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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

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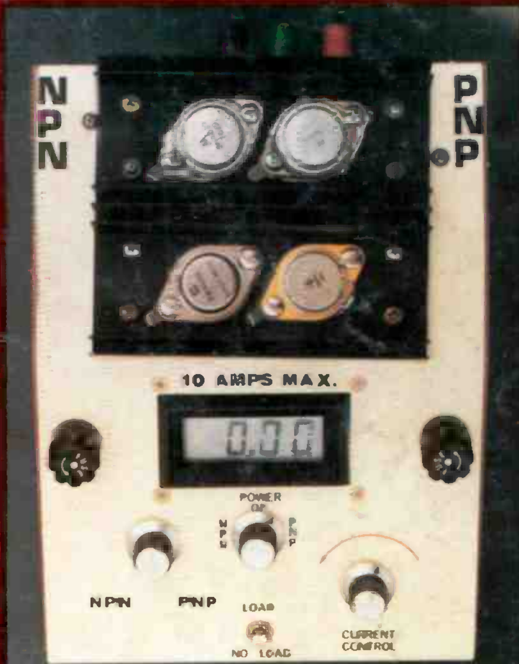
Telephone Call-Screening & Remote Controlling System

Porch Light Controller Deters Burglars

Wide-Coverage Water Detector Sensor



Variable-Load Box & Transistor Tester (p. 40)

Also Featured:

- Variable-Load Box & Power-Transistor Tester
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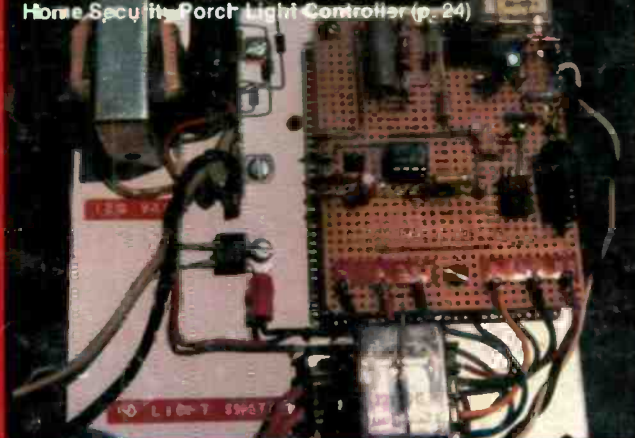

Home Security Porch Light Controller (p. 24)

Infrared-Detector Event Counter (p. 44)

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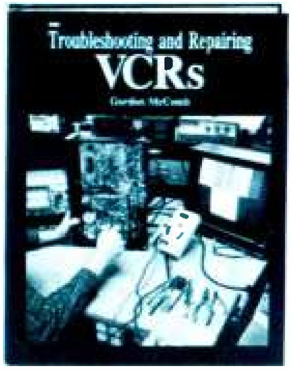

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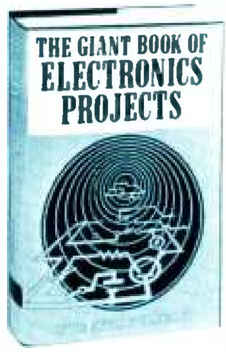

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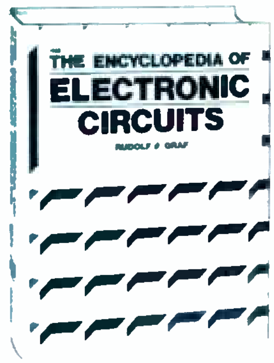

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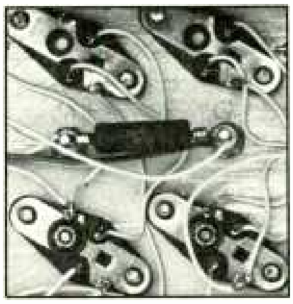
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

JUNE 1990 **VOLUME 7, NUMBER 6**



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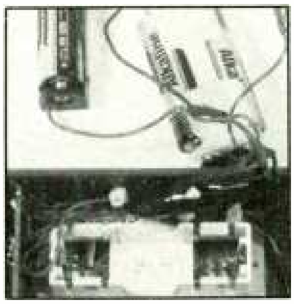

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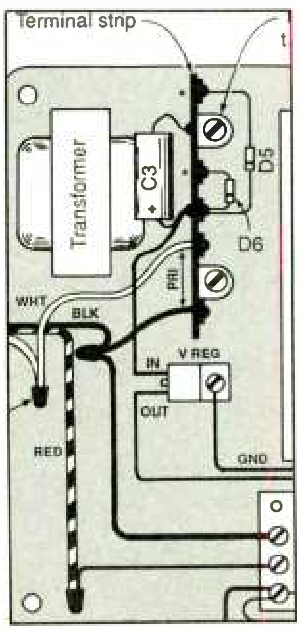

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DEPARTMENTS

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EDITORIAL

Career Upgrading

There are many ways to advance one's career in the electronics and computer fields. Among them is more technical education without pursuing a degree. Aside from reading/studying magazines and books relating to the subject, there are the more disciplined training avenues: home study and class attendance.

