# OPTICAL ENGINEERING NOTE #86:
# WIRING UP LED's

Light **E**mitting **D**iodes have been around for almost 40 years, with their precursors being **I**nfra**R**ed **E**mitting **D**iodes. Thanks to recent advances in the materials that they are made of, we now have the whole spectrum represented by these devices, plus there are some that emit a kind of white light. They are thought to be the environmental illumination source of the future, as they emit much more visible radiation per Watt than incandescent bulbs, which typically emit 80% of their emission in the Infrared which is useless for our vision.

Because LED's* are inexpensive, colorful and can be quite bright, they are tempting for artists to incorporate into their works. Unfortunately they are not as simple as light bulbs to hook up electrically.

The basic principle of these devices is that they are made of two different types of materials, joined at a **junction**, with current pumped through them. Thanks to atomic transitions only certain wavelengths are emitted from the junction, not unlike what gives color to neon signs and lasers. The long red wavelengths were the easiest to develop, and the most common type to get to work, but looking at the catalog clippings below there is everything from 680 down to 466 nanometers.

Because light bulbs use the resistance of the tungsten filament to cause it to heat and emit according to the black body radiation curve, they are engineered to have the proper diameter and length of filament to fit the voltage for the intended application, like multiples of 1.5 volts for battery operated devices or the 110 or 220 volt mains of America or Europe.

However, the LED is locked into requiring a certain voltage to jump the bandgap necessary for the atomic transition to take place. Different wavelengths may require different voltages. Therefore the voltage must be brought to the requisite level, which is not necessarily that of the typical batteries. And that can be a problem for the artist.

The amount of photons flowing out of the LED is proportional to the amount of electrons flowing through the LED. Also specified for each different LED is the current, in **milliA**mperes **(mA)**.

* The **apostrophe s** plural is used because *LED* is an abbreviation and the ' takes the place of iode.

There is a formula that takes into account the voltage of the available battery, and that required to run the LED, plus the operating current measured in Amperes:[1]

$$\frac{\text{Voltage of the battery - Voltage needed for LED}}{\text{Current in Amps required for the LED}}$$

Example: to run Hewlett-Packard # HLMP-CB15, (see following page) which we would like to operate on **3.5 VDC @ 20 mA** from a **9 Volt** Transistor Radio Battery, plug in and chug:

$$\frac{9\text{ V} - 3.5\text{ V}}{.020} = 275\text{ Ohms}$$

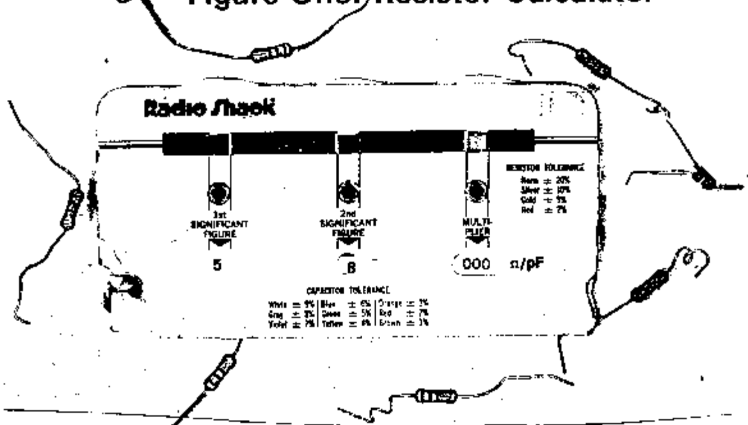
It's not too rough on a pocket calculator. The only difficult part is remembering to change the milliAmps to decimal fraction equivalents: 1000 milliAmps in an Amp, so 40 mA = .040 A. 100 mA = .100 A, etc.

If the voltage and current are not specified, here is a table of default spec's to fall back on for the garden variety LED. For larger devices use the examples given here as a guide.

