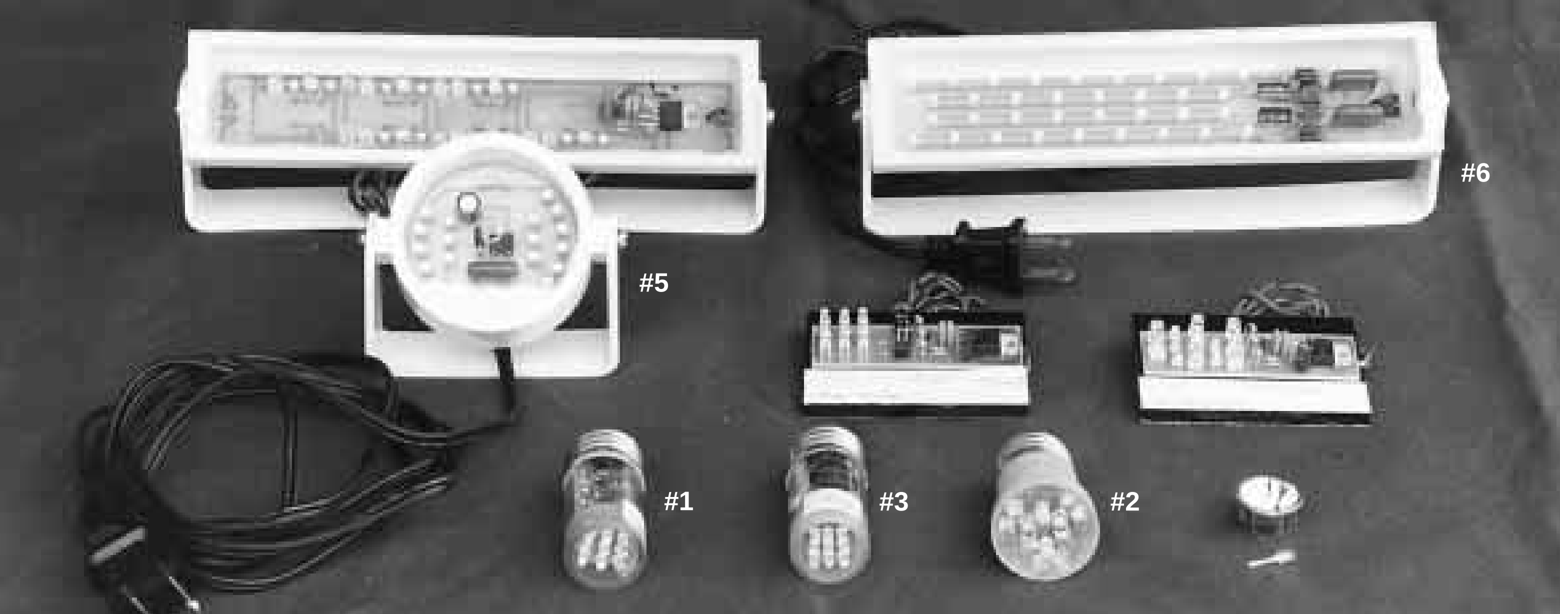
LED Lighting Shootout



Richard Perez

Here is a lighting test—which lighting technology can produce the most light for the least power? The hands down winner is the light emitting diode (LED) which makes three times more light per watt than a compact fluorescent and 30 times more than a standard incandescent.

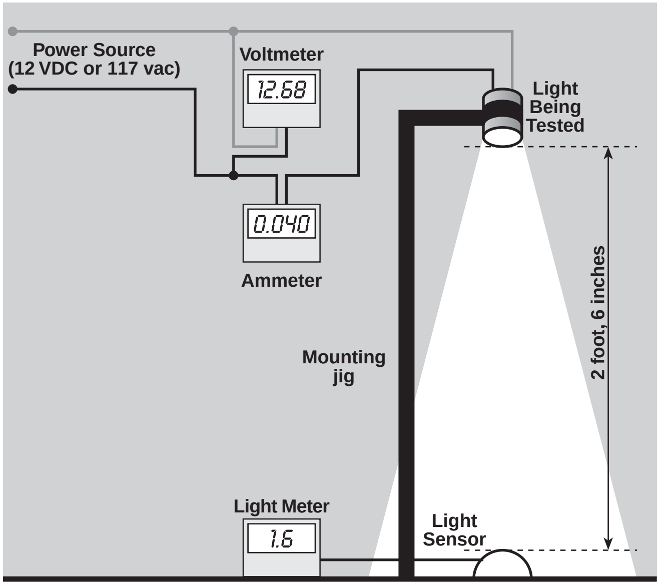
What is an LED?
Just as its name, light emitting diode, implies, the LED is an electronic diode not much different from any other semiconductor diode. What makes an LED special is that its semiconductor junction is designed to convert current flow into visible light. LEDs have been around as discrete colored lights for quite awhile. Just about everyone is familiar with the LED as indicators on electronics. They came in various colors such as red, green, and yellow. Recent advances have made blue and now, finally, white light available from LEDs. The intensity of the LEDs light output is also increasing rapidly. Modern LEDs can have over a hundred times more light output than those available ten years ago. It is now possible to assemble lighting from a collection of LEDs.

