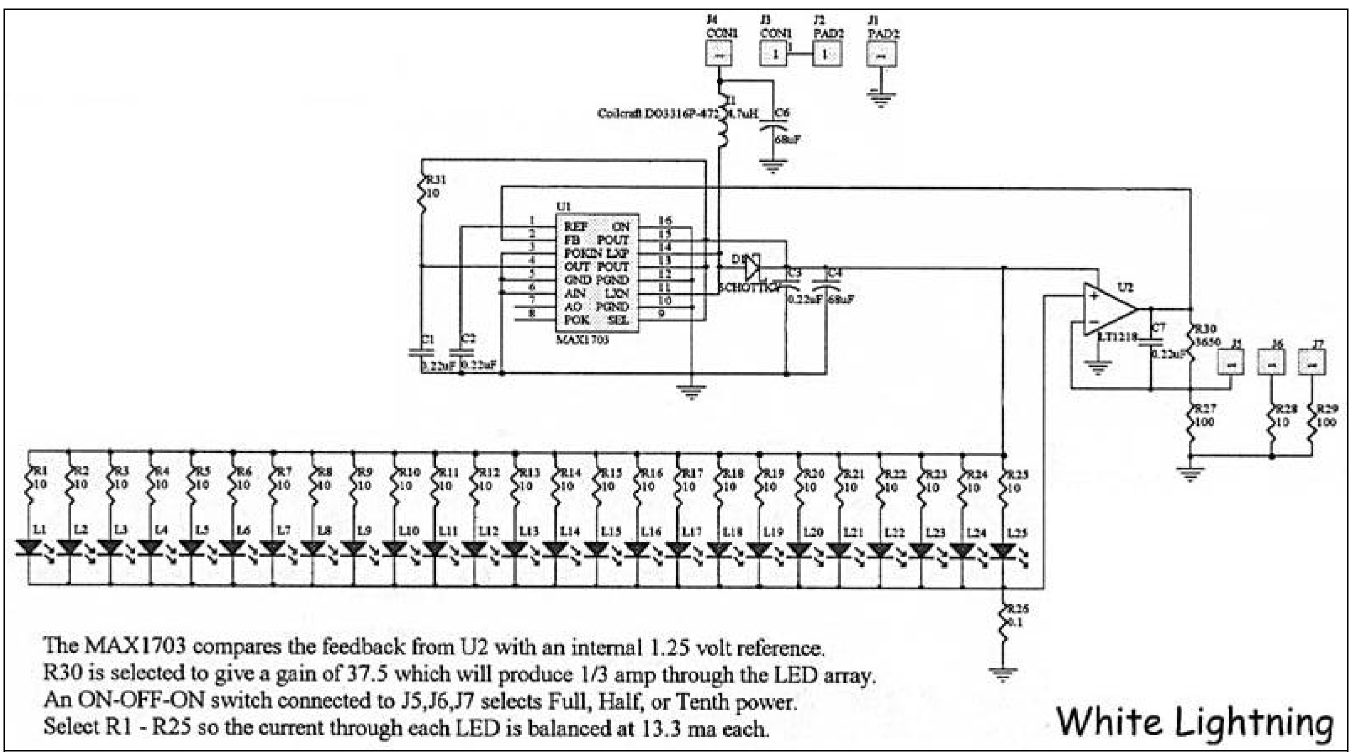
The backside of the housing (circuit board side) has a pair of toggle switches - SPST for power, and SPDT (on-off-on) for power settings. The switches protrude from the lower side of the housing and are protected with watertight switch boots. The entire back side of the lamp is potted with a marine epoxy. Two 1/4" diameter stainless-steel standoffs, used for power input and mounting, are screwed to the circuit board and protrude through the back of the potting material by about 1/8". For helmet mounting, I machine pivoting mounting brackets from Delrin with heavy brass spades.

Alternative Circuit

This is actually my second go at a robust LED caving lamp. My first lamp consisted of 25 of HP's very bright amber LEDs in a housing similar to the one described above. The low forward voltage of these LEDs means it is actually most efficient to use a linear current regulator to drive the array from batteries producing between 2.2 to 3 Volts.

I built an ultra-low-dropout linear current regulator (~60mV at 1/2 Amp) using a low on-resistance, low gate-voltage power MOSFET. A 0.1W current sense resistor feeds an inverting micro-power op-amp, which drives the gate of the MOSFET in its linear region. A regulated charge-pump is used to supply the op-amp and to provide a rough voltage reference.

This linear circuit has some nice advantages over a switching regulator: Simple protection from reversed battery insertion and excellent end of battery life characteristics. When the battery voltage eventually drops below the LED forward voltage (+ regulator dropout voltage), the LEDs very gradually start to dim. With a pair of alkaline D-cells, you get about 20 hours continuous full power burn time, with about 8 more hours of dimming but usable light. The same circuit could be used with white LEDs but it would be necessary to use a 4.5 Volt battery system.



