ELECTRONICS NOTEBOOK

Super-Bright LEDs

By Forrest M. Mims III

n this era of increasingly complex microprocessors and very-large scale memory arrays, it's hard to get excited about a simple component like a light-emitting diode. That's why a few days passed before I got around to evaluating three ordinary-looking LEDS that recently arrived from Lance Kempler, a long-time reader of my columns in this and other electronics magazines.

Lance is with A.C. Interface, Inc., the U.S. company that represents Stanley Electric Co., Ltd., one of Japan's major manufacturers of LEDs and photodetectors. Before sending the sample diodes, Lance had called to say they were on the way and that I'd be a surprised at their brilliance. That prediction turned out to be an understatement. The new LEDs are the most amazing I've seen since first viewing the soft red glow of an early gallium-aresnide-phosphide (GaAsP) red-emitting diode during a visit to Texas Instruments back in 1966.

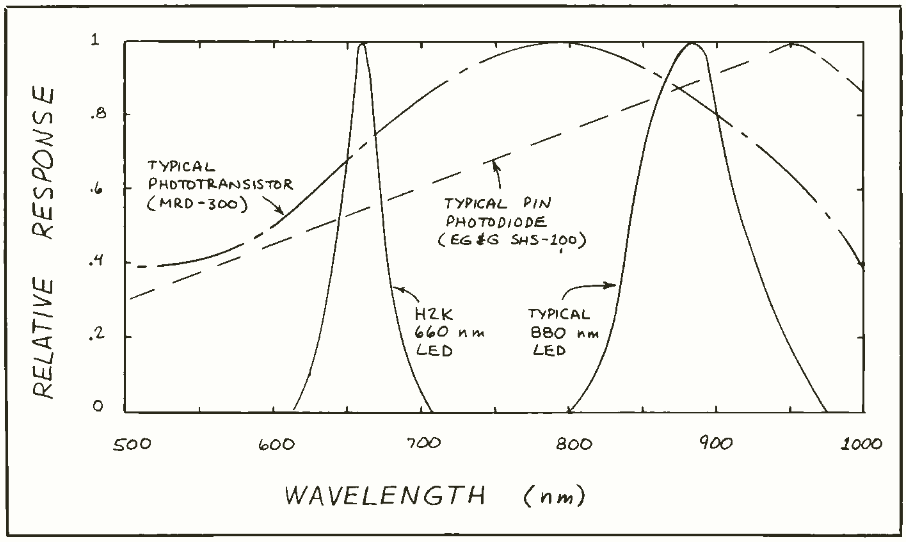


Fig. 1. These plots compare spectrum of the H2K with other LED devices.

Checking It Out

So bright are the new LEDs that when I first tested one there appeared to be a problem with the digital multimeter I used to monitor the current through the diode. When the power supply was cranked up so that the LED was emitting a bright red glow, the multimeter indicated a current of only 3 milliamperes. A normal LED would have required considerably more current than that to achieve a similar level of brightness, so I substituted another meter. But the result was the same. Still not trusting the separate but equal current readings, I determined the current by measuring the voltage across the 100-ohm current limiting resistor in series with the diode and then used Ohm's law to calculate the current (I = E/R). The result was still 3 milliamperes.

After making that third measurement, I suddenly remembered Lance's remarks about being surprised and decided to apply a full 50 milliamperes to the diode. The LED emitted such an astonishingly bright beam it was impossible to stare directly into the end of its epoxy lens.

These super-bright LEDs are designated by Stanley as part number H2K. According to the specification sheet Lance sent with the diodes, the H2K is a gallium-aluminum-arsenide (GaAlAs) device that has a brightness of 2000 mcds (millicandelas) when biased with the industry-standard forward current of 20 milliamperes. At 50 milliamperes, the brightness increases linearily to an incredible 4500 mcd.

How bright is 2000 or more mcds? Prior to the arrival of the H2Ks, the brightest red LEDs in my benchstock were some Hewlett-Packard "ultra-bright" HLMP-3750s. According to the HP data sheet, these diodes are made from GaAsP on GaP and have a typical brightness of 140 mcd at 20 milliamperes. In other words, the brightness of the H2K is more than 14 times greater for the same forward current. In fact, at 2 mA forward current, the H2K achieves a brightness of 200 mcd, higher than that of the HP diodes at 10 times the current level.