**Table One: Default LED Voltages**

| WAVELENGTH (in nanometers) | VOLTAGE |
|---|---|
| 565 green | 2.2 - 3.0 |
| 590 yellow | 2.2 - 3.0 |
| 615 orange | 1.8 - 2.7 |
| 640 red | 1.6 - 2.0 |
| 690 red | 2.2 - 3.0 |
| 880 infrared | 2.0 - 2.5 |

**Figure One: Resistor Calculator**

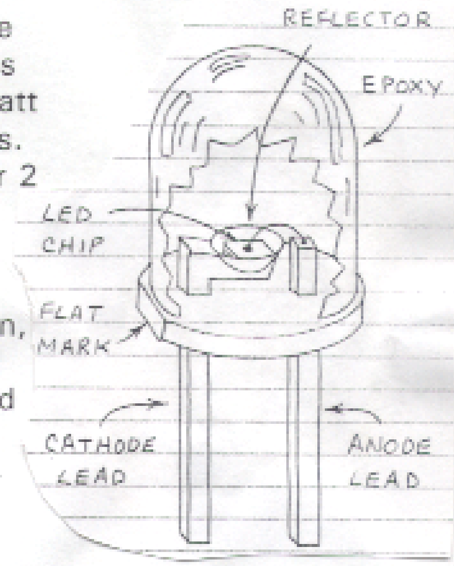



Assume 10 mA (.010 A) in the formula above. If LED doesn't light, cut the resistance in half or quarter it.

## FINDING THE RIGHT RESISTOR

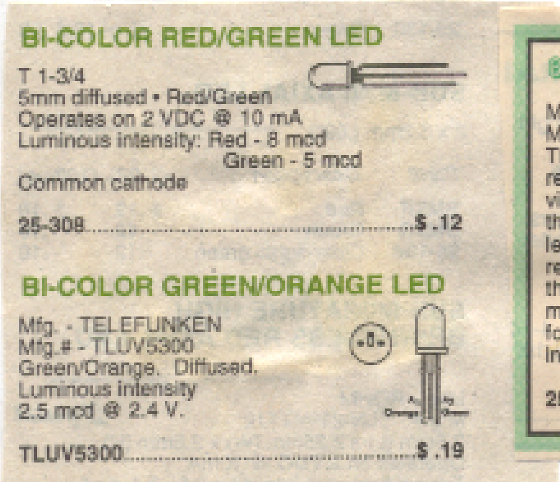
Once the value of the resistor has been calculated, the proper component needs to be found. There is no way to put legible numbers on the small resistors used in circuits like this. The resistors are banded with colors coded to numbers. Look up the code in an electronics book[2], or get one of these resistor calculators illustrated above at Radio Shack (where you can get the resistors).

Since **Watts = Volts X Amps**, even a humongous LED like the Toshiba # TLOH190P (see forthcoming page) which consumes 2 Volts @ 60 mA or 2V X .060mA = .120 Watt, so a 1/4 Watt rated resistor is more than adequate for all the listed examples. Each LED should have its own resistor. Using one resistor for 2 or 3 LED's is bad practice, as well as wiring LED's in series.



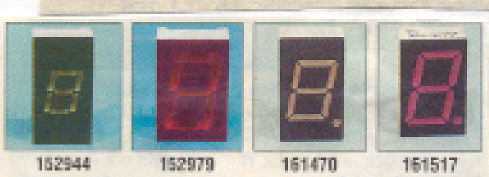

Because the D in LED stands for diode, they are polarization sensitive. Current will only flow through them in one direction, so the LED's leads need to be attached to the proper poles of the battery or power supply. Fresh LED's have one metal lead longer than the other, the +. The flat side on the plastic package is the - side. The resistor should be placed on the + side.

They like DC the best, but will work on the appropriate AC voltage. But they will be blinking on and off at 60 Hz, which would be evidenced by spinning the LED on a long lead wire like a cowpoke's lasso in a darkened room.

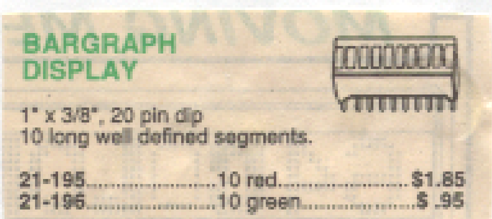


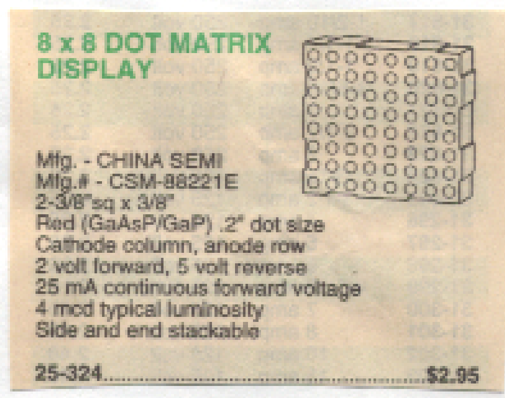


Sometimes there are multiple emitters in a common package. Each emitter's resistor needs to be calculated separately. But the Cree's 8 COLORS are worth the effort!