For a large (300 kb) view of the schematic, please visit :
http://nerve-net.zocalo.com/jg/c/tech/Led/Shifflett/Shifflett_LED_Schematic_Full.jpg

(Continued from page 23)

So, sticking this on the end of my tent pole with a some tapped holes in the aluminum end cap wasn¹t difficult. It is somewhat more fragile than ROCK, which was mounted in a Pomona Box with a clear polycarbonate cover to see through. ROCK II is naked, but it is also very small and flexible. For illumination I have three high intensity red LEDs mounted on perf board, pushed around the lens housing. I bought the lens version instead of the wider angle, more distorted, pin hole version. There are some lithium cells taped in a "blob" hanging on the pole just under the camera. These two AA sized cells are enough to power the LEDs separate from the camera DC. I power the camera as I powered ROCK, with a Justrite battery holder (red plastic) and four D cell lithium batteries from SAFT. They are high current, so I have a Polyfuse protector in the package. The video and power come down a three conductor, shielded, twisted pair that just drapes along the tent pole with rubber bands or duct tape - nothing fancy or even pretty.

Using the same beat up SONY 8mm Watchman VCR, I have probed a few cracks and holes so far this year, and have great results on tape. I am presently downloading to a Quicktime movie to email to my comrades who push with me. I'm looking forward to opening up Lechuguilla II with the assistance of ROCK II.

Not Another LED Headlamp Miracle

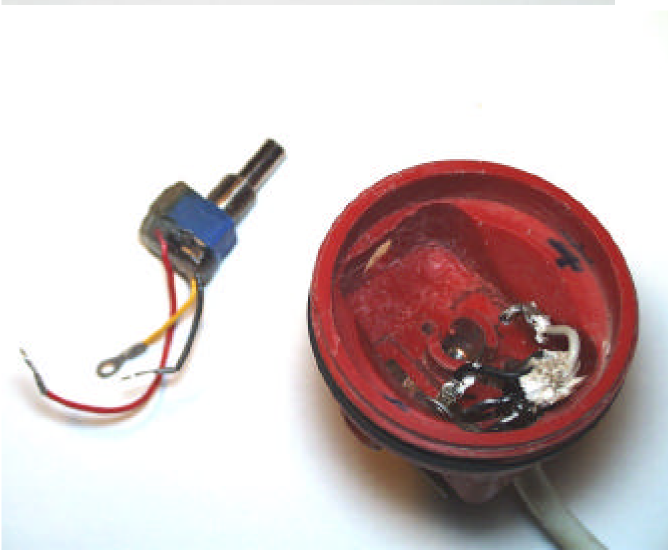
John T. M. Lyles, NSS 19871

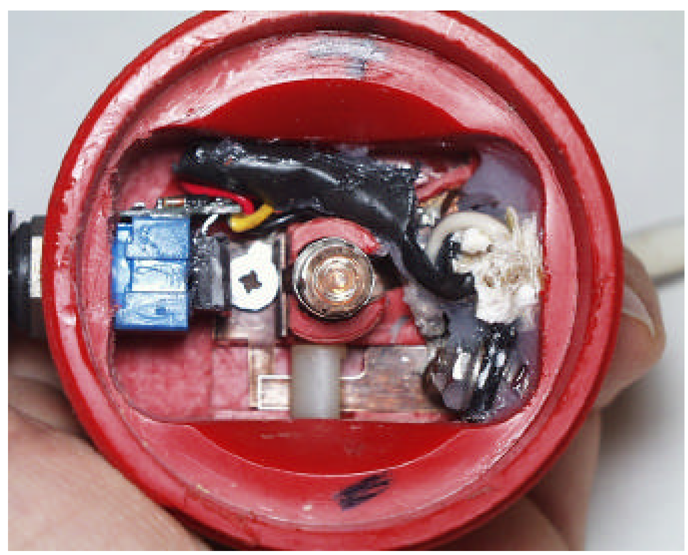
Problem - Battery Weight

- Multi-Day expeditions required 8 to 12 D cells for my 2.5 Watt Halogen bulb
- 35 hours of life on Duracell D's
- Each cell weighs about 5 oz, new or spent
- 3.7 lbs of pack weight used for 84 hours light (week), leaving 8 dead cells, 4 partially spent

Solution - Install Dimmer

- New tiniest CMT model, fits inside lights
- Only use light you need, at all times
- Prevents bulb burnout on turn on
- Nov. Lech, 4 day trip, 4 cells!





Left: Cave Man Technology * (Jim Sturrock) dimmer with milled-out Roosa-Lite

Right: Interior of Assembled Light - Eliminated the spare bulb space

*Dimmers are available from Jim at sturrock@cybermesa.com or through Inner Mountain Outfitters. He has two versions, one which regulates, and one which is a raw dimmer. I used the latter, since it is so compact.