Home study courses provide lesson material that the "student" receives through the mail, completes at his own pace, and returns to the institution for correction, grading and guidance. Depending on what's undertaken, it can range from study assignments that will take but a few weeks to a few years to complete.

The big advantage of studying at home is that you can do it in your spare time at your own pace, and you don't have to give up a job to increase your knowledge and skills. Moreover, you can pick and choose what you want to learn, without being forced to plow through subjects that you may consider to be extraneous.

Check out the home-study schools that advertise in *Modern Electronics* to get detailed course descriptions. You may want to also contact the National Home Study Council, which is a home study accreditation institute that sets school standards (National Home Study Counsel, 1601 18th St., N.W., Washington, DC 20009).

Alternatively, there are evening programs and courses offered by local institutions. Among them are private trade and technical schools, community and junior colleges, and colleges and universities. For the former, private trade/technical schools, you might wish to check them out with your local Better Business Bureau and the National Association of Trade and Technical Schools (2021 K St., N.W. Washington, DC 20006). You'll find the other local institutions listed in local telephone directories. And don't overlook the Certified Electronic Technician program (contact ISCET, 2708 W. Berry, Ft. Worth, TX 76109; Tel.: 817-921-9101), which offers certification for

LETTERS

Part Source

• With regard to my "Darkroom Chemical Temperature Controller" (January 1990), readers should be made aware that Fenwal has changed the part number for the GB32P2 thermistor specified for the probe to 121-202-EAJ-Q01. The company suggests Newark Electronics (write to Administrative Offices, 4801 N. Ravenswood Ave., Chicago, IL 60640-3396 or call 312-784-5100 for address of nearest outlet) as a distributor for this item. In the second paragraph on page 31 the three interconnecting wires referenced go to *R12*—not *R13*.

On another matter, be assured that I did not change my name from Johnson to Richardson, which appears at the beginning of my "Color Film Processing Analyzer" in the February 1990 issue. Also, I feel that Fig. 1, compared to my original, loses sight of the separation between the probe and main chassis and the connections carried between the two by the eight-conductor cable. I also think that the text fails to get across that *S1* positions the filter windows over the photocell and simultaneously selects the proper electrical channel.

Maurice P. Johnson

A Matter of Numbers

• In my article "Maximum/Minimum Voltage Detector" (April 1990), resistor *R3* is 221 ohms at 1% tolerance, as shown in the schematic, not the 21 ohms given in the Parts List.

Jan Axelson

Errata

• In the Parts List for the "Big Score" counter display in the February 1990 issue, regulator *IC9* is listed as a 7812 +5-volt device. It should be +12 volts, of course. If a +5-volt regulator was used here, it would catastrophically fail.

On another matter, *Modern Electronics* is a good source of information and useful projects. I've built several of them and have been happy with the way they turned out. Some of the articles, such as professional electronics technicians.

What you study depends on what you need and want, of course. Is it for purposes of embarking on a career in electronics or computers or for upgrading your knowledge for either? For the latter, there are also seminars offered by private companies, associations or manufacturers that set them up for a few days in local areas around the country. Association conventions often include technical seminars, too. The 1990 National Professional Electronics Convention trade show, for example, which will be held at the Las Vegas Riviera Hotel, August 5-11, will include daily high-tech technical seminars. Call 817-921-9061 for more information and reservations. Promoters of the show have special low room prices guaranteed if reservations are made before July 15.

Colleges and universities are at the apex of the formal non-degree educational pyramid. For example, ivy league Columbia University in New York City offers study during evening hours. At the top is its one-year professional training programs in computer technology and applications (CTA programs), as well as short courses and seminars (and computer science degree programs, of course). These consist of courses that can be immediately applied to the work place.

The CTA career program (there's a choice of four programs of study) is not an open-admission one, though. Most applicants hold a college degree, although this is not a requirement if other qualifications indicate a probability of success in the program. There's also a compulsory entrance examination that tests aptitude and familiarity with computing. Upon completing the program, graduates receive a Columbia University official statement and a transcript of courses taken and grades issued. CTA students, by the way, are considered University students, which means they have full access to the its facilities, which include unlimited time in laboratories on a drop-in basis, use of the Physical Fitness Center, the Libraries, etc.

Whatever your training goals are in electronics and computers, there's an educational place to meet your personal needs. There is financial aid available for many of you through schools, government, and employers, too, to sweeten the opportunity. And again, you don't have to give up your present job to embark on a new career or advance a present one.

Even if you already earned a postgraduate degree, which 13.3% of you have according to our research studies, continuing professional education is an imperative in this fast-moving technological age. So go to it if you wish to increase chances to move on to a faster career path.

Art Salsberg

"Electronics Notebook," are very informative and interesting.

Matt Shaw
Bellingham, MA

• I noted errors in the schematic of the "Dual-Polarity Power Supply" featured in the March 1990 issue. Capacitors *C9* and *C10* are shown in reverse polarity and switch *S2A* is shown in the opposite position of all other switches in the circuit.

Kevin Kennedy
Hackettstown, NJ

Poly Suffix

• I would like to correct an error I made in describing the overhead projector film in my "Quick and Easy PC Boards" article that appeared in the April 1990 issue. I inadvertently used the word "polyethylene" instead of the correct "polyester" descriptive.

