LED Lessons Learned (16 April 2007)

Lessons learned in building the most energy efficient lighting for primitive environment use from commonly available items.

Sanding the round head off to get wider angle: Taking a LED that produces most of its light in a 12 degree angle and sanding or grinding off the rounded head to a flat will produce a wide angle LED.   If one leaves the scratches then the light energy output goes down about 25% of the original. However, if one paints the scratches with anything clear such as epoxy, glue, clear sprays, lacquer, rust-oleum clear top coat, this allows more of the light to go out the front. With scratches some of the light is reflected back and goes out the back. Getting rid of the scratches improves the overall forwarded light output to 125 percent over the round forward light energy readings. The 12 degree light spread changes to about 90-100 degree spread. The light intensity falling at a distance goes down about 11x. However, many times for close up tasks, lighting a wide angle is more usefully than a narrow. The biggest advantage is the change from spot to flood type lighting.

Light measurements: The LX-101 Lux meter from Electronix Express (1-800 972 2225) part no. 01LX101 for $65.95 works well. Comparative measurements at a know distance say one foot will give comparative light intensities. This can be done in a black plastic bag to cut down light from other sources. If the LED is placed in close contact with the light meter then comparative light energy (total light) can be measured between light sources. If one measure the light say 6" or 12" away from the source then one is measuring light intensity. Both of these ways of measuring are good for determining the relative efficiency of the LED one to another.

Another more accurate way to measure total light output energy is to use a silicon photo cell inside a small black box with a hole the size of the LED in one side. The arrangement is such that the LED is held close but at a fixed

distance directly in front of the photo cell. The Photo cell is hooked to a digital current meter to measure relative current flow thus translating to light energy.

MCD (mili-candela) is a measure of light intensity not total light energy. MCD is becoming more and more a sales point without understanding the misleading ramifications it presents. Light intensity is energy over a given unit of area. It only indicates how hot a spot of light one can engineer into the unit. In other words LEDs are being designed to produce more and more mcd and as a result have a hot smaller and smaller spot that is being measured.   Many times the result is too narrow for common use.

LED viewing angle degrees: As the viewing angle for a LED decreases the MCD goes up. Theoretically if all of the light energy for a 120 degree LED were concentrated into a 12 degree angle then we get the ratio of the square of these numbers or 100 times more light intensity. Due to leakage into other directions one doesn't in practice see any where near this result. It turns out to be about a bit more than 10 times more light intensity at the smaller angle.   Thus as a simple rough rule of thumb the intensity goes up as the angle goes down by a bit more than approximately the ratio of the two angles.

Way to determine best series resistor or the number of series connected x-mass tree bulbs. Hook up 3 white or 5 yellow LED's in series with a variable resister adjust source voltage to 15-16 V DC. Use the highest voltage that will be seen when in operation (including charging).   At this maximum voltage adjust the pot to give 20 ma current flow for each parallel combination of LEDs. The best range for the LED operation at 12.5 volts is 10 ma (white) or 15ma (yellow) current flow for each parallel combination of LEDs. Measure the resulting resistance and you have the best value to

use for this circuit. Chouse the next higher standard resistance value that can be found as available.

If using x-mass tree tungsten filament bulbs then start wiring in bulbs in series until the current maximum at maximum voltage is close to being as recommended (10-15 ma for white). When soldering the x-mass tree bulbs together in series the leads need to be sanded or cleaned and tinned with solder. They are thin and will break easily and are hard to tin.   Another way is to continue to use the socket. In this case one solders in series the number of sockets needed. If this is done the contacts with the bulb can be expected to give trouble (make poor contact) with age and wet conditions.

Given a limited number of a given type of mini-x-mass tree bulbs, first find the cold resistance (measure a number of them in series and divide by that number to get bulb resistance) and the operating voltage then attempt to match it with my list (see how to drive LEDs write up). Look up the resulting current for the curve bending point as near to but below the design current.   Chose a number of parallel series combinations that you think might work and test it. Next adjust the number of bulbs in series until 15-16 volts input gives the intended limiting current flow. If too many bulbs are needed then add more LEDs in parallel if the bulb glows too brightly or near operating voltage then drop the number of LEDs in parallel. In this way one can tune up the result to be a minimum number of x-mass tree bulbs being needed and maximize the life of the x-mass bulbs.

