HauntMaven.com - Wolfstone's Haunted Halloween Site

http://wolfstone.halloweenhost.com/Lighting/litled_LightEmittingDiodes.html

Light Emitting Diodes

Light emitting diodes (LEDs) are electronic components that produce light without heat or the use of high voltages.

Why Bother?

LEDs are a little tricky to use. You can't just plug them into the wall and have them light up. And you can't just stick one on a battery and have it work. But despite requiring a little extra work, LEDs are commonly used in many products.

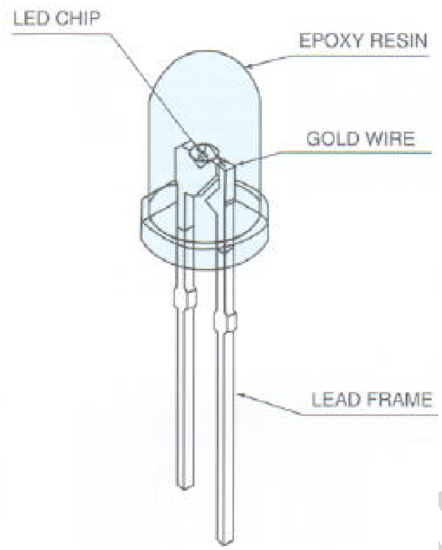
The advantage of LEDs are:

- small
- low power requirements
- fairly efficient
- low voltage; easily powered from batteries
- available in any color you would like
- long life; no filament to burn out
- does not get hot in most uses

Overall Description

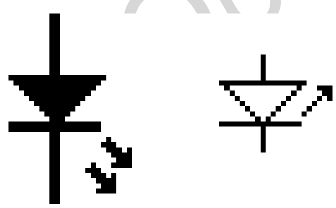
A Light Emitting Diode (LED) is a solid-state component that uses electricity to make light. LEDs produce no significant waste heat and have lives so long that they basically don't burn out.

LEDs come in a huge array of sizes, shapes, and colors.



This drawing, from the Photron catalog, shows the anatomy of a common LED

The part that actually makes the light is the "die", or "chip". The "lead frame" holds the chip and extends out of the package to provide electrical connection. The whole thing is encapsulated in an epoxy plastic package that may be colored or shaped.



This is the schematic symbol for a LED. Expect plenty of artistic variation, such as a triangle that it filled in or hollow, differing number of arrows coming out of it, and sometimes the greek letter Lambda alongside.

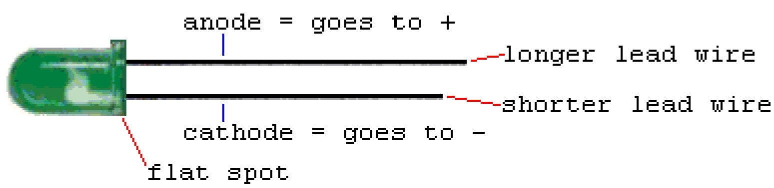
The "triangle" side is the "Anode". This connects to the positive side of your power supply.

The "flat" side is the "Cathode". This connects to the negative side of the power.

Polarity

It is important to remember that LEDs are polarized. If you hook LEDs up backwards, they won't work, and might be damaged. There are several ways to determine the polarity of a LED:

- If the package is round, look for a flat spot on the edge of the LED package. The lead wire nearest this flat spot is probably the cathode.
- If the LED is new (not cut out of some old device), the longer lead wire is usually the Anode.
- The most reliable method of identification is to read the instructions or data sheet, if available.



