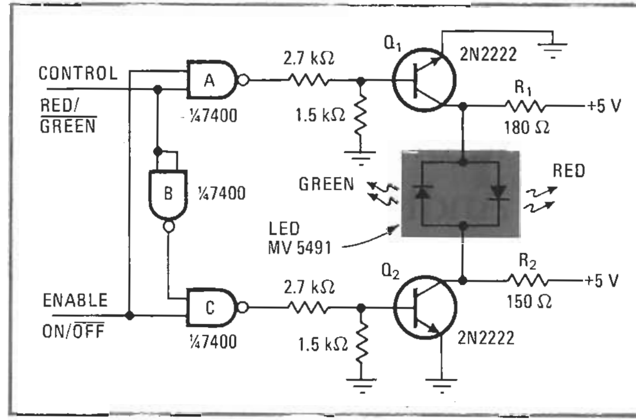
Two-color LED pair is digital status indicator

by Bill Schweber
GTE Sylvania, Needham, Mass.

A red-and-green LED pair in a single package, such as the Monsanto MV 5491, can serve as a status indicator for digital levels with a single supply-voltage circuit. The polarity across the LED is reversed by changing the relative potentials at the two LED terminals, rather than by having one of its terminals at ground and putting positive and negative voltages on the other.

An on/off line enables the entire indicator. Transistors Q_1 and Q_2 serve as LED drivers. When the red/green control line is high (and the enable line is high), the output of gate A is low, turning Q_1 off, while gate C's output is high, so Q_2 is on. Current goes through limiting resistor R_1, and the LED glows red.

When the control line is low, the situation reverses, as does the difference of potential across the LED, which glows green with R_2 limiting current. Note that R_1 and R_2 are of different values because of the different forward drop across the LED, depending on which way it is biased. Pulling the enable line low causes the outputs of gates A and C to go high, so Q_1 and Q_2 turn on, putting both ends of the LED at the same potential; therefore the LED stays off. □



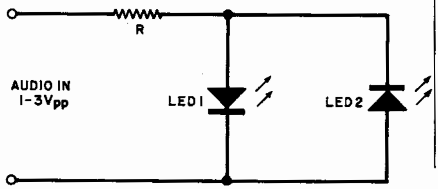
Logic probe. A red-and-green LED packaged pair, such as the Monsanto MV 5491, can serve as a status indicator for digital levels.

LED ZERO BEAT DISPLAY

Q. ***Is there any visual means of detecting when I have "zero-beated" my vfo and a received signal?***

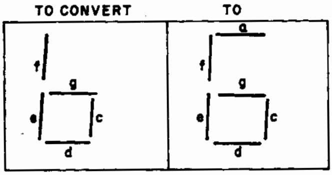
—M. Farber, Las Vegas, Nev.

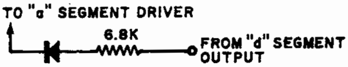
A. If your receiver has an S meter, you can adjust for zero beat while watching its needle. As the two frequencies approach each other, the needle will swing back and forth more and more slowly. At zero beat, the needle will hold one position. The circuit shown will also give a visual display of zero beat. When the vfo has come within 25 Hz of the signal's carrier, the LED's will alternately flicker. At zero beat, neither LED will light up. The circuit can also be used as a polarity checker for dc applications. When the top input terminal is positive, *LED1* will glow, while *LED2* turns on when the bottom input terminal is positive. Select *R* to limit LED current to a safe value, or use a voltage divider.

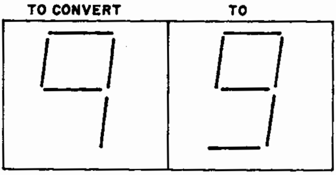


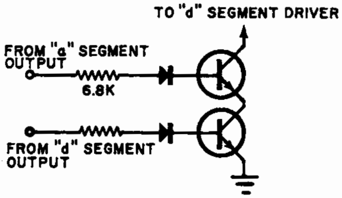
ADD MISSING SEGMENTS TO DIGITAL CLOCK

The "clock on a chip" IC's are very popular, but some of the displayed figures (6 and 9)









look a bit awkward. Here's a simple way to restore the missing segments which can also be used on any seven-segment display (DVMs, counters, etc.). Semiconductors are not critical—"junk box" silicon diodes and transistors will work fine.—*Alan Kong*

EXPERIMENTING WITH LIGHT EMITTING DIODES

LED'S—light emitting diodes—are being used in ever-increasing numbers by hobbyists and experimenters as well as by original equipment manufacturers. Physically small, lightweight, available in several colors, rugged, easily installed, efficient, and with a virtually unlimited service life, they are ideal visual indicators.

As pilot lamps, LED's are rapidly displacing incandescent bulbs despite a somewhat higher initial unit price. The difference in device cost is deceptive, however, at least as far as original installations are concerned. Where an incandescent bulb is used as a pilot, one must provide a socket, mounting bracket and, usually, a colored lens or jewel and suitable mounting. In contrast, a LED can be wired directly and permanently in place and, generally, has its own integral lens. When the *total* installed cost is considered, then, a LED may prove less expensive, in many cases, than an incandescent lamp, while offering the advantages of low power drain and long life.

Probably, simple pilot installations account for the majority of present LED applications. If you feel that LED's can be used *only* in such applications, however, you may be in for a surprise.

Put on your thinking cap and consider their unique electrical characteristics: they are basically diodes, their power requirements are nominal, and they are tolerant of a broad range of currents. A typical low-cost unit is capable of supplying a useful light output with currents as low as 10 mA, while accepting maximum currents of up to 50 mA without damage. These characteristics permit LED's to be used in a variety of valuable, interesting, and practical projects, both individually and in conjunction with other solid-state devices. Several of many possible LED applications are illustrated schematically in Figs. 1 through 3.

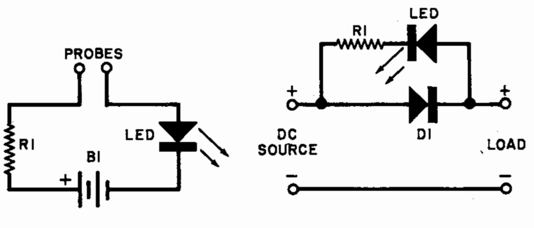


Fig. 1. Circuit (A), left, is continuity checker; (B), right, polarity reversal alarm.

The simple continuity checker circuit illustrated in Fig. 1A can be assembled at minimum cost in a single evening. A standard probe body, a small metal box, or even a large plastic vial can be used for housing the project. The battery may be two or more penlight cells or even a 9-volt transistor battery, while *R1*, a half-watt resistor, has a value chosen to limit the short-circuit current to between half and three-quarters of the LED's maximum rating. Typically, a 1.6 volt, 50-mA LED, used with a 9-volt battery, would require a 240- to 330-ohm resistor.

In operation, the instrument is used just as one would use an ohmmeter for checking the dc continuity of circuit wiring, terminal connections, switch contacts, and even components, such as coils, transformers, loudspeakers and relays. The LED lights if there is a continuous dc path between any two terminals to which the test leads are applied.

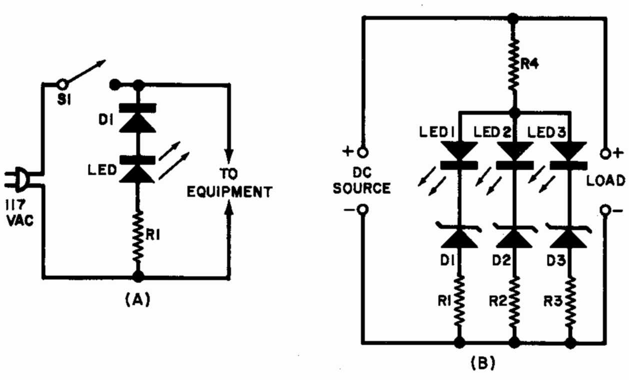


Fig. 2. Two useful applications: (A) Line pilot for ac; (B) voltage monitor for dc.

Unlike many inexpensive commercial continuity checkers, this unit will provide a positive indication even if the circuit's resistance is moderately high. An experimental model assembled using a 9-volt battery and a bargain-package LED provided a useful output with test resistances of up to 3000 ohms.

A useful variation of the polarity reversal protection circuit discussed in our August column is shown in Fig. 1B. Here, the protective diode is shunted by a LED in series with current-limiting resistor *R1*. With correct dc polarity applied, diode *D1* acts as a virtual short, supplying power to the equipment (load). If the supply polarity is reversed accidentally, *D1* acts as an open circuit, preventing equipment damage, while a small reverse leakage current, limited by *R1*, flows through the LED, illuminating this device and signalling the operator.

This circuit may be assembled in an external case attached between the equipment's supply terminals and the dc power source or, if preferred, built into the protected equipment.

Despite their low voltage ratings and dc power requirements, LED's can be used as ac line pilots and low-level night lights (in place of neon bulbs). Simply add a small rectifier diode *(D1)* and a current-limiting resistor *(R1)*, as illustrated in Fig. 2A. Generally, *D1* would be a 200-volt silicon rectifier, the LED a 1.6-volt, 50-mA (max) type, and *R1* a 10,000-ohm, 2-watt resistor.

You can use the inexpensive voltage monitor circuit given in Fig. 2B with any type of equipment in which dc supply voltages are critical. Typical examples are small aircraft radio gear, precision test instruments, and some types of medical electronic equipment. Standard LED's are used in conjunction with zener diodes *D1* to *D3* and current-limiting resistors *R1* through *R4*. The zener values are chosen for the minimum, optimum and maximum voltages which can be tolerated by the equipment, taking into account the voltage drops across the LED's and the series resistors.

Assuming that *D1* is chosen for the low-voltage limit, *D2* for the optimum voltage, and *D3* for the maximum voltage, the three LED's will light in a varying pattern to identify supply voltage conditions. With optimum voltage applied, *LED1* and *LED2* are illuminated. If all three are dark, the supply voltage is either too low or absent, while if only *LED1* lights, the voltage is above the minimum, but below the optimum value. Finally, should all three light, the voltage is at or above the high limit.

With suitable circuit component values, the LED voltage monitor is capable of maintaining a constant check on dc supply voltages to within a half-volt, or better, in practical installations.

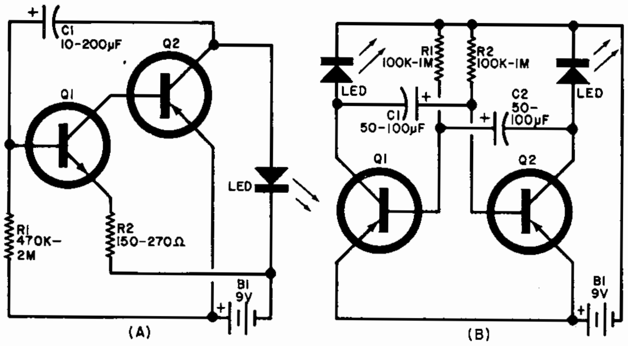


Fig. 3. LED flasher circuits: (A) relaxation oscillator; (B) alternate blinker.

Unlike incandescent lamps, which have a characteristic thermal time lag, LED's can be flashed at rates of less than 1 Hz to many kHz, permitting their use in visual timers or metronomes, toys, opto-couplers, alarms, and similar projects. Any of several techniques may be used to provide an attention-getting repetitive flash. The simplest employ a single special-purpose device, such as a UJT, PUT or MISER. However, quite acceptable results can be obtained using low-cost general-purpose transistors, as found in bargain assortments. Two practical circuits are illustrated in Fig. 3.

The complementary relaxation oscillator shown in Fig. 3A features direct-coupled npn *(Q1)* and pnp *(Q2)* transistors, with the LED serving as the output load. Capacitor *C1* provides the feedback necessary to start and maintain oscillation. The circuit's repetition rate (frequency) depends on the transistors' characteristics, on the component values, and on the supply voltage. If desired, the npn and pnp devices may be interchanged, provided all other dc polarities *(C1,* LED, and *B1)* are reversed.

You can use this circuit as a simple flasher or as a visual timer or metronome, by making one of the frequency determining components variable (such as *R1*).

While the exact component values will vary with the transistors' characteristics and the supply voltage, good starting values for circuits using small general-purpose transistors are shown at Fig. 3A. Generally, the larger the feedback capacitor *(C1)* and the base bias resistor *(R1)*, the lower the flashing rate, and vice versa.

An alternate flashing action is provided by the collector-coupled multivibrator circuit given in Fig. 3B. This is an especially good circuit for use in toys, with the LED's serving, say, as the flashing eyes of a clown or similar character. Although pnp devices are shown, npn types may be used simply by reversing all dc polarities. With a given pair of transistors and a fixed supply voltage, the circuit's repetition rate is determined by the values chosen for *C1, R1, C2* and *R2*. The greater the R-C time constant, the lower the flashing rate.

The circuits described are but a small sampling of those which can be developed using LED's. All were bench-tested using inexpensive 1.6-volt, 50 mA red devices.

Perhaps the most interesting of the new LED devices is the RLC-200 series introduced recently by Litronix, Inc. (19000 Homestead Road, Vallco Park, Cupertino, CA 95014). These devices feature an internal current-regulator IC, permitting their use with 4.5 to 16 volts, without an external current limiting resistor.

Reader's Circuit. The "Wail/Whoop" siren generator circuit given in Fig. 4 offers interesting possibilities whether or not you operate an emergency vehicle. If you're a student, you might consider its use as part of a Science Fair project. If you're part of a rock group or involved in amateur theatricals, it could prove useful for special sound effects. It should make a fine alarm source for an intrusion or burglar detection system. And even if you're not involved in any of these, it's worth tackling.

Submitted by reader Max W. Hauser (1712 Francisco St., Berkeley, CA 94703), the generator features a pair of readily available IC's and is designed for operation on a standard 12-volt dc power source. Max writes that he designed and built the system a little over a year ago.

In operation, a voltage-controlled oscillator, *IC2*, serves as the basic signal source. Its mode of operation is established by selector switch *S2*, while its instantaneous frequency is determined by the voltage applied to its control terminal (pin 5).

With *S2* in the WAIL position, *IC2*'s frequency is controlled by a ramp voltage developed by a network consisting of *R10, C4,* and *C11*. As *S1* is depressed and released, *C4* charges and discharges, changing the control voltage applied to *IC2* and causing a corresponding change in frequency, first rising, then dropping in pitch.

When *S2* is switched to its WHOOP position, *IC2* is controlled by a low-frequency sine wave developed by op amp *IC1A*, connected as a modified Wien bridge oscillator (C1, R4, C2 and R7). The frequency determining feedback bridge develops a signal of about 5 Hz, establishing the cyclic whoop rate.

The characteristic triangular output of *IC2* is shaped into an approximate sine wave by a second op amp, *IC1B*, serving as a nonlinear buffer amplifier. Feedback diodes *D3* and *D4*, in conjunction with shunt resistor *R17*, determine the final output waveform

Max has specified standard components in his design. If preferred, individual type 741 op amps may be used for IC1A and IC1B in place of the 558. All diodes are general purpose types. Except for *C1* and *C2*, which should be either Mylar or polystyrene types and the 15-volt electrolytics, all other capacitors may be either low-voltage ceramic or conventional paper units. Switch *S1* is a momentary contact, NO, spst pushbutton switch, and *S2* is a spdt toggle, slide or rotary switch.

Parts layout and lead dress should not be overly critical as long as good wiring practice is observed and all signal-carrying leads are kept short and direct. Either a suitable etched circuit board, perf board, or point-to-point wiring techniques may be used for duplicating the design. After assembly, checking and preliminary test, *R17*'s value may be changed for an optimum sine-wave output signal. Max indicates that this is the only critical component in his circuit, and suggests that some builders may prefer to substitute a 100,000-ohm trimmer potentiometer for the 56,000-ohm fixed value unit to insure ease of final adjustment.

According to Max, the "Wail/Whoop" generator delivers an output signal of approximate 1 volt, p-p. This is adequate to drive any standard audio amplifier/loudspeaker system. If preferred, of course, a separate power amplifier may be provided just for the generator. In his tests, Max found that a 1-watt commercial modular amplifier supplied an output level quite satisfactory for his applications.

Device/Product News. Every now and again, yours truly is taken to task by an irate reader or manufacturer (not to

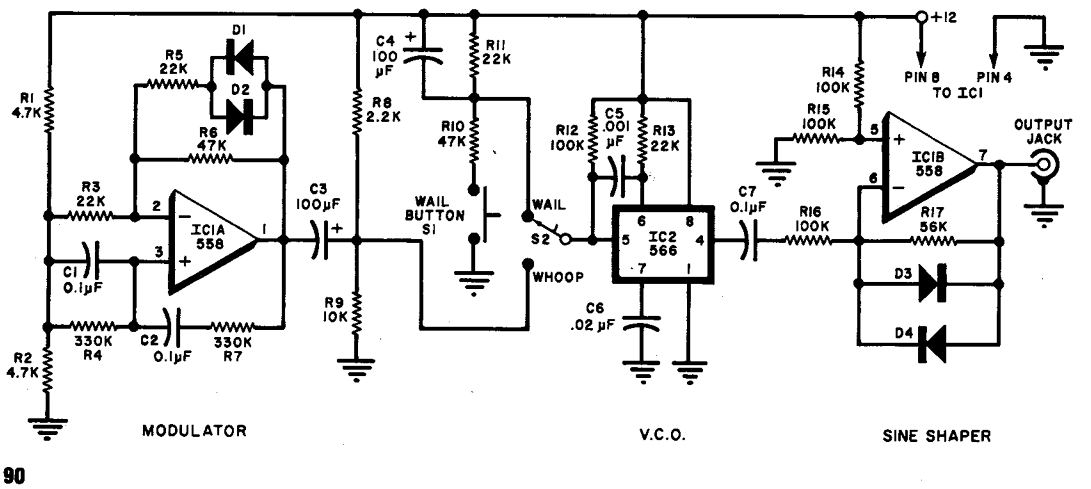


Fig. 4. Wail/Whoop generator circuit uses just two IC's Output is about 1 V.

mention our Editorial Director) for failing to mention a specific new device. Unfortunately, so many new solid-state devices, products and related components are introduced in any given month that it would be impossible to cover them all in the space available, even if the column were doubled in length and devoted entirely to brief discussions of new products. Quite often, a new device of spectacular interest must be omitted simply because it is too costly for average use (would you believe over $300.00 for a single IC?), too complex to describe adequately in a few paragraphs, or is offered only to OEM's (original equipment manufacturers) who purchase in large quantities. My goal, generally, is to offer a representative sampling of new products covering as broad a range as is feasible to insure touching upon (nearly) everyone's special interests. Our featured selections this month, for example, include both discrete and IC devices suitable for linear and digital applications.

From Texas Instruments, Inc. (P.O. Box 5012, M/S 308, Dallas, Texas, 75222), comes news of four new silicon power transistors and several interesting new IC's.

Offered in two series, TI's new power transistors are npn devices. Designated the TIP63, TIP64 Series, and the TIP65, TIP66 Series, these new units are available in TO-66 and TO-3 plastic packages respectively.

Featuring V_{ceo} breakdown voltages ranging from 300 to 350 volts and a continuous power dissipation of 20 watts at 25°C case temperature, the TIP63 and TIP64 series are high-voltage, medium-power units designed for both industrial and consumer applications. The TIP65 and TIP66 Series are horizontal TV deflection transistors designed for line-operated CRT deflection circuits; the units feature 1200- and 1400-volt C-E off-state voltage ratings, 1.5-ampere rated collector current, and fast switching with a typical fall time of 0.7 µs at 1 ampere.

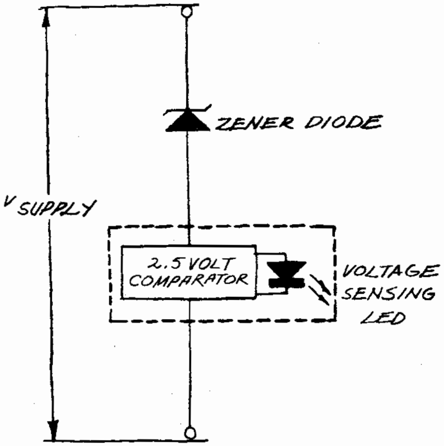
Designated types SN76701, SN76702, SN76710, and SN76711, TI's new IC's are designed for varactor tuned TV applications. All four units are supplied in 16-pin plastic DIP's. The SN76711 is a logic control circuit for 16-channel systems, the SN76710 a similar device for 14-channel applications. Types SN76701 and SN76702 are analog voltage switches. In practice, one SN76701, one SN76711, and three SN76702 devices, used together, could form a complete 16-channel TV electronic tuning system.

Suggesting that it is suitable for use in oscillators, switching regulators, series regulators, converters, and inverters, RCA (Solid State Division, Box 3200, Somerville, NJ 08876) has announced a new epitaxial-base npn silicon transistor designed especially for use in high-current, high-speed switching circuits. Identified as type 2N6500, the unit is rated for a V_{ceo} of 120 volts and a continuous collector current of 4 amperes, with a total saturated switching time of less than 1 µs. It is supplied in a TO-66 package.

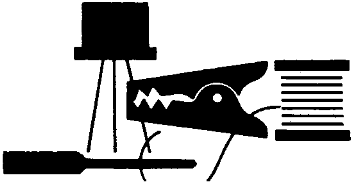
If you're working with digital designs, there's good news this month from your friends at Motorola, Inc., Semiconductor Products Division (P.O. Box 20924, Phoenix, AZ 85036). Not only have the boys from Phoenix introduced three new MECL 10,000 IC's, but they've announced substantial price cuts on many of the standard items in the line, with some reductions ranging up to 45 percent. The new MECL 10,000 devices include the MC10153L quad latch (negative clock), the MC10178L binary counter, and the MC10212L high-speed dual 2-NOR/1-OR gate. All three devices are supplied in 16-pin ceramic DIP's. ◈

LED MONITORS BATTERY VOLTAGE

A new voltage-sensing LED (Hewlett-Packard 5082-4732) can be used to monitor battery voltages in-circuit. Since a good battery will keep its load voltage to at least 85% of its open circuit value, we can employ the LED and a zener diode to give a GOOD/BAD indication. The LED contains a reference voltage and a comparator, which triggers at a nominal threshold of 2.5 volts. The LED will abruptly extinguish below this



voltage. If we have a circuit powered by a 9-volt transistor battery, we want the supply voltage to stay above 7.6 V (85% of 9 V). In this case, we connect a 5.1-volt zener diode as shown, so that the LED will glow at the desired minimum voltage (5.1 V+2.5 V=7.6 V). Other zeners may be used to monitor various voltages. For example, connecting a 2.1-volt zener will have the LED indicate when a 5-volt TTL supply is within 90% of its optimum value (2.1 V+2.5 V=4.6 V). Other applications are limited only by the user's imagination.—*Sol D. Prensky*



Tips & Techniques

COLORED POLYESTER FILM MAKES INEXPENSIVE LED DISPLAY FILTER

An attractive color-matched filter and protective window for LED and incandescent numeric displays can be made from an inexpensive item that you can buy in almost any art supply store. Called Rubylith or Amberlith, the polyester film material is available in deep red, orangy amber, and deep green. The red can be used with good effect with LED displays, while any color can be used with the incandescent display. To use this material, cut it to a size large enough to fit the window cutout of your project plus about ¼ in. on all sides to permit mounting. Run a bead of plastic cement around the perimeter of the film and fix the film into place. Note that the colored non-reflective side should face away from the display. —*William A. Russo*

Driving LEDs directly from C-MOS logic outputs

by C.D. Patterson
Gandalf Data Communications Ltd., Ottawa, Ont., Canada

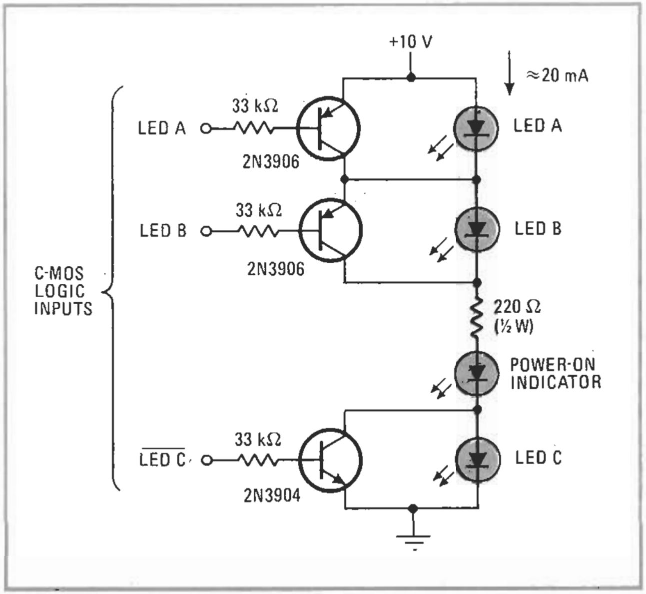
If a complementary-MOS logic system requires a number of light-emitting diodes in its display, the power dissipated in the display may be far more than that for all the rest of the circuitry.