3 cell rechargeable battery packs: Not recommended to use this low a voltage with white LEDs. Its operating voltage is too close to battery voltage. One solid color LED and a series resistor (white 82 ohm or yellow 130 ohm) or x-mass tree bulb can work. However, current will change rapidly with voltage as the batteries discharge.

4 cell rechargeable battery packs: First choice is one series connected white LED and a series connected resistor (white 160 ohm or yellow 220 ohm) or x-mass tree bulbs (6 W-20) current limiter. LM317 current limiter circuit doesn't work because voltage is too low. The rechargeable cells could be Ni-mh or Ni-cad. Typical circuit follows.

LED Night Light

1000 Ohm   X Ohm

LOW   HIGH

LED

ON
OFF

4 AA
+ −
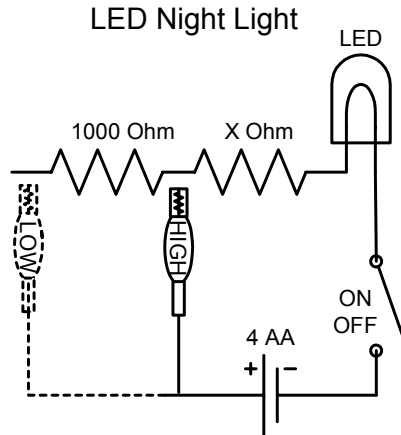
8 cell rechargeable battery packs: First choice is two series connected white LEDs and a LM-317 (using R=82 ohm) current limiting circuit. Second choice is a resistor (320 ohm) or x-mass tree bulb (6 W-20) current limiter. The rechargeable cells could be Ni-mh or Ni-cad. If two sets of 2 series LEDs are connected in parallel then use a LM-317 (with R= 41 ohm).

12 Volt lead-acid batteries: First choice for two parallel of three series connected white LEDs is to use a LM-317 with 62 ohm current limiting circuit. Second choice is a resistor (130 ohms) or x-mass tree bulb (3 series W-20) current limiter. First choice for seven parallel of three series connected white LEDs is to use a LM-317 with 15 ohm current limiting circuit. Second choice is a resistor (40 ohms) or x-mass tree bulb (4 series W-35) current limiter. 5 yellow LEDs is about equivalent to 3 white LEDs in terms of voltage drop thus the same driver circuit should work.

The older LEDs that run at a slightly higher voltage will be fairly close to these measurements giving 5% to 10% lower currents for the same resistance.

For low power light (night light): Use a 500, 1000 or 2000 ohm resistor in series. The more LEDs you are diving use the lower resistance the fewer use the high resistance. It is really surprising the amount of light this low amount of power produces especially considering that the batteries will last approximately 10 times as long.

When wiring in parallel use LEDs from the same batch or same purchase. This helps insure they all run at the same voltage.

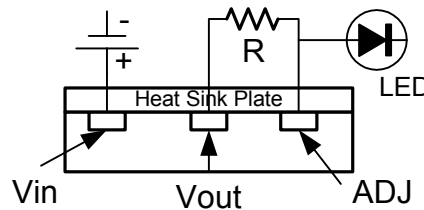**LED Lessons Learned (16 April 2007)**

Always heat sink the leads between the LED and solder point when soldering.   Use an alligator clip between the lead and the LED as a heat sink. The white LEDs are really sensitive to overheating.

