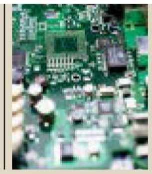


THIS MONTH'S PROJECTS

LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

●○○○ . . . . Beginner Level
●●○○ . . . . Intermediate Level
●●●○ . . . . Advanced Level
●●●● . . . . Professional Level

BUILD A HIGH-POWER LED STROBE

High-power LEDs have received much attention as of late, and jumped in the last few years from a laboratory curiosity into mainstream applications. We all have seen LED flashlights (with their bright bluish white light) and its LEDs incorporated into some luxury auto brands.

The reason for this rise in popularity is very simple: as light sources measured in lumens per watt, they are extremely efficient. These devices easily surpass incandescent lights, even halogen-filled ones. They also seriously challenge fluorescent and high-intensity discharge lighting (which themselves have undergone extensive efficiency improvements). LEDs offer a few extra features: low voltage operation, small size, and solid-state ruggedness. These qualities make them very attractive for portable and automotive environments.

This doesn't mean that high power LEDs are not without problems. Unlike their lower rated brethrens — which max out at 20 or 30 mA — these monsters start at 300 mA, with 700 and 1,500 mA devices available, and even higher rated devices in the pipeline.

With so much power concentrated into such a small volume, heat becomes a major concern. With the LED itself being a semiconductor, heat substantially reduces both the operating life and the efficiency of the device. Thus, thermal management is paramount in a successful application.

LEDs have an additional advantage that none of the light sources discussed above can match: the ability to be turned on and off almost instantaneously. Only Xenon flash tubes have better response times, but their high voltage has precluded them from being used in applications such as cell phone cameras, where high power white LEDs have become ubiquitous. As I needed to build a strobe circuit, I decided I should give them a try.

The Challenges are in the Details

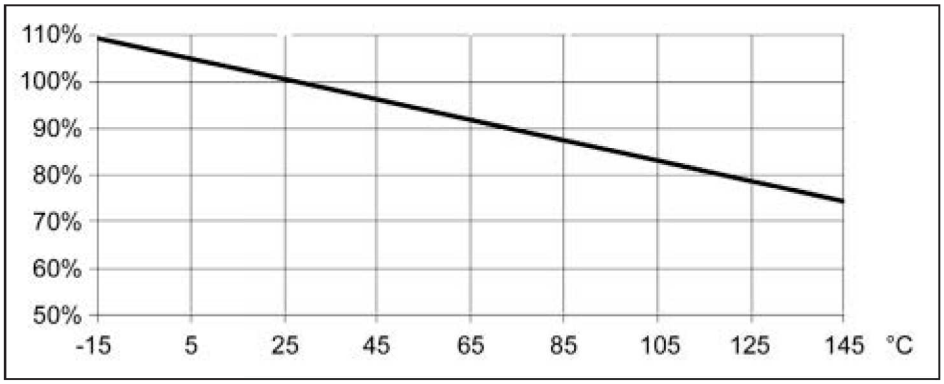
Starting a new project is similar to hiking an unknown trail the first time. One quickly finds unexpected challenges, some of which are tough to solve. But solving those challenges make it all worthwhile, and hopefully, make you a little wiser. This project did not disappoint.

I had originally attempted to build a strobe employing the conventional high-voltage capacitor and Xenon-tube combination — circuits which have been around for a long time — and rapidly noticed the drawbacks. For one thing, it is very easy to exceed the tube's maximum power dissipation at higher repetition rates, causing it to crack. For another, the simple inverter circuits that convert from the battery level voltage to the required high voltage simply do not have enough energy to recharge the flash capacitor in 1/100 second or less. These units are designed for non-repetitive applications, with typical recharge times of two or three seconds — maybe longer — and are two orders of magnitude too weak.

As I pondered how to design the required high power converter, a thought came to mind: This was a perfectly good example for a radical new solution. In this case, employ the newer, high power white LEDs.

BY FERNANDO GARCIA

■ FIGURE 1. Light output vs. junction temperature.



The first challenge was to remove the excessive localized heating which causes a loss of luminous efficiency (shown in Figure 1) and may even set off thermal runaway. Additionally, LEDs are diode junctions, and require their current to be regulated. This is simple, trivial resistor stuff when only a few milliamps are required. Not so trivial — and quite wasteful — when dealing with high currents.