As might be expected, the new LEDs have an exceptionally high power conversion efficiency. An incandescent lamp transforms into visible light only about 5 percent of the electrical current flowing through a hot filament. The new super-bright LEDs are three times as efficient as incandescent lamps. If not for losses of light caused by internal reflection and re-absorption inside the LED chip and additional losses conributed by the LED package and chip header, the new diodes would posess considerably higher efficiency.

Applications for Super-Bright LEDs

Stanley's new state-of-the-art LEDs are so much brighter than previous devices that several important new applications are made possible. One of the most obvious uses is to form arrays of the new diodes into burnout-proof lights for automobile taillights and traffic signals. When placed behind a plastic diffuser, a single super-bright LED can function as a bicycle taillight. Linear arrays of the new diodes can function as high-brightness light sources for xerographic-style copy machines that also function as computer printers. A warning flasher could be made by connecting one of the new LEDs to a simple pulse generator circuit.

A more sophisticated role for the new LEDs is as a light source for both optical fiber and free-space lightwave communication systems. Low-cost plastic fibers transmit well at the 660-nanometer wavelength emitted by the new LEDs. The optical diodes used in free-space systems are almost always the infrared-emitting variety since they are so much more powerful than conventional red LEDs. However, and this is truly impressive, the new LEDs are just as powerful as most of their infrared-emitting counterparts. Therefore, in applications where a visible beam is acceptable, the new red LEDs will make an excellent alternative.

If you've ever attempted to point the invisible beam from an infrared communicator directly at a distant receiver, you can better appreciate the value of an easily modulated source like an LED that happens to emit a very powerful yet visible beam of light.

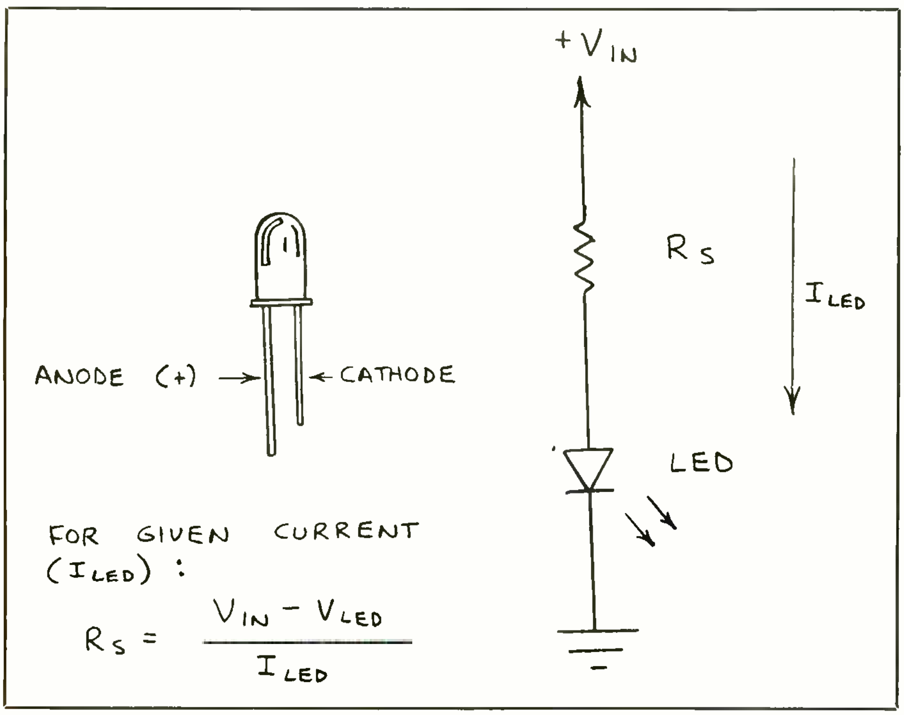
In preliminary tests, the new LEDs perform well as light sensors. Therefore, they can be used as dual-function source-sensors in two-way lightwave links. I have used this method extensively in the design of lightwave communication systems that send and receive information over a single optical fiber.