To get a nice bright display, each LED should receive more than 15 milliamperes of current. If the requirement is for, say, four LEDs, then something like 60 mA must be provided by the supply. In addition, each LED must be driven from a high-current C-MOS inverter, such as a 14019 device wired as a current sink.

One way to cut down on current consumption is to connect all the LEDs in series in a 20-mA current chain, as shown in the figure. Each LED can then be controlled by shorting it out with a transistor.

A pnp transistor will allow a LED to turn on for positive C-MOS levels, while an npn transistor will allow a LED to turn on for negative C-MOS levels. Also, since the transistor can be operated with less than 0.3 mA of base current, normal C-MOS logic outputs can provide sufficient current for driving the LEDs.

LEDs controlled by pnp transistors should be inserted at the top of the chain, and those controlled by npn transistors at the bottom. This avoids excessive reverse emitter-base voltages. □



Current-saving design. Inserting a bipolar transistor between a C-MOS logic output and a LED indicator permits the C-MOS logic device to control the LED. The current supplied by the C-MOS logic-level output is sufficient to turn on the transistor, which, in turn, causes the LED to go out. A pnp transistor is used for positive logic signals, and an npn transistor for negative logic signals.

Solid State

By Lou Garner

A UNIVERSAL LIGHT EMITTING DIODE

IF YOU think of light emitting diodes (LED's) only as indicators, a new breed introduced by the National Semiconductor Corporation (2900 Semiconductor Drive, Santa Clara, CA 95051) may change your mind. Unlike standard LED's, which are useful only in dc circuits and require current limiting, the new type NSL4944 can be used with dc *or* ac, will operate over a wide range of voltages without external limiting devices, and can be the principal active device in a variety of interesting and useful projects. Compared to an incandescent lamp, the new LED might well boast, "anything you can do, I can do better."

Represented symbolically as a constant current source in series with a light emitting diode, Fig. 1A, the NSL4944 comprises an integrated circuit chip and a GaAsP high-intensity red LED in a single plastic package. The IC includes (Fig. 1B) a pnp pass transistor, a voltage reference network, a voltage comparator, and a series current reference resistor. Since most of the regulating circuit is not in series with the LED, the complete device requires only about 300 mV more than a standard red LED. Further, because all of the current is through the pnp transistor's emitter, the device can serve as a medium level rectifier and a constant-current source *in addition* to its role as a lamp.

Physically, the NSL4944 is no larger than conventional LED's and, with only two leads, can be interchanged with these in most applications. Its cathode lead is identified by a flat area on the circular base. Equipped with a diffused lens, the device can be panel mounted by means of a standard two-piece plastic adaptor or can be installed directly on circuit boards for wrapped or soldered connections. It can be mounted vertically, or horizontally, as shown in Fig. 1C. The rated operating and storage temperature range is −55 to 100°C., but with linear derating of 0.125V/°C above 25°C.

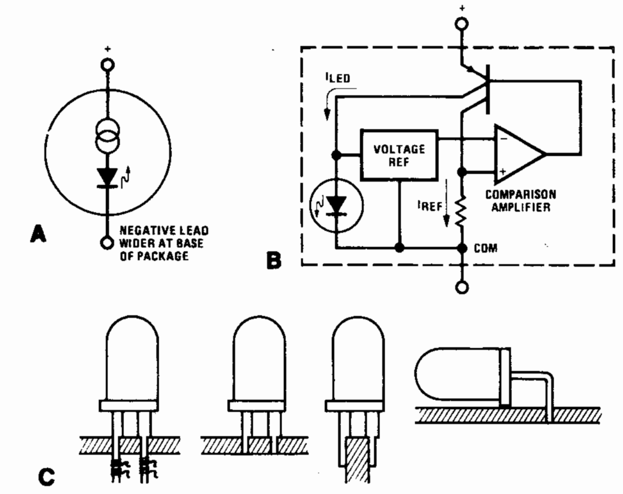


Fig. 1. (A) Schematic symbol for NSL4944. (B) Internal circuit. (C) Mounting methods.

The new device has an operating voltage range of (approximately) 2.0 to 18.0 volts and also can withstand reverse voltages up to 18.0 V. The light output remains essentially constant at (typically) 0.8 mcd from about 3 volts to maximum rated voltage. With a power dissipation rating of 300 mW at 25°C, the forward current varies from 12 to about 14 mA over the full voltage range. The device will operate at reduced intensity with sources of 1.6 to 1.9 volts capable of furnishing at least 8 mA, and can be switched on and off by any circuit capable of supplying 10 to 20 mA and a voltage swing of at least 1 volt. Typically, an applied voltage of 1.3 volts will result in little or no light output, while an increase to 2.3 volts will develop 70% to 90% of full light intensity.

National Semiconductor's specification sheet for the NSL4944 and a 4-page application note AN-153 suggest a number of practical circuits for the device.

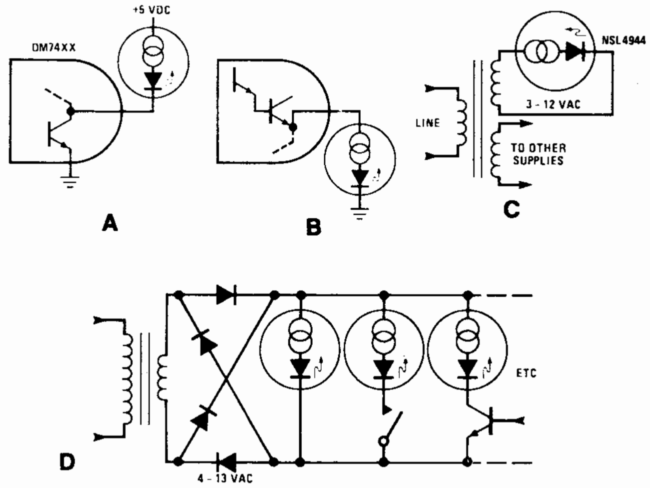


Fig. 2. NSL4944 applications: Low (A) and high (B) logic indicator; on ac (C) and dc (D) sources.

As a simple indicator, for example, the unit is ideal for applications ranging from digital logic designs to conventional pilot lamps. When driven by standard TTL devices, the NSL4944 can serve as a low or high status indicator, as suggested in Figs. 2A and 2B, respectively. The unit's ability to operate on ac as well as dc sources allows it to be used as a pilot lamp when powered by the low-voltage filament winding of a standard power transformer, as shown in Fig. 2C. When operated on ac, the unit's actual light intensity is halved, but the output level is more than adequate for most applications. The NSL4944 can also be used on unfiltered and unregulated dc sources, either alone or in conjunction with other components, such as switches, relays, or other solid-state devices (Fig. 2D).

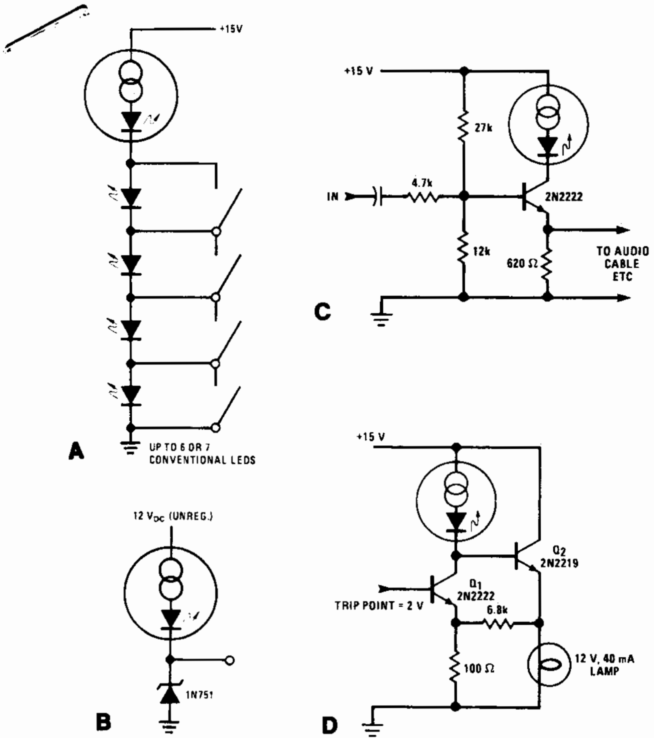


Fig. 3. Current source for LED's (A) and zeners (B). Load for line driver (C) and Schmitt lamp driver (D).

Another broad range of applications for the NSL4944 is when it is used as a constant current source. With a 15-volt dc supply, for example, it can furnish a controlled current for six or seven series-connected conventional LED's, (Fig. 3A). Shorting any number of the LED's in the string with switches, relay contacts, or other means will not affect the remainder, nor the NSL4944. Such an arrangement might be used, typically, to indicate relay, switch, or circuit-breaker closures. The device's constant current characteristic also is useful for operating a zener diode in voltage regulator circuits (Fig. 3B). If used in the collector circuit of an emitter follower preamp or line driver, as in Fig. 3C, the device will limit the output transistor's total current without affecting signal voltage swing, thus protecting the stage against damage due to line, cable or load shorts. Another application is shown in Fig. 3D. Here, the NSL4944 serves as an active load for a lamp driver circuit, increasing *Q1*'s useful voltage gain, but still permitting nearly full base bias on *Q2*. Substituting an LM195 for *Q2* and adding a 4.7-kilohm series base resistor will allow this circuit to handle 12-volt lamps rated at 1 ampere.

Several useful, easy-to-build projects featuring the NSL4944 are illustrated in Fig. 4. They include an ultra-simple "HI-LO" logic probe for TTL circuits, a time delay relay, and a small trickle charger for batteries (from 1.5 to 6 volts). The logic probe uses a pair of series-connected devices and is intended for use on standard 5-volt dc sources. The upper LED lights when the circuit test point is low, the lower LED when the TTL level is high. With a time delay of approximately six seconds, the relay circuit requires only two additional components, a large electrolytic capacitor and a sensitive high-impedance electromagnetic relay. The NSL4944's constant-current feature limits the timing variation to about 3% over a supply voltage range of 14 to 18 volts (much less than the variations due to temperature and capacitor tolerances). Finally, the simple trickle charger utilizes all three of the NSL4944's unique characteristics—as an indicator, a rectifier, and a constant

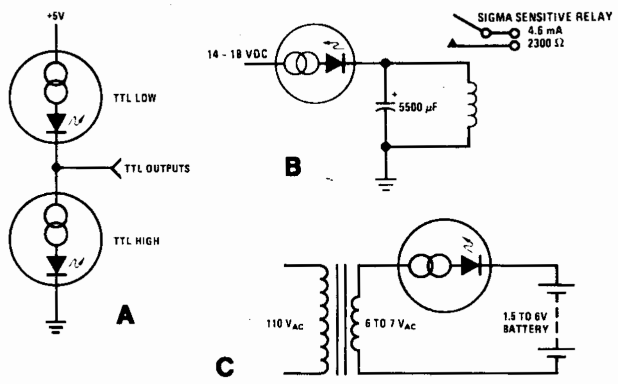


Fig. 4. Simple NSL4944 projects: (A) TTL probe; (B) time-delay relay; (C) trickle battery charger.

current source. Supplying a trickle charging current of 10 mA or more, the design requires only one additional electrical component—a small step-down transformer.

The circuit applications we've examined, although representative, are but a fraction of those possible with the versatile NSL4944. In addition, National Semiconductor suggests that the device can be used as a shorted SCR indicator in low-voltage circuits, a constant-current load for precision amplifiers, a reverse-voltage monitor for power supplies, a current limiter, and a regulated current source for voltage dividers or transducers, such as thermistors.

Right On! Although the bicentennial year has not yet run even half its course, a number of the predictions made in last January's column have materialized. At the Consumer Electronics Show in Chicago, Texas Instruments, Inc. (P.O. Box 5012, Mail Station 84, Dallas, TX 75222) introduced a line of electronic digital watches at suggested retail prices starting at $19.95, thus fulfulling my prediction of *digital electronic watches retailing for less than $25.00.* The watches TI-501 and TI-502, feature a five-function electronic module in black, brown, beige or white polysulfone cases (the impact-, heat- and abrasion-resistant material used in the visors of the Apollo Astronauts). A metal-cased version offered in chrome and gold tone, the TI-401, lists at prices starting at $29.95.

Another major manufacturer, Fairchild's Consumer Products Group (4001 Miranda Ave., Palo Alto, CA 94303) also has introduced a line of low-cost digital LED watches. Fairchild's new line *Timeband*™ features all metal cases with either gold or chromium finish, single-button five-function operation, and list prices starting at $29.95.

Another prediction, *a substantial drop in the prices of microprocessors and memory IC's,* has been fulfilled not only by substantial price cuts in older models but by the introduction of new devices at lower prices. Already within the budget limits of many hobbyists and experimenters, microprocessor and memory IC prices probably will drop even further before year's end.

Reader's Circuit. With potential applications as a digital logic clock, electronic metronome, wide-range test oscillator, harmonic generator, relay pulser, time marker generator, scope sweep oscillator, and frequency divider, the astable pulse oscillator circuit in Fig. 5 requires only two transistors, yet provides nine octaves of frequency coverage with a single control. Easily duplicated at home, the design was submitted by Peter Lefferts (1640 Decker Ave., San Martin, CA 95046).

Timing capacitor *C1* is charged slowly by the dc source, *B1,* through voltage-divider *R1-R2* until *Q1* is forward-biased and starts conducting. When this occurs, a forward base bias is applied to *Q2* through *Q1*'s split collector load *R3-R4.* As *Q2* starts conducting, a pulse is developed across its collector load, *R6,* which, coupled back to *Q1*'s base through capacitor *C2* and series resistor *R5,* drives *Q1* to a heavily conducting state, rapidly discharging *C1.* Then the cycle starts over. In essence, *Q1* and *Q2* form a high gain amplifier with *C2* providing positive feedback. Diode *D1* reduces feedback capacitor *C2*'s recovery time, while potentiometer *R8* establishes *Q1*'s base bias level and thus the point at which timing capacitor *C1* charges before feedback and capacitor discharge is initiated. The lower *Q1*'s initial base bias, the higher the circuit's repetition rate. Potentiometer *R8,* therefore, serves as the circuit's frequency control. Circuit power is supplied by dc source *B1,* controlled by a spst power switch, *S1.*

The circuit can be assembled using any standard construction method, provided good wiring practice is observed. Transistors *Q1* and *Q2* are types 2N1304 and 2N1372, respectively, while *D1* is type 1N34A. Except for the 10-kilohm potentiometer, *R8,* the resistors can be either 1/4 or 1/2 watt. Capacitors *C1* and *C2* are low-voltage ceramic, paper or plastic film units. Power switch *S1* can be any spst type. The circuit will operate with dc sources of 5 to 25 volts, but a 12-volt dc source is optimum.

Although designed primarily as a pulse generator, other waveforms may be obtained at various points in the circuit, including the *D1-C2-R5* junction and at *Q1*'s collector. A sawtooth signal suitable for use as a linear scope sweep is

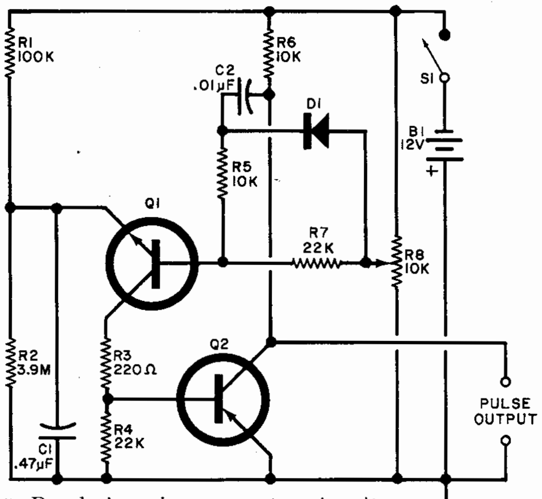


Fig. 5. Reader's pulse generator circuit.

available across *C1*. For frequency-divider, sweep-generator, and time-marker applications, synchronization pulses can be applied to *Q1*'s base through a small coupling capacitor. The circuit's frequency range can be shifted by using other values for *C1* and *C2*. With values of 100 µF for *C1* and 3 µF for *C2*, the circuit will operate down to approximately 1/20 Hz. Lower values than those given in Fig. 5 will permit operation at ultrasonic frequencies, but it may be necessary to reduce resistor values to 1/10 of those listed, except for *R3*, which should not be less than 100 ohms.

Device/Product News. In addition to its versatile NSL4944 universal LED, the National Semiconductor Corporation has introduced a number of new devices of interest, including a family of four Tri-State octal buffer IC's. The buffers, types DM81LS95, DM81LS96, DM81LS97 and DM81LS98, offer typical power consumptions of under 80 mW and propagation delays of less than 14 ns. Each device provides eight 2-input buffers in a single package, with one of the two inputs to each buffer used as a control line to gate the output into a high-impedance state and the other to pass data into the buffer. Types DM81LS95 and 97 present true data at their outputs, while the DM81LS96 and 98 invert the data. In the DM81LS95 and 96, all eight Tri-State enable lines are common, with access gained through a two-input NOR gate. In the DM81LS97 and 98, four of the eight buffers are enabled by one common line, the other four through another common line.

A TTL-compatible NMOS digital frequency synthesizer for use in CB, marine and avionics transceivers as well as digital TV tuners has been announced by Nitron, a division of the McDonnell Douglas Corporation (10420 Bubb Road, Cupertino, CA 95014). The new IC, type NC6400, requires only a reference oscillator, a VCO, an appropriate data input and an optional prescaling counter to form a complete digital frequency synthesizer system. The device is internally programmable to provide up to 80 channels with different transmit and receive frequencies available for each. The frequency desired is called up by keying the appropriate channel number into either a 3 × 4 matrix keyboard or by presenting it in BCD code on a four-line data bus. Decoded seven segment (or 4-line BCD) outputs are provided to display the number of the channel called up, plus three additional outputs which can be programmed to indicate illegal channel entry, emergency channel, or similar information. ◈

Negative feedback keeps LED intensity constant

by Ken Erickson
Interstate Electronics Corp., Anaheim, Calif.

In applications where a passing object is detected as it partly obscures a light beam, a light source with a constant intensity may be desirable. A light-emitting diode, which has a longer life and switches faster than an incandescent lamp, would also be desirable, if it weren't for the fact that its light intensity may vary with temperature, especially as the device ages. But a LED's light intensity can be kept constant by the circuit shown here.

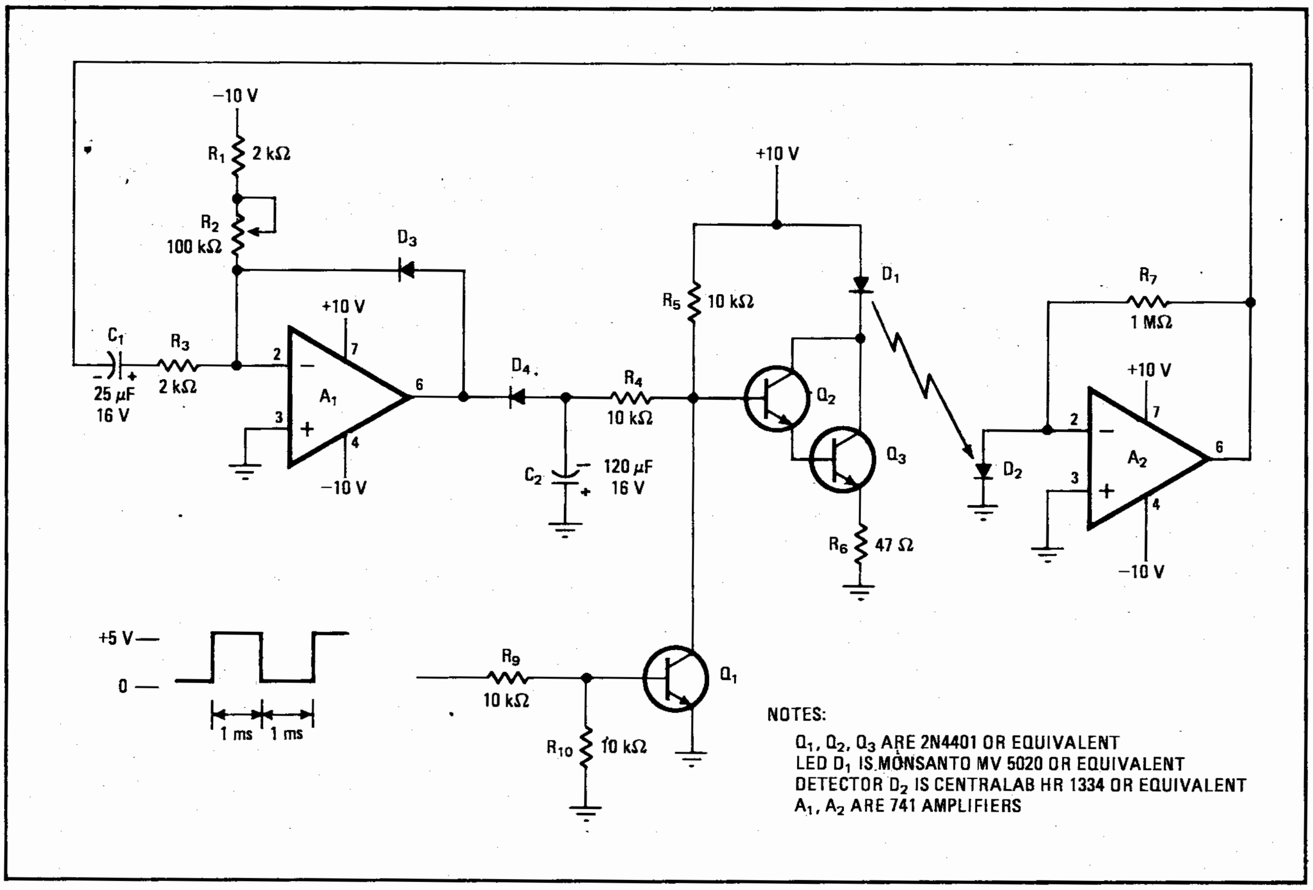
Light intensity is regulated by a silicon planar photovoltaic diode, D_2, the ac response of which is almost constant with temperature or time. Its current is converted to voltage by amplifier A_2 and resistor R_7. This diode is connected in a short-circuit mode to minimize its dark current.

D_1, a light-emitting diode, is driven by Darlington-connected transistors Q_2 and Q_3; its current is proportional to the voltage at the base of Q_2. Transistor Q_1, which is driven by a positive-going square wave, chops the dc level at the base of Q_2 so that it operates in an ac mode.

When the capacitively coupled output of amplifier A_2 is positive, amplifier A_1 charges capacitor C_2, when necessary, to maintain the current through R_3 equal to the current through R_1 and R_2. Because the current through R_1 and R_2 is constant, the amplitude of the square-wave signal at the junction of C_1 and R_3 is held constant.

When the output of A_2 is negative, the capacitively-coupled output of amplifier A_1 goes positive, but is clamped to 0.7 volt by diode D_3. This clamping maintains the output of the amplifier in the active region so that a virtual ground potential is maintained at its summing point. The light intensity level is adjusted by potentiometer R_2. The peak-to-peak voltage at the output of amplifier A_2 is held at $40/(R_1 + R_2)$ volts, where R_1 and R_2 are in kilohms.

Diode D_2 can be mounted near the LED, but to one side of the direct beam, so that it picks up enough light to generate the feedback signal but doesn't interfere with the primary detection function. □



Steady glow. Feedback loop senses variations in output of light-emitting diode, which may occur as temperature changes. Photodiode response is almost constant with temperature; it is amplified, and signal controls another amplifier whose output controls LED drive circuit.