A possible solution would be a current regulated switchmode power supply. However, switchmode supplies do not tolerate excessive current swings, especially when going from zero to full blast and again back to zero in a millisecond. (Hmmm ... who said this would be a simple project?)

To top it all off, these LEDs have a Lambertian light distribution; "Lambertian" being a fancy word meaning "all over the place." Some sort of lens or reflector would be required to form a useful beam.

First things first ... which LED source should I employ? After reading countless datasheets, I settled for Luxeon's K2 in a "star" configuration. As shown in Figure 2, the LED die is attached to an aluminum star-shaped plate, which itself is to be mounted to the heatsink. This plate also provides the necessary solder pads to attach the wires.

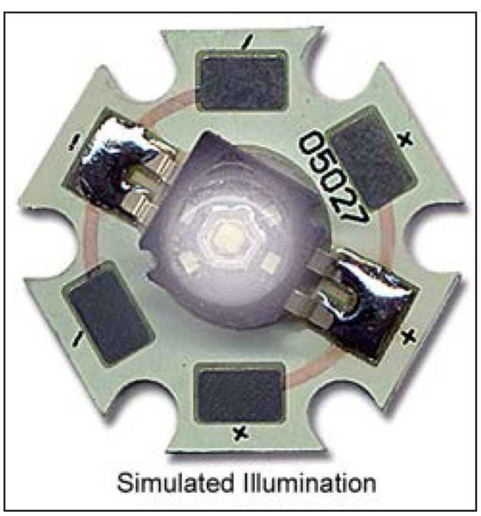
I quickly determined that an all-aluminum box would both house the project and serve as a heatsink. I could then use hardware (similar to what is used to mount TO-3 transistors) to attach it to the aluminum box. But this hardware caused an interference with the optical lenses. As discussed above, the LEDs require lenses to focus the light, and as shown in Figure 3, these are attached to the LED assembly with an adhesive pad.

A possible solution would be to employ an adhesive thermal co pound, but I wanted something that is widely available to hobbyists. A workable solution was found: Apply a tiny bead of silicon thermal compound in the center of the star (on the flat side that will attach to the aluminum box) and push the star firmly against the aluminum box's face.

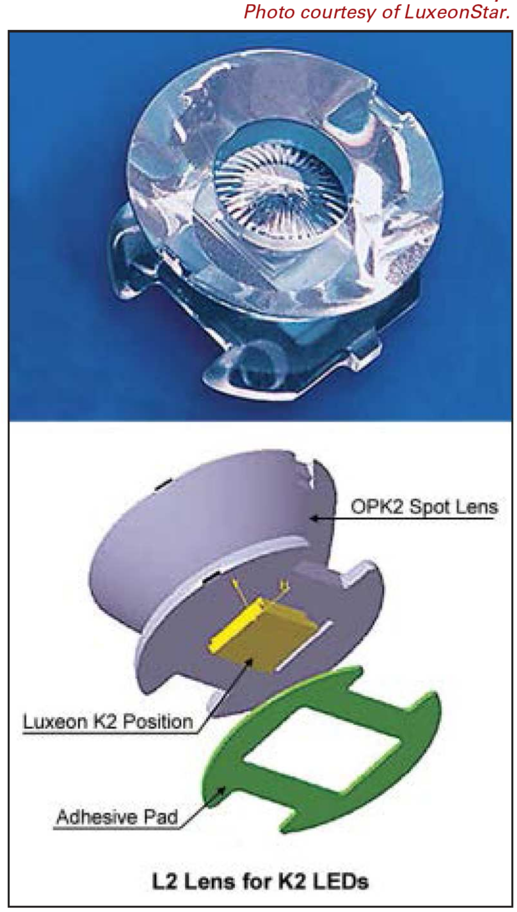
If done correctly, the bead will spread out evenly and NOT smear out. This is important, and it make take a couple of trials to get it right. Then, cyanoacrylate superglue is employed on the star's periphery to perform the actual bonding. Done correctly, this provides a good thermal interface and fairly secure attachment.

