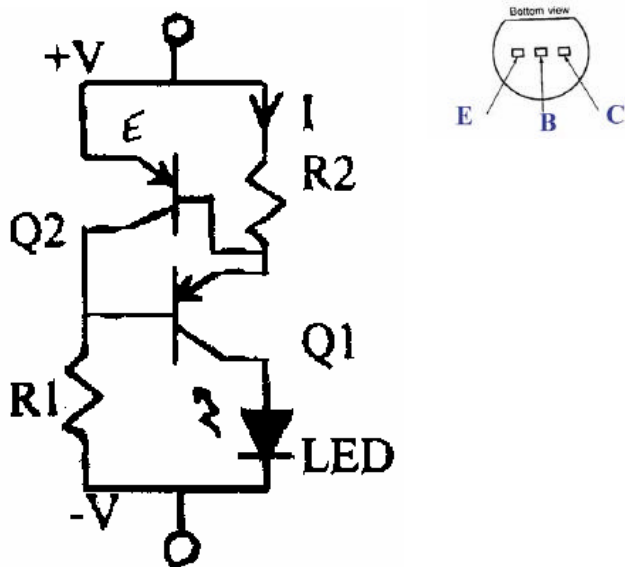


This article has been written to assist those who wish to construct a headlamp using white LEDs.

Unlike incandescent lamps, LEDs (with rare exceptions) require some means of regulating the current they draw when powered by a battery. In its simplest form this can be a resistor inserted in the circuit between the battery and the LED. The disadvantage of this arrangement is that the current to the LED will vary as the battery voltage varies. For application as a primary headlamp, a far better circuit is one that will supply a constant current to the LED even as the battery voltage varies. In its simplest form, this can be achieved using a circuit comprised of only 2 resistors and 2 transistors. This circuit can maintain a constant current to the LED as long as the battery voltage is at least 0.6V greater than that of the LED at the desired current. In the common T1 3/4 size, Nichia offers white LEDs with viewing angles of 20, 50, and 70 degrees. The viewing angle is that angle within which the intensity is at least 1/2 of the peak intensity. These LEDs do not differ in total light output but only in how widely or narrowly that light is projected. Those LEDs with viewing angles of 20 and 50 degrees are of most interest for headlamp application. White LEDs are reported to be electrostatic discharge (ESD) sensitive. During handling and construction good ESD hygiene should be observed. While the absolute maximum rated current for these LEDs is 30mA, significant efficiency gains can be had by operating below this maximum. While current prices preclude taking this to the extreme of operating huge numbers of LEDs at 3mA each, the reduction from 30mA to 20mA will net an efficiency gain of 18% and a reduction from 30mA to 15mA a gain of 31% (on a current, not power basis). **VERY IMPORTANT:** The following point cannot be over emphasized. Good thermal management is essential to long-term reliability of headlamps based upon white LEDs. While operating at power levels sufficient for a primary headlamp, a watt or more of power is likely to be dissipated among the LEDs and the current regulating circuitry. This heat must go somewhere. The light output of these LEDs will deteriorate over time if operated at excessive temperatures. For groups of 7 or more LEDs with a combined current of 200mA, it is recommended that they be mounted on a doublesided PCB, preferably with 2 oz (.0028") copper cladding. The cathode (negative) leads of the LEDs should be soldered to both sides of the PCB and the maximum area practical of both sides of the PCB be devoted to the cathode connection. Due to the construction of the LED, almost all heat conduction from the LED die is via the cathode lead. From the cathode lead heat must be conducted away and dissipated by the copper cladding of the PCB to which the LEDs are soldered. More is better in terms of both copper area and thickness. If operating at average currents above 20mA per LED it would be prudent to individually test each LED and avoid using those which have voltage drops significantly below the group average at a constant test current.

A simple and effective circuit for maintaining a constant current to LEDs is:



This circuit is well suited to powering white LEDs from a battery comprised of 4 alkaline cells.

$$R1 \approx 500/I$$

$$R2 \approx 0.54/I$$

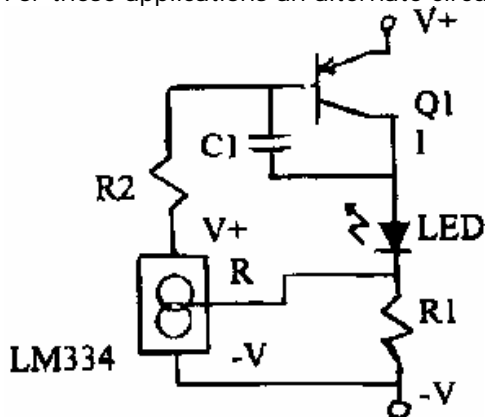
Where I is the desired total LED current

R2 determines desired current

It should be understood that the LED depicted can be any number of LEDs in parallel.