The LED is inherently a low voltage DC device. LED junctions operate at between 1.8 VDC to just over 3.1 VDC. This junction voltage drop is built into the physics of the diode. While different colored LEDs have different junction voltage drops, they all fall into the 1.8 to 3.1 VDC range. When it comes to using LEDs efficiently, the data here shows that they are best employed using low voltage DC as a power source.

The LED has several advantages in addition to high efficiency electricity to light conversion. The LED is the longest lived light making device ever invented. LEDs now commonly last 500,000 hours before failure. With use every night, all night, this means that an LED will last for over 100 years! Physically the LED is very rugged and can withstand moisture, vibration, and shocks which would easily destroy a compact fluorescent or incandescent lamp. The LED lamps also produce no radio frequency interference (RFI), while the same cannot be said for many compact fluorescents.

I've been using LED lights around our home for several years and decided it was time measure their performance against other efficient lighting technologies.

The Test Jig
I set up the simple light testing jig shown in the illustration here. I designed this particular test jig to simulate a desk lighting situation or reading in a chair situation. I used a Greenlee Textron model 93-1065F Digital Illuminometer to measure the light output of the various lamps tested. This light meter is designed to measure light levels from lighting fixtures for the purpose of verifying that lighting specifications or



standards have been met. The Greenlee reads out in foot-candles. The distance from the lamp to the light sensor on the Greenlee was 2.5 feet (0.77 meters). I made the electrical measurements (voltage and amperage) using two Fluke 87 digital multimeters.

Please note that this test jig simulates "task" or focused lighting. This jig was not designed to simulate wide area lighting. Since the Greenlee's light sensor is in a specific location, light not falling on the sensor is not measured. This jig measures light that is focused on a specific area, such as a desk or a reading chair. All LEDs contain a lens which focuses their light in a single direction, much like a reflector used on conventional lighting. This focused beam output makes the LEDs suited to task lighting.

The Test Results

In all I tested nine different lights. The majority were LEDs, but I also tested two compact fluorescents and one standard incandescent lamp. The data on the table speaks for itself. The bold figures at the right edge of the table show the bottom line—how many foot-candles of light do you get per watt of power. Here the LEDs show a clear superiority to other lighting technologies. In some cases, this is a comparison of apples and oranges because the power consumption and gross light output varies so widely between the various technologies. While the conventional lamps tested consumed around 20 watts of power, the LEDs consumed between 0.5 watts and 6.9 watts. Light output varied from 1.6 foot-candles to 5.6 foot-candles on the LEDs, while the conventional lights put out between 1.4 and 23.9 foot-candles. So how many foot-candles do we need to be able to read? Well that depends on the person and the situation. In my particular case I can easily read with around 1 foot-candle of light. In fact, I have been using Light #7 to read by every night for the last five months. I find it far brighter than the 12 VDC incandescent it replaced (and 15% of the power consumption even though it runs on 117 vac).

The Players

Here is a brief description of each of the lights tested. I realize that there are many conventional lighting technologies not represented in this test. I included the three conventional lights so that we would have some common basis for comparison. This is primarily a test of LED lights. The data on the lighting table is sorted by the right most column—foot-candles per watt. Hence the most efficient light falls at the top of the table and the least efficient on the bottom.

Light 1

This light is made from nine white LEDs and is powered by 12 VDC. Since all LEDs are low voltage DC devices, this 12 VDC model is far more efficient than Lamp #7 which has about the same light output, but is powered by 117 vac. This light has a standard screw in lamp base and can be used with conventional medium screw base light sockets. Delta Lights makes this lamp and the retail cost is $75.

How LEDs compare with other energy efficient lighting technologies

Light #	*Light Description*	*Power Type*	*Measured Volts*	*Measured Amps*	*Measured Watts*	*Light in Ft.-Candles*	*Ft.-Candles per Watt*
1	Delta Lights LH2 9 white LEDs	12 VDC	12.68	0.040	0.507	1.6	**3.155**
2	Jade Mtn 9 red, 3 blue LEDs	12 VDC	12.65	0.069	0.873	2.6	**2.979**
3	Delta Lights LH2-LVD-P 9 white LEDs	12 VDC	12.72	0.067	0.852	1.7	**1.995**
4	Osram EL11R CF w/ reflector	117 vac	118.70	0.169	20.060	23.9	**1.191**
5	Delta Lights LAC10WL 17 white LEDs	117 vac	118.40	0.029	3.434	2.9	**0.845**
6	Delta Lights LAC7WL 34 white LEDs	117 vac	118.30	0.058	6.861	5.6	**0.816**
7	Delta Lights LH4 10 white LEDs	117 vac	118.30	0.033	3.904	1.6	**0.410**
8	Osram EL15 compact fluorescent	117 vac	118.30	0.242	28.629	11.2	**0.391**
9	GE 25 watt incandescent lamp	117 vac	118.20	0.196	23.167	2.4	**0.104**

Light 2
This 12 VDC lamp uses nine red LEDs and three blue LEDs to produce a fairly color correct white light. While not as color correct as the white LEDs, this combination is fine for reading and, as the figures show, brighter than the white LED models. This lamp is made by Jade Mountain and costs $49 retail. See HP # 57, page 74 for a Things that Work! review of this light.