LED lifetime: The red and solid color LEDs can run near 20 ma with about half light output after 100,000 hours. The white LEDs being more heat sensitive should be designed to run about 10 ma to get the better results. Running at 15 ma in my experience would be the absolute max to be used for temporary over voltage conditions. The 20 ma max as the manufactures recommend causes rapid degradation in the white LEDs.   Always heat sink the leads of white LEDs when soldering them (especially true for the hotter type soldering irons)

See separate write up on how to drive LEDs for more detail on LM-317 and how to use series resistors. The following shows how to hook up a LM-317 to limit the current flow. The battery source can range from 5 to 35 volts.
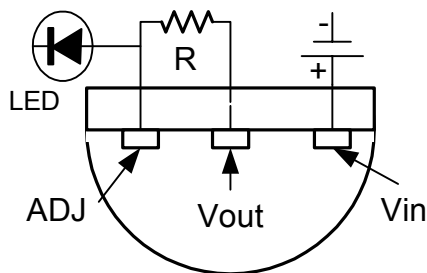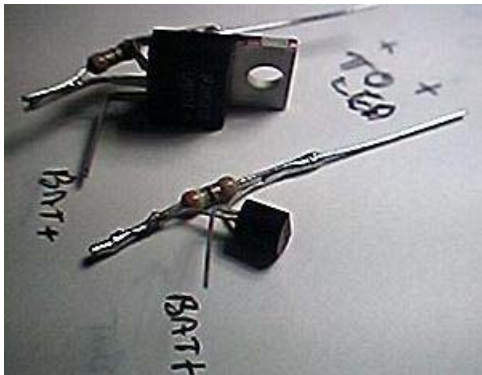

TO-92 Bottom View   TO-220 Bottom View

This is what it looks like with the resistor in place.

Good technical resource:
http://www.intl-lighttech.com/library/calculators/
http://www.gizmology.net/LEDs.htm

Theoretically a resistor needs to be added to each series combination of LEDs that will be put in parallel with others of like combinations.   In practice this may not be necessary.

You built it. So if one series combination goes out in the ensuing years then you know how to repair it. Either cut the circuit open for the bad series combination and adjust over all current flow or solder in a new series set. Or replace the bad LED with preferably an LED that came from the same batch and has been ruining for about the same time frame. In other words repair when you have several series strings of the same types broken to get one working. Use one series string for spare parts for the others.

The way to tell the ones going bad is to lower the current down below .5 ma for the combination. Any that does not light or are low in light output or out of balance or are suspect.   They could be going bad due to over heating either by soldering or by use.

12 volt lead acid batteries have a usable range of 11.5 volts to 15 volts when vigorously charging. The typical most common range of voltage encountered under normal use is 12 to 13 volts.   Thus the LED should be designed to work between the extreme ranges with focus on the optimum desired current in the usual range of 12 to 13 volts.

Adding a 1000 ohm resistor for a low setting gives 4 to 5 ma flow between 12 and 13 volts. Plan to use the amber for as much as you can. This will minimize bugs being attracted. White for task lights and red for distance at night. Amber, red and green are said to help protect against night blindness.

Bugs are attracted to UV LED light. One can try different shapes and types of pans of water. Put a little bit of soap in to cut down surface tension and helps keep the bug in the pan. The following is a low power way of killing bugs and mosquitoes.

With power applied.

Ultra Violet light can be used to spot urine and blood. It can be used to spot skin conditions where something (like fungus) is growing on it. It can be used to spot organic growing things in water.   If enough power can be used it can purify water or air.   A strong UV flash light or task light could be usefully in a primitive environment.

LED Tail Light Bulbs

Count number of LEDs and divide by 3 then multiply by 20 ma (3-5mm) for white and 30 ma for Amber to get the maximum current that the unit should use. Design the circuit to draw about half this or 10-15 ma as a max per each LED. Thus for 9 LEDs draw should be no more than 30ma (white) to 45ma (amber) and, for 12 LEDs 40 ma (W) 60 ma (A), for 19 LEDs = 70 ma (W) 105ma (A). If you're chosen LED draws more than this amount at 14 Volts than a resistor in series will defiantly be needed. I have found that typically a 51 ohm ¼ watt will work in most cases.   Another very good way to determine resistance needed is to measure the current at about 14 volts and adjust a series variable resistor such that the current ends up be about half of what was measured. Then measure the adjustable resistor and replace it with the nearest fixed resistance standard value.