The features that make the new super LEDs well-suited for lightwave communications are equally desirable for such applications as reflection-mode and break-beam detection systems. The new diodes could also be used in visible-light versions of infrared remote-control units for home appliances and toys.

For applications in which the LED is paired with a sensor, it's important to consider the spectral sensitivity of the sensor. Figure 1, for example, compares the spectral emission of the H2K with the spectral sensitivity of two photodetectors. Some photodiodes have better sensitivity to the 660-nm wavelength of the H2K than the one shown in the figure. Note how the 880-nm near-infrared emitter more closely matches the peak sensitivities of the two photodetectors.

Finally, a number of scientific applications for super-bright LEDs come to mind. For example, since LEDs can be pulsed on and off in tens of nanoseconds, an array of super LEDs could be used to illuminate ultra-fast moving objects in high-speed photography. Another scientific application would be to use a 660-nm super LED in an array with a conventional AlGaAs 880-nm diode and a GaAs: Si 950-nm emitter to quickly measure the reflectance of objects at three distinct optical wavelengths.

Fig. 2. Basic LED drive circuit and formula for calculating R_S value.



Measuring the Power Of Super-Bright LEDs

Prior to trying the sample super-bright H2K LEDs in some simple circuits, I first used a Centralab CSC-12 calibrated silicon solar cell to measure their power output. Figure 2 shows both the basic drive circuit for these tests and the formula for calculating the value of the required current-limiting resistor. The actual tests were made with power supplied by an adjustable supply.

According to a technical paper prepared by scientists from Stanley Electric Co., at a forward current of 20 milliamperes, the typical H2K emits 6 milliwatts. At 50 mA, the typical power output rises to 14 mW. At the 660-nanometer wavelength emitted by the H2K, the CSC-12 detector used to measure the power in the beam from the diodes has a responsivity of 0.42 mA/mW. In other words, for every milliwatt of 660-nm radiation that strikes the detector, an output current of 0.42 milliamperes is produced.

The three sample diodes I tested emitted less power than specified in the Stanley paper. At 50 milliamperes forward current, the measured output power for each diode was: LED 1: 5.55 mW; LED 2: 7.10 mW; LED 3: 5.05 mW.

Each LED was measured within one second after power was applied since the power output falls somewhat as the chip becomes warm. At 50 mA forward current, the minimum specified output for these LEDs is 70% of the typical value of 14 mW, or 9.8 mW, still significantly more than the measured results. Why?

My tests measured only the power contained within the focused beam emerging from the lensed end of the LEDs. However, some light is emitted from the sides and even the base of epoxy-encapsulated LEDs. Manufacturers usually measure the *total* power emitted by an LED by collecting virtually all the radiation with an