Timer IC and photocell can vary LED brightness

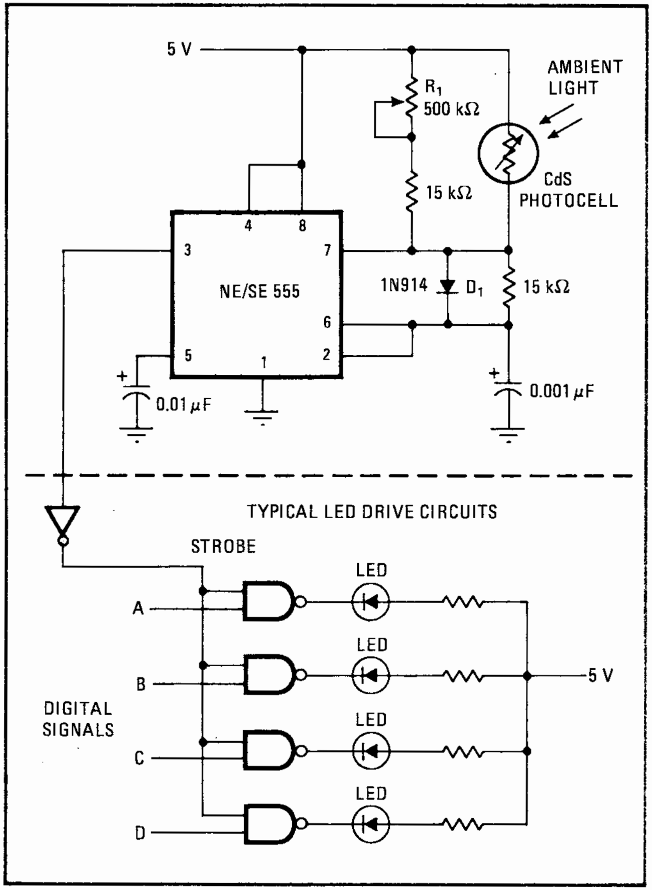
by F. E. Hinkle and Jim Edrington
Applied Research Laboratories, University of Texas, Austin

The relative brightness of a light-emitting-diode display can be varied automatically by combining a cadmium-sulfide photocell and a 555 timer into a pulse-width-modulated astable multivibrator. Such variability is obviously important in aircraft and automotive instrumentation, as well as in calculators and digital watches, or wherever ambient light conditions vary.

The circuit is the standard astable configuration for the 555, with two modifications: the photocell replaces one of the timing resistors, so that ambient light controls the duty cycle of the astable oscillator; and diode D_1 bypasses the 15-kilohm timing resistor during the charging of the timing capacitor, increasing the maximum duty cycle of the 555 beyond the normal 50% limit, and allowing the display to obtain full brightness.

As increasing ambient light level decreases the photocell's resistance, the timer's duty cycle increases. The varying duty cycle controls the length of time the display drivers are on, and this controls the brightness.

This circuit varies the duty cycle from less than 5% in total darkness to more than 90% in sunlight. Manually setting control R_1 establishes the minimum brightness level in total darkness; if such adjustment is considered unnecessary in a particular application, R_1 could be replaced with a fixed resistor. □



Fader. Brightness of LED display is varied by using a photocell in place of one timing resistor in a 555 timer, and bypassing the other timing resistor to boost the timer's maximum duty cycle. Result is brighter display in sunlight, fainter in the dark.

Using an LED's polar diagram to determine its power output

by P. R. Thomas
University College of North Wales, Gwynedd, Wales

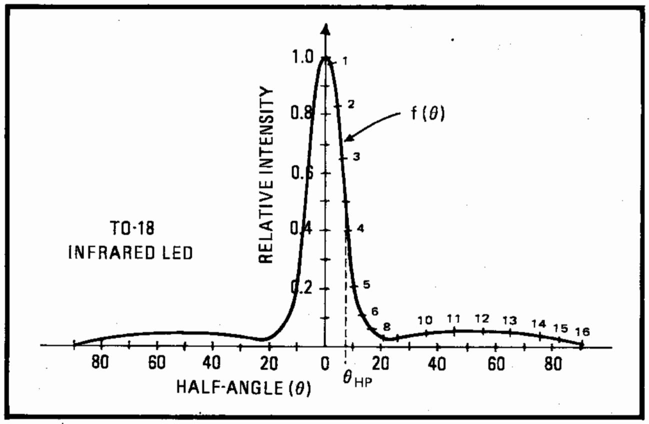
The percentage of total power contained within the central lobe of an optical diode's radiation pattern cannot always be directly determined from its polar plot. But it can be calculated from the information contained in the plot if the radiation pattern is detailed through angles of 90° with respect to the optical axis.

Generally, the polar plot alone is useless for finding the relative power because its two dimensions cannot accurately or adequately characterize the three-dimensional radiation pattern of the LED. Essentially, the plot must be normalized for every angle. Although some data sheets provide complete information on the diode's radiating properties—that is, the plot plus a curve of the percentage of output power versus angle—most provide only a polar plot and do not indicate the radiation in the sidelobes. Data sheets that do not provide sidelobe information are the least useful to the engineer.

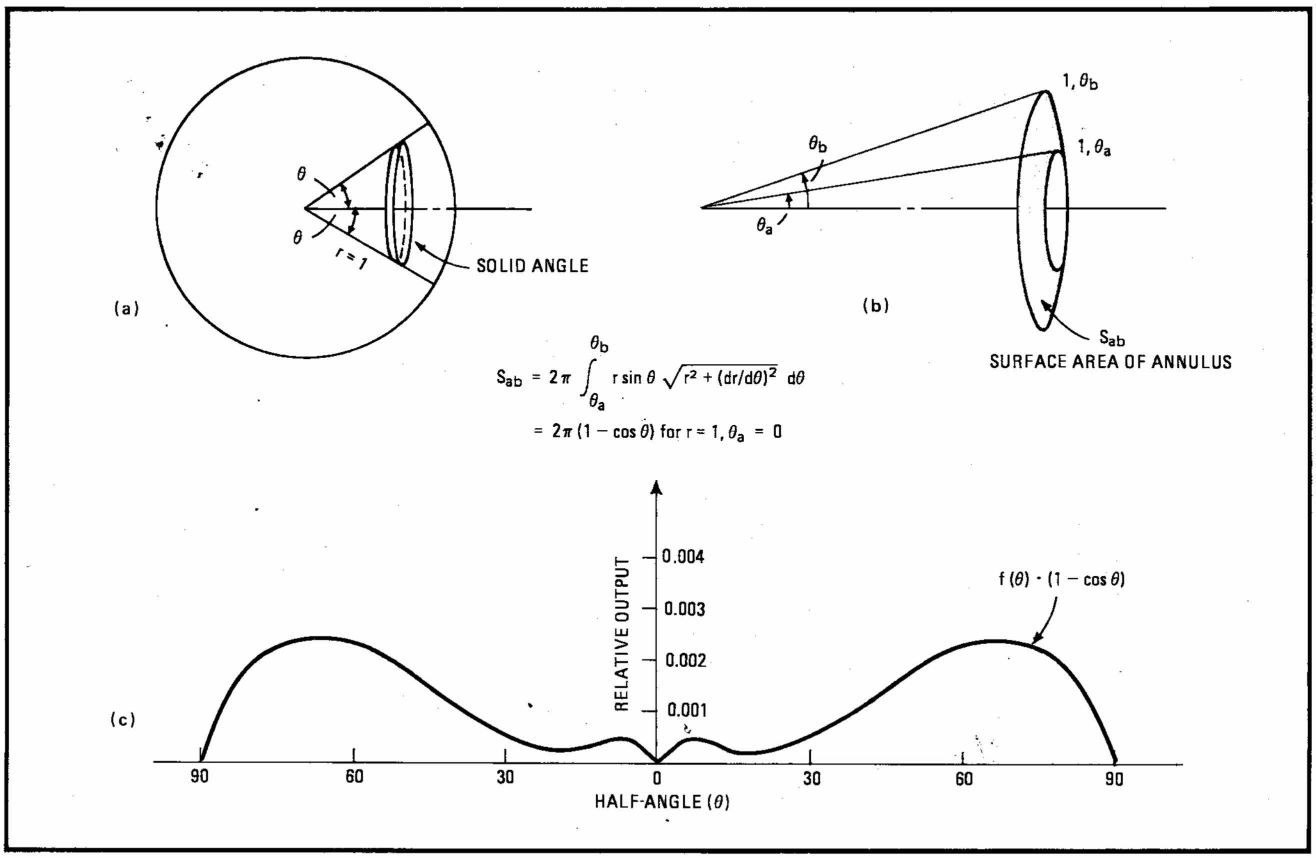
A polar diagram of a typical infrared-light-emitting diode (IRLED) is shown in Fig. 1. Only 26.5% of the total power is contained within the central lobe, although it appears that most of the power lies there.

To show this, it is necessary to visualize the LED's energy as emanating from the center of a sphere and passing through a solid angle into a three-dimensional region of space, as shown in Fig. 2a. It is necessary to know the solid angle swept out by a given half-angle θ.

The solid angle contained within the cone of θ is defined as the surface area of the curved section where the cone cuts the sphere of unity radius, as shown in Fig. 2b. The solid angle is calculated by the standard



1. Polar plot. Only about one quarter of total optical output of TO-18 infrared LED appears in central lobe, although it seems that most of the power is contained there. Two dimensional polar plot is insufficient for characterizing three-dimensional radiating pattern of LED.



2. Correction. Polar plot must be normalized for every optical angle by taking three-dimensional radiating pattern of LED into consideration (a). Relation of solid angle S to optical angle O is determined by classical formulas (b,c). Proportion of power emitted at high angles is more significant than appears from observation of polar plot alone (c). Almost 75% of the LED's total power is contained in the 20° to 90° range.

DETERMINATION OF RELATIVE OUTPUT POWER FROM POLAR PLOT				
Point	Relative intensity output — polar plot	Half angle $\angle\theta$	Partial sum Σ	Relative power output for θ_i (%)
0	1.00	0	0	0
1	0.98	2	0.0006	1.3
2	0.83	4	0.0023	5.2
3	0.65	6	0.0045	10.1
4	0.40	8	0.0067	15.1
5	0.20	10	0.0084	18.9
6	0.10	13	0.0099	22.3
7	0.05	16	0.0109	24.5
8	0.03	20	0.0118	26.5
9	0.03	25	0.0128	28.8
10	0.04	35	0.0158	35.5
11	0.05	45	0.0209	47.0
12	0.05	55	0.0276	62.0
13	0.04	65	0.0343	77.1
14	0.03	75	0.0401	90.1
15	0.02	82	0.0431	96.9
16	0.00	90	0.0445	100

SAMPLE CALCULATION: $\sum_5^6$

- Average intensity$_{5,6}$ = ½(0.20 + 0.10) = 0.15
- $\cos\theta_5 - \cos\theta_6$ = 0.9848 − 0.9744 = 0.0104
- Contribution to integral = 0.15 × 0.01 = 0.0015
- Partial sum to point 6 = 0.0084 + 0.0015 = 0.0099
- Relative power output for θ_6 = 13°: (0.0099 / 0.0445) 100 = 22.25%

formula for the surface area of the annulus generated when an arc ab of the curve $r = f(\theta)$ revolves around the $\theta = 0$ axis. The solution is given in Fig. 2c. Thus, if the polar plot is multiplied by $2\pi\ (1-\cos\theta)$, the relative power output through any solid angle can be determined (actually, the 2π term can be disregarded when plotting relative powers, as it is a constant). The result of the multiplication is given in Fig. 2c, to illustrate the fact that the proportion of power emitted at larger angles is much more significant than would appear from observation of the polar plot alone.

To calculate the amount of power that is emitted within the solid angle swept out by a 90° half-angle, it is necessary to:

1. Pick two points on the polar plot in Fig. 1.
2. Calculate the cosines of the angles corresponding to those points.
3. Find the mean intensity between each pair of points by simply adding the intensity at both points and dividing the sum by two.
4. Multiply the mean intensity level by the difference of the cosines (this is the partial sum of power between those two points).
5. Sum the results of step 4 to find the total power.

The result is in effect the integral of relative intensity times volume.

To find the proportion of power contained in the solid angle swept out by a particular half-angle, take the partial sum up to that angle and divide it by the total integral. The proportion of power contained in the central lobe in the example is 26.5%. A sample calculation using the five-step procedure, performed for points 5 to 6 on the LED polar plot, is shown in the table.

The total integral is also useful in finding another important parameter, the on-axis radial intensity. This parameter is useful for detectors placed some distance away from the infrared-LED, as the angle which they subtend as measured from the source is very small.

The on-axis radial intensity is $I_r = P/2\pi S$, where P is the total output power of the infrared-LED in milliwatts (always given in the data sheet) and S is the sum of the integral for all angles (in this case, 0.0445 as shown in the table). This equation is much more accurate than the half power equation given by many manufacturers.

For example, consider the case where P = 1 mw and there is a half-power angle of 7.2° for the TO-18 IRLED, as shown in Fig. 1. From the preceding equation, it is clear that I_r = 3.5 mw/steradian. Using the half-power formula, which is $I_r = P/2\pi\ (1-\cos\theta_{hp})$, the answer is 20 mw/steradian, a highly optimistic figure.

Further problems await the designer contemplating pulsed LED operation. As with power transistors, the user needs comprehensive plots of the diode's safe area of operation, the optical power output for the full range of duty cycles, peak currents, and peak widths. Unfortunately, these are rarely provided, and it is necessary to extrapolate from a single set of pulse conditions. □

Engineer's notebook is a regular feature in *Electronics*. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.

Shunt diode extends linear range of LED

by R. W. Dawson
Bell Laboratories, Crawford Hill, Holmdel, N. J.

A standard diode in series with a resistor can be used to extend the linear operating range of a light-emitting diode, increasing its effectiveness as an intensity-modulated light source in an optical communications system.

In essence, the linear region of the LED's output becomes responsive to the modulating signal, which can therefore be larger than when its influence is confined to a small segment of the LED's nonlinear region. Admittedly, the resistor-diode combination can draw considerable power, but a larger current source is often less expensive than an LED capable of greater output.

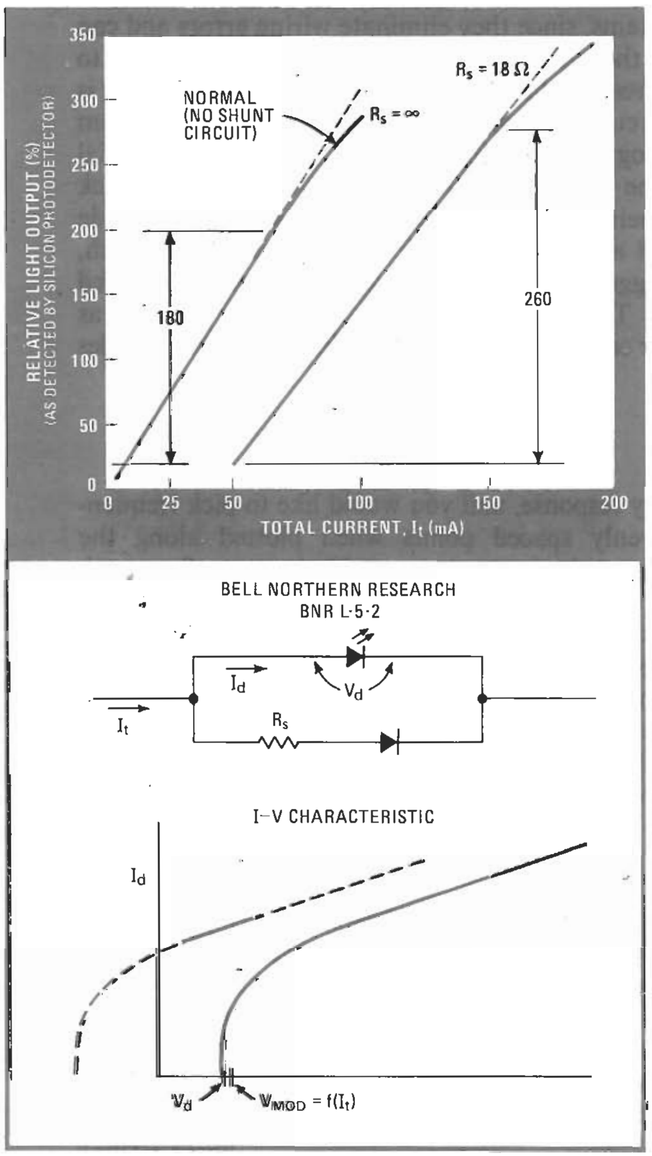
The LED on which the circuit is based is made of alternating layers of gallium aluminum arsenide and gallium arsenide. Also known as a double-heterostructure injection LED, it has an output characteristic that varies linearly for a current input of 20 to 65 milliamperes. To improve on that linearity, the diode-resistor network need only lower the LED's barrier potential, shifting the operating curve so as to bring the nonlinear knee point well below the minimum modulating signal. Thus, any diode will do, provided its barrier potential is lower than the LED's—that is, less than 1.5 to 2 volts.

The diode is connected in series with a current-limiting resistor, and the combination is connected across the LED. This acts to increase the relative optical output by 20% to 60%, depending on the diode used and the series resistance. The diode-resistor combination is normally selected to allow nearly all the current to pass through the shunt at low values and through the LED at high levels, but this ideal is not always attained.

In operation, the standard diode reaches its switch-on point before the LED reaches its barrier potential, so that the LED sees a low voltage across its terminal at low currents. This pre-biases the LED toward its conducting region, or in other words, shifts the entire current-voltage characteristics to the left, as shown in the lower part of the figure. As viewed by a given modulating signal, normally operating near the LED's knee, the curve is shifted from a nonlinear Q point to the linear portion, as shown.

Several types of standard diodes were tested as shunt diodes, including GaAs, silicon, and point-contact germanium devices. The one that did the most to improve the linear range of the GaAlAs-GaAs device was a germanium-alloy diode. (Other types of LEDs have slightly different current-voltage characteristics and might require a different type of shunt diode.)

The germanium alloy diode, together with a series resistance of 5 to 20 ohms and roughly three times the normal current input, increased the linearity of the LED used in this circuit by (260 − 180)/180, or 44%, as may be determined from the main figure. Use of a smaller series resistance would extend the range still further, but at the cost of raising the total drain current to about 300 milliamperes. □



More linear. The optical diode's linearity is improved when a standard diode-resistor combination is placed in shunt with it. This shifts the LED's I-V characteristics to left, as shown in lower part of figure. The percent improvement is found from the curves at top.

LINE-O-LIGHT cont.

C2) the length of pulse available at the mono output. IC1 is, in effect, used as a pulse-width modulator.

Fig. 2 shows the relative timing of the clock, 555 trigger and 555 output waveforms, together with the 'ON' times of the individual LEDs.

If the value of Vin is such that the 555 pulse length is approximately equal to nine clock pulses, then TR1 will be on almost continuously and the LEDs will all appear to be on. As Vin is reduced, TR1 ON time will become less than nine clock pulses; consequently, the +ve supply to the LEDs will be removed at the same point in every count cycle. This will have the effect of 'shortening' the row of illuminated LEDs. Because the mono pulse length does not decrease in definate steps of one clock pulse, the row of LEDs will decrease in length by the highest gradually dimming, then the next highest, etc. – a rather pleasing effect.

Some experimenting with the value of C2 may be required to achieve a realistic rane for Vin, and to prevent the mono pulse length being greater than ten clock pulses at maximum Vin.

The values for C1, R3 and C2 given are those used in the prototype.

FIG. 1.

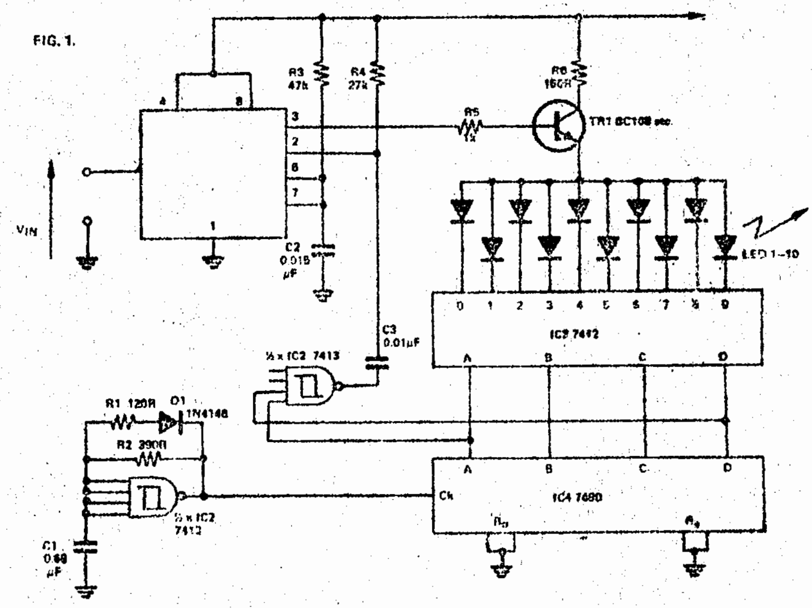
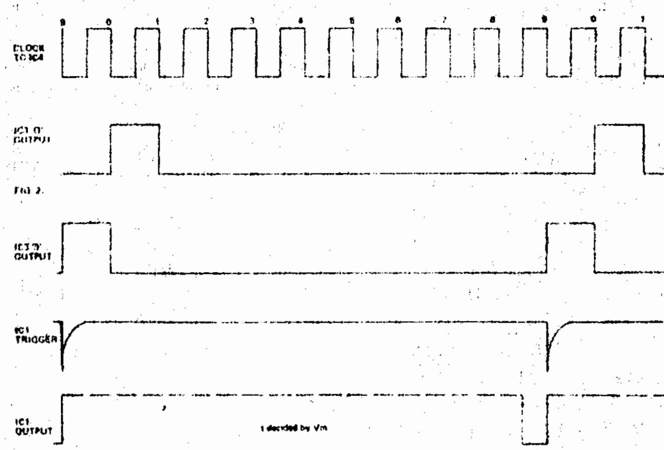


FIG. 2.



CONSTRUCTION

BY FORREST M. MIMS

COMMUNICATE OVER LIGHT BEAMS with the FIRST SINGLE-LED Transceiver

REDUCES COST AND SIMPLIFIES CONSTRUCTION

THE EVOLUTION of the new light-beam communicators has opened a whole new vista in modern optoelectronics. So far, all previous light-beam communicators have required separate light sources and detectors for proper operation. Now, for the first time, it is possible to build an optical communicator that uses a single semiconductor diode as both source *and* detector of near infrared radiation.

The semiconductor source/detector is an ordinary light-emitting diode (LED), a semiconductor device designed for the efficient generation of visible or infrared light. What has not been bruited about is that LED's, just as most semiconductor diodes, can be made to detect as well as generate light; so, LED's can be used as detector elements, too.

Using a single LED as both source and detector accrues certain important advantages. As can be seen in the accompanying photos, the POPULAR ELECTRONICS Infrared Transceiver employs only one lens, a feature not found on any other present light-beam communicator. Besides reducing the cost and simplifying the construction procedure of the project, a single lens greatly simplifies optical alignment between two infrared transceivers. Of even more significance is the fact that the entire front of the transceiver can be taken up by the lens. This results in narrower beam-widths and much higher light-collection efficiency than is obtained with conventional dual-lens systems installed in an identical space.

Construction. Assembling the infrared transceiver is a straightforward job. A 6″ × 4″ × 3″ hinged steel chassis box is ideal for the project, but other similar size boxes will suffice. As shown in Fig. 2, begin fabrication by drilling the holes to accommodate the panel switches and jacks. The amplifier, modulator, speaker, and battery holder holes come next. (Note: Don't forget to drill holes to permit the sound from the speaker to escape.)

The hole for the lens is best cut with a 2″ chassis punch. But if such a large punch is not available, you can drill a 2″ circle of small holes, knock out the center, and use a file to smooth the edges of the opening.

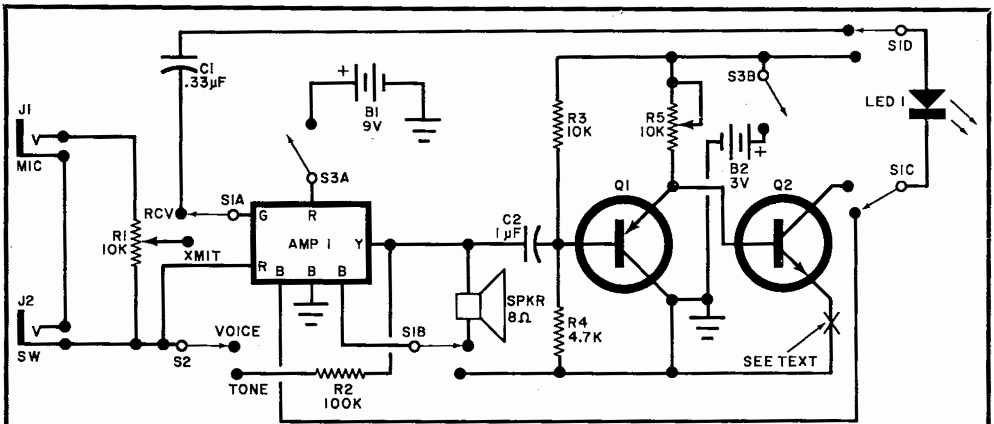
When you mount the switches and jacks as shown in Fig. 3, make them only finger tight. It may be necessary to remove some of these parts during soldering to facilitate easy connection of hookup wire. When you install *R1,* be sure its lugs are easily accessible since connections will be made to all three.

Mount the modular amplifier with four 4-40 × ½″ machine screws and nuts, sandwiching between the board and chassis box small rubber grommets at all four locations to serve as spacers. A Radio Shack No. 277-1240 four-transistor modular amplifier was used in the prototype, but any general-purpose audio amplifier can be used so long as impedance matching between the microphone and speaker is provided.