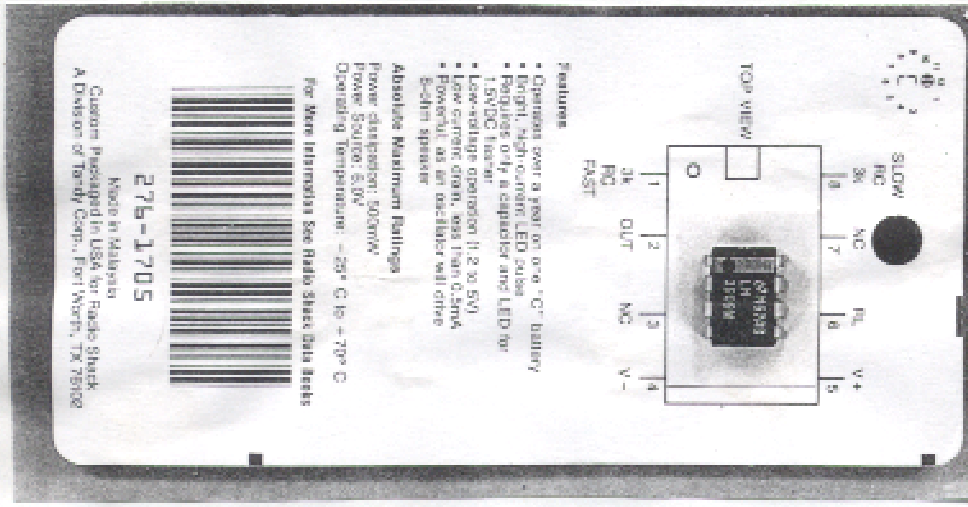



Arrays of LED's can make colorful **DISPLAYS**, although the wiring to drive all of them can get rather involved. But who says that a *Seven Segment Display* has to show only numbers?



Some LED's come with a built-in **blinking** feature, but circuits based upon the **3909 Blinking LED Driver Chip** or the **4017 Decade Counter** used as a **Sequencer** give more flexibility.[3]





## DIODE LASERS

or **LD**'s, like those found in laser pointers and CD players, are not as straightforward to wire up as their divergent cousins. In addition to the + and - leads coming from the semiconductor device, there is a third one which is the photodiode that measures whatever leaks out of the rear of the laser chip. This sensor is part of a feedback loop that stabilizes the output. Simply putting a dropping resistor in line with the package is not enough, although it has been known to be done. Pre-packaged drivers are necessary which stabilize output and prevent burnout on startup from power surges. See a forthcoming **OPTICAL ENGINEERING NOTE** tackle this problem.*


But in the meantime, a helpful hint for laser pointer users: they can be run for longer periods on larger batteries, like C or D cells instead of the small watch batteries that fit in the small packages. Run wires out of the pointer package to the proper battery terminals, and the driver will meter out the proper amount of electrons into the laser chip. *Wall Warts*, those black boxes that plug into electrical sockets, can be used, but they should be well-filtered with a capacitor before being attached to the Laser Diode.

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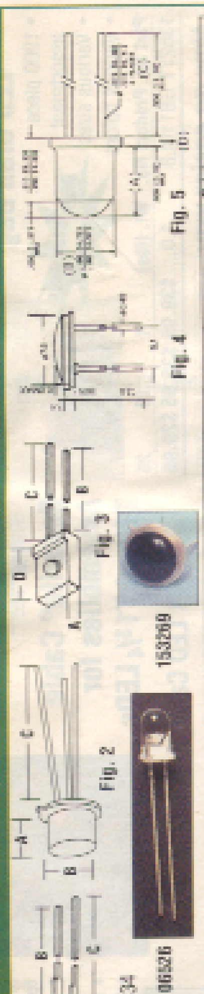
*You can wait until ... (Choose your own ending; who knows when I'll get to this!)