Electrical Considerations

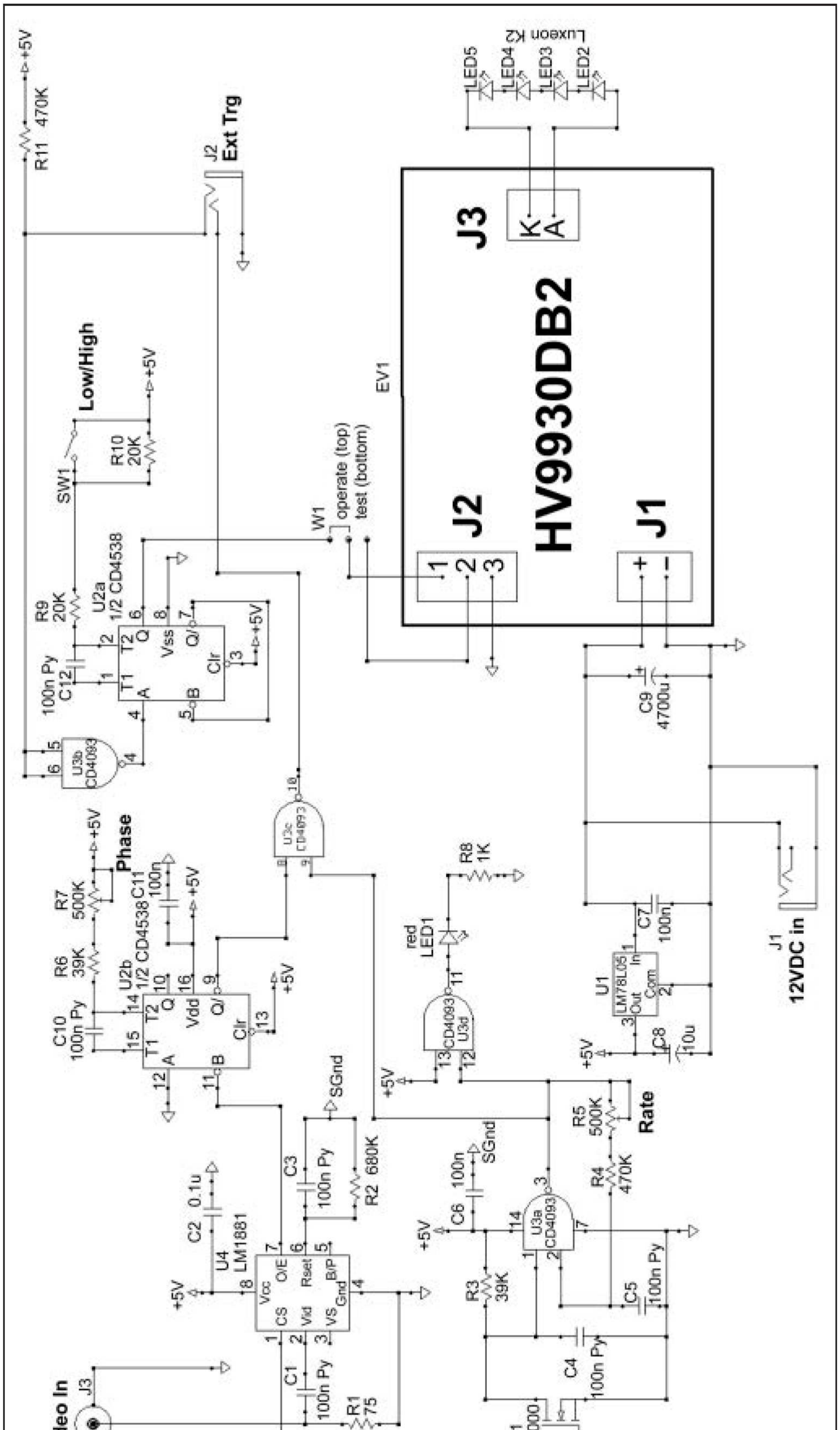
Having solved the thermal, optical, and mechanical aspects of the assembly, then came the fun part. How to drive these LEDs? There are literally dozens of high output, constant current switchmode LED drivers available from different IC vendors. However, they either are in nightmarishly-tiny SMT packages, or optimized for steady state output and/or a single light shot such as a flash.