Note: A word to the wise, I have not had good luck with running LEDs close to rated power. They quickly fade and lose brightness. As a rule of thumb always use more LEDs and design them to run half current where you can. As a result they will become more energy efficient at producing light and save power and end up lasting two to three times longer than at the rated current. The only exception to this rule is short term use emergency task flashlights. These can be run at .15 ma for a max rating of about 20 ma and .22 ma for a maxim rating of 30 ma. The thinking is the mechanics of the flashlight and or the batteries will ware out well before the LED. Use this where light weight or minimum components is desired.

The following table shows my experience with tail light bulbs. Any 12 volt bulb will work it doesn't have to be a one pin type. If two level of brightness bulbs are used they can be wired in parallel if needed to gain more light. Or one can use the lower light output terminal on multi-terminal bulbs if this gives plenty of light (it will defiantly save power).

LEDs	Draw	light output	Description
No.	ma	ma	Tested at 13.6 volts
12	132	12.5	1156 white purchased 4 years ago.
12	44	4.8	1156 white purchased 4 years ago after 51 ohm
12	8.5	.83	1156 white purchased 4 years ago after 510 ohm
12	34	4.5	1157 white purchased 4 years ago low side.
12	144	14.6	1157 white purchased 4 years ago high side.
12	42	4.4	1157 white purchased 4 years ago high side (51 ohm).
12	7.7	0.7	1157 white purchased 4 years ago high side (510 ohm).
12	94	14.5	1156 White JDM no resistor
12	49	9.2	1156 White JDM after 51 resistor
12	8.3	2.0	1156 White JDM after 510 resistor
19	143	7.0	1156 Amber no resistor
19	74	3.8	1156 Amber after 51 ohm resistor
19	14.4	0.5	1156 Amber after 510 ohm resistor
9	78	10.7	1156 White plastic cone no resistor
9	42	8.3	1156 White plastic cone after 51 ohm resistor
9	7.9	0.9	1156 White plastic cone after 510 ohm resistor

For a low setting use a 510 ohm resistor. It will use 10 times less current and power. The apparent light brightness between high and low is about one

third or one half as bright. A little light at night can be used as nearly as good as a lot of light. Use only what is needed to save power.

A clip is used in place of the switch.

Final result with high-low slide switch (center possition is off):


Close up on the wiring.

Construction notes:

Strip the insulation off number 12 or 14 solid wire for a 2 inch distance from one end of a 12 inch cut section of wire. Cut off a .25" section of the insulation and put it back on the end of the stripped bare wire. Slide it down so that about .25" of bare wire shows. Solder this to the base of the LED. Solder one side of the switch to the wire large copper wire. Solder the 18 gauge speaker wire copper color to the center of the 1156 bulb or to the brightest terminal of an 1157 or multi-terminal bulb. Solder the 51 ohm across the front terminals (ones closest to bulb) and solder the 510 ohm

across the back terminals. Bend the bolt tabs up on each end of the switch to provide a flat area to push against. Make a loop in the end of the solid 14 gauge wire for fasting to the wall.

The slide switch can be purchased from http://www.allelectronics.com/ Search for the part number "SSW-37" $.25 to $.33 depending on quantity.