## Infrared Diodes and Detectors

### Infrared Diodes and Visible Light Detectors

- Use for remote control or fiber optics
- P/N 133946 can be used w/ cameras – see pg 133 & 134 (peak emission wavelength – 940nm @ If 20mA
- P/N 153269: Vf= 20V; 1/2 angle ±60%




| Part Number | Product Number | Color | Fig. | Description | Size | Diameter inch/mm | Dimensions (inches) A | B | C | D | Vf @ If (mA) | nm | mWatts | Pricing 1 | 10 | 100 | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 112150 | TLN100 ★ | Infrared | 1 | Infrared diode | T1 | .125/3 | 0.18 | 0.96 | 0.58 | 0.03 | 1.2V @ 20mA | 940 | 1.2 | $.39 | $.29 | $.19 | $.12 |

## BRIGHT WHITE LEDS

### 1000 mcd 3mm

3mm T1 GaInN
3.6 - 4 VDC @ 20mA
1000 mcd typical luminosity
Full spectrum white with water clear le

25-352..........

# THE SPECTRUM of LED RADIATION

All the wavelengths of the rainbow are represented here in these clippings cut and pasted from Hosfelt and Jameco catalogs. Even the *IR* is available, although technically the emitters should be named **IRED's. UV Emitting Diodes** are not yet available, so those high frequency photons are still generated the old fashioned way, by the discharge of **Mercury atoms** in an evacuated tube.

**OPTICAL SPECIFICATIONS:**

Besides the electrical requirements the catalogs will spec' out the optical properties: the principal **wavelength**, the **intensity**, and the **divergence**.

If you remember your spectrum (**ROYGBIV**) and the wavelengths associated with each color (in

## 7000 mcd 10mm RED LED

Mfg. - TOSHIBA
Mfg.# - TLRA190P
Operates on 1.85-2.4 VDC @ 20mA
**7000 mcd** typical luminosity
10mm GaAlAs Red
660nm peak emission wavelength
Water clear lens, lights red

25-340..........$2.99

## 18,000-36,000 mcd 10mm ORANGE LED

Mfg. - TOSHIBA
Mfg.# - TLOH190P
Operates on 2 VDC @ 60 mA
10mm InGaAlP Orange
**18,000-36,000 mcd** luminous intensity
Peak emission wavelength: lp = 620 nm
Colorless, transparent lights orange

25-276..........$3.49

## 23,000 mcd 10mm YELLOW LED

Mfg. - TOSHIBA
Mfg.# - TLYH190P
Operates on 1.9-2.5 VDC @ 20mA
**23,000 mcd** typical luminosity
10mm InGaAlP Yellow
590nm peak emission wavelength
Water clear lens, lights yellow

25-342..........$3.49

**Pure Green**
*10,000 mcd* typ. luminosity, 525nm

25-377..........$3.99

## AQUA AND PURE GREEN LEDS

***Extreme INTENSE Beam!***
***Unusual Scarce Colors!***

T 1-3/4 (5mm), Clear lens
3.2 VDC @ 20 mA
InGaN, 15°

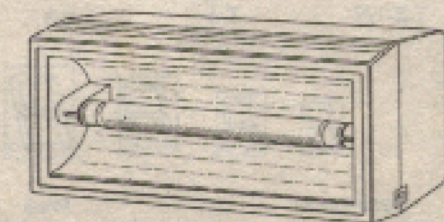
**Aqua**
*7,000 mcd* typ. luminosity, 505nm

25-376..........$3.99





## BLACK LIGHT



7" x 3-1/8" x 2-5/16"
Black light detects watermarks and counterfeiting. Causes white surfaces to glow and dark surfaces to become visible. Detect hidden damages in glass, porcelains, paintings, pottery and china. Light sees through the surface and will reveal hidden repairs, cracks, glue, imperfections, composition changes and other irregularities. (F4T5 bulb) housed in a dark brown plastic enclosure. Auto turn off after 50 seconds. Powered by a 12 VDC @ 500mA AC adapter (included).