In summary:

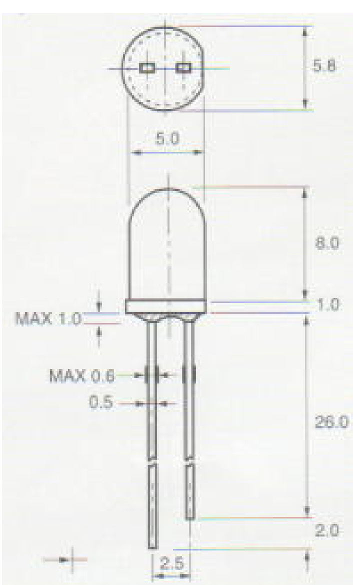
anode	cathode
hooks to + supply	hooks to - supply
longer lead wire	shorter lead wire
case stays round	flat spot on case

LED Selection

There is a nearly infinite assortment of LEDs to choose from. Some selection factors are:

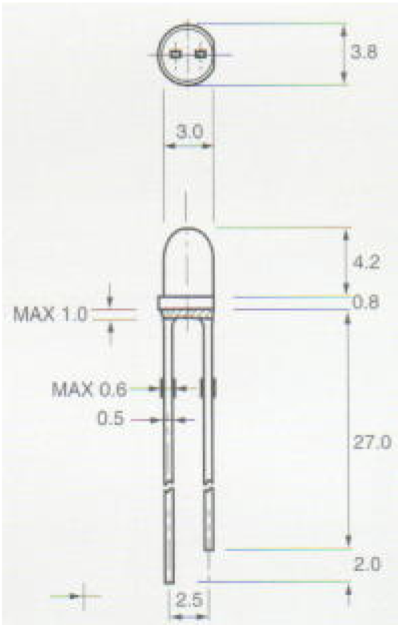
- size
- shape
- color of emitted light
- color of the case
- brightness
- beam pattern (spread)

Size and Shape



LEDs come in a huge variety of sizes and shapes. Perhaps the most common size is called "T1 3/4". His smaller brother is "T1".

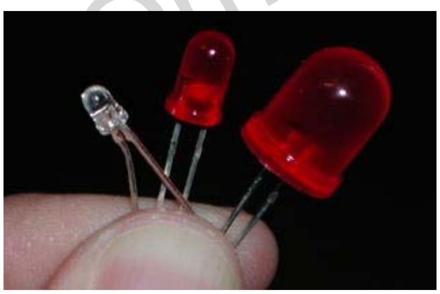
Dimensioned drawing, from the Photron catalog, of the standard LED size called T1 3/4. All dimensions are in mm.



Dimensioned drawing, from the Photron catalog, of the standard LED size called T1. All dimensions are in mm.

Note that the drawings of T1 and T1 3/4 both show one wire longer than the others, and one side of the package with a flat spot on it. These are important indicators of device polarity. If you apply power backwards, the LED will not function, and can be destroyed.

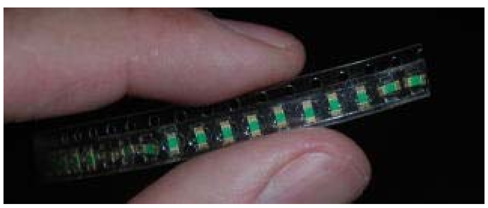
When it comes to LED performance, "size doesn't matter". You might have a huge LED, the size of a gumdrop, and the chip inside is the same one that is normally built into a much smaller case. If you want something bright, get one that is specified as high brightness, or has a large MCD rating.



Three red LEDs, in sizes T1, T1 3/4, and 10mm.

Some common round LED sizes:

name	slang	diameter
T1	miniature	3mm
T1 3/4	standard	5mm
	jumbo	8mm
		10mm



This strip contains "surface mount" LEDs, each the size of a grain of rice.

Light Color

The color of the plastic case around a LED chip doesn't always indicate the color of the light coming out.

When a LED emits a "pure spectral color", the color can be objectively described in terms of the wavelength of the emitted light. This is usually specified in nanometers (nm).

LEDs emitting other colors, such as purples and pinks, are often described by their position on the CIE chromaticity diagram.

LEDs sold through electronic surplus outlets, a common source for hobbiests, may not be so precise. You might find them described as "red", "crimson", "orange", "yellow", "amber".

Light from LEDs tends to be monochromatic. Exceptions are (a) LASER LEDs, which are also coherent, and (b) LEDS that produce interesting colors via secondary emission from phosphors.

Case Color

The color of the LED case sometimes has little to do with the color of light coming out of it. These are all green LEDs. Even the yellow one. :-)

Cases described as "milky" or "diffuse" will spread the light around more.