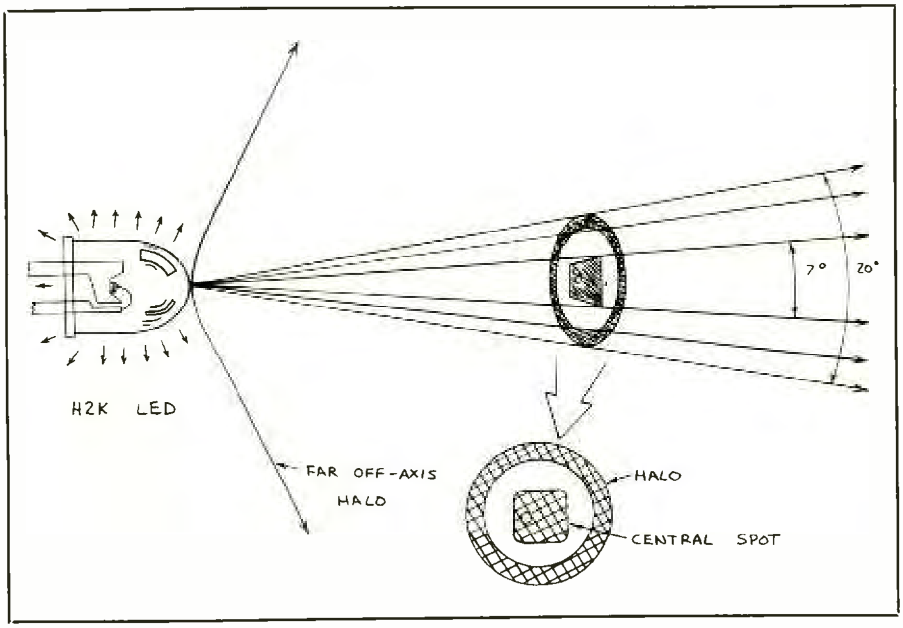


Fig. 3. Details of how author measured the beam profile of the H2K LED.

integrating sphere, a hollow sphere coated on its inside with highly reflective white paint. The LED being measured is inserted in one aperture and a detector is inserted in another. Though the calibrated detector I used collected all the focused beam, it collected none of the off-axis light spilling out the sides of the epoxy package.

In other words, the power within the central beam of the H2K is only about half the total power emitted by the LED. Nevertheless, the power is still substantial. Only a few years ago, the best near-infrared emitting diodes made from GaAs:Si and encapsulated in epoxy much like the H2K were considered good quality devices if at 50 mA forward current their central beam contained 3 mW, only about half the power of the H2Ks I tested. AlGaAs near-infrared 880 nm diodes emit approximately the same power as the red H2K LEDs.

Figure 3 shows the beam pattern emitted by an actual H2K. Like other visible and infrared optical diodes in which the chip is installed within a miniature reflector, the far-field beam structure is a bright central spot surrounded by a somewhat dimmer halo. The central spot is the imaged surface of the LED chip. The dark spot in the center is the point of attachment for the chip's upper lead.

The halo effect is caused by the tiny reflector in which the LED is installed. The reflector captures light emitted from the sides of the chip and reflects it toward the lens formed by the curved end of the epoxy package. Since the reflector is larger that the chip, it is imaged as a halo around the chip. The halo has a broader beam spread or divergence (about 20°) than the chip (only about 7°).

Note that considerable light emitted by the LED is *not* within the central spot and halo. Some is contained within a very broad, off-axis halo that surrounds the central halo and spot. The rest emerges from all sides of the diode's package.

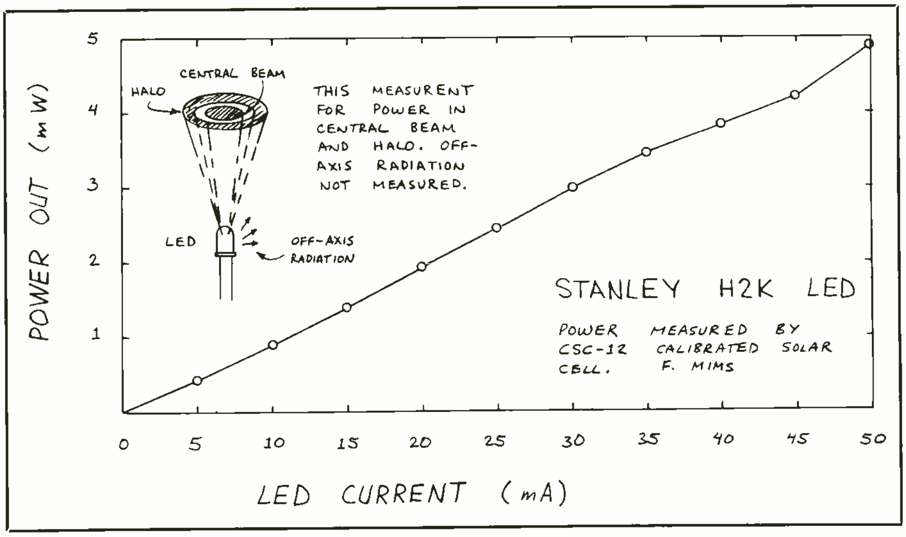
Figure 4 shows the power output of the lowest-powered H2K I measured. For these measurements, continuous power was supplied to the LED. The power output would have been somewhat greater if the measurements were made within a second or two after power was applied.