Use two sets of 4-40 × ¼″ machine hardware to mount the dual AA-cell holder (see Fig. 2). The 9-volt battery that supplies power for the amplifier can be mounted between two 8-32 × 1″ screws, being held in place by a metal or plastic retainer and two 8-32 nuts.

The LED modulator is so simple that a perforated phenolic board can be used as the assembly medium, using Fig. 4 as a guide to parts layout. Note how potentiometer *R5* is mounted with its adjustment screw facing upward for easy access. Mount the LED to one side of the board, at the midpoint of the cabinet's vertical dimension. Then use a pair of L brackets and some 4-40 machine hardware to attach the modulator assembly. Be sure the mounting holes orient the LED at the horizontal midpoint of the cabinet. (Before the mounting holes are drilled, measure the focal length of the lens so that the LED can be placed approximately at the focal point.)

The lens used in the prototype is made of red plastic to filter out unwanted light when the devices are in the RECEIVE mode. Its 2″ diameter and 4″ focal length give an f-number of 2, which is very inefficient in the TRANSMIT mode since only about 20 percent of the infrared radiation from the LED is collected by it. Somewhat more radiation can be collected by a lens with a



NOTE: ALL SECTIONS OF S1 SHOWN IN RCV POSITION

PARTS LIST

AMP1—Audio amplifier module (see text)
B1—9-volt battery
B2—Two 1.5-volt AA cells
C1—0.33-µF, 10-volt capacitor
C2—1-µF, 10-volt unpolarized capacitor
J1—⅛″ miniature phone jack
J2—3⁄32″ subminiature phone jack
LED1—Light-emitting diode (see text)
Q1—2N2907 transistor
Q2—TIP33 power transistor
R1,R5—10,000-ohm miniature trimmer potentiometer
R2—100,000-ohm, ¼-watt resistor
R3—10,000-ohm, ¼-watt resistor
R4—4700-ohm, ¼-watt resistor
S1—4pdt rotary switch
S2—Spdt switch
S3—Dpdt switch
Misc.—Chassis box (see text); lens (see text); battery holders; speaker (miniature 8-ohm); low-impedance microphone with built-in switch; perforated phenolic board; grommets; hookup wire; solder; etc.

Fig. 1. A single LED is used for both transmitting and receiving. A two-transistor current modulator and a commercial audio amplifier complete the circuit.

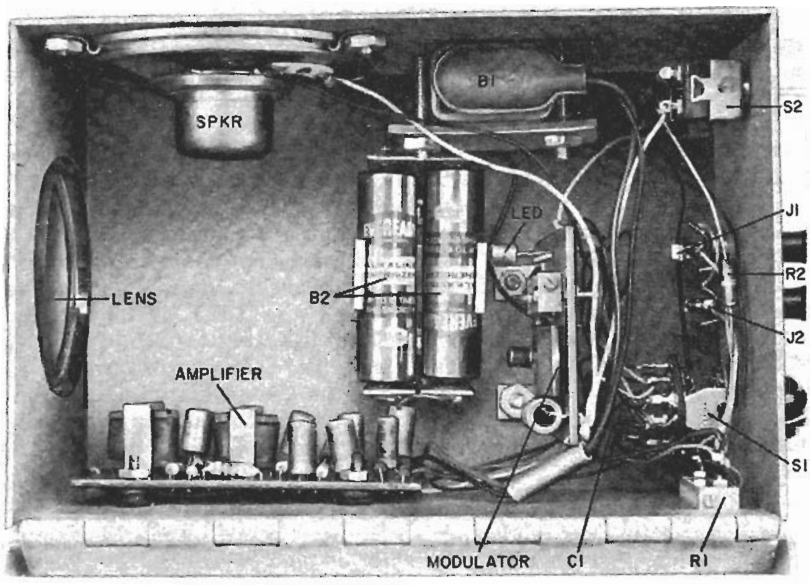


Fig. 2. Make sure that none of the components get in the way of the light path between the LED and the lens. The photo is of prototype.

focal length similar to its diameter. (A great variety of lenses is available from Edmund Scientific Co., 300 Edscorp Bldg., Barrington, NJ 08007. You might write for a catalog to find out what they have.) Do not mount the lens at this time.

Mount the speaker with three sets of 4-40 × ¼" screws and nuts. You will have to make three small tabs from 1/16"-thick aluminum stock.

Complete internal assembly by soldering all connections, referring to Fig. 1 as you proceed. Use particular care when soldering to *S1* since an error will cause the transceiver to malfunction. Note that *R2* is soldered directly between S2 and *C2*, and *C1* is soldered directly to *S1*. It may be necessary to extend some of the leads from the amplifier module.

Assembly of the project is completed with the mounting of the lens and labelling of the controls. You can use GE Silastic® silicone cement to mount the lens. Ideally, the lens should be cemented to the inside of the chassis box for best external appearance. Use dry-transfer letters to label the controls.

LED Selection. Any LED will operate as both a source and a detector in the finished transceiver, even visible red, yellow, and green units. For best results, however, use a silicon compensated near-infrared LED made from gallium arsenide (GaAs). These LED's are by far the most efficient available. Note that all LED's emitting 930 to 940 nanometers (9300-9400 Angstroms) are silicon compensated. For the prototype, a General Electric SSL-55C was used. This is one of the most efficient LED's commercially available.

Current compensation may be required for the LED. As designed and shown in Fig. 1, the circuit will operate with LED's capable of handling 100 mA continuously without a heat sink. Most metal-glass-packaged LED's are rated at this current level. If a low-current LED is used, a current-limiting resistor must be installed at point X in Fig. 1. Determine the value needed for the resistor by temporarily installing a 100- or 500-ohm potentiometer at X and a 0-100-mA meter movement in series with the pot. Set *R5* at about midpoint to allow for circuit adjustment and adjust the potentiometer until the milliammeter indicates the maximum allowable LED current. Without disturbing its setting, disconnect the potentiometer and measure its resistance. Solder an equivalent fixed resistor into the circuit at point X.

Transceiver Operation. Unless you have a conventional amplitude-modulated LED communicator such as the Opticom (November 1970), it will be necessary to build

HOW IT WORKS

In spite of its novel detection scheme, operation of the infrared transceiver (Fig. 1) is straightforward. In the XMIT mode, a commercial solid-state amplifier *(AMP1)* is connected to a two-transistor *(Q1* and *Q2)* current modulator via XMIT/RCV switch *S1*. Audio signals from the amplifier are fed into the modulator via *C2*, and *Q1* and *Q2* provide linear modulation over a range greater than 75 percent.

LED's are current-sensitive devices. The peak current through *LED1* is normally determined by the setting of *R5*. Since a variety of LED's can be used in the circuit, additional current control may be necessary to prevent exceeding device specifications.

To simplify the alignment of two transceivers, the transmitter circuitry is provided with *R2*, which causes feedback oscillation when connected from the output to the input of the amplifier via TONE/VOICE switch *S2*. With *S2* set to TONE, the transmitter generates a tone whose frequency can be changed from a low to a high pitch by disconnecting the microphone at *J1* from the circuit with its self-contained switch plugged into *J2*.

In the RCV mode, the same LED used to transmit the optical signal is switched to the input of the modular amplifier via *S1*. Capacitor *C1* blocks undesirable dc signals from *LED1* from getting to *AMP1*. In the RCV mode, the modulator circuit is disconnected from the power source to conserve battery power.

Incoming optical radiation striking the sensitive surface of *LED1* generates a photocurrent that is proportional to the amplitude of the signal modulations. The photo-current is amplified by *AMP1* and passed to a miniature 8-ohm speaker.

two transceivers to test the circuit. Plug in a low-impedance microphone and set *S1* to XMIT and *S2* to TONE. An audio tone should be heard from a second transceiver pointed toward the first when *S1* is set to RCV. If no tone is heard, check all battery connections and the batteries themselves to assure that they are fresh. Then check the wiring, paying particular attention to the connections made to *S1*. When the transceivers are operating properly, reverse both *S1*'s and check RCV/XMIT operation.

When two-way operation has been verified, check voice operation by repeating the above procedure with *S2* in the VOICE position. If the receiver seems to be overmodulated, try slightly misaligning the two units to reduce the amount of IR radiation falling on the LED in the detector mode. If volume is too low, try adjusting *R1* in the transceiver set to the XMIT mode. Reverse *S1* in both units and repeat the test.

The initial tests should be followed by a check of LED current to avoid possible overheating of the LED in the XMIT mode. This is easily done by temporarily inserting a 0-150-mA meter in series with the LED at point X. Alternatively, connect the meter in series with one of the batteries by removing one cell and using clip leads to connect cell and meter to the holder; be careful to avoid a short circuit.

The current reading should not exceed the peak allowable current through the LED if a heatsink is not used. If the current is too high, adjust *R5* to reduce it; if well below the peak allowable value, again adjust *R5* to bring it up. A quick test for excess current can be made by touching the LED. If it is hot, immediately turn off the power and adjust *R5* to reduce the current. It may be necessary to insert a permanent limiting resistor at point X as described above.

Range Testing. Place one transceiver on a steady support and point it along a path unimpeded by obstacles for several hundred feet. Set *S1* of this transceiver to XMIT and *S2* to TONE. Set *S1* in a second transceiver to RCV. Now, walk about 15′ away from the first transceiver, pointing the second one toward the first until a tone is heard. Due to the very narrow field of view of the receiver and the tight beam of the transmitter, alignment will be difficult at first. This highly directional nature of reception illustrates the significance of optical communications—totally private, jamproof transmissions.

Complete the testing by walking away from the transceiver with the receiver while listening to the tone. Daylight range will be shorter than night range due to the in-

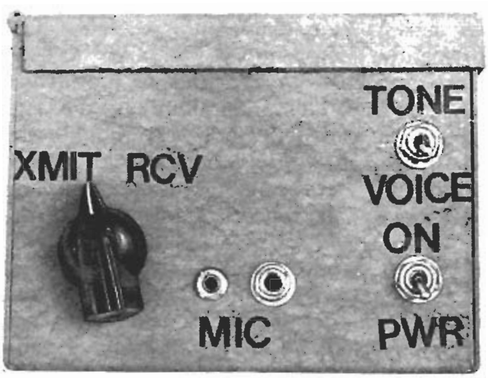


Fig. 3. Suggested front-panel arrangement.

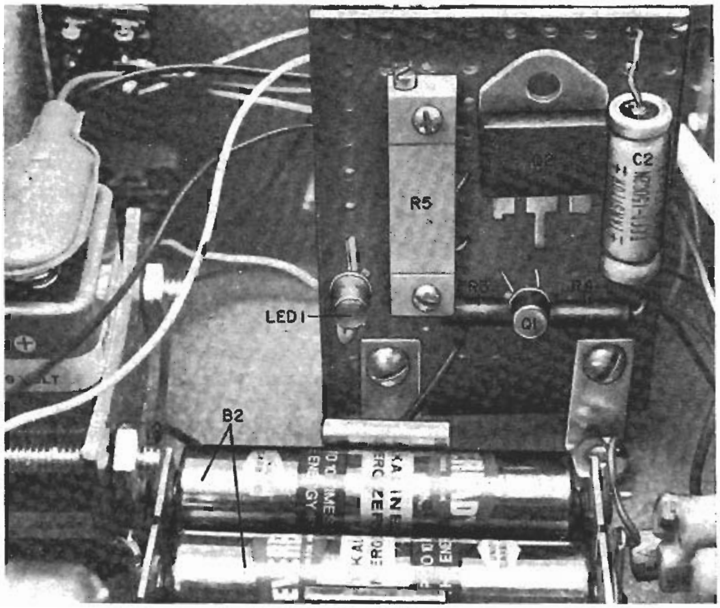


Fig. 4. Current modulator is built on perf board. LED must align with lens and adjustment R5 must be available after mounting board.

crease in detector noise caused by ambient light.

Modifications. Although the Infrared transceiver can be used as is, it lends itself to several interesting modifications. First, for permanent field installations, mount each unit on a tripod. This will greatly ease optical alignment and make possible continuous transmissions with few realignment problems.

For more range, increase the size of the lens. The light-collecting area of a lens is proportional to the square of its diameter; so a small increase in diameter yields a significant increase in receiving area. A lens 3″ in diameter has more than twice the collecting area of a 2″ lens. A diverging beam of light follows the inverse square law. Therefore, doubling the lens collection area will, in theory, double the range. But due to variations in atmospheric absorption and ambient light, doubling lens area will not necessarily double the range.

The most interesting modification of all is to connect two transceivers together with a single fiber-optic link. A transceiver can be converted for both atmospheric and fiber-optic operation by mounting the LED to the modulator board with a miniature phone plug and jack. For fiber-optic operation only, the LED's become an integral part of a single fiber optic assembly.

A hole bored through a vacant corner of the front of the transceiver will facilitate installation of the optical fiber link. Use a rubber grommet to line the hole to protect the fiber from damage. For best results, choose a length of large-diameter (40-mil) fiber. Remove the caps from the LED's and place a layer of optically clear epoxy over the chip and cement the fiber as close as possible to the chips with the epoxy. Secure the assembly in a fixed position until the epoxy has fully set. Exercise care during the epoxying operation to avoid damaging the delicate LED chip and electrodes. Solder the leads of each LED to a miniature phone plug and pack the connections with more epoxy to make a rigid, durable assembly.

The fiber-optic mode of operation is a precursor of what telephone systems of the future are likely to resemble. For this reason, the Infrared Transceiver is an entertaining, educational, and highly functional project. ◈

(Editor's Note: The author is pursuing patent protection for concepts described in this article. However, readers may build the project for personal use.)

MORE RANGE FROM LED TRANSCEIVER

In "Single LED Transceiver" (March 1974), the efficiency of the system could be improved by doing a bit of rearranging. Although the LED's output is high in frequency, it can still be reflected by shiny surfaces, such as the cases of the AA cells. Hence, some of the strength of the received and transmitted signals will be lost. Moving the battery holder to another location and installing a matte black shield around the light path would increase range and clarity in both operating modes.

DAVID W. PAUL
Charlottesville, Pa.

Chart aids selection of optimum LED driver

by William A. Palm
Minnetonka, Minn.

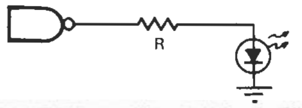
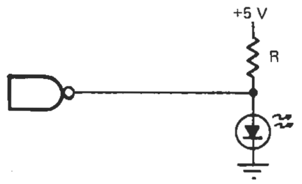
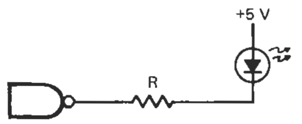
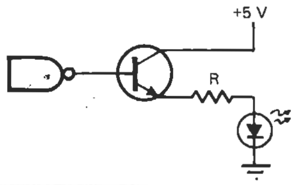
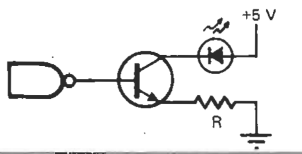
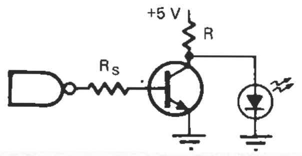
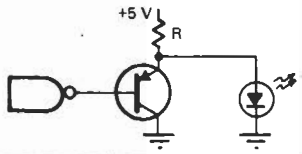
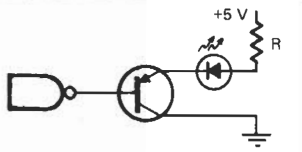
There is no single best way to drive a light-emitting diode from a transistor-transistor-logic output. Fanouts, polarities, and circuit loading must all be considered in choosing a drive configuration. The table lists eight different arrangements along with their respective characteristics and tradeoffs.

In methods 1, 2, and 3, the TTL outputs drive the LEDs directly and because of fanout limitations cannot drive any other inputs. The remaining five arrangements employ drive transistors to avoid loading the outputs. When both pnp and npn transistors are readily available, method 4 may be used to light the LED with a logic 1 output, while method 8 indicates a logic 0. If it is desirable to have a single driving scheme, then inverters can be added to indicate both logic levels.

Need for low power consumption rules out methods 6 and 7, since they consume more power with the LED off than on. The on current in method 1 depends greatly on the chip's internal pull-up resistor. Logic levels other than TTL must be handled differently and are not considered in the table. □

Engineer's notebook is a regular feature in *Electronics*. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.

EIGHT METHODS OF DRIVING LEDs FROM TTL OUTPUTS

Method		Output that turns on LED	Circuit loading		Comments
			Output high	Output low	
1		high	$I \approx (5 - 1.7)/R$	negligible	• Do not use output to drive logic inputs
2		high	negligible	$I = 5/R$	• Do not use output to drive logic inputs • Use open-collector outputs only • Consumes power when LED is off
3		low	negligible	$I \approx (5 - 1.7)/R$	• Do not use output to drive logic inputs • Can use open collector or active output
4		high	negligible	negligible	• Use active output only
5		high	negligible	negligible	• Use active output only
6		low	negligible	negligible for R_S > 5 kΩ	• Consumes power when LED is off • Use active output only
7		high	negligible	negligible	• Consumes power when LED is off • Can use open collector or active output
8		low	negligible	negligible	• Can use open collector or active output
Use R = 200 Ω OR 300 Ω					

LEDs can survive in 120-V ac circuits

A light-emitting diode can be made to operate directly in a 120-volt ac circuit, says Alan R. Miller of New Mexico Institute of Mining and Technology. You must **place a 1N1461 rectifier across the LED (but with reverse polarity) to guard against destructive reverse voltage,** and you must also put a capacitor of about half a microfarad in series with the parallel diodes to limit the LED forward current to a safe 20 milliamperes without consuming appreciable power. The capacitor must be nonpolar and be rated for at least 200 volts.

The case builds against using LEDs on the ac line

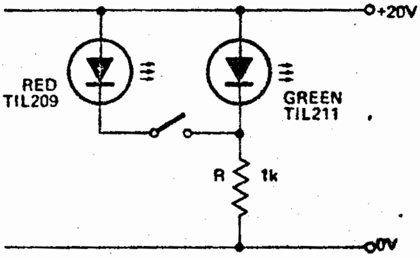
Alan R. Miller's suggestion [*Electronics*, June 10, p. 132] of connecting a light-emitting diode and series capacitor directly to the ac line has come under fire from Nathan K. Weiner, American Science & Engineering, Woburn, Mass., as well as Elliot S. Simons [*Electronics*, July 22, p. 124]. Weiner says that the LED current is governed by the phase of the line when the LED is switched on and by how large a portion of the active chip area is conducting during the turn-on transient. "Current is limited only by the bulk resistance of the junction and the equivalent series resistance of the capacitor," he explains. **Localized high-current densities can burn out portions of the active chip area and eventually destroy the entire LED.** He guesses that Miller's success with this circuit may be due to the use of a low-quality capacitor (not an ac type), having either high series inductance or resistance that limited LED current.

LED CHANGEOVER CIRCUIT

This configuration allows a green LED to be turned off and a red LED turned on by the operation of one 'make" contact only, thus simplifying the design of circuitry to indicate, for example, safe/unsafe or standby/on states.

The circuit relies on the fact that a green LED has a slightly higher "on" voltage than a red LED of the same size, and hence is turned off when the red LED is paralleled with it.

For the diode types shown, R should be chosen to give a current drain of about 20mA from the chosen supply rail voltage.



A LED Traffic Light

BY RAY WILKINS

For model railroad and car layouts

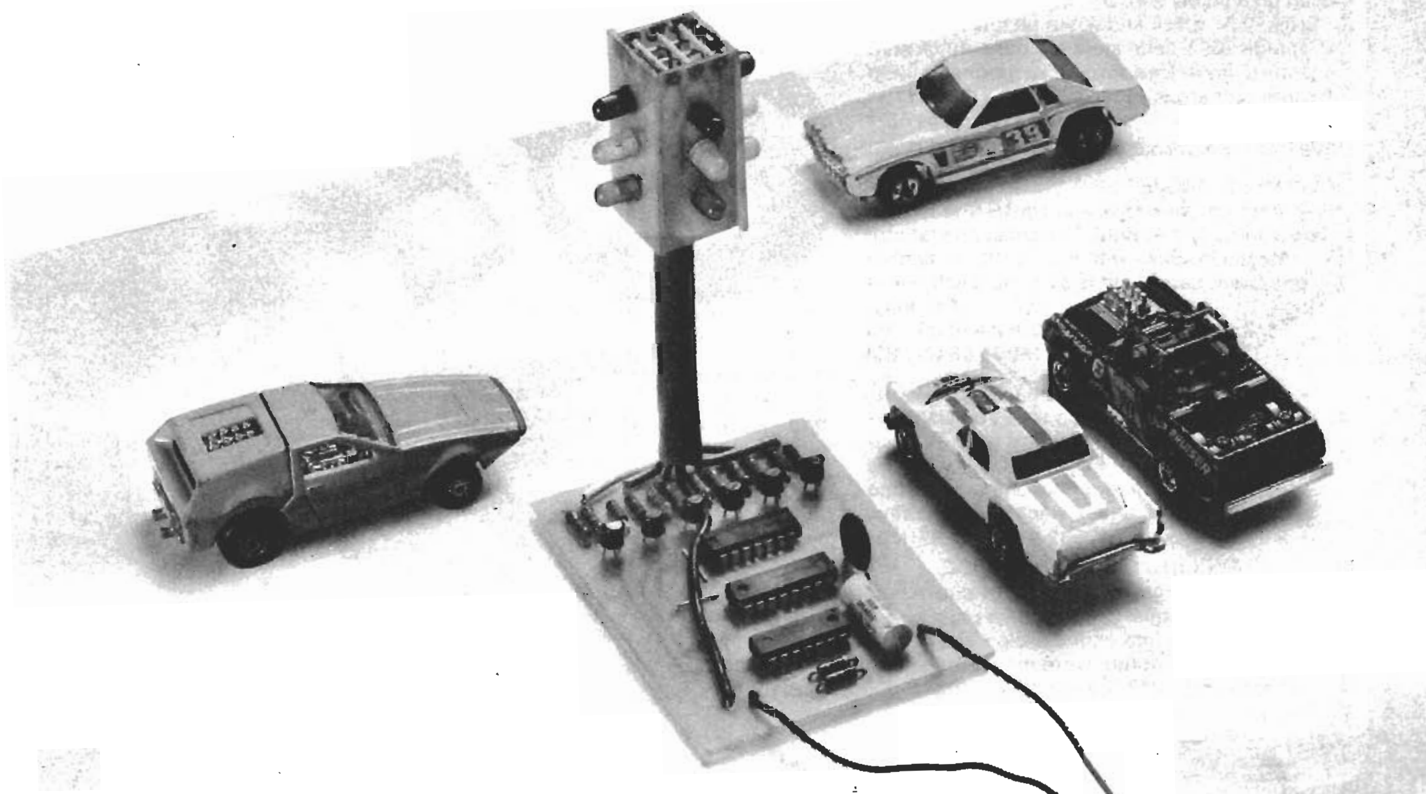
MODEL CAR and model railroad buffs will find the miniature traffic-light project presented here an attractive device to add to their layouts. It also makes an interesting "do-nothing" attention getter on an office desk or home coffee table. And now that the holiday season has arrived, those of you who have visions of setting up a miniature village display for ornamental purposes can add a touch of realism with our miniature traffic light.

Unlike other miniature systems, our traffic light emulates real traffic signals, with only a brief display of the yellow cycle, which comes on just before the switch to red. The light even has signals for crossing traffic. Built around high-brightness LEDs and a low-power CMOS system, the traffic light can be powered from a standard 9-volt battery or any dc supply rated at 7 to 15 volts.

About the Circuit. The six signals required to sequentially operate the traffic lights are illustrated in Fig. 1. They are generated by the circuit shown in Fig. 2.

The basic timing oscillator in Fig. 2 is made up of *R1*, *R2*, *C2*, and two sections of *IC1*. The rate at which the LEDs sequence is determined by the value of *C2*. Therefore, if you wish to speed up or slow down the sequencing rate, simply

(Continued on page 54)



Model cars supplied by Sol Salsberg

(Continued from page 51)

adjust *C2*'s value accordingly. The clock signal drives CMOS decade counter/divider *IC2*, whose outputs are decoded to provide the on times for each LED.

LED driving output Y1 (Y is for yellow, G is for green, and R is for red) is on only during clock pulse 8 from pin 9 of *IC2*, while Y2 is on only during clock pulse 3 from pin 7 of *IC2*. The R1 and R2 red and G1 and G2 green LEDs obtain their longer on-time pulses from set/reset flip-flops made up of cross-coupled NOR gates in *IC1* and *IC3*. For example, G1 comes on with clock pulse 4 and goes off with clock pulse 8, for a total time on of four clock pulses.