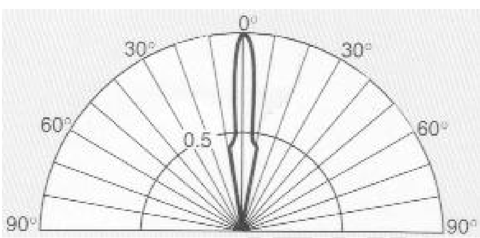
Brightness

LEDs sold through electronic surplus outlets, a common source for hobbiests, are seldom uniformly rated for brightness. Instead, you might find local teminology like "bright", "super bright", and "ultra bright". I have never seen a merchant selling "rather dim" LEDs.

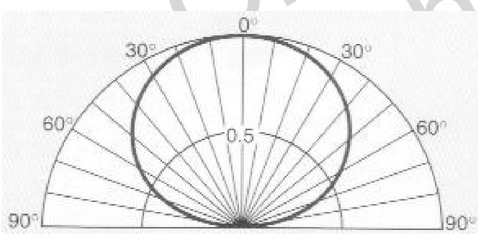
The better sources rate their LEDs in millicandella (mcd), a measure of luminous intensity. A higher number is a brighter LED.

Beam Pattern

The light coming out of a LED doesn't always shoot out in a straight line. There is a pattern to it.



This radiation diagram shows the output of a blue LED with a water-clear case (Photron PL-BA31). Most of the light is shooting straight out the front of the package.



This radiation diagram shows the output of a green LED with a diffused colored case (Photron PL-GB574G).

If you have the manufacturer's part number for a LED, you can probably look up information about the beam pattern - at the very least a viewing angle.

If you are buying LEDs surplus and the part number is unknown, just remember that a "milky" or "diffused" case will spread the beam more, affording a wider viewing angle, but at a reduced intensity.

All LEDs Are Not Created Equal

In the section on LED Selection, I described some of the ways that LEDs can differ. But I feel the need to hammer home the point that if you are building a project that calls for a "yellow LED", and that's what you ask for, you could get something that is very different from the original. Perhaps your yellow LED will work as well, or even better. But without more specifications, it will probably be different.

The following table was compiled from the web sites of Hosfelt Electronics and Jameco Electronics, two companies that offer a wide range of LEDs at competetive prices. The information was collected 24 September 2004, and will certainly be out of date by the time that you read this. But it does a good job of pointing out the range of options.

I looked only for yellow LEDs. I tried to use only LEDs with lenses that are clear or transparent yellow. The prices are for just one LED, but when purchased in quantities of 10. There may well be errors: Hosfelt provided less technical information, but Jameco provided details that sometimes conflicted with the basic description of the part.

vendor	*part number*	*price*	*brightness*	*test current*	*voltage*	*size*	*lens color*	*wavelength*	*mcd/penny*
Hosfelt	25-342	$3.49	23000mcd	20mA	1.9-2.5V	10mm	water clear	590nm	66
Hosfelt	25-408	$1.45	9500mcd	20mA	2-2.4V	5mm	clear	587nm	66
Hosfelt	25-335	$.75	8000mcd	20mA	2.1-2.5V	5mm	colorless, transparent	?nm	107
Jameco	197641	$.62	7800mcd	20mA	2.3V	oval	transparent yellow	590nm	126
Jameco	215597	$.55	5000mcd	20mA	2.2V	5mm	water clear	?nm	91
Hosfelt	25-357	$.49	3600mcd	20mA	2.1-2.5V	5mm	water clear	?nm	73
Jameco	197675	$.36	2800mcd	20mA	2.8V	5mm	water clear	592nm	78
Hosfelt	25-337	$.45	2000mcd	20mA	2.1-2.5V	5mm	water clear	?nm	45
Jameco	152792	$.24	1040mcd	20mA	2.1V	5mm	?	593nm	44