Light 3
The lamp is exactly the same as Light 1, but contains an automatic photosensor that shuts it off during the day and a low voltage disconnect to prevent the lamp from overdischarging a small battery. Note that the electronic controls significantly increase the lamp's power consumption while not providing any more light. This Delta Light has a retail cost of $93.

Light 4
This is a regular 117 vac compact fluorescent made by Osram. This model uses a reflector to focus its light output making it ideal for task lighting. This is the light we normally use over all of our work spaces here at Home Power. In many cases, like reading in bed at night I have found the EL11R to have way more light than I need. Retail cost is around $15.

Light 5
This LED lamp is powered by 117 vac and uses 17 white LEDs. I find that I can easily read at a distance of over four feet from this lamp. Its efficiency is lower than the 12 VDC LED models because of the power supply necessary to change the 117 vac into low voltage DC to operate the LEDs. It is, however, easy to use—just plug it into any 117 vac power outlet. Delta Lights' retail price for this model is $140.

Light 6
This lamp was the brightest LED light I tested. It used 34 white LEDs and delivered 5.6 foot-candles to the light meter. This lamp makes a fine replacement for the Osram EL11R (Light 4 in the test) and consumes less than 1/3rd the power. Delta Light's retail cost is $240 for this light.

Light 7
I have chronic insomnia and wake up and read every night for several hours. Over the years I have tried just about every light imaginable for this service. They are either too bright, not bright enough, or consume too much power. This LED light screws into any conventional medium base lamp fixture and runs directly from 117 vac. Delta Light's retail cost is $75 for this model.

Light 8
This is a standard twin tube compact fluorescent with no reflector. As you can see from the table, without a reflector it is poorly suited to task lighting. I included it in the test because it is commonly used in homes. Retail cost is around $15.

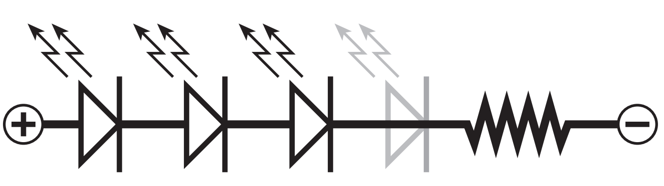
Light 9
This is a conventional incandescent light made by General Electric. I guess that, by this time, everyone knows that the incandescent light is a better heater than illuminator. Well, here is measured proof. Retail cost is less than $1.

Cost
For the data here, it's easy to see that LED lighting is still fairly expensive. The new high intensity LEDs, particularly the white ones, cost between four and ten dollars each. Once you get a collection of a dozen or more of them, then the price of the light is high. Expect prices to come down in the future.

At this time and at these prices, LED lighting is cost-effective primarily in small battery-powered, portable systems. If you are backpacking, or biking, or canoeing, or carrying a flashlight (Delta Lights makes an LED lamp for flashlights priced at only ten bucks), then LEDs are the only lamp to use. If you want to squeeze the maximum performance from your low voltage RE system, then LED lighting can help.

Homebrewing LED Lights
If you want to save some bucks, then consider making your own LED lights. It's very easy. The only hard part is getting ahold of the high intensity LED lamps. Radio Shack sells a fairly high intensity orange LED (RS part number 276-206) for $3.99 each. This LED has a forward voltage drop of 2 Volts and a junction current of 50 mA. The schematic here shows how to put three of these LEDs on 12 VDC power. Simply wire three LEDs in series and use a 150 Ω resistor (RS part number 271-1109) to limit the current through the three LED junctions. If you want to put four of these LEDs in series, then use a 100Ω (RS part number 271-1108) current limiting resistor.

If you manage to get ahold of the new white LEDs you will find that their junction voltage loss is around three



Volts. You can easily construct a series string of many LEDs to run on 12 or 24 VDC. Simply add up the voltage loss of each series junction and subtract this amount from the battery voltage. Divide this figure by junction current and you have the resistance value of the current limiting resistor. It's really simple Ohm's Law kinda stuff and a great place to start learning homebrew electronics.

Conclusions

If you want the ultimate in efficient lighting, then use LEDs. If you want the ultimate in reliable lighting, then use LEDs. If you want the batteries in your portable light to last as long as possible, then use LEDs. If you want the cheapest light, then buy a light bulb and pay for the energy forever more….

Access

Author: Richard Perez (N7BCR). c/o Home Power. PO Box 520, Ashland, OR 97520 • 916-475-3179
FAX: 916-475-0836
E-mail: richard.perez@homepower.org
Web: www.homepower.com
Amateur radio: 146.400 MHz simplex

Delta Lights, PO Box 202223, Minneapolis, MN 55420 • 612-980-6503. Delta Light will custom make just about any configuration, color, and intensity of LED light. They also offer low voltage disconnects, photo sensors, and/or motion detectors built into their LED lights.

Jade Mtn., PO Box 4616, Boulder, CO 80306
303-449-6601