Bill Eubank

Reminiscences and Observations

• I enjoyed reading Joe O'Connell's "A Tide Clock" in the March 1990 issue of *Modern Electronics*. It brought to mind a similar mechanical clock I saw years ago. That clock used a complicated gearing scheme to generate the tidal display and indicate the locations of the moon and sun, the magnitude of the tide, when the moon aligned with sunrise or sunset, the occurrence of a spring tide (extra high) and when the moon was overhead at noon or midnight.

As I was reviewing the Tide Clock project, I noted another use for it. By setting the frequency to 60.16427496 Hz, a typical amateur astronomical telescope can be made to track the stars with this project. Of course, the tidal frequency will track the moon.

Gary Karshner
Gettysburg, PA

UV Lamp Supplier

• I built the "UV Exposure Light" featured in the March 1989 issue of *Modern Electronics* and am very happy with the result. I'd like to pass on to readers a convenient source for the black-light tubes required for this project. Spencer Gifts, a nationwide chain of stores, sells for $20 its own house brand of one-tube black-light fixtures, which yields one F15T8-BLLB UV tube, a ballast, starter and line cord. The chain also sells the tubes alone for $12 each. If you don't see the tube on display, ask the store manager for it.

Creighton R. Jensen
Tacoma, WA

A Better Switch

• After building the "Switch Multiplier" that appeared in the February 1989 issue of *Modern Electronics*, I noted erratic switch sequencing. I discovered the solution to this problem was to replace the resistor shown as *R5* in Fig. 2 with a wire jumper. This reduces the input impedance to *IC1* and allows the circuit to operate in a predictable manner.

William Herron
San Diego, CA

WIRELESS R-F MODEMS. Ferranti Datacom (Sunnyvale,CA) introduced a wireless radio-frequency modem for fixed or mobile wireless data applications. It operates on up to 52 channels in the 902-928 MHz frequency range. Range is said to be up to 10 miles, with data rates to 9600 bps. The device interfaces with a terminal's RS-232C serial port. The spectrum used was opened under the new FCC Part-15 rules that allows unlicensed use of spread spectrum transmission at 1-watt power.

FORD DRIVING SIMULATOR DISK. The Ford Motor Company offers a new diskette--Ford Simulator II-- that combines details on its new lines of automobiles and a driving simulator game. With the disk(s), available in IBM-compatible 5.25" or 3.5" or Macintosh 3.5" format, all you need is an IBM or compatible PC with 512K memory and CGA color graphics or a Macintosh Plus with 512K or an SE with 800K. The road games are colorful and spirited, providing the user with a variety of challenging choices, from Test Track to Back Roads, with three levels of difficulty. Road games can be operated by keyboard or mouse. Cost is $6.95 including shipping/handling. Call 1-800-462-4356.

COMMODORE 64 PROGRAMMING CONTEST. Brown Boxes, Inc. announced a software contest for the Commodore-64 computer. The company, which produces the "Quick Brown Box" battery-backed RAM cartridge for storing C64 and C128 programs, notes that there are 8-million C64s that exist. The contest seeks a database or spreadsheet program that can be stored in the "Box" and saved to disk. Highly desirable, but not required, is file compatibility with "The Write Stuff" word processor. First prize is $1,000; second is a 256K "Box"; third is a 128K "Box" and fourth is a 64K "Box." There's no entry fee, but to get the full contest rules, you must send 45 cents in U.S. stamps. For "Quick Brown Box" documentation and programming hints, send $2. Entries must be on disk, either 1541 or 1581 compatible. Deadline is September 1. Contact Brown Boxes, Inc., 26 Concord Rd., Bedford, MA 01730.

ELECTRONIC POCKET PRODUCTS. Texas Instruments announced an advanced handheld electronic Thesaurus/Spell Checker that includes a "chaining" feature. It allows users to move from one meaning to other lists of completely different meanings. That is, you can start out with one word and keep selecting one of its synonyms and get synonyms for that word, and so on. It incorporates 590,000 synonyms, hyphenates words properly, and has an "endings" key that lists a word's most common endings to eliminate errors about doubling a final consonant, dropping a letter such as "e," etc.....SelecTronics, Inc., which merged recently with Microlytics, introduced a line of handheld electronic translators based on the Berlitz Phrase Books and Dictionaries. The ROM-cartridge-based product permits extending the information as new cartridges are provided. Called the Berlitz Interpreter, it contains five language translations: English, French, German, Spanish and Italian, with 12,500 words and 300 phrases per language. Users can scroll through phrases and/or switch from language to language. $99.95.

For more information on products described, please circle the appropriate number on the Free Information Card bound into this issue or write to the manufacturer.

Microprocessor-Controlled Four-Digit DMM

Beckman Industrial's new portable four-digit full autoranging digital multimeter, Model RMS225, features a host of interesting capabilities not usually offered in its $149 price class. With four-digit measurement ability, its resolution is 10,000 counts, as compared to a 3½-decade meter's 3,200 counts. A supplemental 41-segment analog bargraph display at the bottom of the LCD window to observe slowly varying signals is one-third better in resolution than provided by 3,200-count meters.