Jameco	206501	$.19	700mcd	20mA	2.2V	5mm	transparent yellow	595nm	37
Hosfelt	25-275	$.12	550mcd	30mA	2V	5mm	colorless	?nm	46
Jameco	206480	$.14	450mcd	20mA	2.3V	3mm	transparent yellow	595nm	32
Jameco	253796	$.24	150mcd	20mA	2.2v	5mm	?clear	585nm	6
Hosfelt	25-414	$.04	80mcd	10mA	2V	3mm	yellow	?nm	20
Hosfelt	25-285	$.10	80mcd	30mA	2V	3mm	?clear	?nm	8
Jameco	175695	$.15	60mcd	10mA	2.1V	5mm	water clear	585nm	4
Hosfelt	25-411	$.05	50mcd	20mA	2.5V	5mm	clear	?nm	10
Hosfelt	25-328	$.06	40mcd	10mA	2.1V	3mm	?	585nm	7
Jameco	136493	$.19	38mcd	20mA	2.3V	5mm	water clear	589nm	2

To summarize, by just checking two vendors, I found 19 different kinds, with properties ranging:

- brightness 38mcd- 23000mcd
- wavelength 585nm - 595nm
- voltage 1.9V - 2.8V
- current 10mA - 30mA
- size 3mm - 10mm
- cost $.04- $3.49

Special LEDs

There are various special LEDs on the market:

- resistor LEDs - Contain their own current-limiting resistor.
- blinkers - Contain a timer chip that makes them automatically flash on and off.
- multichip - Contain more than one LED of the same color. Takes more power, but lights brighter.
- nonpolarized - Contains two LED chips of the same color, back-to-back. Lights up the same when voltage is positive, negative, or AC.
- multicolor - Contains two or more LED chips that light different colors.

Multicolor LEDs

Multicolor LEDs contain two or more LED chips that light different colors.

The most common type has one red chip and one green chip. There are two common types of packaging: a three-lead package that allows independent access to the two LED chips, and a two-lead package that connects the two chips back-to back (to change color, reverse polarity).

This T1 3/4 package contains two LED chips.

- Apply power to one wire and the package lights green.
- Apply power to the other, and it glows red.
- Apply power to both, and the package glows yellow.

Self-Flashing LEDs

Self-flashing LEDs are packaged in a normal LED case, but include an integrated circuit that makes the LED flash on and off.

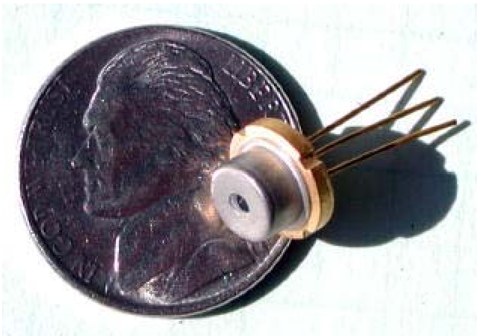
Built-in flashing unit 3 - 5 Vdc operation	CAT#	1-99	100	1000
T-1 3/4 (5mm) RED - diffused High Brightness	LED-4	2 for .90	.40	.30
T-1 3/4 (5mm) GREEN - diffused	LED-4G	.50	.45	.40
T-1 3/4 (5mm)YELLOW - diffused	LED-4Y	.50	.45	.40
SPECIAL - RED T-1 3/4 - water clear	LED-84	3 for $1.00	.25	.18
T-1 (3mm) RED - diffused	LED-72R	.65	.55	.45
T-1 (3mm) GREEN - diffused	LED-72G	.75	.65	.55
T-1 (3mm) YELLOW - diffused	LED-72Y	.75	.65	.55

This section of the All Electronics catalog offers several different kinds of self-flashing LEDs [January 2004].

LASER LEDs

LASER LEDs are Light Emitting Diodes that emit LASER light. They are often called simply "LASER diodes". This was a technological breakthrough that transformed LASERS into simple and inexpensive gadgets. LASER diodes are used in everything from DVD players to light beam pointers.

CAUTION: Because LASER light is coherent, it packs a punch far greater than its brightness might suggest. LASER light can be dangerous. Keep it away from eyes.