■ FIGURE 2. K2 Star. *Photo courtesy of LuxeonStar.*



■ FIGURE 3. Lens assembly. *Photo courtesy of LuxeonStar.*



■ FIGURE 4

As mentioned previously, switchmode supplies respond sluggishly to sudden load changes, which would be the norm for this project. Severe overshoot and ringing usually occur as the control loop attempts to stabilize, which could (in the worst case) cause permanent damage to the unit. There is a control scheme however, known as the hysteretic — or ripple — regulator, which responds the fastest for sudden load changes.

As its name implies, it self-oscillates between two user-set ripple boundaries. Using this search string plus the LED driver, I found a very exciting device from Supertex, Inc. The HV9930 feature set not only satisfied the hysteretic current control scheme, but it also employs the Cuk (buck-boost) powertrain topology, meaning that the output voltage may be higher or lower than the input voltage for increased versatility. It also drives an external MOSFET, and thus its output drive may be as large as required, depending on the external device ratings.

The device is available in both eight pin thru hole and SMT packages. It is available through Mouser — important since all the wonderful specs are meaningless to a hobbyist, if the device is only sold through a distributor network which caters to small orders.

Better still, the device has an available plug-and-play evaluation board (HV9930DB2), which is a major plus if one doesn't have the time or inclination to design a switchmode supply from scratch. The board has a quick responding enable input which can be used for either PWM dimming, or in this case, for pulsing.

One last consideration when employing this module is that it has a minimum eight volts DC input requirement, with 12 volts DC preferred. This is okay, since the high power requirements demand much more juice than what four AA cells can realistically provide.

The evaluation board is preset to 750 mA, which dictates that 700 mA grade stars be used. I would have liked to use 1,500 mA stars, but that means substantial EV board modifications, which are beyond the scope of this article.

Control Circuit Description

I had some goals for the control circuit: It should be capable of driving the HV9930 evaluation board from three different trigger sources: component video to synchronize with a camera; an external open collector or TTL level signal; and an internal variable frequency oscillator. It must also have calibrated power levels achieved by precisely controlling the light pulse's output width. The schematic is shown in Figure 4.

A +12 volt DC external source is fed via J1 to both the evaluation board EV1 and a five volt regulator U5 that feeds the control circuit. Capacitor C9 should be located very close to EV1, to smooth out the demand for high current pulses.

An external NTSC/PAL video component signal is applied to J3, with resistor R1 providing the proper termination impedance, and is fed via C1 to sync separator U4. This IC has many functions, but we are using only two: The composite sync output is employed to turn on MOSFET Q5, which discharges capacitor C4. This low voltage applied to NAND gate U3a disables it from oscillating when a valid video signal has been connected. Another of U4's functions — the Odd/Even field output — is employed.

A little explanation is required here. Individual TV images — or frames — are comprised by two interlaced fields, which each include the odd and even scan lines. Modern video sensors capture the entire frame simultaneously, but to comply with this legacy TV standard, the signal is processed and interlaced before sending it to the video output. For the purposes of this project, this would create double light pulsing while the frame is acquired, causing a double exposure. The Odd/Even output effectively chooses a single field, synchronized to the video capture. Since the CCD's actual frame capture timing (with respect to this signal) is unknown, we must delay its phase such as both coincide. This is achieved by monostable U2b, which is triggered on O/E's falling edge.

The phase delay is set via C10, R6, and potentiometer R7. By adjusting the latter, the light pulse can be made to coincide with the actual video capture. This can easily be accomplished empirically: One turns R7 fully to one end, and then start backing up slowly until the image on the camera's viewfinder becomes the brightest.

Both the composite sync and O/E outputs become a logic low when a video signal is absent. This has two effects; first, U2b is no longer triggered and no further pulses occur. Second, Q5 is no longer turned on, and C4 charges through R3. When a logic high is reached, U3a is allowed to oscillate via positive feedback via R4 and R5, and in conjunction with C5, sets the frequency. This is coupled to U3c which is no longer receiving pulses from U2b, which serves to select which pulse (video or free run) passes through.

In essence, all this circuitry selects a free running pulse when no video is available, and a field synchronized pulse when a valid video signal is present. U3d only buffers the signal to drive a small red LED, which indicates oscillator activity.

The selected signal goes to the normally closed contact of "external trigger" jack J2. When no plug is connected, the signal will continue to U3b and then to the next monostable U2a. The reason for employing U3b is to provide a Schmitt-Trigger action for the external signal, which provides noise immunity and the fast trigger edge required by U2a. This monostable is wired in a non-retriggerable configuration, to prevent pulsing stretching due to noise.