The six signals are fed through transistor drivers *Q1* through *Q6*, each of which is capable of driving two LEDs. Hence, two traffic-light display systems can be driven by the transistor array. Current-limiting resistors *R3* through *R14* have been selected to provide additional current to the less-efficient green and yellow LEDs so that all three colors appear to be equal in brightness. The system is designed to be powered by 9-volt battery *B1*. However, you can use a standard regulated 12-volt dc supply, but you must double the values of the current-limiting resistors if you do so.

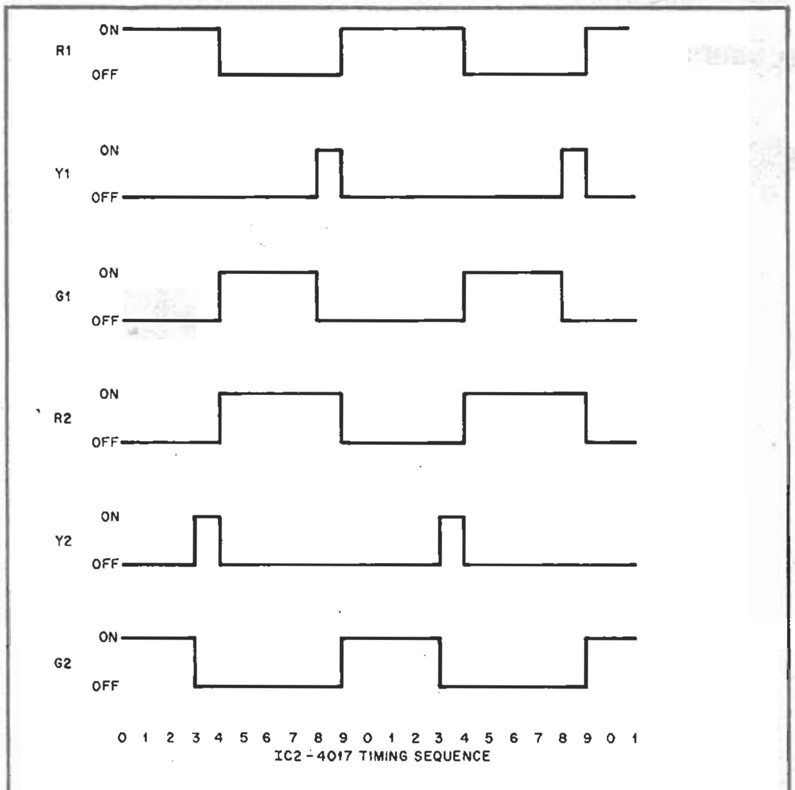


Fig. 1. Waveforms at specified outputs on main board.

Construction. To keep the project as compact as possible, it is recommended that you use printed-circuit boards for parts mounting and wiring. An actual-size etching-and-drilling guide and a components-installation diagram are shown in Fig. 3. Do NOT cut apart the etching-and-drilling guide to make the boards separately. Rather, etch and drill all nine pc boards as a single piece and

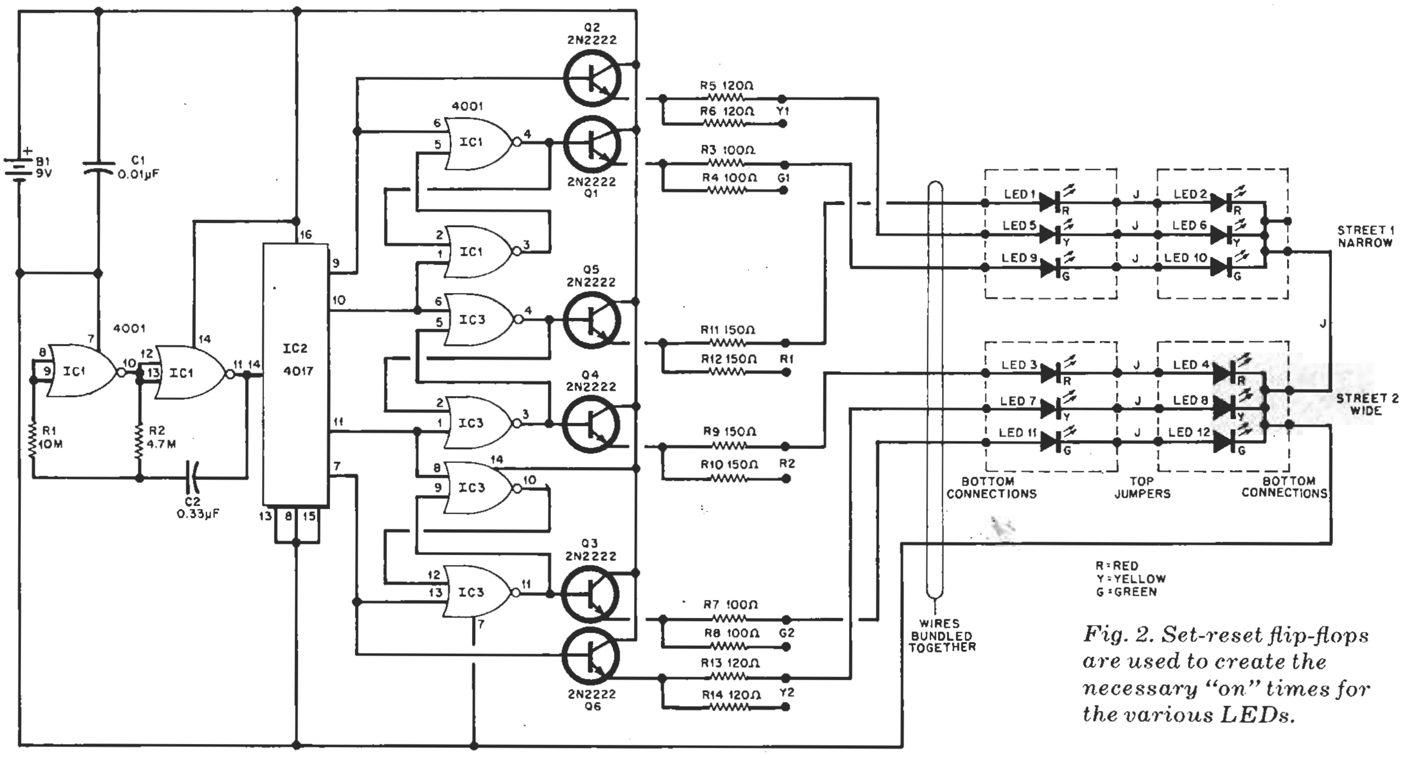


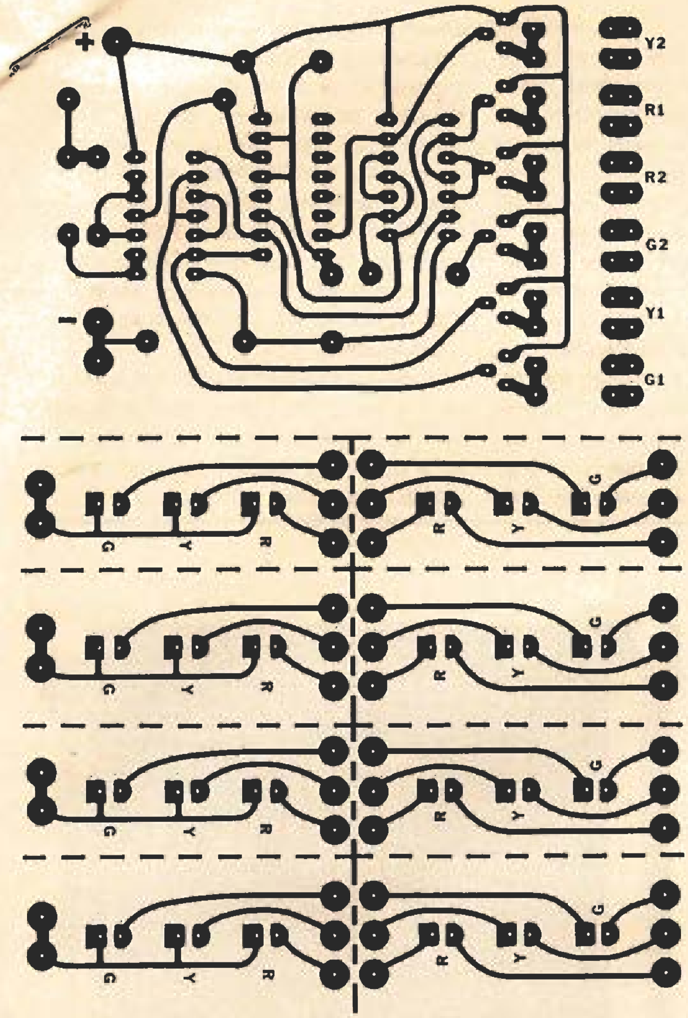
Fig. 2. Set-reset flip-flops are used to create the necessary "on" times for the various LEDs.

then carefully cut along the dashed lines to separate the individual boards. Note that of the eight LED boards four are slightly wider than the others.

Wire the large board as shown. Do not forget the three jumpers. The eight small boards can be used to make two traffic lights, each built on two wide and two narrow boards, with the small boards propped between the larger ones. Install the LEDs in their respective locations on the boards, making certain that their cathode leads are inserted in the holes surrounded by the *square* pads.

Now, stand the two narrow and two wide boards up, positioning the red LEDs at the top and with the boards forming a square when viewed from the top. Use silicone-rubber adhesive to cement the sides together along the edges where they meet. Then set the assembly aside until the adhesive sets.

Looking down into the assembly from the red-LED top end, note at the top edge there are three solder pads on each board. Use short insulated wire jumpers to connect from one pad to the pad directly opposite it on the other



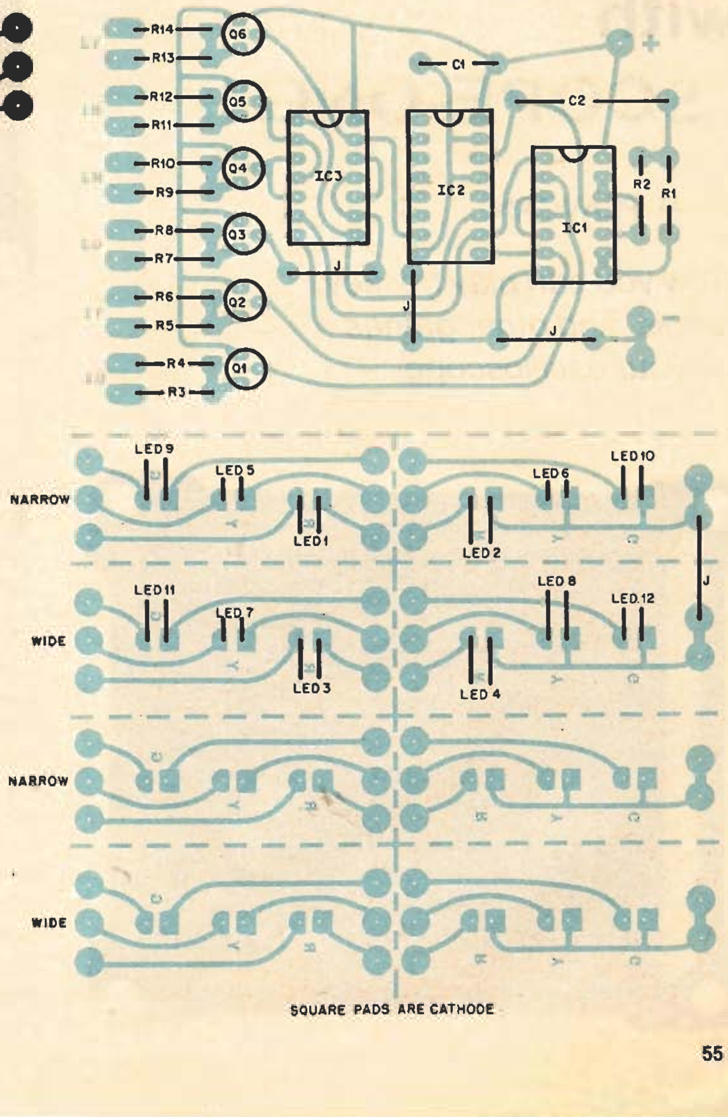


Fig. 3. Actual-size foil pattern (above) and component layout (right). Board is divided into nine sections.

PARTS LIST

B1—9-volt battery or 7-to-12-volt dc power supply (see text)
C1—0.01-µF disc capacitor
C2—0.33-µF capacitor
IC1,IC3—4001 CMOS quad 2-input NOR gate
IC2—4017 CMOS decade counter/divider
LED1 thru LED4—Red light-emitting diode
LED5 thru LED8—Yellow light-emitting diode
LED9 thru LED12—Green light-emitting diode
Q1 thru Q6—2N4401 or 2N2222 transistor
All resistors ¼-watt, 10% tolerance:
R1—10 megohms
R2—4.7 megohms
R3,R4,R7,R8—100 ohms (see text)
R5,R6,R13,R14—120 ohms (see text)
R9 thru R12—150 ohms (see text)
Misc.—Printed-circuit boards; battery connector; silicone-rubber cement; insulated hook-up wire; on/off switch (optional); machine hardware; spacers; plastic tape; etc.

Note: The following are available from Ray Wilkins, Box 551, Hanover, NH 03775: etched and drilled glass-epoxy pc board for $7.50 and extra-bright LEDs for 75¢ each.

Fun Projects

continued

board. Repeat for the other two sets of pads on the first pair of boards. Rotate the assembly 90° and interconnect their pads in the same manner. When you are through, there should be six insulated jumpers forming a tic-tac-toe pattern with one extra horizontal and one extra vertical line.

Invert the assembly so that the green LEDs are at the top. Looking into the open end of the assembly, you will note that two of the boards have three independent solder pads while the other two boards have only two pads that are bridged together. Solder a bare-wire jumper diagonally across the corner to interconnect the common-pair pads.

Now, determine the desired distance between the decoder/driver board and traffic-light display assembly. Cut six lengths of color-coded insulated hookup wire to this length and a seventh wire to a 3½" (90-mm) longer length. Solder one end of the long wire to the diagonal jumper in the LED assembly and the other wires to the six pads on the green-LED end of the assembly.

Referring to Fig. 2, connect and solder the free ends of the wires into their respective holes in the decoder/driver board. (The free end of the long wire goes to the pad labelled – on the main board.) Note that the pads on the main board are set up for two traffic-light assemblies. Use only one of each pad if you plan to use only one light assembly and, if desired, you can eliminate the unused resistors.

Bundle and tape together the wires to form a "lamp post." Plug a 9-volt battery into the connector or connect the project to a dc power supply and your traffic light is ready to go. ◇

BY RAY WILKINS

FOUR EASY-TO-BUILD LED PROJECTS

WITH THE prices of LED's and CMOS IC's continuing to drop, electronics experimenters should take advantage of the circumstances and build some of the many interesting projects that can be made using these devices. The four circuits described in this article are not only fun to build, they also teach the builder quite a bit about the devices and their uses.

The circuits take advantage of the fact that CMOS devices require very low power, so no power on/off switches are used. The quiescent current drawn by the CMOS chips (when the LED's are off), allows normal battery shelf life. Once the pushbutton switch on a project is operated, the circuit "does its thing," and then stops.

Blinker. As shown in Fig. 1, this circuit uses a single CMOS hex inverter to provide both timing and drive to make the two LED's blink alternately. Built with two small red LED's, the circuit makes

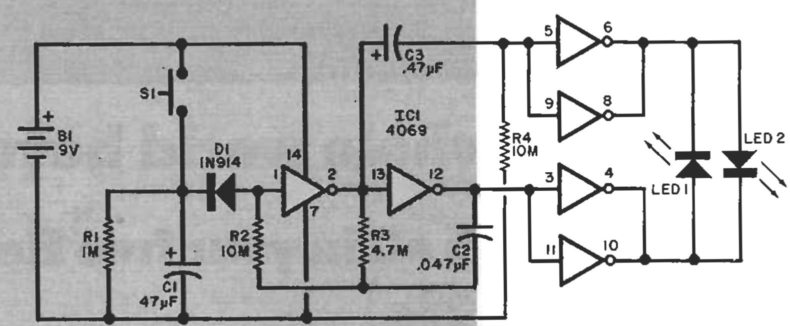


Fig. 1. Dual LED alternate blinker uses parallel gate output for more LED driving current.

BLINKER PARTS LIST

B1—9-volt battery
C1—47-µF, 10-V electrolytic
C2—0.047-µF disc capacitor
C3—0.47µF, 10-V electrolytic
D1—1N914 diode
IC1—4069 CMOS hex inverter
LED1, LED2—Light emitting diode (2 red, or 1 red/1 green)
R1—1-megohm resistor
R2, R4—10-megohm resistor
R3—4.7-megohm resistor
S1—Normally open pushbutton switch

an ideal HO-gauge model railroad crossing blinker. With LED's of two different colors (in one package), it can be used to obtain other effects.

Resistors *R2* and *R3* and capacitor *C2* determine the flash rate, while *R1* and *C1* set the total display time. The component values shown here produce a blinking rate of two per second and an on time of about 20 seconds. To change the timing, change the values of the capacitors since decreasing the value of the resistors will increase the quiescent battery current drain.

Flasher. A simple variable-rate LED flasher is shown in Fig. 2. The voltage across *C1* determines the flash rate. When the pushbutton switch is closed, capacitor *C1* charges to 9 volts and the flasher blinks rapidly. As the voltage is discharged through *R1*, the flasher slows down until the charge on *C1* reaches about 4.5 volts, at which point the oscillator stops and the LED stays off. The flash rate is set by the values of *R2*, *R3*, *R4*, *R5*, and *C2*. Capacitor *C1* and bleeder resistor *R1* create the slow-down period.

Binary Counter. A circuit that demonstrates the operation of a six-bit binary counter is shown in Fig. 3. When the

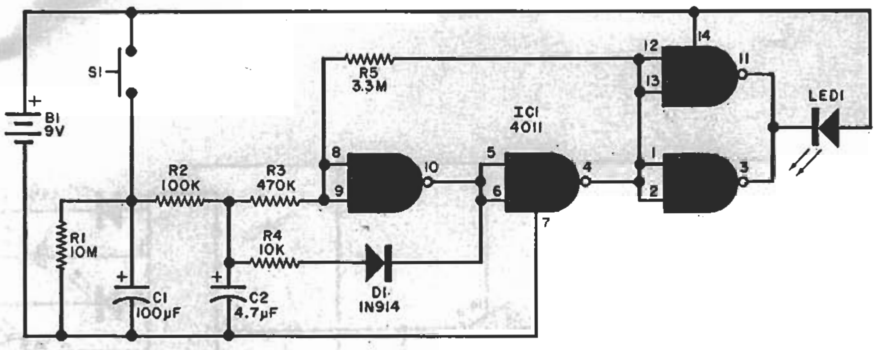


Fig. 2. Single LED flasher also uses parallel gate output for driving the LED.

FLASHER PARTS LIST

B1—9-volt battery
C1—100-µF, 10-V electrolytic
C2—4.7-µF, 10-V electrolytic
D1—1N914 diode
IC1—4011 CMOS quad 2-input NAND gate
LED1—Red light emitting diode
R1—10-megohm resistor
R2—100,000-ohm resistor
R3—470,000-ohm resistor
R4—10,000-ohm resistor
R5—3.3-megohm resistor
S1—Normally open pushbutton switch

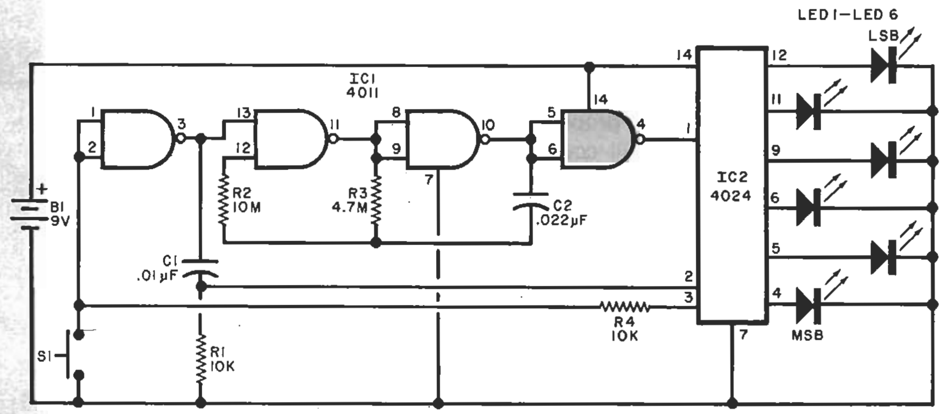
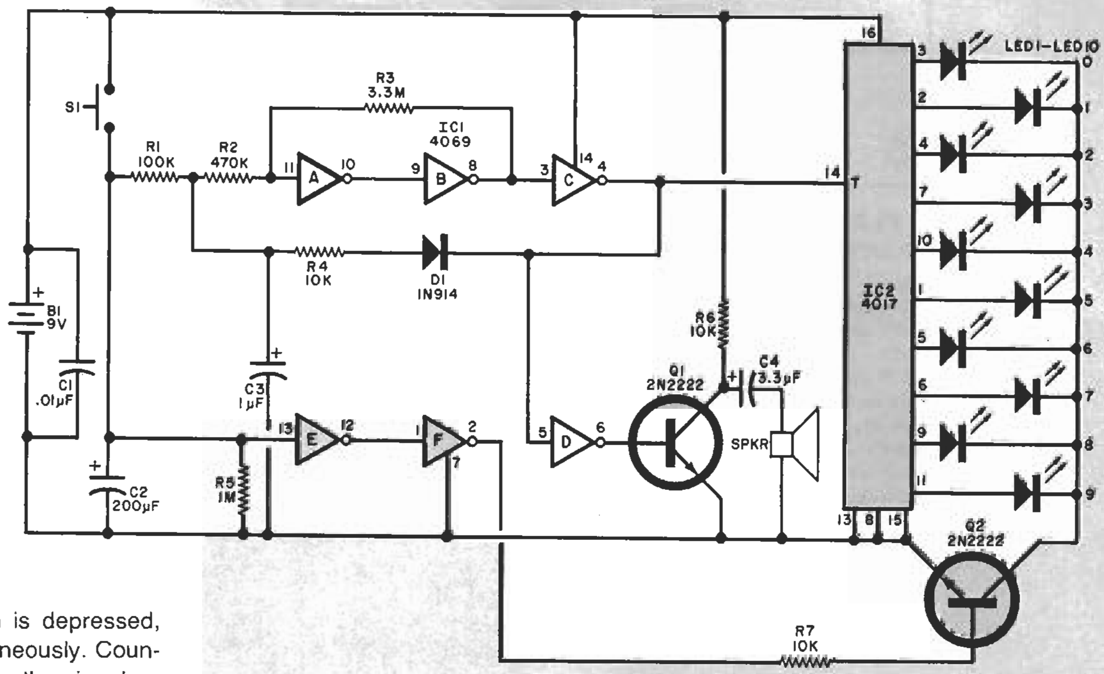


Fig. 3. Simple binary counter illustrates counting in the 1-2-4-8-16-32 mode.

BINARY COUNTER PARTS LIST

B1—9-volt battery
C1—0.01-µF disc capacitor
C2—0.022-µF disc capacitor
IC1—4011 CMOS quad 2-input NAND gate
IC2—4024 CMOS binary counter
LED1-LED6—Red light emitting diode
R1, R4—10,000-ohm resistor
R2—10-megohm resistor
R3—4.7-megohm resistor
S1—Normally open pushbutton switch

pushbutton switch is depressed, the circuit starts counting from zero (all LED's off) to 63 (all LED's lit). After reaching the full count, the circuit automatically resets to zero and shuts itself off. The six LED's come on in a binary (1, 2, 4, 8, 16, 32) sequence which is typical of digital counters.



When the pushbutton is depressed, two things occur simultaneously. Counter *IC2* is reset to zero by the signal on pin 2, thus placing all of the *IC2* outputs at their low states (0 volts). Thus, none of the LED's can glow. The second action is an enable level signal (+9 volts) at pin 13 of *IC1*. This action allows the oscillator (the middle two gates) to start, thus producing an input signal to the counter IC through the last gate of *IC1*.

The counter then counts until it is full, illuminating the LED's in the proper sequence. One count after full count is reached, pin 3 of *IC2* goes high. This signal is inverted by the first gate of *IC1*, and its output goes low, thus disabling the oscillator. The circuit then remains in the "all LED's off" state until the pushbutton is depressed again. The value of *C2* can be changed to increase or decrease the counting speed.

Wheel of Fortune. The circuit shown in Fig. 4 is a 10-LED spinning wheel with audible 'clicks' as the wheel passes each point. The rotation starts fast, then gradually slows down to a random stop (with a click at each position). After the rotation ceases, the selected LED stays lit for about 10 seconds, then goes out. The cycle restarts by depressing the pushbutton switch.

The logic requires only two IC's. Of these, *IC1A*, *IC1B* and *IC1C* form a vari-

Fig. 4. "Wheel of Fortune" sequentially lights one of 10 LED's and generates audible clicks.