Additionally, the RMS225 is a true rms meter, making possible accurate measurements on non-sinusoidal ac voltages and currents. An Auto Max Min™ function records minimum and maximum readings while remaining in the auto-range mode. Probe Hold™ captures a stable reading, beeps an acknowledgment and holds the reading in the display until the user is ready to view it, even after removing the probes from the test points. It updates the reading with each new measurement. A RELATIVE mode permits zeroing out test-lead resistance and determining the difference between two measurements. A self-resetting electronic "fuse" protects the current ranges to 40 mA.

Simplified operation is a key feature of this DMM. A built-in microprocessor controller provides this via a series of three pushbutton switches and the LCD display. A MENU button displays a menu of special function choices and steps through them. When the cursor is on the desired choice, a SELECT button is pressed to activate it. To exit the function and return to normal power-up state, a CLEAR button is pressed. All of this can be done intuitively with the thumb of the hand that holds the meter.

Automatic power down, except in Min Max mode, conserves battery life. An Overload Alert™ audibly warns when input ratings are exceeded, an audible beep sounds during continuity tests, and a lethal voltage indicator appears in the display when hazardous conditions exist during a test.

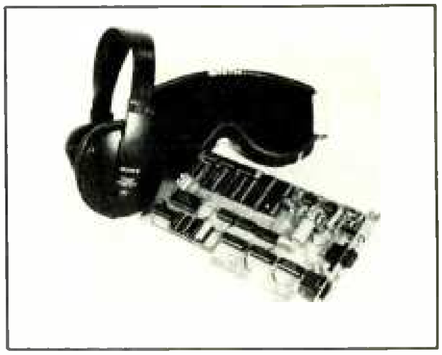
The RMS225 measures ac/dc voltages to 1,000/750 volts with 1,000 μV/1 mV resolution and 0.25/1.0% basic accuracy; ac/dc current to 10 mA, 40 mA and 10 amperes with 1 μA resolution; and resistance up to 40 megohms, with overload protection to 500 volts.

A soft plastic holster protects the meter from accidental drops, provides a means for propping the meter at either of two viewing angles and provides storage for the probes. It also doubles as a protective cover by placing the meter in it face-down during storage. The attached Flex-Strap™ can be bent to permit the meter to hang from a pipe, hook, etc. The Model RMS225 measures 6¾" × 2⅞" × 1¼".

CIRCLE NO. 79 ON FREE INFORMATION CARD

Light/Sound Pattern Generator for PCs

Synetic Systems, Inc.'s (Seattle, WA) MindsEye Synergizer plug-in board



turns IBM PC, XT, AT, 386 and compatible computers into a laboratory-grade audio/video synchronizer. Although usable with a monochrome monitor, MindsEye offers better programming control for the two inputs when used with color screen graphics to assist in setup of the two program inputs. The system allows the user to program sessions of almost any length and complexity.

Included software provides full flexibility in programming the board. Each eye and ear can be programmed to shift from one to another independently, and as many as 32,768 separate ramps and levels can be included in a single session. A session may cause the lamps and sounds to begin pulsing in the 20-Hz beta brainwave region and gradually drop to the 8- to 12-Hz alpha or 4- to 7-Hz theta regions.

The board generates precise patterns of pulsating light and sound via special goggles and headphones. These pulses are claimed to "train" the electrical activity in the brain, causing dominant brain-wave rhythms to fall into lock-step with the pulsating patterns. Eight flashing LEDs inside the goggles induce semi-psychedelic geometrical images. Light brightness, sound volume level and other parameters are controlled directly from the keyboard or an optional control unit.

The stereo synthesizer is programmed by a separate screen to allow the user to select a variety of waveforms, filters and other sound

(Continued on page 12)