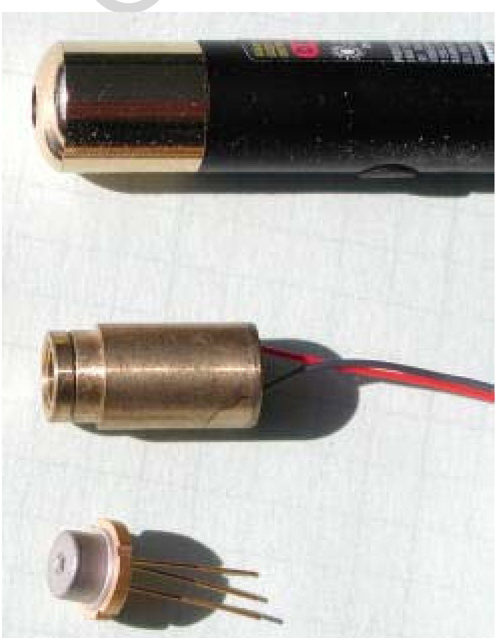
You can purchase LASER LEDs by themselves, but I don't recommend it. You can't just hook them to a battery and resistor and have them work properly. They require special driving circuitry.

LASER diodes are also available built up into "modules" that contain the LASER LED, driving electronics, and lenses.

These are very convenient for the experimenter.

The simplest, cheapest, and easiest way to get LASER light is to take a cheap LASER pointer and modify it to suit your purposes.

So you start with a LASER diode, build it up into a module, and then do something useful with it.



As of this writing, commonly available LASER diodes are confined to the red and infrared portion of the spectrum. Laboratory prototype blue LASER diodes exist, but have short lifetimes, or need to sit in liquid nitrogen. Green LASER diode assemblies exist, but they cheat: an infrared LASER diode is used to pump a frequency-doubling crystal.

Black Light LEDs

After 40 years of research, you can now buy LEDs capable of emitting black light.

We have a page dedicated to black light LEDs.

Also, see Don Klipstein's web site on black light LEDs.

High Power LEDs

LEDs that consume a lot of power aren't particularly desirable. When we refer to "high power", we mean lots of light output!

The brightness of a LED can be increased in numerous ways:

- Use a larger piece of light-emitting material.
- Make the LED more efficient, so that more of the electrical power going in comes out as light and less as heat.
- Shove more current through the LED so that it produces more light and more heat.
  - Heat kills LEDs. Accept a shorter operating life time.
  - Make the LED out of material that better resists the extra heat.
  - Modify the LED package to carry more heat away from the essential part of the LED and dissipate it.
- Change the output wavelength(s) to where the human eye is more sensitive, making it look brighter.
  - This can be done by altering the chemistry of the light-emitting part of the LED itself.
  - This can be done by using secondary emission from phosphors or frequency-doubling crystals to take in the generated light and emit light of a different wavelength.
- Make the LED more efficient, so that more of the light coming out is in the useful part of the spectrum.
- Use a LASER LED, which emits coherent light. You aren't getting any more light out, but the light waves are synchronized, so they pack more punch.
- Increased power via pulse drive is something of an urban legend. But if you turn off the LED while nobody is looking at it (e.g. during video retrace interval), you can increase the current while it is visible.

Of course you can combine these techniques.

Powering LEDs

We have moved all the information about LED power and wiring to powering LEDs

History

The history of Light Emitting Diodes (LEDs) is the struggle for shorter and shorter wavelengths: the quest for blue, with efficiency improvements along the way.

The first light-emitting semiconductor was a yellow-glowing piece of Silicon Carbide invented by Henry Joseph Round in 1907. There was not enough light to be useful, and silicon carbide is hard to work with, so the invention was mostly forgotten.

The modern LEDs were based on Gallium Arsenide (GaAs) and emitted infra-red light. If memory serves me, the early lab models needed to sit in liquid nitrogen while operating. Getting them to operate with reasonable efficiency at room temperature was a big breakthrough, providing a commercial product useful in things like object sensors and remote controls.

Red LEDs came next, using Gallium Arsenide Phosphide (GaAsP on GaAs substrate). Eventually these led to the development of high efficiency red, red-orange, and orange LEDs by changing to a GaP substrate.