The external trigger may be either a TTL-compatible square wave, a switch, or a transistor closure to ground. In this last instance, R11 serves as a pull-up.

The pulse width is selected by switch SW1 and associated components C12, R9, and R10. This will provide an output pulse duration of either 1/250 or 1/500 second for high or low power mode. This pulse is now applied to LED driver evaluation board EV1 which, in turn, drives the four series-connected Luxeon LEDs.

A jumper wire must be installed to select an operating mode: Connecting EV1's pins 1 and 2 together will turn on the LEDs continuously, regardless of any other conditions, and is useful for testing. Connecting EV1's pin 1 to U2a pin 6 reverts the circuit to normal operational mode.

Assembling the Circuit

As shown in Figure 5, the whole project is assembled in a small aluminum box. Prior to any electronic assembly, all the holes must be drilled and deburred. Afterwards using a pencil, mark the location of the LED stars, noting the orientation of the plus and minus signs to allow them to be connected in series. Attach them using the thermal compound and

■ FIGURE 5. Completed project.

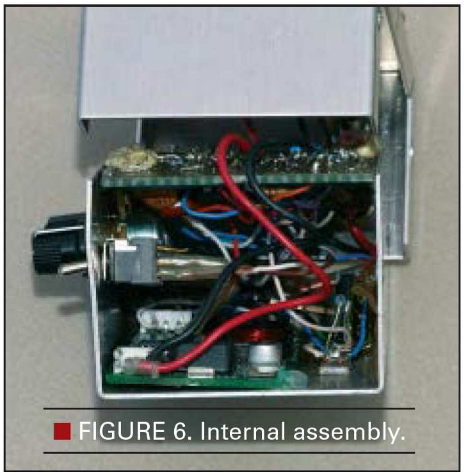


FIGURE 6. Internal assembly.

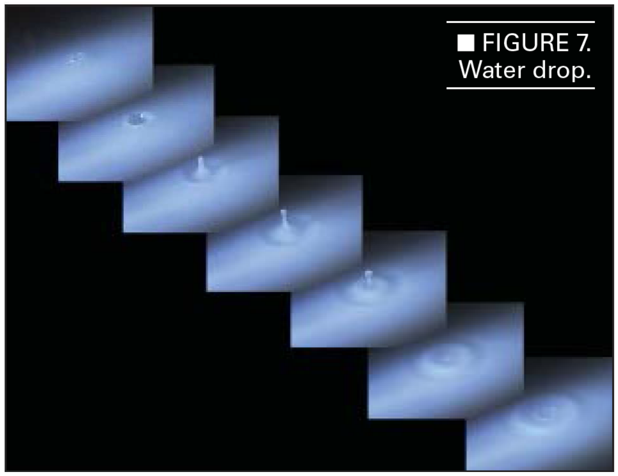


FIGURE 7. Water drop.

PARTS LIST

ITEM	DESCRIPTION
The following are available through Mouser.	
Resistors (all resistors 1/4 W, 5%, unless noted)	
❑ R1	75 ohm
❑ R2	680K
❑ R3	39K
❑ R4,R11	470K
❑ R5,R7	500K linear pot
❑ R6	39K
❑ R8	1K
❑ R9,R10	20K 1%
Capacitors	
❑ C1,C3,C4, C10,C12	0.1 µF, 50V, 10% poly
❑ C2,C6,C7,C11	0.1 µF, 50V, X7R ceramic
❑ C5	0. 0.1 µF, 50V, 10% poly
❑ C8	10 µF, 25V, electrolytic
❑ C9	4,700 µF, 16V, low-Z electrolytic
Semiconductors	
❑ Q1	2N7000 MOSFET
❑ U1	7805 voltage regulator
❑ U2	CD4538 CMOS monostable
❑ U3	CD4093 Schmitt NAND CMOS gate
❑ U4	LM1881 TV sync separator
❑ LED1	Miniature red LED
Miscellaneous	
❑ J1	Power jack
❑ J2	Mini phono jack
❑ J3	RCA jack
❑ SW1	Mini toggle SPST switch
❑ EV1	HV9930DB2 white LED driver board
❑ All aluminum box 4.0"x 2.2"x 3.0": Hammond 1411FU	
❑ Perfboard, wire, pot knobs, silicon thermal compound, Krazy glue™.	
*The following are available from LuxeonStar LEDs (**www.luxeonstar.com**):*	
❑ LED2-LED5	Luxeon K2 Star, 5027PW12
❑ L2 spot base 3° lens for LEDs, OPK2-1-003	
❑ L2 spot diffuser 12° sub lens, OPK2-1-012S	

superglue techniques described previously. Let them set, but do not install the lenses on the LEDs yet, as they have to be wired in series, carefully observing the polarity.