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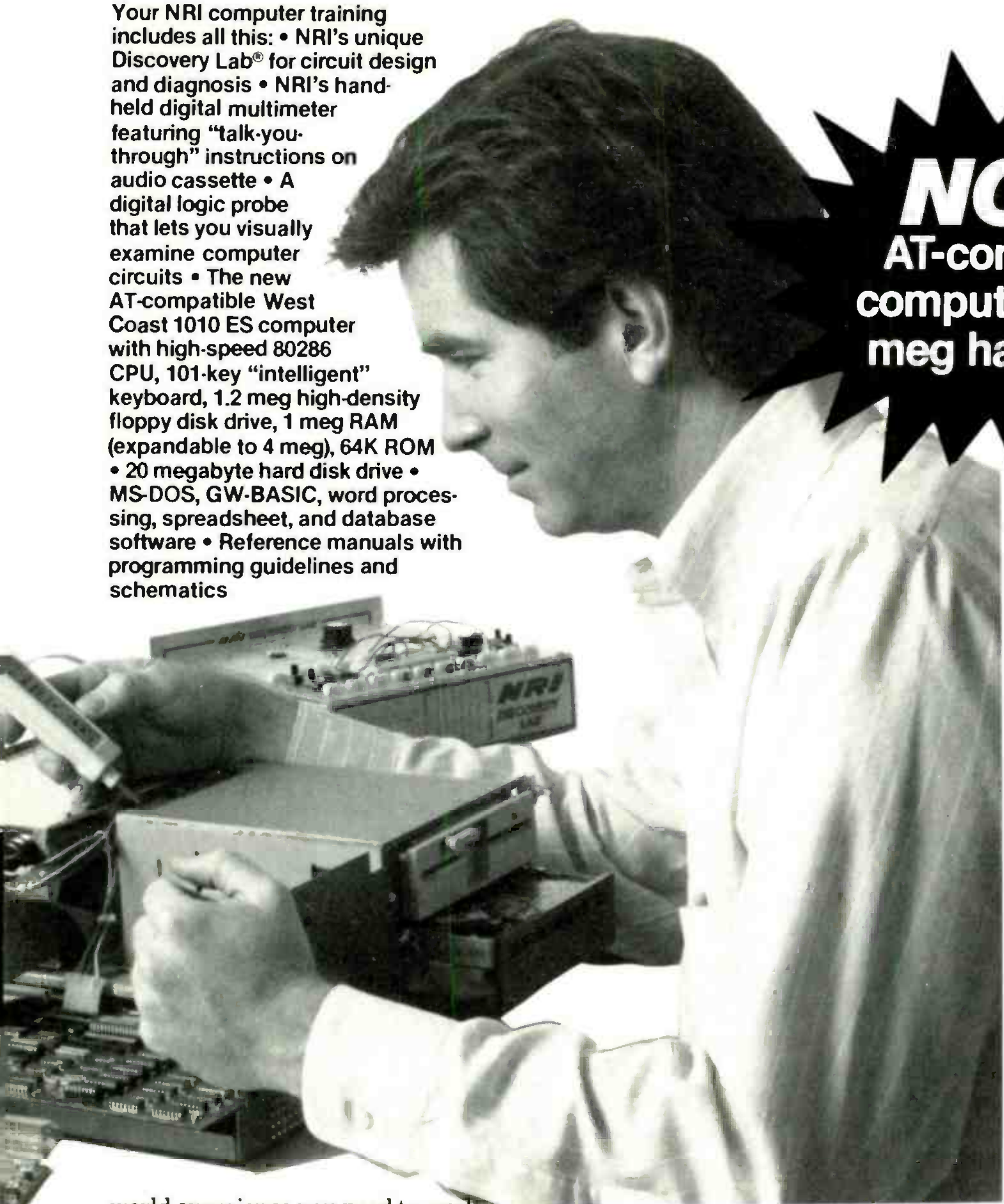

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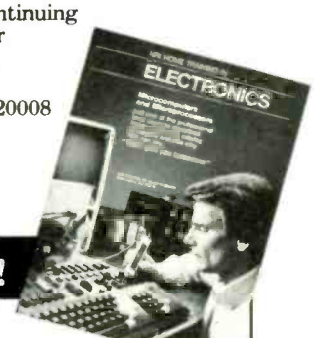

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parameters. Requires DOS 3.0 or later, 512K of RAM and hard drive. $395, Synergizer and goggles; $35, headphones; $95, optional external control unit.

CIRCLE NO. 80 ON FREE INFORMATION CARD

SVHS Video Processor

Vivanco's new Model 3066 video processor (available from GMI Photographic, Farmingdale, NY) can handle Super VHS, HI-8 and composite video signals. It provides a 750-line resolution capability with a 7.7-MHz bandwidth for superior pic-

ture definition. Switching functions are all solid-state in design and LEDs provide status indication.

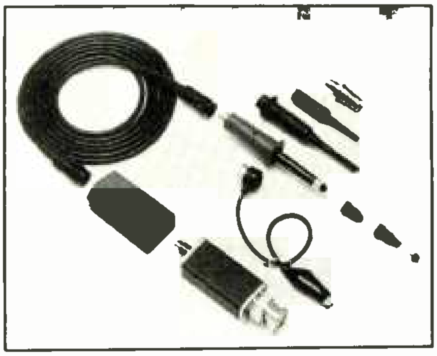
In stereo, or as monophonic signals, three individual audio fade controls can be used to mix or insert audio tracks for dramatic sound effects. This is in addition to the master fade control provided. Frequency range of the audio section is a linear 20 Hz to 20 kHz with a 70-dB S/N.

The processor can duplicate up to four copies simultaneously while maintaining the same high-quality signal strength due to a special built-in power distribution amplifier. The sleek Euro-style packaging features a matte-black finish and aircraft-style lever type fade controls.

CIRCLE NO. 81 ON FREE INFORMATION CARD

Repairable 300-MHz Scope Probes

Test Probes Inc. (San Diego, CA) now has thin-cable 300-MHz repairable probes that fit all makes of oscilloscopes with 1-megohm inputs. They have a sawtooth-shaped center



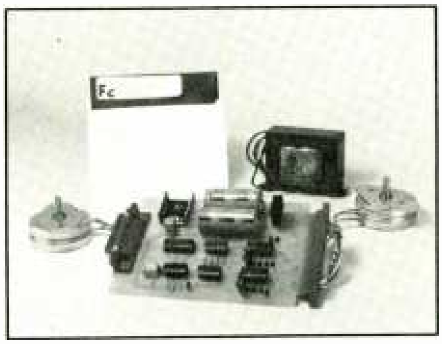
conductor that is claimed to eliminate microphonics and provide superior resistance to breakage from pulling and bending for longer useful life. The cable is thinner and more flexible than its straight-conductor counterparts.