Super-Bright LED Flasher

Figure 5 shows a an ultra-simple but effective flasher circuit for a super-bright LED like the H2K or similar devices. This circuit flashes approximately 1.5 times per second using the values shown. The flash rate is directly proportional to the value of capacitor *C1*.

For applications in which maximum brillance is not required, *R3* can have a very high value. Since the H2K has a brightness of hundreds of millicandelas at only a few milliamperes forward current, the current drain of the flasher cir-

Fig. 4. Graph plots output power in central beam of H2K super-bright LED.



cuit will be exceedingly low and battery life will be quite long.

Going Further

If you haven't previously worked with LEDs, you can find some basic information about these and other solid-state optoelectronic devices in a book I've written for Radio Shack called *Getting Started in Electronics.* The book also includes some circuits you may wish to try.

For additional information about the H2K and similar super-bright red LEDs, contact Lance Kempler at A.C. Interface, Inc. (17911 Sampson Lane, Huntington Beach, CA 92647). Since the yield of the superbright H2K LED is low, the diode's price is a rather steep $14. The minimum order from A.C. Interface, Inc. is two pieces.

Incidentally, at a time when high-power near-infrared emitting diodes can be purchased for a few dollars or less, the price of the H2K probably seems out of line. On the other hand, old timers can readily remember when very dim red LEDs cost about the same as the H2K. As for near-infrared emitters, the first ones I experimented with back in 1966 cost $365 each! No doubt the price of the H2K device will decrease over time as the yield is improved.

If you want to explore fiber-optic communication applications for super-bright LEDs, Stanley makes the FH511 emitter and FS511 detector. These devices are encapsulated in special flat-ended packages in which the sensing and emitting chips are very close to the surface. Stanley also makes plastic connectors for coupling fiber optics to these devices.

Many other companies also make inexpensive LEDs and detectors designed to be installed within plastic connectors. At the present time, the chief advantage of the Stanley diodes is that their peak wavelength of emission is transmitted well by inexpensive plastic optical fiber.

Though the H2K is one of the most exciting LED developments to occur in some time, other big developments are on the horizon. LED technology was first invented in and extensively developed in the United States long before Japanese companies entered the business. Since the U.S. companies have been making various kinds of powerful GaAlAs near-infrared emitting diodes for more than five years, there should be no fundamental reason why they can't also develop superbright visible LEDs. Should this development occur, super-bright LEDs will become very cheap.

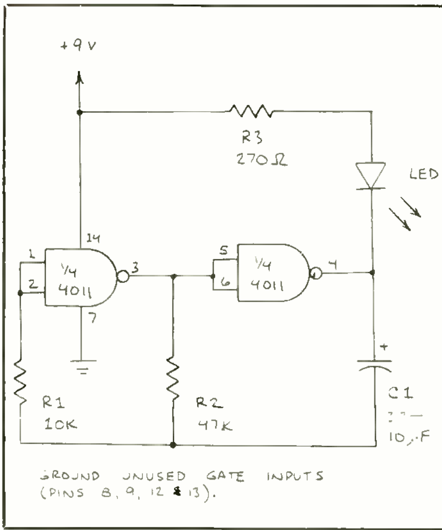


Fig. 5. Flasher circuit for driving a super-bright LED uses a pair of 4011 NAND gates arranged as an oscillator.

After several false starts, watch for the eventual availability of the elusive blue LED. Finally, considerable work is underway in several countries in an effort to solve the very difficult problem of reducing to below 700 nanometers the wavelength of continuously operating laser diodes. The objective of making laser diodes that emit at visible red wavelengths is to make them better suited as a readout device for audio and video laser-disk players. Considering the enormous market for laser-disk players, visible-light laser diodes that emit the same power as the H2K LED should one day be quite affordable. The advantage of the laser over the LED, of course, is that the light emitted from a laser can be collimated, by means of a simple convex lens, into a much tighter beam, since it originates from a much smaller point. **ME**