LED Tail Light and Wall Mounting Fixture

12-14 Gauge Insulated House Wire

510 Ohm   51 Ohm

Slide SW

LED BULB

12 Volts

− +
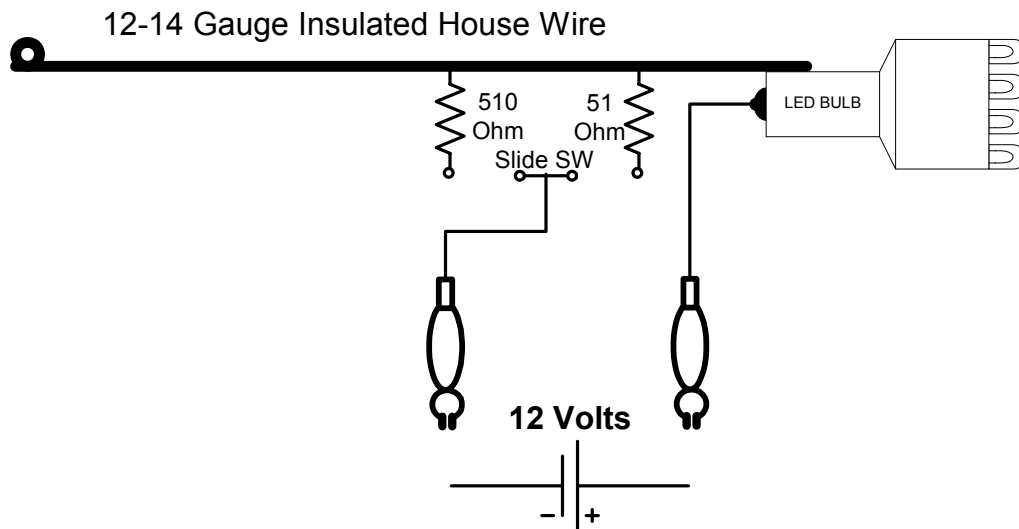
How the slide switch looks when wired. Note the tabs on the top of the switch are bent up to give a surface to push against.

Apr 1, 2007 15:30

Don't bother buying bulb sockets; instead solder directly to the bulb your power lead wire. I soldered a number 12 solid wire to the side of the base that is about 6" to12" long that has a small loop bent into the other end. This is used to fasten it to a wall with a wood screw and washer.   The stiff wire is intended to be bent to direct the light to the users needs. Ends up with a high and low setting depending on if the 510 ohm resistor is in or out of the circuit. In a pinch one can use a clip lead for the switch.

How to make a 115 Volt AC LED Bulb

Take apart the socket from a burnt out florescent bulb. Cut a circle of plastic or cardboard that will just fit into the shell. Solder 28 LED in series and place them around the perimeter of the circle and push in the circle of plastic to hold the LEDs.
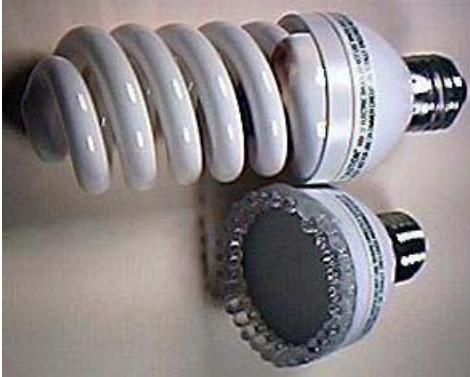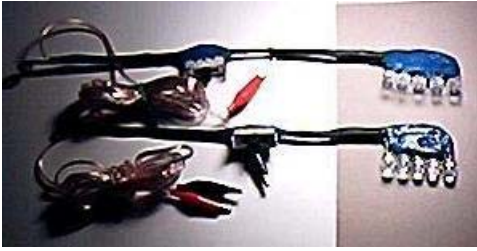
The following is one way of how to wire a 1.1 Watt white LED light bulb that uses 115 Volt AC.