Mid 1970's brought Gallium Phosphide (GaP) diodes, providing greater efficiency, but a somewhat orangeish red light. Soon GaP diodes were putting out pale green, and dual chip GaP LEDs (red and green) were emitting yellow. Then they got to a pure green.

In the mid 1970s, yellow LEDs were made in Russia using Silicon Carbide. The rest of the world used Gallium Arsenide Phosphide (GaAsP on GaP substrate).

Mid 1980's saw the arrival of super high brightness (GaAlAsP) LEDs, first in red, then yellow.

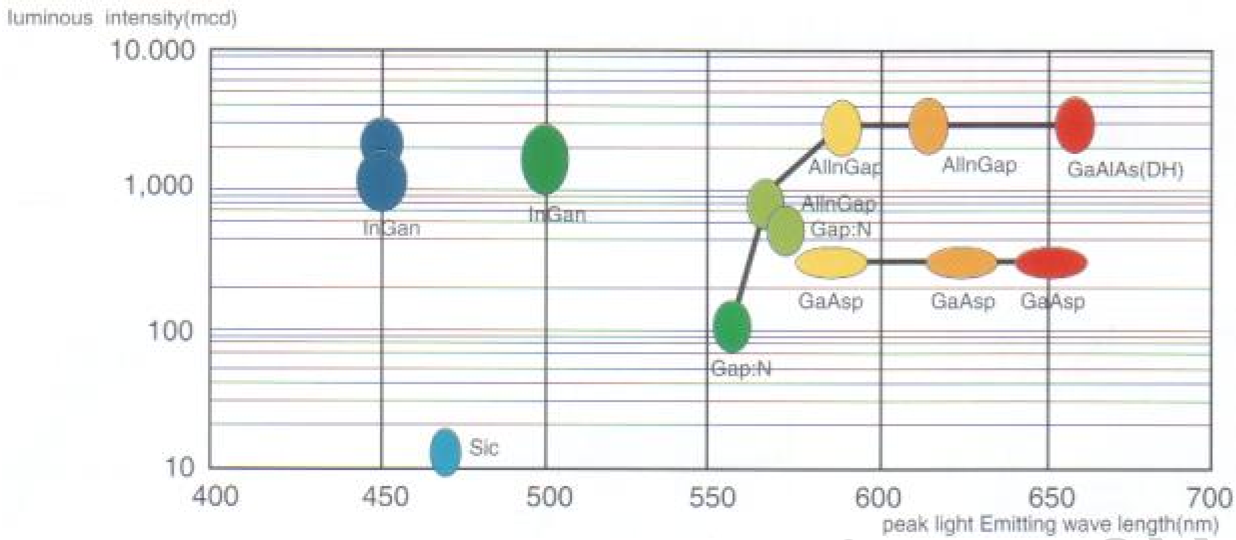
In the early 1990's, ultrabright InGaAlP LEDs were made in orange-red, orange, yellow and green.

The first significant blue LEDs came in the early 1990's, using Silicon Carbide. This was a throwback to the earliest semiconductor light sources.

The mid 1990's brought ultrabright blue GaN LEDs, then Indium Gallium Nitride (InGaN) LEDs, producing high-intensity green and blue.

The bright blue LEDs were then made the basis of white LEDs by painting the LED chip with fluorescent phosphors. This same trick can produce virtually any visible color.

There are now LEDs that emit black light.



This chart, from the Photron catalog, shows the various LED materials and the colors and intensities they can produce, circa 2001.

Breakthrough: Secondary Emissions

The wavelength of light naturally emitted by LEDs depends on their manufacturing process, but generally turns out to be the commonly found red, yellow, green, and recently blue. It is possible to make other colors by mixing light with two or more light emitters within a single package. But the wavelengths that are available to work with make this problematic.

An important LED breakthrough of 1990s was the application of fluorescent phosphors to change the spectrum of light emitted by LEDs. In this process, blue and near-UV emitting LEDs are painted with a mix of phosphors that absorbs the incoming light and emits the desired mixture of wavelengths.

Playing With LEDs

LEDs can be a lot of fun to experiment and play with. It's even affordable, now that they no longer cost $10 apiece.