These modular probes screw together without soldering for on-site repairs and are claimed to have a more secure contact than snap-together probes. The probe provides measurements with less than 3% overshoot and 1.2-ns risetime. Some models have an activator pin for readout and scale factoring on oscilloscopes that have this feature. $74.

CIRCLE NO. 82 ON FREE INFORMATION CARD

Stepper-Motor Controllers

Future Circuits (Fullerton, CA) has a line of stepper-motor controllers for use with IBM and compatible com-



puters. The parallel-input controller boards require a 12-volt ac power transformer capable of delivering 4 amperes of current to operate. Each 6″ × 4.5″ board controls two multiple-axis, 48-step motors and is expandable to 16 motors on one interface. Each board is also individually addressable. Supplied with each motor controller board is the required stepper-motor software on a 5.25-inch floppy disk. $199.95.

CIRCLE NO. 83 ON FREE INFORMATION CARD

Wireless Security Alarm

Dicon Systems' (Willowbrook, IL) 3000 wireless Home Burglar Alarm has a built-in telephone dialer, emergency message system and computerized vocal central console. The system monitors itself and reports its status. The vocalizing central console guides the user through a brief set-up procedure and provides messages in regular use. The console has a built-in microphone for recording into digital memory a 15-second message.

When it detects an intrusion, the console automatically places calls to

up to four numbers entered during initial set-up. The system then plays the recorded message several times to the answering party, automatically hangs up and dials the next number. The message system is also compatible with professional digital monitoring stations.

The console monitors the power level of its back-up battery and signals when replacement is needed. In use, the console identifies which module triggered the alarm and reports this information to the user. The basic system comes with a motion-detecting sensor that can be placed anywhere within 500 feet of the console. A variety of additional wireless sensors for various applications and a remote-control keypad are available as extra-cost options. The miniature sensor/transmitters communicate with the central console via radio link and use 16-bit digital encoding to assure system reliability and integrity. Each "checks in" with the console every hour to confirm that it is operating properly and that battery power is adequate.

Sensor/transmitters are powered by 9-volt batteries that last about a year. A low-battery signal is sent to the console about a month before the battery needs replacing. The console vocally informs the user which sensor needs a new battery and repeats the message every time the system is armed until the battery is replaced. If the battery dies, the console tells the user that that sensor/transmitter is not working.

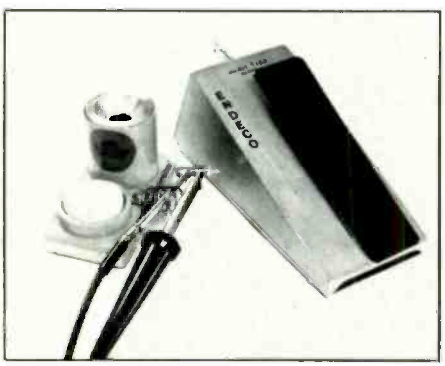
Up to 30 sensors and any number of remote keypads can be used with one Dicon 3000 system. $399.

CIRCLE NO. 84 ON FREE INFORMATION CARD

Foot-Actuated Vacuum Desoldering Station

The Endeco Model 7300 spike-free power vacuum desoldering station from Leads Metal Products, Inc. (Indianapolis, IN) is a foot-operated console that sits on the floor, freeing valuable bench-top space. It uses a patented desoldering process of timed maximum vacuum followed by a rapid expulsion of contaminants.

A 20/40-watt (750° to 950° F) iron enables the user to heat leads and de-



solder quickly to prevent overheating the board and neighboring components. The powerful instantaneous vacuum pulls solder quickly through multi-layer boards and tight lead-to-hole clearances. Conformal coating, contaminants and spent solder are ejected into a receptacle to eliminate clogging. There are no filters to replace and no collection chambers to disassemble and clean.

The gold-anodized console measures about 10" × 4" and has a slanted front panel with foot actuator. It operates on standard shop air pressure between 40 and 120 psi. The desoldering station comes with a 20/40-watt heating element, combination spittoon-iron holder and eight desoldering tips. Another version, the

(Continued on page 79)

Dual-Application Telephone Security System

(Part 1)