28 White LEDs @ 10 ma
1.1 Watt

200 V 47 uf

1000 Ohm

200 V 1 amp

1000 Ohm

110 V AC Light Socket
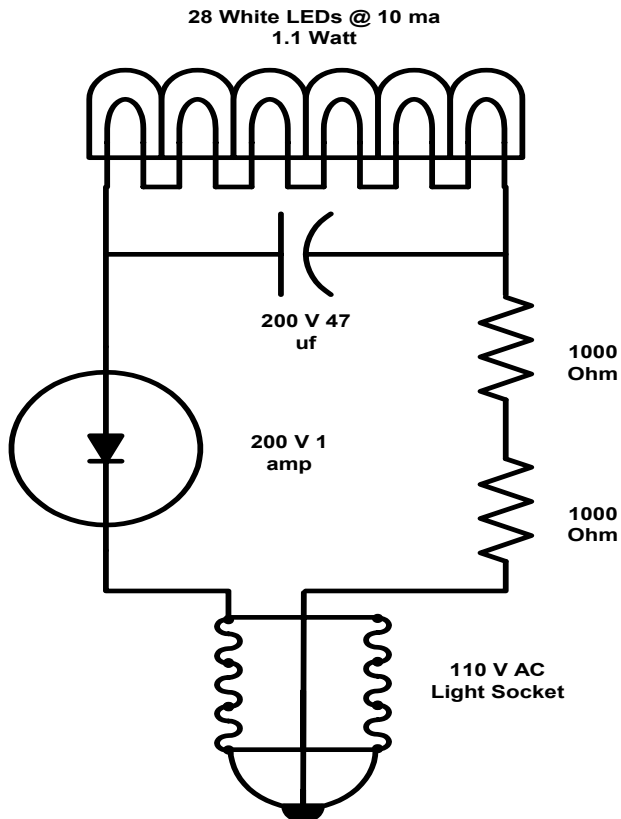
The following is an example of what can be done with LEDs held in place with silicon rubber (RTV Silicon Instant Gasket).


Different shapes for the end can be made for different purposes.

The pigtails on the LEDs can be bent around the support wire as show below. This didn't work as well as using a PC board with holes in it. The LED leads have to get really hot during soldering to the number 12 wire. It is very easy to over heat the LED.
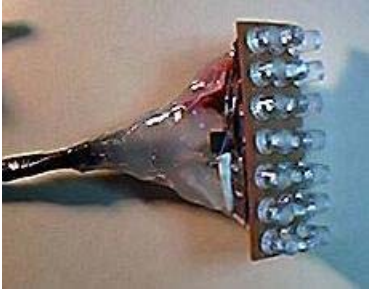

The use of a PC board with holes in it worked the best to organize and point the LEDs. Note that this rendition uses the LM-317 to limit current to 84 ma.
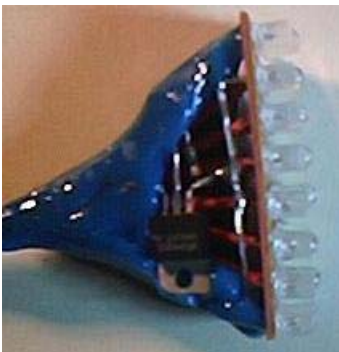
In this case sanding some of the LEDs flat and leaving some round to get the right light distribution.

Small stick on push to turn on battery operated LED lights can be found on the market these days.   These were bought at a local store.

Or this can be made from an older tungsten filament version by taking it apart and replacing the bulb by several LEDs. This one has 3 LEDs a series resistor and runs on an exteranal 12 Volt battery.
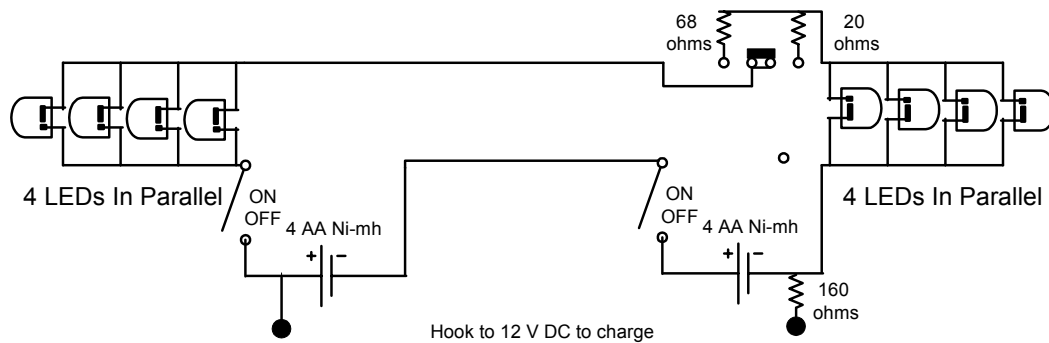
LED Lessons Learned (16 April 2007)

This task light is designed to be supported over the back of the neck. It uses 8 cells and runs at 55 ma on high and 18 ma on low. 2 sets of 4 parallel LEDs are in series.