10-113..........$4.95

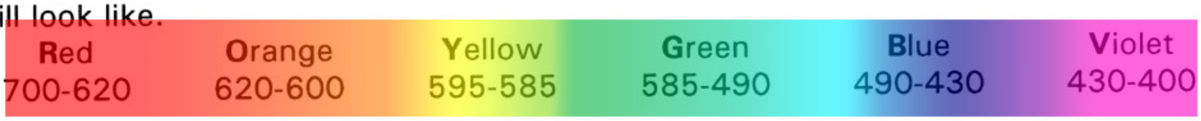
## BRIGHT BLUE LEDS

### 1100 mcd 5mm BLUE LED

Mfg. - HP
Mfg.# - HLMP-CB15
Operates on 3.5 VDC @ 20 mA
1100 mcd typical luminosity
T1-3/4 (5mm) InGaN Blue
473 peak emission wavelength. Colorless, transparent lights high intensity blue

HLMP-CB15..........$3.49

nanometers) you shouldn't have too much trouble imagining what the emitted light will look like.




LED's do not radiate light in all directions like a bulb, so the angle of divergence is sometimes specified. Sizes are sometimes measured in ***miniature light bulb*** sizes, or **ANSI T-sizes**, with **T-1** < 3mm diameter.

## OUTPUT POWER

The **intensity** is measured in candelas*, which takes into consideration the unequal spectral response of the eye (greens appear brighter than reds or blues). This makes it easy to balance colors when blending LED's for illumination. (Notice that the **IRED'S** are rated in milliWatts, not *millicandela*.)

Color temperature ratings do not apply to these devices, as they are somewhat monochromatic, emitting only part of a spectrum. Viewing them through a diffraction grating shows only a partial rainbow, with a bandwidth of 5 to 10 nanometers on either side of the dominant wavelength**. Characterizing white LED's color temperature may be a problem, as they are of two types; multi-emitters utilizing RGB primaries, or simply blue ones with phosphors on them to glow at the longer wavelengths, like the way that a broad spectral range is created in a fluorescent tube. Since their output is so small for now that they aren't used for illumination, it is a trivial point.

## SOURCES

H&R CORPORATION
401 East Erie Avenue
Philadelphia, Pa 19134-1187
800-848-8001
www.herbach.com

DIGI-KEY CORPORATION
701 Brooks Avenue South
Thief River Falls, MN 56701
800-344-4539
www.digi-key.com

MARLIN P. JONES & ASSOC.
P.O. BOX 12685
Lake Park, FL 33403-0685
407-848-8236
www.mpja.com

C&H SALES
2716 E. Colorado Blvd.
Pasadena, CA 91107
818-796-2628

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* One *candela* = Intensity of **One Standard Candle** measured one meter away.

** If a Classical Laser Transmission Hologram is illuminated with a diode, a blurry but three-dimensional image will be formed.

JAMECO ELECTRONICS
1355 Shoreway Road
Belmont, CA 94002-4100
800-831-4242
www.jameco.com

RADIO SHACK
Down your street

HOSFELT ELECTRONICS, INC.
2700 Sunset Blvd.
Steubenville, OH 43952-1158
888-264-6464 or
800-524-6464

R&D ELECTRONIC SUPPLY
100 E. Orangethorpe Ave.
Anaheim, CA 92801
714-773-0240
"Nuts and Volts Magazine"

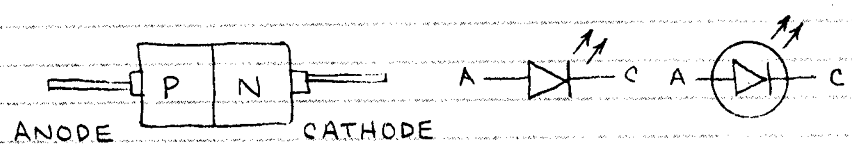
## REFERENCES

1. Mims, Forrest M, III, **GETTING STARTED IN ELECTRONICS**, Written Exclusively for Radio Shack, 13th Printing, 1996, pp 66-69.

2. Mims, p. 29.

3. Mims, Forrest M III, **THE FORREST MIMS ENGINEER'S NOTEBOOK**, Hightext Publications, Inc., Solana Beach CA, 1992; pp. 30-31; 104-105.

☐ LED SYMBOL.
BOTH SYMBOLS
SHOWN HERE
ARE USED.




68