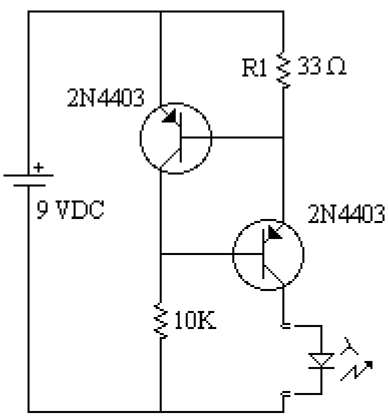
Sooner or later, you will run across an electronic parts vendor who offers "grab bag" kits of assorted LEDs or support parts (perhaps 100 LED's for $5 or 300 1/4W Resistors $2.50). Should you do it?

If you don't want to experiment, but are just building a project that is described by somebody else, avoid grab bags. Instead, buy exactly what you need. If you demand instant gratification, pop down to Radio Shack. If you want to save a couple bucks and time is not an issue, buy mail-order.

If you like to experiment, it is a good idea to build a "junk box" of parts that you can play with and rummage through. In the old days, hobbiests populated their junk boxes with components removed from old equipment. Nowadays, the grab bag is a good way to get started. You will probably get an assortment of different shapes, colors, and sizes. Some of them you might never use, but at least you will have an assortment of different things to play with. And if you burn up a LED in your experiments, no worries - they only cost a few pennies apiece.

LED Tester

When experimenting with LEDs, it is handy to have around a simple way of testing them. This circuit is a constant-current source, providing about 20 mA, which is a good rule-of-thumb for LEDs.



The current is set to V_{BE}/R1, where V_{BE} of a 2N4403 transistor is a minimum of .75 V and a maximim of .95 V. Depending on exactly which transistor you use, a little fiddling with R1 can be set to any convenient current. [David threw one of these together with junk box parts and it delivers 17 mA, which is close enough.]

More Info

For more information on LEDs...

- Virtual LED Museum
- Don Klipstein's web site
  - LEDs in General
  - Bright and Efficient LEDs

Safety

In the 1980's, LEDs were so inefficient that they were largely incapable of outputting a damaging amount of light. But technology marches on.

As of 2000, it appears that ordinary LEDs (not LASER) that lack optical gain (no lens) are quite a bit brighter, but still safe. As the trend towards more efficient and powerful LEDs continues, danger will increase.

LASER LEDs are a different story, and should be treated with all the cautions suitable for LASERs.

International Commission on Non-Ionizing Radiation Protection:

- Light-Emitting Diodes (LEDS) and Laser Diodes: Implications for Hazard Assessment, Health Physics, Vol. 78, No. 6, pp 744-752, 2000. - http://www.icnirp.de/Documents/Led.pdf

Sources

Although originally exotic electronic components, Light Emitting Diodes are now built into many consumer products, and readily available as components.

Here are several sources, in no particular order:

- Hosfelt Electronics
- Jameco Electronics
- Fry's Electronics
- All Electronics
- Herbach & Rademan
- Radio Shack
- Marin P. Jones & Assoc. Inc.
- Mouser Electronics

If you need just a couple of LEDs and need them now, I suggest going to whatever local store caters to electronic hobbiests. Even at premium prices, LEDs aren't terribly expensive.

If you require a larger quantity and are willing to wait for them, ordering over the web or e-mail will save you money and probably provide a larger selection.

Consumer Products

Quite a few consumer products use LEDs, but they are embedded within the device, not always obvious for what they are.

Here are a few consumer products that *conspicuously* use LEDs...

This is a string of 20 red LED Christmas lights, operated on two "C" cells.

The LEDs are embedded in small translucent red balls that also act as effective diffusers. The effect is nice: they look a bit like berries.

$4.95 at Target (4 December 2002).

This is a string of red, yellow, and orange LED lights, intended for Halloween use, powered from 110 VAC.

The LEDs are embedded in small transparent colored balls. The balls act more like lenses than diffusers: the viewing angle is good, but you can distinctly see a little bright light inside an outer sphere.

Target wanted $9.99 (October 2002), but I got them on sale for about half that, day after Halloween.