WHEEL OF FORTUNE PARTS LIST

B1—9-volt battery
C1—0.01-μF disc capacitor
C2—200-μF, 10-V electrolytic
C3—1-μF, 10-V electrolytic
C4—3.3-μF, 10-V electrolytic
D1—1N914 diode
IC1—4069 CMOS hex inverter
IC2-4017 CMOS decade counter decoder
LED1-LED10—Red light emitting diode
Q1, Q2—2N2222 transistor
R1—100,000-ohm resistor
R2—470,000-ohm resistor
R3—3.3-megohm resistor
R4, R6—10,000-ohm resistor
R5—1-megohm resistor
S1—Normally open pushbutton switch

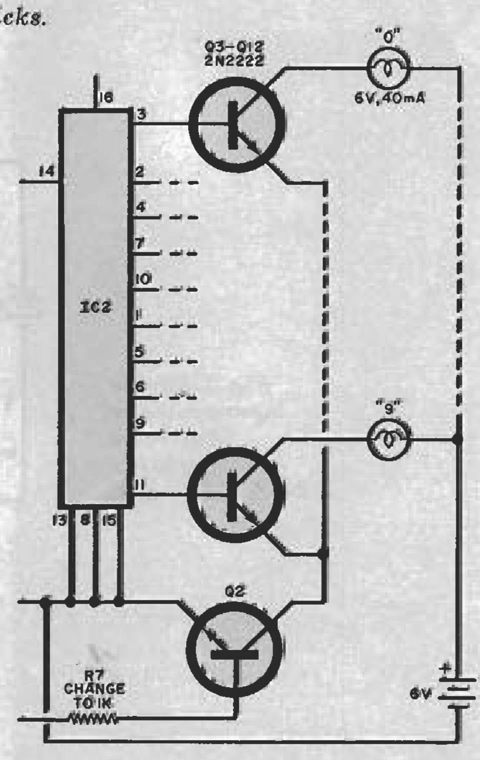


Fig. 5. Modifying the Wheel of Fortune for use with conventional 6 volt lamps.

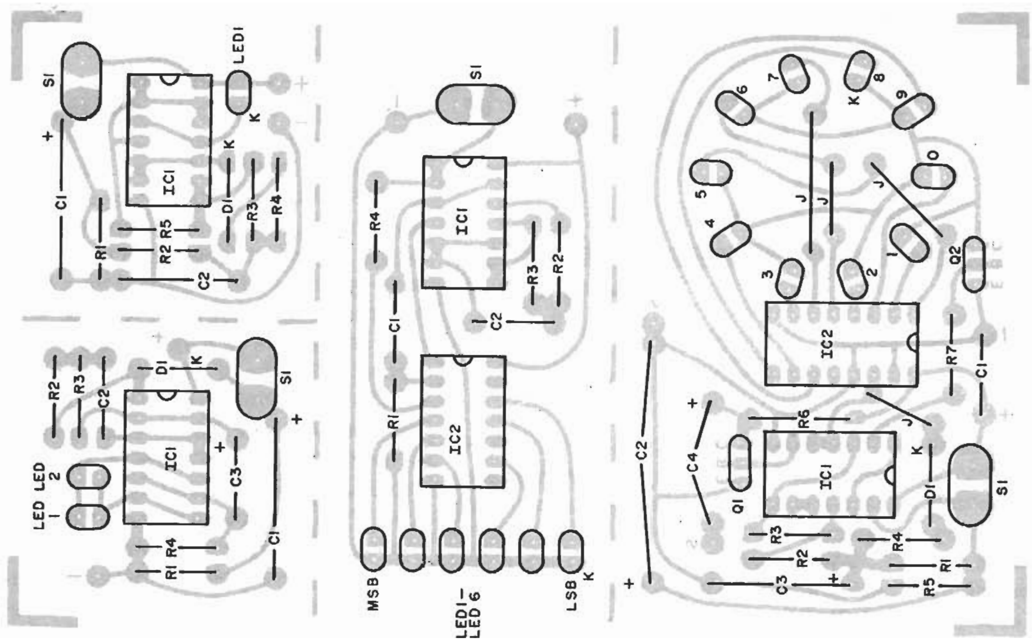
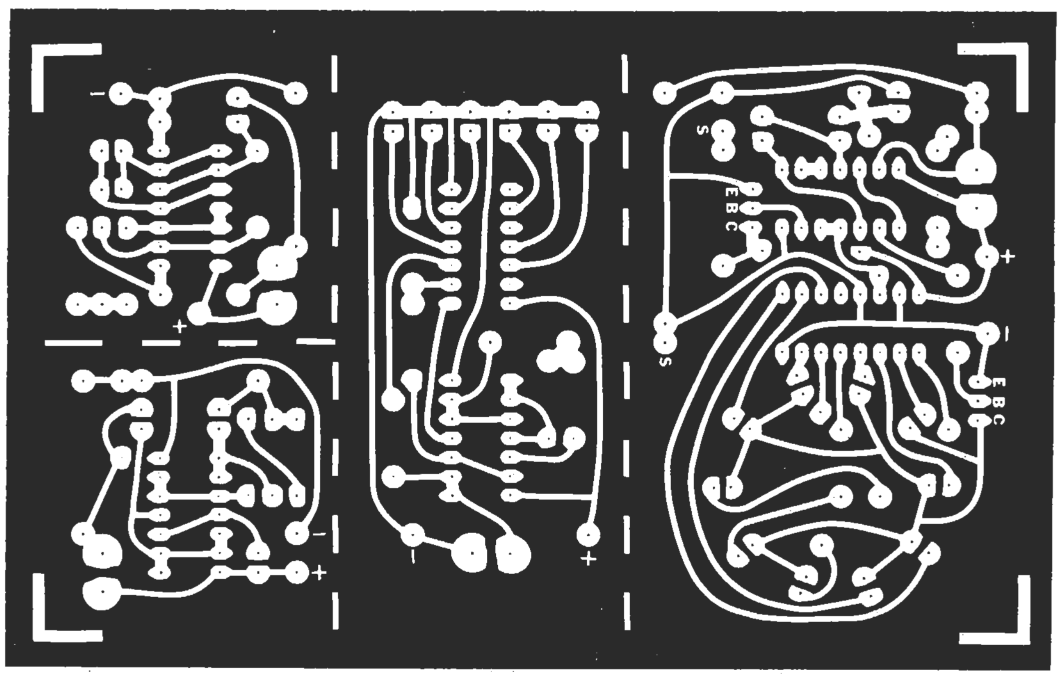


Fig. 6. Foil pattern and component installation. The four circuits are separated along the dotted lines.
Note: Pc board available from Ray Wilkins, Box 551, Hanover, NH 03755 for $4.50 ppd.



able frequency oscillator operating exactly like the oscillator in the Fig. 2 flasher circuit. Then *IC2* is a combination decade counter, decoder and driver that powers 10 LED's in sequence, with the LED's arranged in a circular display. Each pulse from the oscillator advances the count by one.

The oscillator pulses are buffered by *IC1D* and amplified by transistor *Q1* to drive a small loudspeaker. Capacitor *C3* affects the speed of rotation, while *C2* determines the total length of time that the display stays lit. The dc voltage across *C2* is also applied to a pair of buffering inverters (*IC1E* and *IC1F*) with the output used to turn on switching transistor *Q2*. When this transistor is saturated, it allows the LED's to turn on. When the voltage across *C2* drops, the output of inverter *IC1F* drops to zero, causing *Q2* to cut off, thus turning off the LED's.

It is possible to substitute conventional 6-volt, 40-mA lamps in place of the LED's by using the circuit shown in Fig. 5. To operate these optional lamps, an extra 6-volt battery is required.

Construction. Any type of construction can be used for any of the projects. If you want to use a printed circuit, you can use part or all of the foil pattern shown in Fig. 6. The four sections of the pattern can be separated at the dotted lines. Component layouts are also shown in Fig. 6. Install passive elements first, then the IC's. Be sure to observe the polarities of the electrolytic capacitors, diodes and IC's. Use a conventional 9-volt battery clip and leads for the connections. The red lead is positive, and the black lead is negative. ◇

Dual light-emitting diode synthesizes polychromatic light

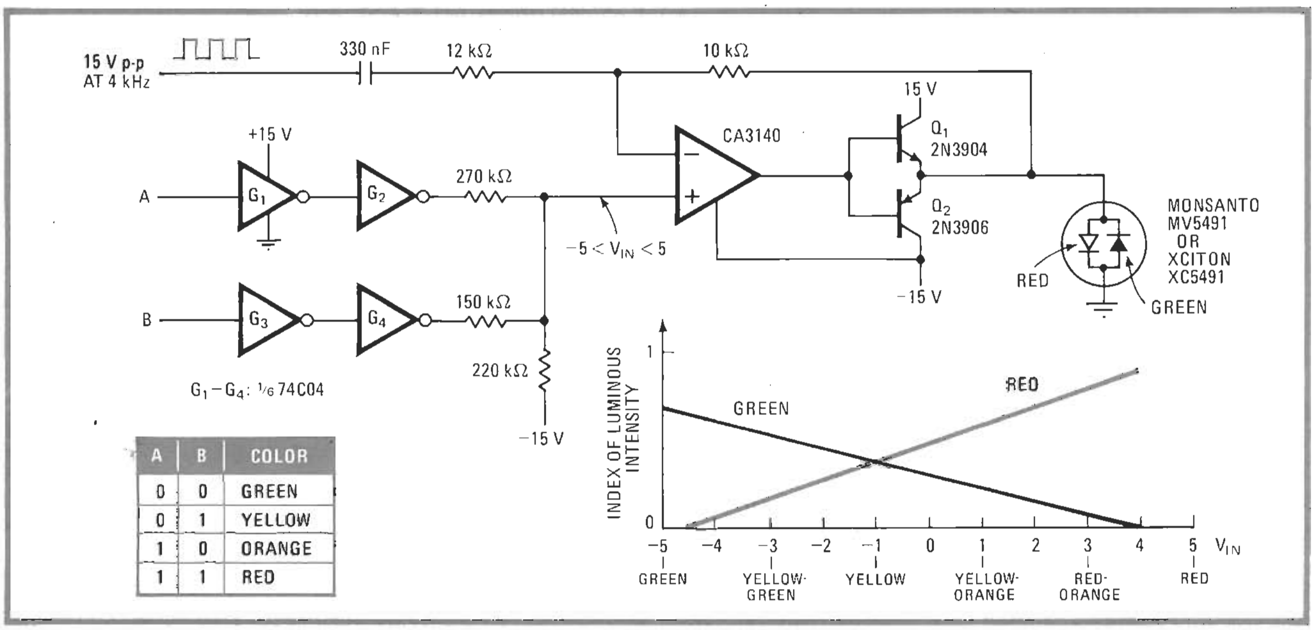
by Leonard M. Smithline
Ithaca, N. Y.

By controlling the drive to each element of a dual red or green light-emitting diode so as to mix the red and green lights in varying quantities, this digital circuit synthesizes four distinct hues from the two primary optical colors. With a slight modification, it can also make the diode vary gradually from green through yellow and orange to red in response to an analog input.

The LED used here may be either the Monsanto MV5491 or the Xciton XC5491 (Fig. 1). The diodes inside either device are wired back to back and so cannot be driven simultaneously. They therefore need a multiplexer circuit to drive them at a fast enough rate for them to appear to be on simultaneously. Here a 4-kilohertz square wave provides the desired chopping action. The relative proportions of drive to the green or red LED are controlled by adding a dc bias to the square-wave drive at the noninverting input of the CA3140 operational amplifier, as shown.

Thus, the states of A and B determine the color perceived by the mixing process, as seen in the table. Alternatively, an analog signal can be applied to the noninverting input of the op amp, whereupon the circuit response will be as shown in the graph.

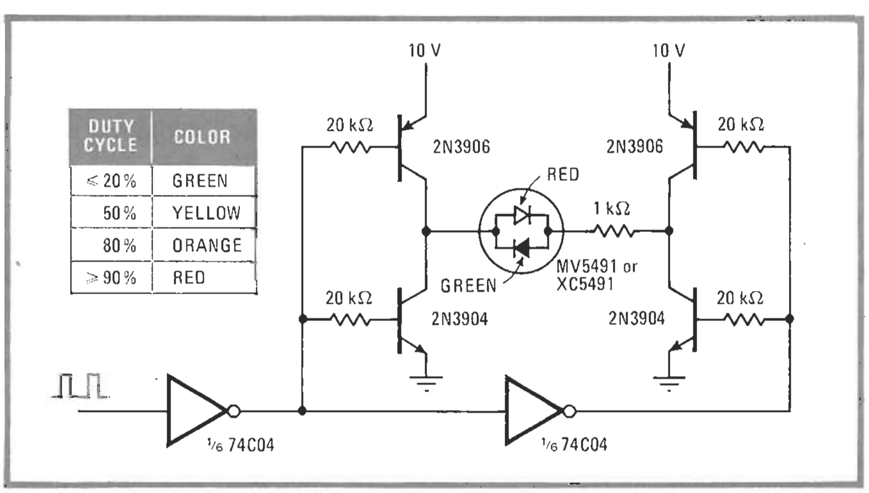
For a thorough mixing of colors, the primary light sources should not only be viewed simultaneously (as



A	B	COLOR
0	0	GREEN
0	1	YELLOW
1	0	ORANGE
1	1	RED

1. Thoughts of hue. Multiplexer's 4-kHz square wave, suitably offset with dc bias controlled by states of A and B, provides desired drive to each element of green/red photodiode for deriving perceived four-color output. Alternatively, analog signal may be applied to noninverting input of op amp for effecting gradual change in color, from green through red. Circuit response in either case is given in table and graph.

2. Color cycle. Generation of yellow and orange from red and green light may also be achieved through control of duty cycle of pulses driving light-emitting diodes. Pulse-width modulation requires only single supply.



DUTY CYCLE	COLOR
≤ 20%	GREEN
50%	YELLOW
80%	ORANGE
≥ 90%	RED

they virtually are in this case) but ought also to overlap one another homogeneously. The concept is an old one and was first used widely in color television. (Note that the colors produced in this way are only products of the human visual system, and no objectively new optical wavelengths are actually generated.)

In fact, the sources in the MV5491 or XC5491 are in close enough physical proximity, but differences in the patterns of radiation of the two LEDs will prevent the color mixing from being entirely uniform, giving rise to unwanted tinges of color. This situation may be ameliorated either by roughening the lens slightly to increase the diffusion of light or by limiting the angle of view. Incidentally, the Xciton XC5491 has better uniformity of field than the Monsanto device, but the MV5491 has a decidedly better appearance in the red region.

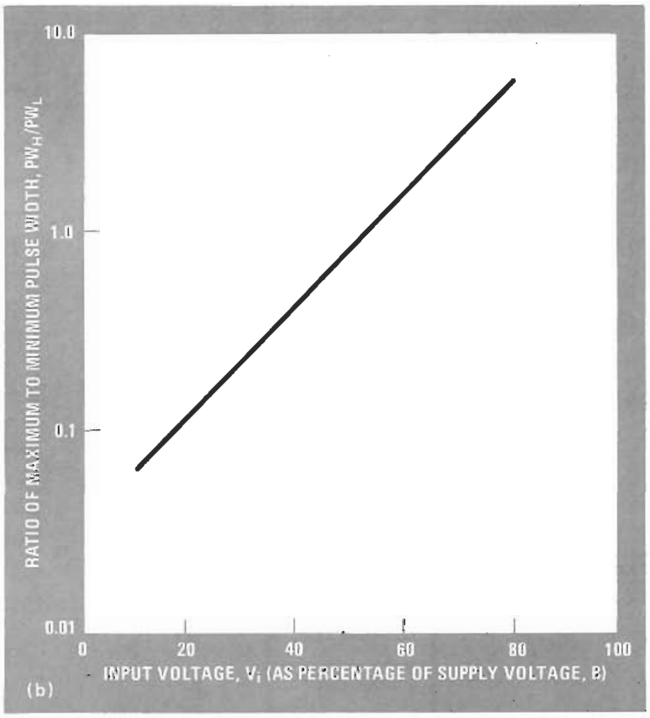
As an alternative way of synthesizing colors the duty cycle of the pulses driving each LED may be changed as shown in Fig. 2. This circuit has the advantage of requiring only a single supply. □

Chip changes the colors of light-emitting diodes

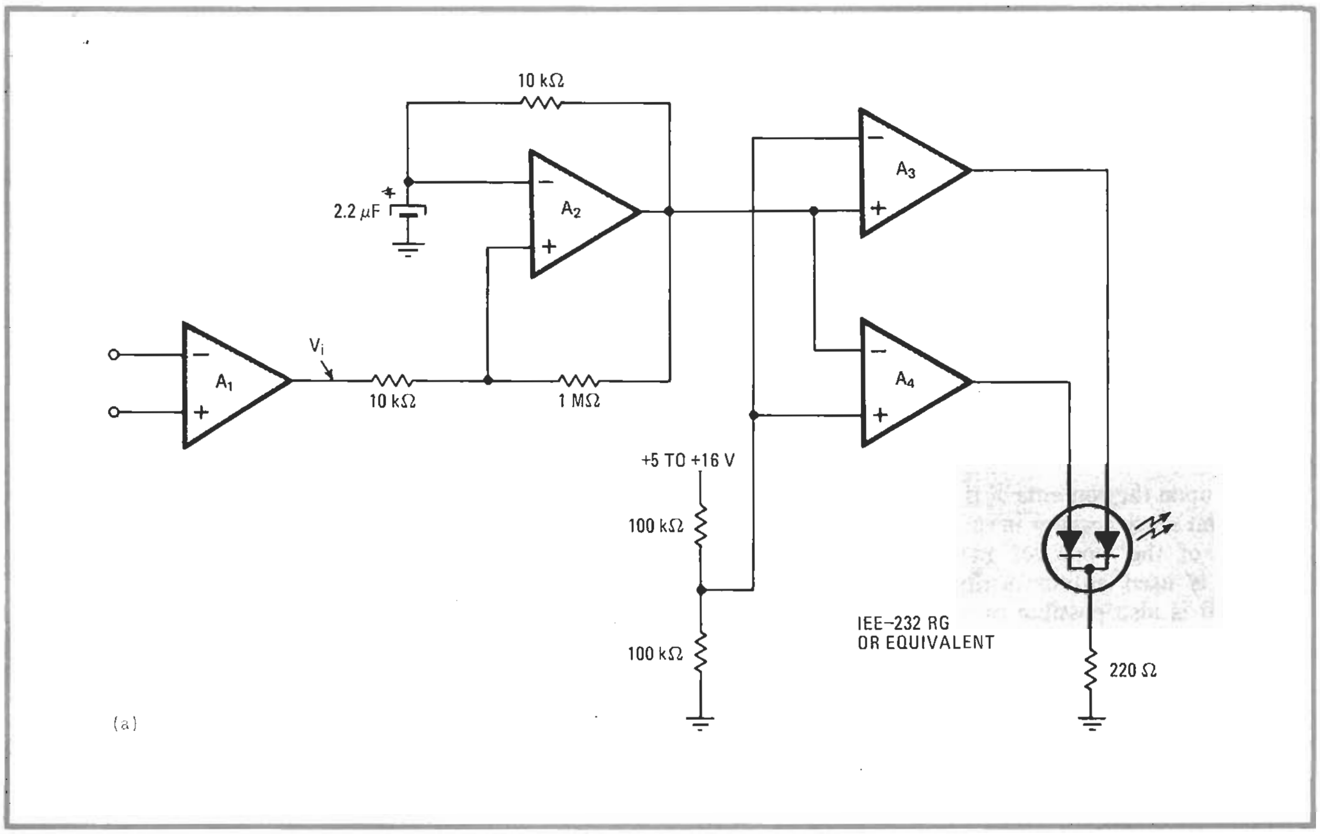
by Marvin Burke
Novato, Calif.

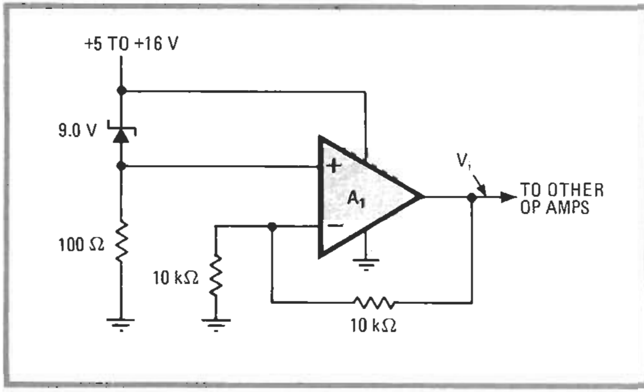
A light-emitting diode that changes color as a function of the input voltage is useful for instrumentation and equipment displays, since both the presence of the light and the color convey information. A simplification of the circuit by Smithline,[1] this design needs no separate frequency generator and requires only a single supply voltage in the range of 5 to 16 volts.

As shown in Fig. 1a, the new design needs only one integrated circuit, six resistors, a capacitor, and a bicolor LED. Operational amplifier A_1, part of the quad LM324 package, interfaces with some external voltage source such as a voltage follower. Its output is the input, V_i, to A_2. For its part, A_2 is set up to act as a voltage-controlled pulse-width-modulation oscillator. The duty cycle of its output pulse varies exponentially with V_i as a percentage of B, the supply voltage. As seen in Fig. 1b, the ratio of A_2's pulse-width high level to its pulse-width low (PW_H/PW_L) follows the exponent of V_i linearly over two decades. That is more than enough to get a full



1. Multicolored outputs. Just one integrated circuit is required to construct a voltage-controlled multicolor light-emitting-diode display (a). Pulse-width modulation of A_2's output by means of input voltage V_i (b) is the key to obtaining any LED output color from green to red.





B	V_i	V_i/B	PW_H/PW_L	COLOR
13.0	8.0	0.62	2.00	GREEN
12.5	7.0	0.56	1.25	GREEN/YELLOW
12.0	6.0	0.50	1.00	YELLOW
11.5	5.0	0.43	0.60	ORANGE
11.0	4.0	0.36	0.40	RED

2. Watcher. The LED color modulator can monitor the supply voltage of a music synthesizer. Here, op amp A_1 replaces part of the same number in Fig. 1. The table shows yellow for the normal voltage (12 V), green for the high one, and red for the low one.

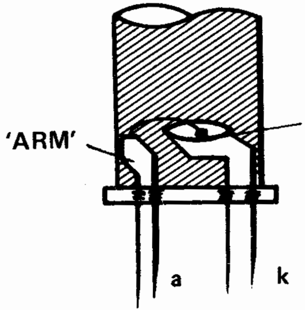
range of color output from the LED. The output of A_2 is fed to A_3 and A_4, which act as noninverting and inverting buffers, respectively, for A_2's pulse.

The buffers power the bicolor LED so that when the green LED is on, the red one is off, and vice versa. Since the overall color perceived is dependent on the relative power through each LED (provided they are flashing quickly enough for blending to occur), it depends strictly on the ratio of PW_H to PW_L. Thus, V_i, which determines PW_H/PW_L, is ultimately in control of the color. The color mix for a given range of V_i may be modified by placing separate resistors in the red and green leads of the LED and adjusting the ratio of the resistors until the desired effect is achieved.

A direct application of the technique is shown in Fig. 2. Here, A_1 is set up to monitor a synthesizer's supply voltage. With the parameters shown in the table, colors shift from green for high voltage to red for low voltage, keeping a close tab on the supply. □

References

1. Leonard M. Smithline, "Dual light-emitting diode synthesizes polychromatic light," *Electronics*, Aug. 16, 1979, p. 130.



LED Spotting

A. Kenny

Since the leadout on LED's varies according to the manufacturers preference, leadout diagrams are not always worthy of the trust placed in them. In some cases a reverse connection will destroy the device being used.

A simple way to avoid this is to use the following technique.

If the LED is held up to the light, the structure can be clearly seen. There is a "cup" and an "arm" carrying a fine wire to the LED itself, which is in the "basin" of the cup (see drawing).

The lead with the cup is the cathode, and the other is the anode (of course).

PROJECT OF THE MONTH

BY FORREST M. MIMS

HIGH-CURRENT LED PULSER

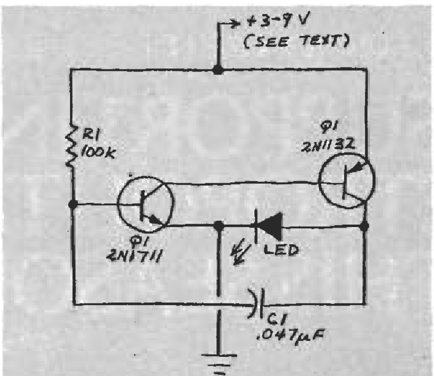


Fig. 1. High-current LED pulser.