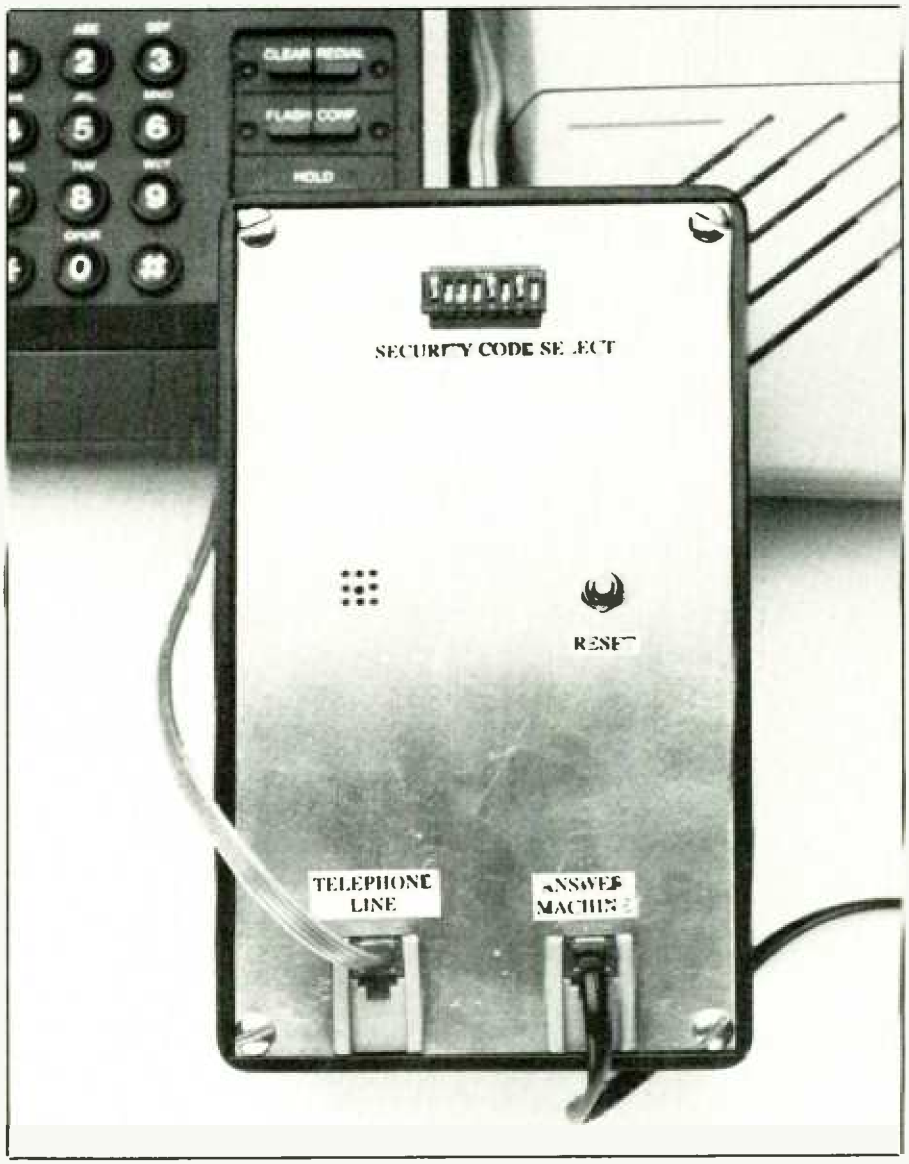
Circuit operating details for automatic screening of incoming telephone calls and calling in to remotely control an electrically operated device

By Anthony J. Caristi

If you now own a telephone answering machine, equipping it with the Dual-Application Telephone Security System device described here allows your telephone to ring only when a caller keys in a security code from a Touch Tone-type telephone. You select the code and can change it at any time or defeat it. With this automatic screening feature, only those people who know your code can get through.

In addition to call screening, our Dual-Application Telephone Security System can be used by you to call in and remotely activate any electrical device in your home or business when you enter the security code via the telephone keypad. This can be handy for turning on a light, air conditioner or heater before you arrive home. Moreover, the sophisticated coding system gives you a large measure of control security, unlike the case with the simple code generally used by such devices, and shared in common by all owners.

It is not necessary to have a telephone answering machine to be able to take advantage of either function available with the Security System. You can build an optional low-cost "Answer Module" to take the place of the answering machine. This auto-



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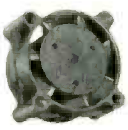

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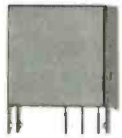

Module operates on 5VDC, board mountable. $^{5}/_{8}$ x $^{1}/_{2}$ x $^{19}/_{32}$". With data. #276-137

Simplifies IR Design

IC Tool Set

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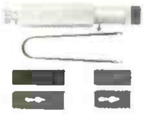

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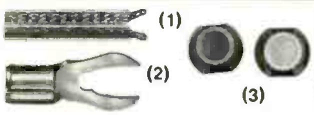

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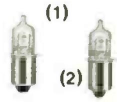

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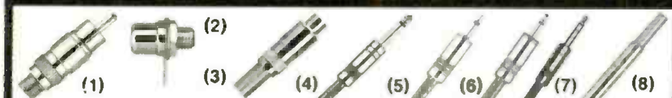

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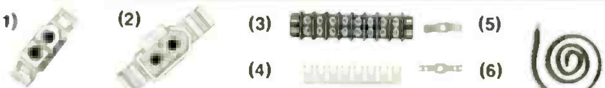

Fig.	Pos.	Type	Amps	Cat. No.	Each
1	2	Male	20	274-151	.99
-	6	Male	15	274-152	1.69
-	12	Male	12	274-153	1.99
-	2	Female	20	274-154	.99
2	6	Female	15	274-155	1.69
-	12	Female	12	274-156	1.99

(3) **2-Row Strip.** #274-670 . . . 1.99
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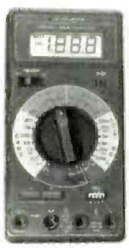

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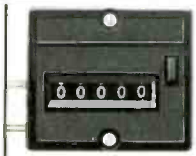

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CIRCLE NO. 64 ON FREE INFORMATION CARD

matically answers any call so that the security code can be keyed in by the person calling your number.