Now that the LEDs are attached and heatsunk, wire them to the evaluation board EV1 and power them up. Prepare yourself to be awed at the huge light output, but DO NOT leave them powered longer than a few moments at a time, since the aluminum chassis is insufficient to remove all the heat generated in continuous mode.

Now that you are satisfied with the circuit operation, attach the lenses to the LEDs. They should sit flat for the adhesive pad to make proper contact. You may find that the soldered wires interfere a little with the placement; use an X-acto knife to remove any small section that gets in the way.

Besides the preassembled evaluation board, one must build the control circuit in a separate board. It is simple enough to be built using point-to-point wiring techniques in a small perf board. The boards may be assembled and wired as shown in the prototype photo of Figure 6.

It proved to be a tight and somewhat difficult fit, and I would recommend a larger enclosure for an easier and neater assembly. The recommended enclosure in the parts list is larger than the one in the photo. An extra bonus is the additional heatsinking capabilities.

Using the Circuit

Strobe lights have long been used by mechanical engineers to study vibrating or rotating elements. By adjusting the frequency fed from a signal from an external oscillator, one can "freeze" the rotational or vibrating movement. Since the oscillator frequency can be measured very accurately, the mechanical frequency may be accurately established, too.

The strobe typically may be triggered upwards of 100 Hz or up to 200 Hz in low power mode, making measurements of 12,000 RPM possible. Be aware of the increased heat generation and a current draw close to 0.5 amps at 12 volts at higher frequencies, both of which decrease linearly

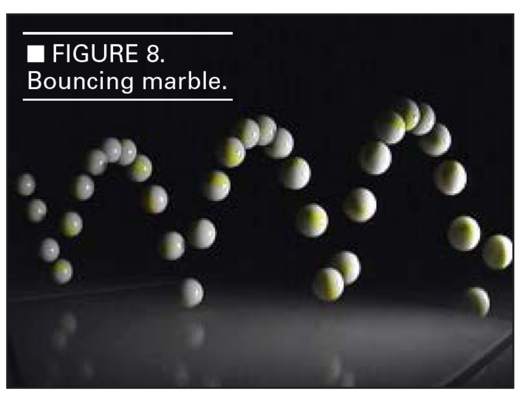


FIGURE 8. Bouncing marble.

with operating frequency.

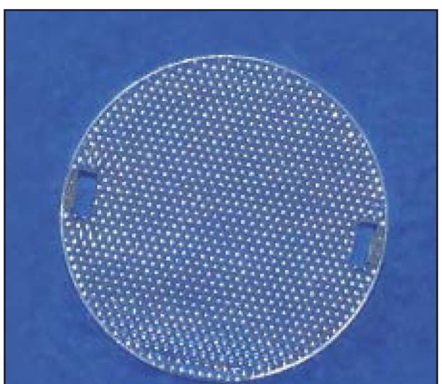
Although the light output is necessarily low power — because of its repetitive nature — compared to a one shot Xenon flash, the circuit may still be used for some photography tricks. In this instance, the video input comes in handy.

Connecting the composite video signal from a camera will synchronize the flash to the actual frame capture. As described previously, you may need to adjust the "Phase Delay" control to obtain maximum brightness, as observed in the viewfinder.

The water drop sequence in Figure 7 and the bouncing marble in Figure 8 were obtained employing this technique.

You may find that the LED lenses produce a beam that is perhaps too narrow (± 3 degrees) for practical photography usage. Fortunately, the sub lens shown in Figure 9 (that attaches to the top of the main lens) will widen the beam to ±12 degrees.

Finally, the project may be used in the free run mode, much like the disco strobe lights so popular in the '70s. So, load your favorite funky music CDs and enjoy! **NV**



■ FIGURE 9. Sub lens.