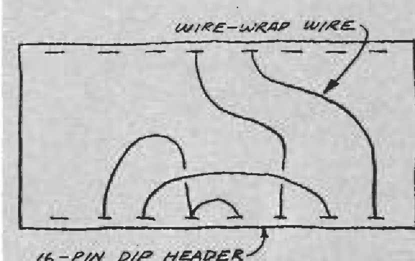


Fig. 2. Connections for LED pulser.

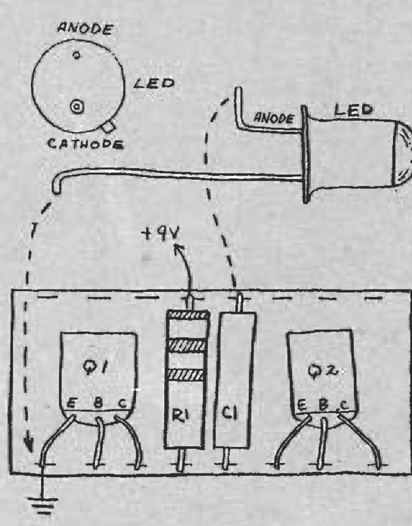


Fig. 3. Pulser component placement.

INFRARED LEDs make ideal optical sources for remote controls, intrusion alarms, reflective and break-beam object sensors, signaling devices and TV commercial killers. However, unless an efficient heat sink is employed, most infrared LEDs are restricted to a maximum continuous forward current of no more than 100 milliamperes. At this current, a high-quality GaAs:Si LED will deliver from 6 to 10 milliwatts of optical power. This is roughly equivalent to the *visible* radiation emitted by a small one- or two-cell penlight with a prefocused lamp.

Rapidly pulsing a LED at very high current levels makes it possible to obtain much higher power outputs. For example, a G.E. 1N6264 LED that emits 6 mW at 100 mA of forward current will emit 60 mW when driven by 1-ampere pulses a few microseconds wide.

Figure 1 shows a simple circuit that can deliver high current pulses to an LED. This pulser is considerably more powerful than the LED transmitter module that was the Project of the Month for February 1979. With the parts values shown, it will apply hefty 2.7-ampere pulses at a rate of about 100 Hz to a LED. The pulses are about 17 microseconds wide. They can be readily detected by a simple phototransistor receiver such as the Project of the Month for January 1979. Current drain from a small TR175, 7-volt mercury battery is 5 mA.

Many different LEDs can be used with the pulser. For most LEDs, the peak current exceeds by a factor of three the component's maximum continuous rating. Applying even larger pulses will not necessarily destroy a LED, but might shorten its useful life. For best results, use infrared emitters made from GaAs:Si rather than GaAs diodes. Good choices include the TIL-32 (Texas Instruments), 1N6264 (General Electric), OP-190 and OP-195 (Optron) and 276-142 (Radio Shack).

You might have difficulty finding the transistors specified in Fig. 1. If so, you can substitute a common npn silicon device such as the 2N3904 or 2N2222 for *Q1*. The choice of *Q2* is more critical, however. If maximum current is to be delivered to the LED, *Q2* must be a *germanium* transistor. A germanium pn junction has a smaller forward voltage drop than a silicon pn junction, and this causes a germanium transistor to have a lower effective "on" resistance. The LED therefore receives more current if a germanium device is used.

The 2N1132 works better than any other germanium transistor I've tried. The 2N1305 is easier to find and will deliver about 2 amperes to the LED. If you can't find a suitable germanium transistor you can substitute a common pnp silicon switching transistor such as the 2N3906 or 2N2907. Less current will be delivered to the LED, but the optical output will still be adequate for many applications.

For example, if *Q1* is a 2N3904, *Q2* is a 2N3906 and the circuit is powered by a standard 9-volt battery, 1.1-ampere pulses will be delivered to a LED. Because of the different characteristics of the silicon transistors, the repetition rate will jump to 1400 and the current demand will increase to about 100 mA. That's enough to quickly deplete even an alkaline battery, so for best results the resistance of *R1* should be increased to reduce the pulse-repetition rate and the operating current. For example, if the value of *R1* is changed to 1 megohm, the repetition rate will decrease to 120 Hz and the current drain to a much more reasonable 8 mA.

Once you've made a final selection of component types and values, you can assemble a permanent version of the LED pulser on a DIP header or postage-stamp-sized perforated board. I took the latter approach for my germanium-transistor unit because the transistors are packaged in TO-5 cans. It was still possible to install the pulser, TR-175 battery, switch and adjustable lens in a brass tube measuring 0.5" × 3.25" (1.3 cm × 8.3 cm).

Figure 2 shows how to assemble the pulser on a DIP header if silicon transistors in plastic packages are used. Interconnect the pins on the header with Wire-Wrap leads, but don't solder them in place yet. Use lengths of wire that are longer than necessary, securing them in place by wrapping their free ends under the header.

Figure 3 shows where the components go. To make things as compact as possible, use a miniature tubular capacitor for *C1* instead of a ceramic disc. Any capacitance from 0.01 μF to 0.05 μF is satisfactory, but the smaller values will increase the pulse-repetition rate and reduce the current to the LED somewhat. If you must use a disc for *C1*, try bending it over the top of the header so that it will present a lower profile and leave room for the LED.

If you use a miniature tubular capacitor for *C1*, the completed circuit will use only half the space in the DIP header's cover. Instead of installing the cover, I clipped all the pins from the header and mounted it on a snap terminal salvaged from a discarded 9-volt battery. The conductive strips at each terminal were trimmed to size and folded over each end of the header to secure it in place. Taking care to observe the polarity, I soldered short connection wires from the header to the two metal strips. The result is a tiny but powerful LED transmitter that snaps directly onto the terminals of a 9-volt battery.

Whether you use germanium or silicon transistors, with a little care you can install the complete pulser in a pen-light, lipstick tube, pill bottle or other small container. Although the germanium unit is more powerful, even the silicon pulser projects a beam that can be received at 1000 feet or more at night using a simple phototransistor receiver—provided you use a 2- or 3-inch lens at each end of the link. ◇

FLASHER LED APPLICATIONS

The flasher LED is a new component. Learn how it works and keep it among your arsenal of components for use when designing projects

CALVIN R. GRAF, W5LFM

THE FLASHER LED HAS RECENTLY BEEN INtroduced into the electronic parts market. It is inexpensive and offers some very interesting possibilities for circuit innovation. This article describes some applications of that simple device, which has its own built-in IC switch. With the use of a few components—a 9-volt battery, LED flasher, photocell and resistor—a series of novel circuits can be configured. They cover the areas of a continuous LED flasher for a night light, a basic flasher for TTL and CMOS circuit applications, attention-getter applications, a troubleshooting aid, and ambient light or dark detecter. The Flasher LED is currently available at Radio Shack stores (part No. 276-036).

How it works

The basic LED is made to flash at a three-times-per-second (PPS) rate by a small integrated circuit that operates off a 5-volt DC power supply. The flasher LED is indeed unique when you consider that the LED is the same size as a regular LED but contains the following electrical components: the LED, the IC chip that establishes the flash rate (in effect containing an R–C time-constant circuit to switch the current to the LED), and an "effective resistor" that drops the supply voltage from 5 volts DC to a nominal 1.6 volts DC for application to the red LED. The flasher LED draws 20 mA from a 5-volt source, so for a normal red LED (which draws 20 mA) a series-dropping (current-limiting) resistor of 170 ohms would be required. So a lot is accomplished by the small IC chip that can be seen as a small black speck inside the LED epoxy case. At the present time, the flasher LED is available with a red lens only but other colors—such as green and yellow—probably will be forthcoming from LED manufacturers.

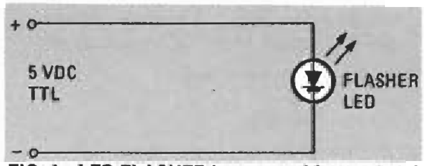


FIG. 1—LED FLASHER is powered from a 5-volt supply and flashes at a 3-PPS rate.

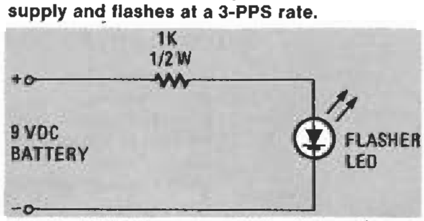


FIG. 2—POWER can be obtained from a 9-volt source if a dropping resistor is used.

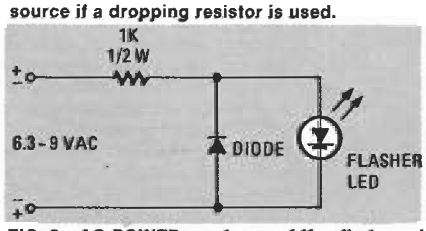


FIG. 3—AC POWER can be used if a diode and dropping resistor are included as shown.

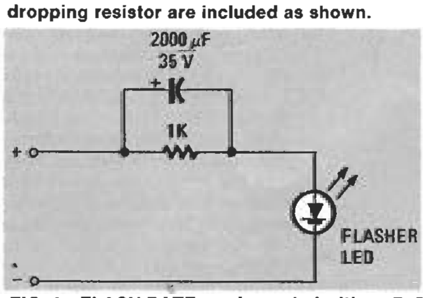


FIG. 4—FLASH RATE can be varied with an R-C circuit.

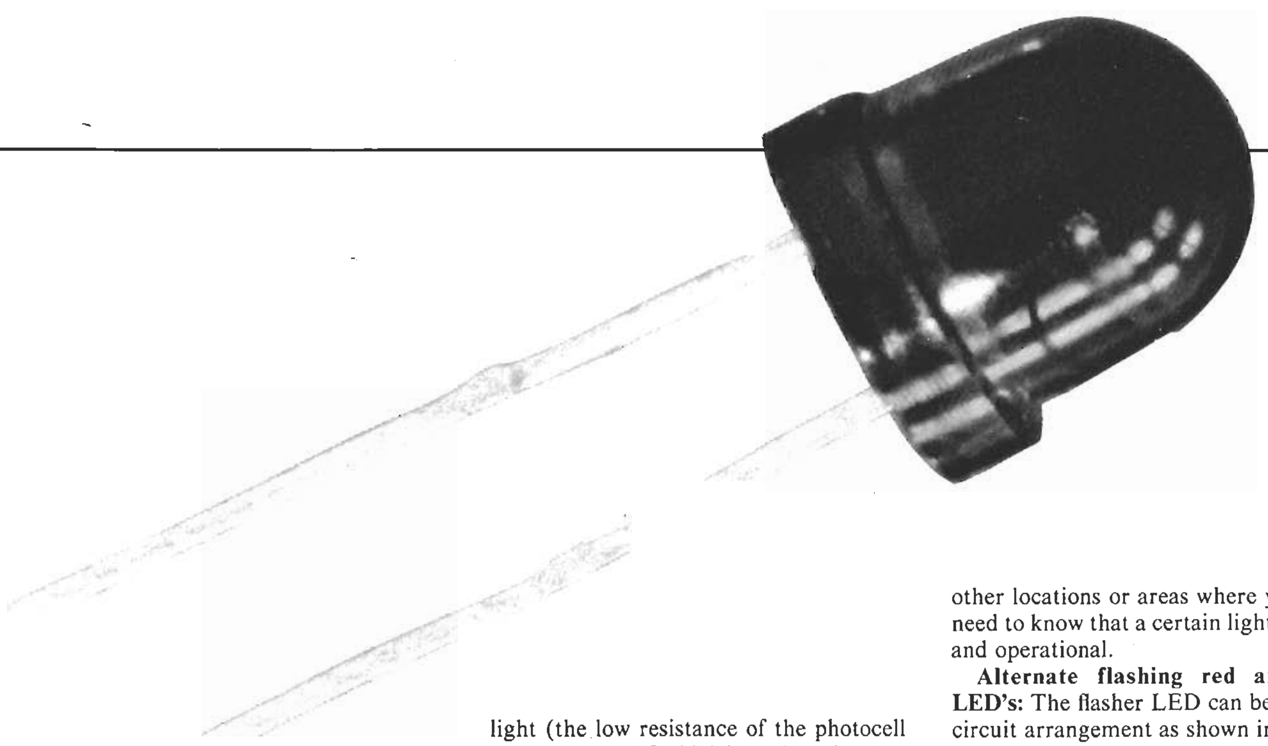
Applications

Normal flash rate. In Fig. 1 we see the basic hookup for the LED IC flasher operated off 5 volts DC. This configuration is used to drive the flasher directly off TTL and CMOS circuits and it will flash at a nominal 3 PPS. Note the electrical schematic symbol we have used for the IC flasher LED. We have added a small rectangle to the cathode symbol of the LED to differentiate it from a regular LED. Perhaps this symbol for the flasher LED will be adapted for wider use. Figure 2 shows an arrangement for flashing the LED from a 9-volt transistor battery at a 3-PPS rate. A 9-volt battery will provide sufficient power to flash the LED for about a week, so for continuous operation you can use a 9-volt battery eliminator or charger available at radio supply houses for under $5.00. Note that in the circuit of Fig. 2 we have added a 1000-ohm series resistor to drop the voltage across the flasher LED to a nominal 5 volts. The resistance value is not critical and the brilliance of the LED and flash rate will vary slightly with applied voltage as it is varied below 5 volts.

An alternating current (AC) power supply of a nominal 6 to 9 volts can be used to power the flasher LED by adding a diode to the circuit to protect the LED/IC chip during negative voltage swings of the AC voltage. This circuit arrangement is shown in Fig. 3. The 6.3- to 9-volt AC power supply can be obtained by using a 115-volt to 6.3 volt filament transformer or an AC pocket calculator charger which usually has a nominal 8-volts AC output.

Fast flash rate. We can increase the flash rate by adding a large capacitor across the series-dropping resistor as shown in Fig. 4. The flash rate is increased to a nominal 10 PPS by the R–C circuit introduced in series with the IC chip. The capacitor can be any value from 500 to 3000 μF at a nominal 10- to 35-volts DC working voltage. Experiment with the value of R and C until you reach the flash rate you want.

If the flash rate is increased to slightly above 10-to-12 PPS, the LED will appear to be on continuously as the eye cannot perceive faster flash rates. To observe the



LED flashing (if your circuit leads are long enough), wave the LED back and forth slowly and you'll observe it to make on on-off streak as it moves.

Ambient light detector: When we put a photocell in series with the flasher LED as shown in Fig. 5, it will flash only in the presence of light. Photocells available from any radio-supply house have a nominal resistance of 1-to-10 megohms in darkness and their resistance drops rapidly to a nominal 100-to-1000 ohms in bright light. In darkness, the circuit will draw virtually no standby power as the total resistance in the circuit is over 1 megohm. Considering the IC chip as a short at this time, the circuit will draw only 9 microamperes from the battery, virtually its shelf life. You can use this circuit to tell you when it gets dark outside (if you are in a windowless room) or it you *really* want to see if the refrigerator light goes out when the door is closed! For light levels in between light and dark, where the applied voltage to the IC chip will vary from 0-to-5 volts, we will find the flasher LED doing some strange things such as flashing faster, slower, staying on or off, and varying its brilliance.

When we place the photocell across the flasher LED as shown in Fig. 6, we now find that the LED will not flash in bright light (the low resistance of the photocell shorts out the IC chip) but when the photocell is in darkness, the LED will flash. In darkness the photocell resistance rises to about 10 megohms and this appears as an open circuit to the IC chip, 5 volts appears across the chip and the LED begins to flash. That circuit will draw power from the battery in the standby (light-present) condition and nominal power when flashing, so you might want to use a 9-volt battery eliminator for long-time operation. This circuit is handy for a flashing night-light in use in hallways and other locations or areas where you might need to know that a certain light is still on and operational.

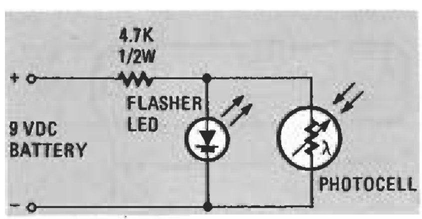


FIG. 6—PARALLEL PHOTOCELL permits LED to flash only in dark ambient light conditions.

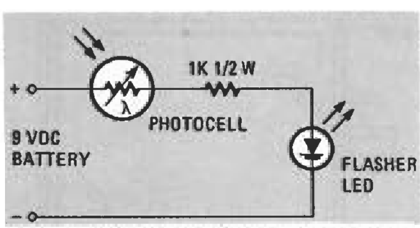


FIG. 5—SERIES PHOTOCELL permits LED to flash only in bright ambient light conditions.

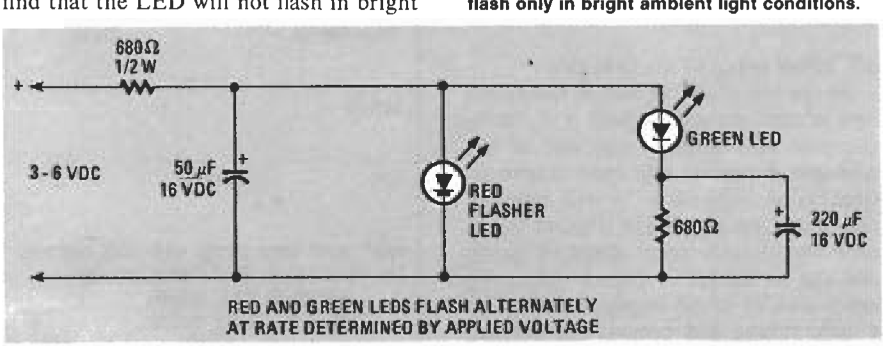


FIG. 7—RED AND GREEN LED's flash alternately at a rate determined by the applied voltage.

Alternate flashing red and green LED's: The flasher LED can be used in a circuit arrangement as shown in Fig. 7 to alternately flash a second LED. The two LED's can be spaced several inches or feet apart to attract your eye back and forth to each LED as it flashes. Alternately flashing red and green LED's are particularly interesting as they are eye-catching and can serve as baby sitters, novelties, or attention-getters. The circuit of Fig. 7 will operate from a nominal 3-to-6 volts DC, the flash rate increasing as the voltage is decreased. At 6-volts DC, such as you get from a Type-F lantern battery available at hardware stores, the flash rate is the nominal 3 PPS. If the circuit voltage is increased past 6 volts, up to 7 or 8 volts, the LED's will stop flashing and remain on continuously. That condition should be avoided for use over long periods of time as it might damage the IC chip in the flasher LED.

As the voltage is reduced to about 3 volts, the flash rate increases to about 10 PPS and the LED's are not as bright as at 6 volts. The LED's will flash faster and faster as the voltage is reduced below 3 volts until they appear to be on continuously, though they are dim at this time.

As you experiment and work with the flasher LED, you will find it a very interesting electronic component. You may observe that its flash-rate changes, depending on the amount of ambient light striking the IC chip inside its epoxy case. Depending on the manufacturer of the LED, the flash rate will be a nominal 3 PPS in bright bench light or sunlight. But as you darken the room, the flash-rate will decrease slightly, depending on the circuit you are using at the time. Do your own experimenting with this unique device until the manufacturers correct for some of its interesting characteristics! They might add a Zener voltage-regulator to keep the flash-rate constant with applied voltage and then hide the IC chip in a lightproof case—and that would take away all the fun! **R-E**

ETI DATA SHEET

NSL 4944 UNIVERSAL LED — NATIONAL

THE NSL4944 IS A simple two-lead device normally used as an AC or DC indicator whch can also be used as a rectifier and constant current source at the same time in associated circuitry. Further, most of the regulating circuitry is not in series with the LED. This allows the complete regulated LED to operate at only about 300 mV more than a standard red LED. Thus the NSL4944 operates on half the voltage needed by previously available regulated or resistor LEDs. The device is rated for a maximum of 18 V forward and reverse.

These characteristics provide several advantages. Unloaded TTL gates provide enough voltage, in either high or low states, to directly drive the universal indicator. Size and weight can be saved in instruments with a number of indicator lights by reducing the size of filter capacitors or voltage regulators. The NSL4944 can operate on unfiltered DC or at somewhat reduced intensity on 3 to 12 VAC. Since the IC within the regulated LED blocks reverse voltage, the device can be used as a low voltage rectifier or polarity indicator.

Equivalent Circuit

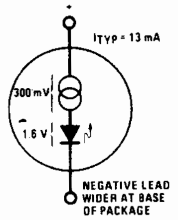


FIGURE 1. Equivalent Circuit

The LED and its current source, as illustrated in Fig. 1, both fit within a standard LED package. The typical operating voltages shown allow the device to operate with lower supplies and take up less room than an LED and resistor.

Schematic

Figure 2 shows how some of the operating features of the device are achieved. The rectifying characteristic occurs because the only input to the device passes through the IC's PNP emitters. These have a high reverse voltage in standard linear processing. The voltage reference and compari-

Features

- Supply range 2 V to 18 V
- Reverse polarity protection
- Constant light output over 3 V
- No larger than normal LED
- 12mA to 14 mA current
- 300 mW dissipation
- Low cost per unit

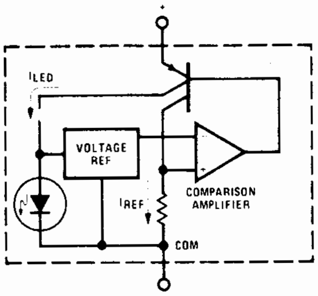


FIGURE 2. Schematic Diagram.

son amplifier operate from the same low voltage that the LED does. The big PNP transistor which passes both I_{LED} and I_{REF} can be operated almost in saturation since the comparison amplifier can pull the PNP base down to only one volt from common.

Unfiltered AC

Power and parts count is minimized by powering the indicator from a low voltage transformer winding as shown in Fig. 3. This method, however, provides only half intensity light, but the apparent visual decrease is not as great. Some flicker occurs if the observer moves his head rapidly. The supply of Fig. 4 will provide up to 87% of maximum light output. The bulk of a filter capacitor is still not needed, and at 12 VAC in, flicker will be almost imperceptible since the LED "off" periods will be less than a

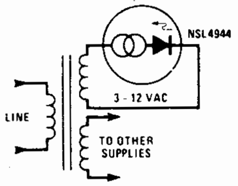


FIGURE 3. AC Power

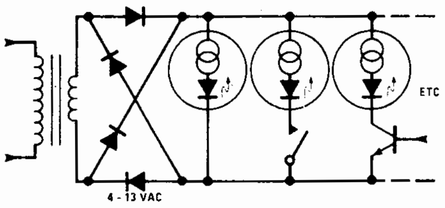


FIGURE 4. Unfiltered DC Power

millisecond. In both situations, the indicator may be switched a number of ways, including bipolar transistors, since only DC can pass through the indicator.

Full Intensity

As shown in Fig. 5, full intensity and zero possible flicker are achieved by minimal DC filtering. The small capacitor shown operates with 10 V p-p ripple and only about 8 V average DC, while the constant current drain characteristics of the NSL 4944 allow

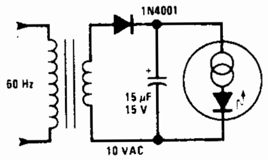


FIGURE 5. Minimizing DC Filtering

only a few percent change in light intensity. If a system or instrument with a regulated supply has a number of LED indicators, regulator size and dissipation can be minimized by powering the regulated LEDs from the unregulated voltage.

Reduced Intensity

The low operating voltage and constant current characteristics make the regulated LED an ideal status indicator for digital circuitry. An interesting fact to keep in mind is that full regulator current is not needed to light the LED. If, for example, only 8 mA is available (from a voltage of 1.6 to 1.9 V) the LED will light at a somewhat reduced intensity. The regulator will be switched full on instead of current limiting . . . but in such a situation it doesn't matter.

TTL Drive

Any circuit capable of supplying 10 to 20 mA and a voltage swing of at least 1 V can switch the NSL4944 from an off to an on state Fig 6a, b. Within 25° C of room temperature, an input voltage of 1.3V will produce little or no light, and 2.3 V will produce 70% to 90% of full output. However, with a small signal change, the pre-existing biases must be correct. The output swing of a TTL stage goes much closer to ground than to the 5 V supply.

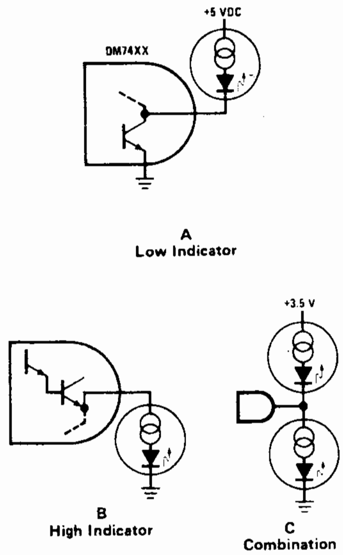


FIGURE 6. TTL Indicators

Therefore, Fig. 6-C requires a 3.5 V supply for the indicators to have complete off-on switching.