Over the Shoulder LED Task Light

4 LEDs In Parallel   ON OFF   4 AA Ni-mh

68 ohms   20 ohms

ON OFF   4 AA Ni-mh   4 LEDs In Parallel

160 ohms

Hook to 12 V DC to charge

LED Lessons Learned (16 April 2007)

Silicon rubber was used to hold the LEDs and PC boards to the battery box. This unit as was built does not give enough flexibility to adjust the position of the LEDs and at the same time allow the battery packs to rest flat against the body. I recommend a 12 gauge short wire stand-off so that the LEDs direction can be adjusted.

This next unit is a night light using minimal power. The battery packs shown in this report can be purchased from your local Radio Shack.

LED Night Light
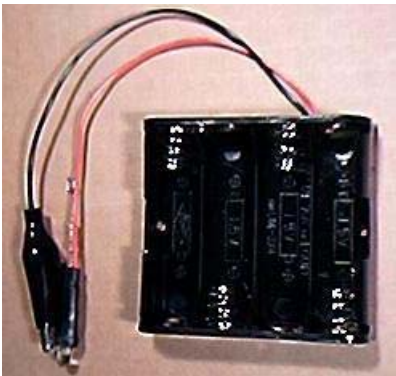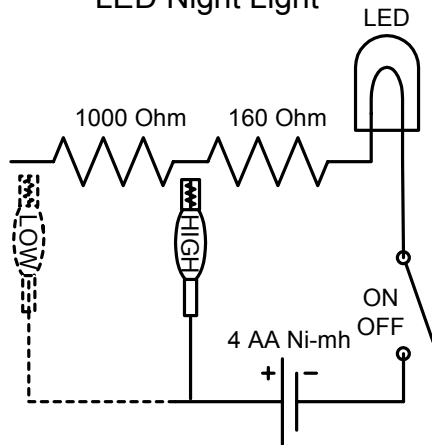
LED Lessons Learned (16 April 2007)

One charge of the cells will last (turned on full time) about 4 to 6 days on high and 1 to 2 months on low (1000 ohms) depending on the capacity of the batteries used.

The clip is used to change from high to low setting. The switch on the battery case is used to turn on and off the unit. Other colors like amber are also useful to help keep bugs away at night.
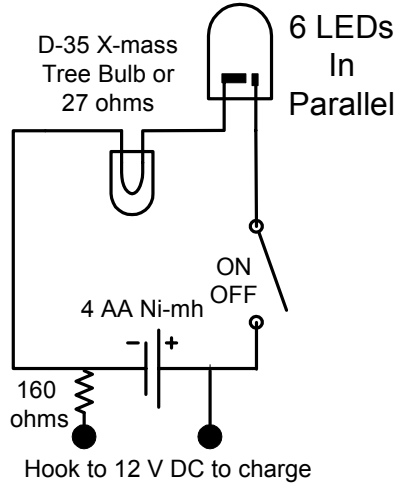

This next picture shows a clip on a hat task light that works extremely well. It can last up to 24 hrs of on time at 90 ma. 6 LEDs running at about 75% power with 40 to 90 degrees LEDs work best for tasks with-in arms reach. Most commercial units have too small a spot size to be usefully at close range. They can be used when walking or longer distances. Most commercial units have too small a battery to last long. This unit has a wide angle of light with more intensity and bigger batteries.

Clip on LED Task Light

D-35 X-mass
Tree Bulb or
27 ohms

6 LEDs
In
Parallel

ON
OFF

4 AA Ni-mh

− +

160
ohms

Hook to 12 V DC to charge

The clip was salvaged from a small clip-on LED "astro lite" bought at a 99 cent store. It was cut down to size with a hack saw. A pc board with holes in it was cut to size and 6 white LEDs were wired in parallel as per the diagram and picture above. 5 min epoxy was used to hold the LEDs in place.   Silicon rubber gasket sealer was used to hold the resistor or x-mass tree bulb and charging leads in place.

This report should give one a good start on what can be made to assist survival in a primitive environment in terms of LED lighting.