Q1 is the power dissipating element in this circuit and appropriate mounting consideration must be given to heat dissipation. Generally for TO-92 packages and small surface mount packages the collector lead is the one by which most of the heat is transported from the package. The PCB layout should maximize the copper connected to the Q1 collector lead. Q2 may be any SS PNP with good gain (H_{FE}). For Q1, a recommended device in a TO-92 package for through-hole construction technique is the ZETEX ZTX788A. For surface mount construction technique a recommended Q1 is the ZETEX FM717 or FM718 which come in the SOT-23 package. Suitable Q2 in through-hole TO-92 package include 2N3906, 2N4403, and 2N5087. Suitable Q2 in surface mount package (SOT-23) include MMBT3906, BCW61D, and MMBT2907A. Resistors R1 and R2 may be 1/8 watt size unless the desired current is greater than .25 amp in which case the wattage of R2 should be increased. By use of surface mount devices for Q1 and Q2 it is possible to construct the current regulating circuit on a 0.32" x 0.32" x 1/32" double-sided PCB that will fit inside the base of a "PR" style (flanged base) bulb. By soldering the PCB that holds the LEDs directly to the flange of the bulb base one can thereby create an LED version of a "PR" style bulb. In the case of some headlamps, the only required modification to the headlamp itself to accommodate the use of the LEDs will be enlargement of the hole in the reflector to accommodate the diameter of the LED cluster. By devoting the majority of the LED PCB to the cathode (negative) side of the circuit and soldering this PCB directly to the bulb base flange, the bulb base becomes part of the heatsink for the LEDs. Due to the limited area of PCB that can be fitted into a "PR" style base, about the absolute maximum current that can be handled by a current regulator circuit fitted into a "PR" base is .25 amp assuming use of 4 alkaline cells as the power source. Even so, this value assumes use of DS 2 oz clad board with the maximum area possible allotted to the collector lead of Q1. Pushing this limit risks reliability degradation due to the thermal stresses upon Q1. Those who wish to operate at higher currents or wish to simplify layout considerations on the PCB can enlarge the PCB that holds the LEDs and move the current regulator circuit to this PCB. **HELPFUL HINT:** Even if you don't have the capability to fabricate PCBs by chemical etching techniques, simple PCB circuits such as these can be created using a Dremel-type tool to remove the unwanted copper from clad board stock. All that is required is a small burr and a steady hand. **USING OTHER POWER SOURCES:** The current regulation circuit of Figure 1 will maintain regulation for battery voltages >0.6V above that required by the LEDs. This circuit is marginally acceptable for use with 4V Pb acid batteries if the average LED current is 15mA or less. For other battery choices such as 3 Ni-Cd or Ni-MH cells, or a single Li-ion cell, there is less than this required 0.6V of "headroom" for a significant portion of the discharge.

For these applications an alternate circuit is offered in Figure 2 below:



This circuit will maintain regulation for battery voltages as low as 0.1V above that required by the LED.

$$R1 = 0.064/I$$

$$R2 \approx 300/I$$

Where I is total LED current

$$C1 > 1\mu F$$

The LM334 is a 3-terminal adjustable current source. It operates to maintain 64mV between its R and V- terminals (hence across R1) and does so by passing current into the V+ terminal and out of the R terminal. Assuming adequate cell voltage, the LED current is the beta of Q1 times the R2 current. R1 sets the LED current which is $64\text{mV}/R1$ for reasonably high Q1 beta. Hence $R1 = 64\text{mV}/I$ where I is the desired LED current. R2 is selected to regulate the base current to an appropriate value when the battery voltage drops to the point that the circuit falls out of regulation. Under this condition the LM334 will draw all the current it can through R2. C1 prevents the circuit from oscillating and any value from 1 to $10\mu F$ works well. Suggested Q1 choices are the same as given for the previous circuit. The LM334 IC is available in both TO-92 and SO-8 packages.

My LED array looks like this:

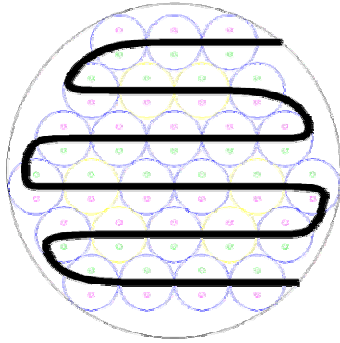


This fits inside the Petzl headlamp resting on top of the constant current circuit board. It is all held in there with nylon threads.

Another example of someone else's Petzl Micro design:



Heres how to make the array:



The drawing shows the layout for an array of 27 5mm LED array, 21 white (blue in drawing) and 6 yellow LED's. The circle is 35mm in diameter. Although the leads of the LED's are spaced 0.10" apart, the a layout in which the LED's touch in three directions can not be built on the standard 0.10" perf-board. The board should be made of double sided, copper clad, generic circuit board, like the type available at Radio Shack. Fix the pattern of the layout on the circuit board and drill or punch out the holes for the LED's. The smaller pink and green circles indicate the holes for the LED leads. With an etching tool, etch out the black serpentine design, on both sides, which separates the positive and negative parts of the array. Remove the copper around the positive holes for the yellow LED's. The array is laid out without any extra space in between the LED's to account for misalignment of the holes for the leads. If placing the LED's is difficult, gently sand off the step around the bottom of the plastic housing. Solder all of the LED's in place, starting from one side of the array to the other. Periodically, test for shorts with a multi-meter and test for defective LED's or placement (reversing the leads) by powering the array with two alkaline batteries. Clip the leads off after testing, except for the yellow LED's. Bend, touch and solder together the positive yellow leads in a manner not to make contact with another parts of the circuit board. Connect a 15ohm, 1/2 w resistor between the collection of yellow positive leads and the positive section of the circuit board. Solder tack a black wire to the negative section of the circuit and an orange wire to the positive section.

You can buy your LED's from:

<http://www.whitelightled.com/>

It is a legit site, worked out well more me.

You want the 5mm, 20 deg, 6400 mcd white leds. They run at 3.6 volts @ 20 mA.

The above info was taken from several sources mainly Doug Strait and Garry Petrie.