Replacing FETs

In many circuits or small instruments the need for a constant current source or current limiter arises. FETs can generally only be used as low current sources, so for 10 mA or more parts. If an indicator or pilot light is also needed, the regulated LED may be a very economical source of the needed constant current.

The examples below illustrate all three characteristics of the NSL4944. It is a combined rectifier, constant current source, and pilot light.

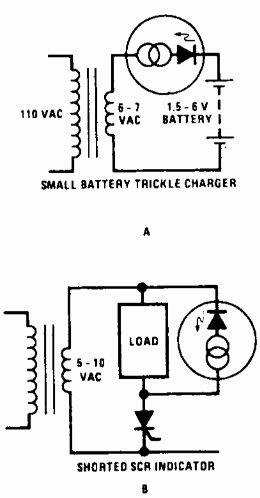


FIGURE 7.

Shortproof Circuit

A current source can also be a current limiter. Fig. 8 shows an NSL4944 put in the collector of an emitter follower such as might be used in a pre-amp or mike mixer cable driver.

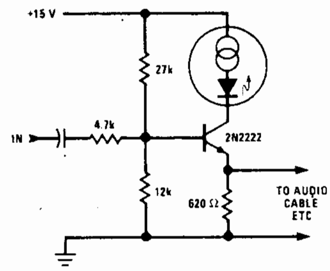


FIGURE 8. Current Limiting and Short Protection

Normally voltage across the LED is only 2 V, allowing almost full supply-to-supply swing of the emitter follower output. In comparison a limiting resistor would either greatly increase output impedance, or severely limit output swing. However, if the output cable is accidentally shorted, only a little more than the rated current of the LED will flow. Output transistor dissipation actually decreases under emitter short conditions.

Delay Tactics

Logically, a constant current source is helpful in designing time delay circuits. If the circuit of Fig. 9 were built with a resistor, the timing period would only be half the amount shown, and timing would vary over 50% with the supply variations shown.

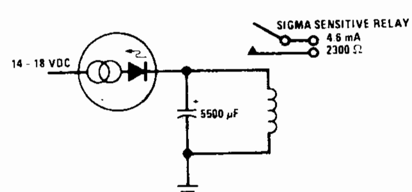


FIGURE 9. Six Second Time Delay

Instead, the current regulated LED is still drawing within 10% of full current when the relay reaches its 11 V pull-in voltage. The 14 to 18 V supply variation will produce only about a 3% timing variation, a considerable improvement. Variations due to temperature and electrolytic capacitor tolerances will remain however.

A number of LEDs can "share" a single constant current LED. Further, any of the ordinary LEDs can be turned on and off by a shunting switch without affecting operation of any of the others.

Active Loads

The lamp-driver Schmitt of Fig 10 illustrates a still further use of the NSL4944's constant current source. Substituting a current source for the collector resistor increases the useful voltage gain of Q_1. Further, almost full base current remains available to Q_2, even when supplying 12 V output, which would not be possible using a resistor. When the lamp and Q_2 are off, most of the LED current flows in

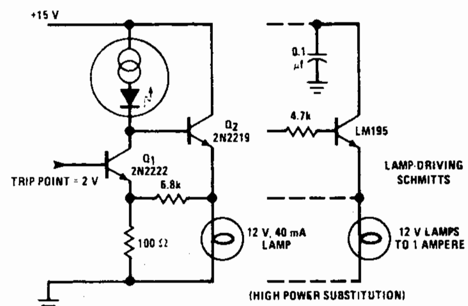


FIGURE 10. Use as Active Load

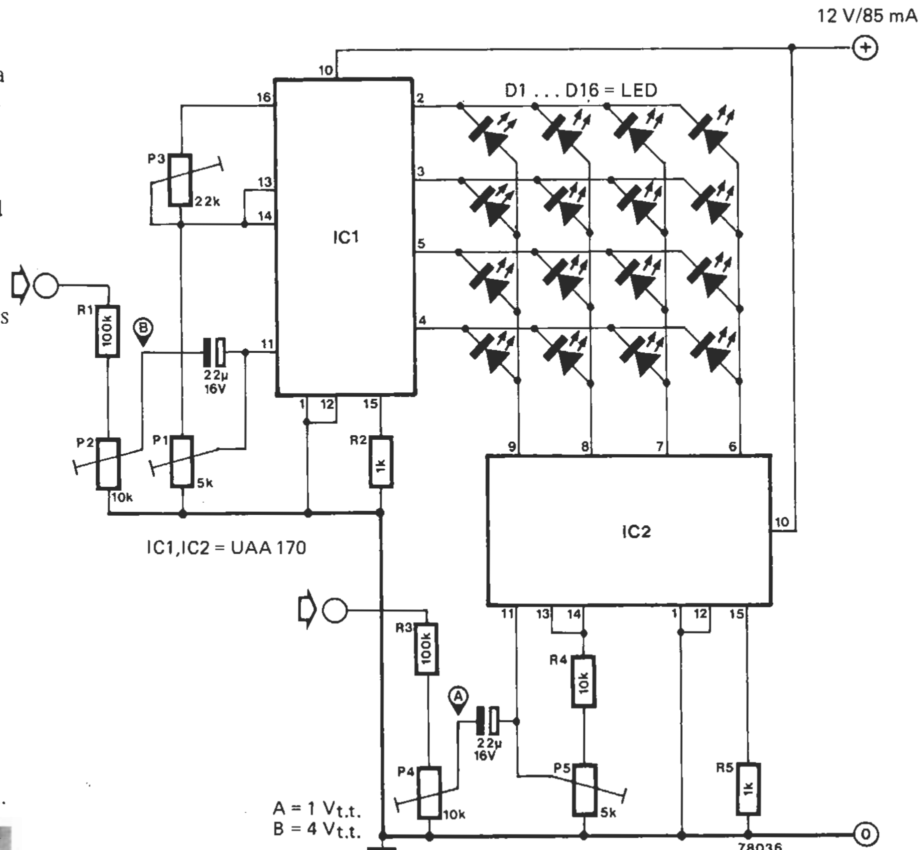
the 100 R resistor, thus determining the circuit's switching or trip point of 2 V.

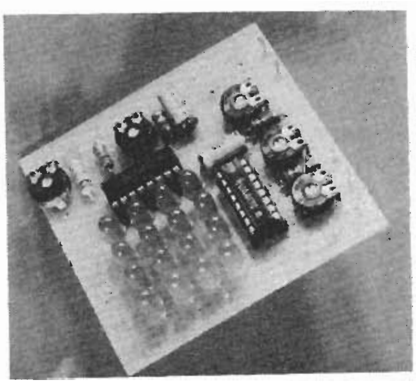
With Q_1 saturated, Q_2 still provides a volt to the bulb, contributing some preheating and reducing the bulb's starting current surge. On, Q_2 provides the bulb with 12 V due to the minimum voltage drop in the constant current LED. The 6k8 feedback resistor sets hysteresis at a measured 50 mV at the input. This can be varied without having to change the rest of the circuit. 10k provides almost "0" hysteresis (undesirable and unstable) while 2k sets a hysteresis of 0.5 V.

The NSL4944 is available from National stockists, all branches of Marshalls should have stocks. Price is 62p including VAT.

68 stereo vectorscope

Using two UAA170 LED voltmeter ICs it is possible to construct a novel type of stereo indicator which gives a display determined by the amplitude and phase relationship of the two input signals. IC1 is fed with the left channel signal and drives the rows of a 4 x 4 LED matrix, whilst IC2 is fed with the right channel signal and drives the columns of the matrix. At any time one LED in the matrix will be lit depending on the instantaneous amplitudes of the two input signals. Since AC signals are being fed to the circuit the display will be continuously changing, the pattern produced being dependent, not only on the amplitude but on the relative phase of the two signals. For example, if the two input signals have the same frequency then a kind of Lissajous figure will be produced. If they have the same amplitude and phase then this figure will be a diagonal line.
The circuit has five adjustment points. P1 and P5 set the quiescent DC bias at the inputs of the two ICs and hence determine which LED in the display is lit with no input signal.





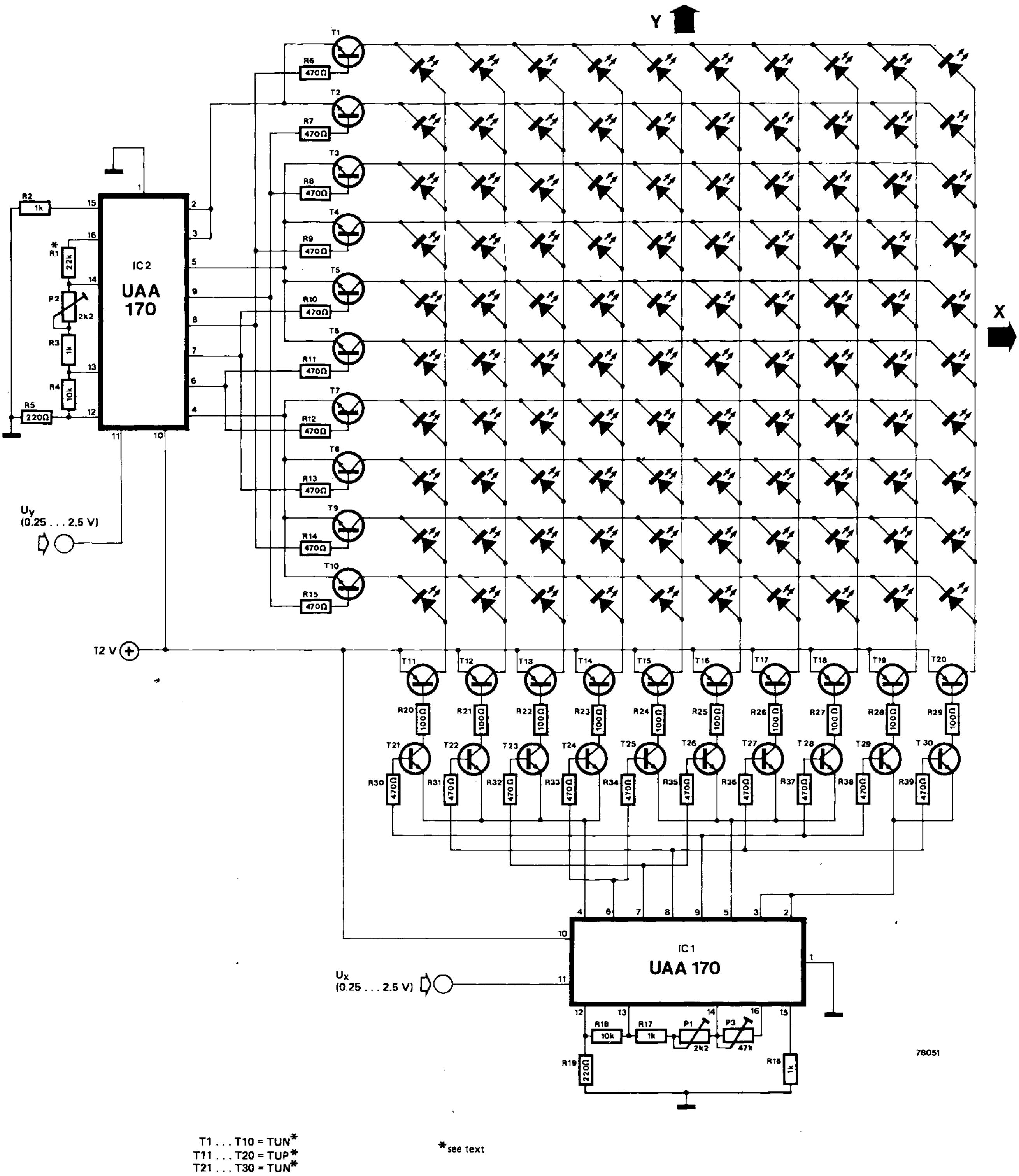
Normally these controls would be adjusted so that the four centre LEDs were all glowing dimly.
P2 and P4 adjust the sensitivities of the vertical and horizontal inputs respectively, while P3 sets the display brightness. The current consumption at peak brightness is approximately 100 mA.
The sensitivity of the two inputs is different. A 1 V p-p signal is required at the wiper of P4 to give maximum output level from IC2, whereas 4 V p-p is required at the wiper of P2 for maximum output from IC1. However, by adjusting P2 and P4 and/or varying the values of R1 and R3, the sensitivity of the two inputs can be made the same. For small input signals R1 and R3 may be omitted entirely, but care should be taken to ensure that the peak input voltage at pin 11 of either IC does not exceed 6 V.

105 LED X-Y plotter

The steady fall in the price of LEDs now makes it an economic proposition to construct an X-Y display using a LED matrix. Two UAA 170 ICs are used to drive a 10 x 10 matrix of LEDs. Since the UAA 170 is normally intended to drive 16 LEDs arranged in a 4 x 4 matrix, the outputs of the UAA 170s must first be decoded to give a 1 of 10 output, using transistors T1 to T10 and T11 to T30.

A voltage applied to IC2 (U_y) will drive the vertical axis of the display, whilst a voltage applied to IC1 (U_x) will drive the horizontal axis of the display. At any time one LED in the display will be lit at the intersection of the row and column outputs which are active at that time. As the circuit stands the input voltage range is +0.25 to +2.5 V which is set by P1 and P2. However, the upper limit can be increased by the use of attenuators on the inputs.

Low frequency AC signals may be displayed as Lissajous figures by AC coupling the inputs and DC biasing pin 11 of each IC such that the centre LEDs of the display light with

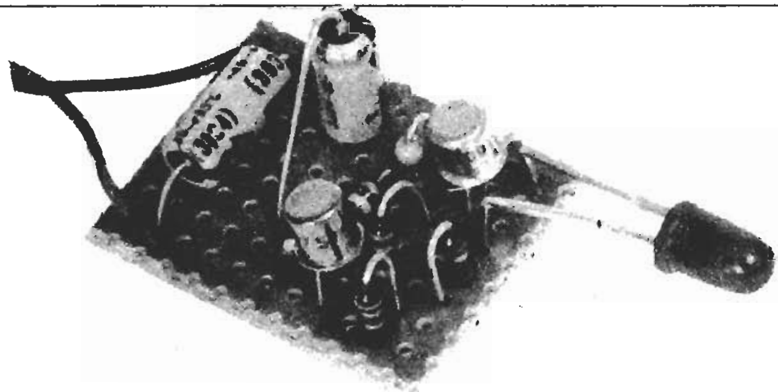


no input signal.
By feeding a sawtooth waveform into the X input and a signal into the Y input the display may also be used as a simple low-frequency oscilloscope (maximum input frequency 1 kHz).

Literature:
Siemens 'Bauteile Report' 6/77.
Elektor No 12, April 1976 p. 441 'LED meters'.

Editorial note: tests show that the maximum input frequency quoted is optimistic, 50 Hz being nearer the truth. At higher frequencies display 'splash' occurs (this can be reduced by using faster transistors), and display brightness suffers (this can be improved by reducing the value of R1 to 2k2).

Low Power Pilot Light



Build yourself this simple circuit to fit inside battery-powered equipment — it will warn you that you have left the equipment on and that you are wasting valuable battery power.

HOW MANY TIMES have you gone to your radio to listen to your favourite program, only to find that the battery is dead because the last time you tuned in you forgot to turn it off? This sort of thing can happen quite often to battery-powered equipment and the chances are you won't have any fresh batteries.

Now, wouldn't it be nice if you could fit a LED pilot light to the equipment to give a visual warning when it has been left on? The problem with such a method is that the current drawn by the LED (about 20 mA) could result in the pilot light using more power than it saves.

A more practical alternative is to use a low power pilot light such as this one. The ETI Low Power Pilot Light flashes a LED for only very short periods, at intervals of about 1s. Because the LED is on for only a small fraction of the total time, the average current consumption is very low. Thus battery life will not be significantly reduced with the use of this project, even if the battery is a small, low capacity type.

A flashing LED pilot light also has the advantage of being more noticeable than a non-flashing type.

Construction

Insert and solder the five resistors into the Veroboard, according to Fig. 2, followed by the two capacitors. Make sure you polarise the capacitors correctly.

Now, mount transistors Q1 and 2, checking before you solder each one in that it is the right way round.

Solder in LED1, the same way round as shown in Fig. 2. Now, bend it down so that it lies in a horizontal line with the Veroboard.

Finally, solder a couple of coloured leads from the corresponding points (red to +9V; black to 0V) long enough to go to the supply points of the equipment into which the project fits.

The circuit board does not need to be fastened down because it is adequately mounted when LED1 is fitted into its panel clip. So, all you need to do now is drill a hole in the panel of your battery-powered equipment to fit the LED panel clip, push in the LED (complete with circuit board) and connect the board to the supply points of the equipment.

Parts List

RESISTORS (All ¼ W, 5%)

R1	1M2
R2	100k
R3	18k
R4	10k
R5	1k8

CAPACITORS

C1	1u0, 16V electrolytic
C2	10u, 16V electrolytic

SEMICONDUCTORS

Q1	MPS6515 NPN transistor
Q2	2N3905 PNP transistor
LED1	0.2" red LED + panel clip

MISCELLANEOUS

Veroboard, 8 strip x 11 hole, 0.1" matrix

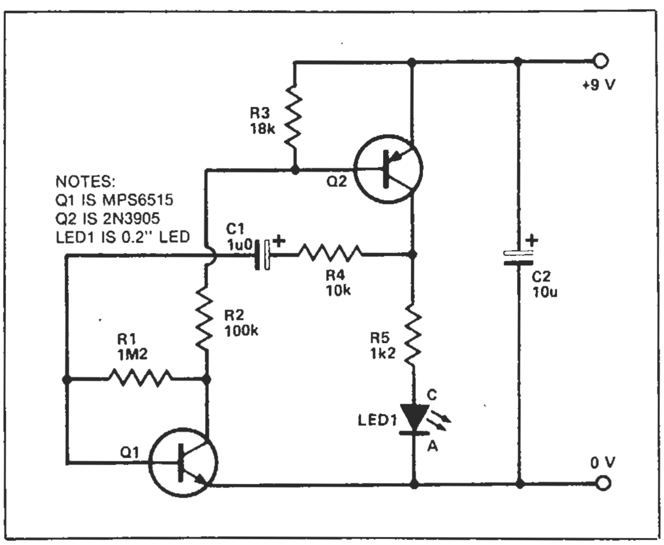


Fig. 1. Circuit of the Low Power Pilot Light.

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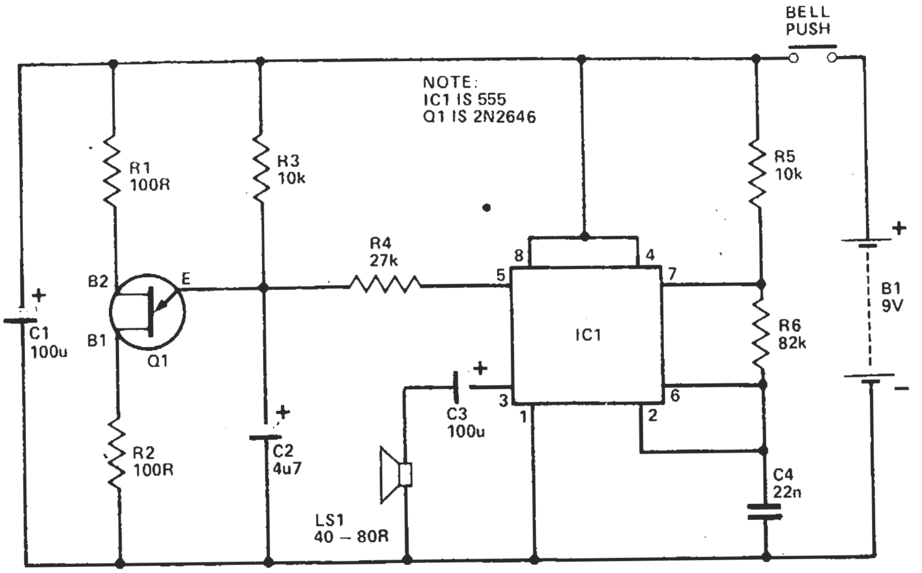


Fig. 1 Circuit of the ETI Electronic Doorbuzzer.

Parts List

Resistors (All ¼ W, 5%)

R1, R2 100R
R3, R5 10k
R4 27k
R6 82k

Capacitors

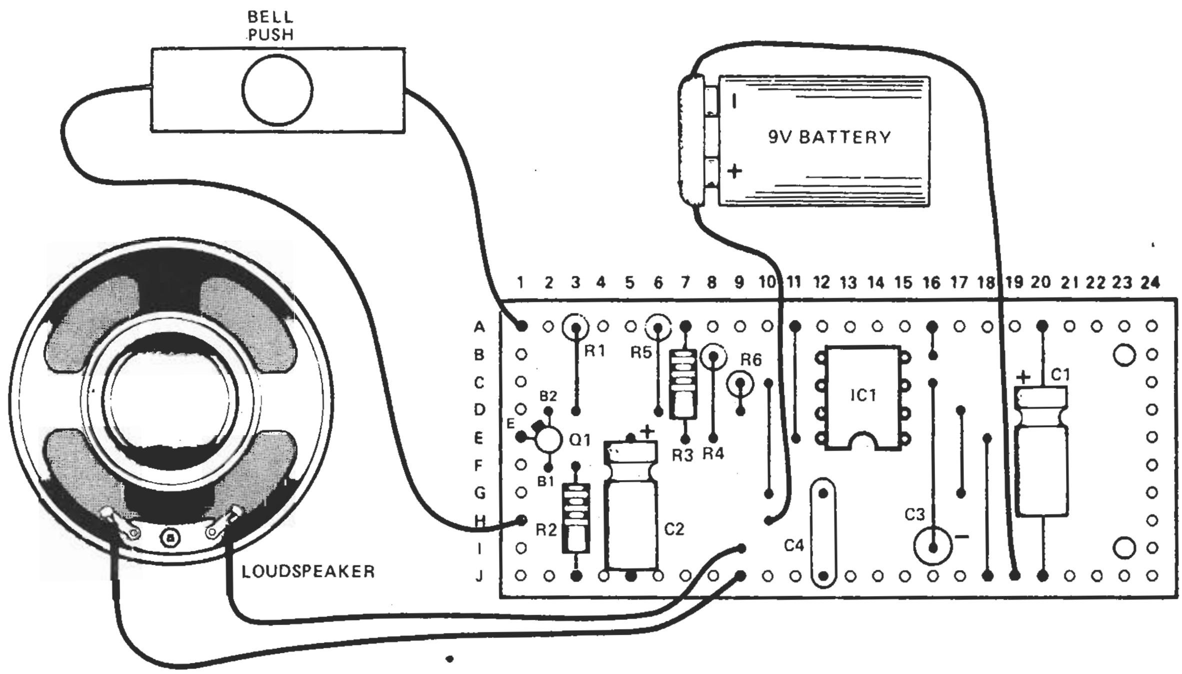
C1,3 100u, 10V electrolytic
C2 4u7, 25V electrolytic
C4 22n polyester

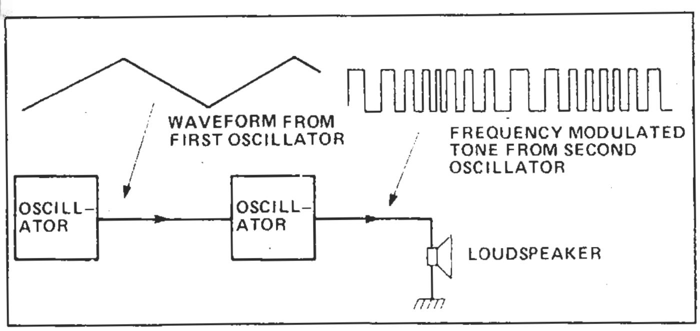
Semiconductors

IC1 555 timer
Q1 2N2646 unijumction transistor

Miscellaneous

LS1 miniature 40-80R loudspeaker
Veroboard 24 hole x 10 strip, 0.1" matrix
Case to suit
9V battery and clip
Doorbell button and connecting cable





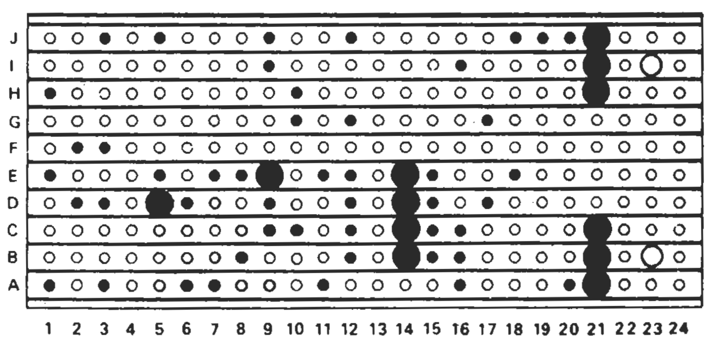


Fig. 2 Veroboard overlay, underside track breaks and component locations, and connection details.