This month, we discuss the circuit operating details of the Security System, an optional Answer Module that takes the place of a telephone answering machine and a series of interfacing circuits for controlling appliances. Next month, in the conclusion of this article, we will discuss construction of the project, testing it out and installation and use of the system.

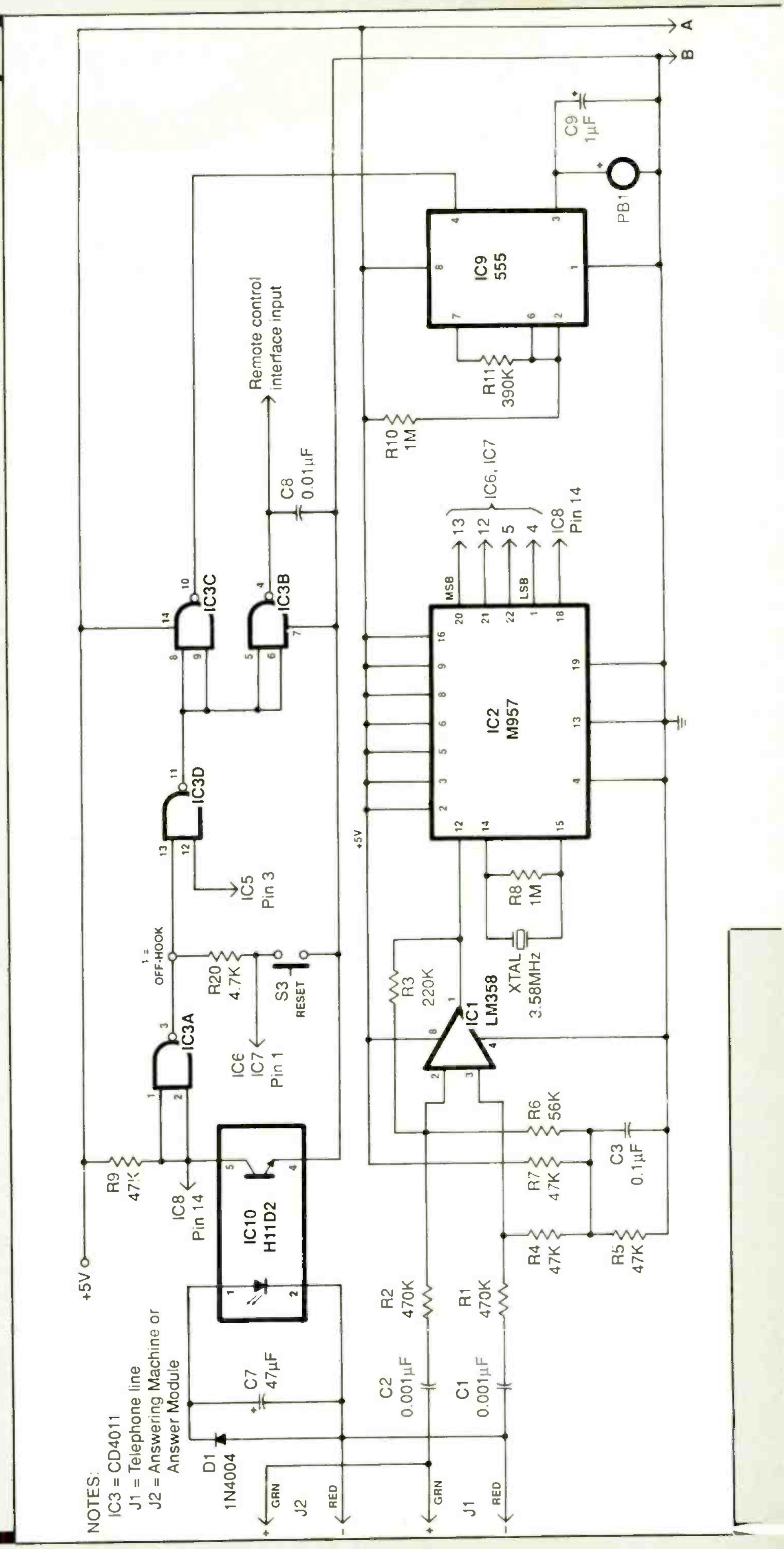
System Details

When used with an answering machine, the outgoing message tells the caller to enter the security code that calls you to the phone or to leave a message if you are not available to pick up the receiver. If a caller does not know the code, your telephone does not ring.

The security code consists of two digits you program and which can be changed at any time simply by setting a set of switches on the project. You must give the code to any callers you wish to have the code and advise them how to key in the code from a Touch Tone-type telephone instrument.

When a caller keys in the correct code, a ring signal is initiated to alert you that the caller is someone you wish to get through to you. Should a caller not know the code, he has the option of leaving a message or not on your answering machine. As you may have surmised, the answering machine operates in the normal way.

When the project is equipped with the optional Answer Module in place of an answering machine, this module automatically answers any incoming call. There is no outgoing message to advise the caller to enter the security code, and the caller hears only silence. If you already have given the code to those people you want to have it, the caller will know to enter the code when the device answers the call. If no or an incorrect code is entered, your phone will not



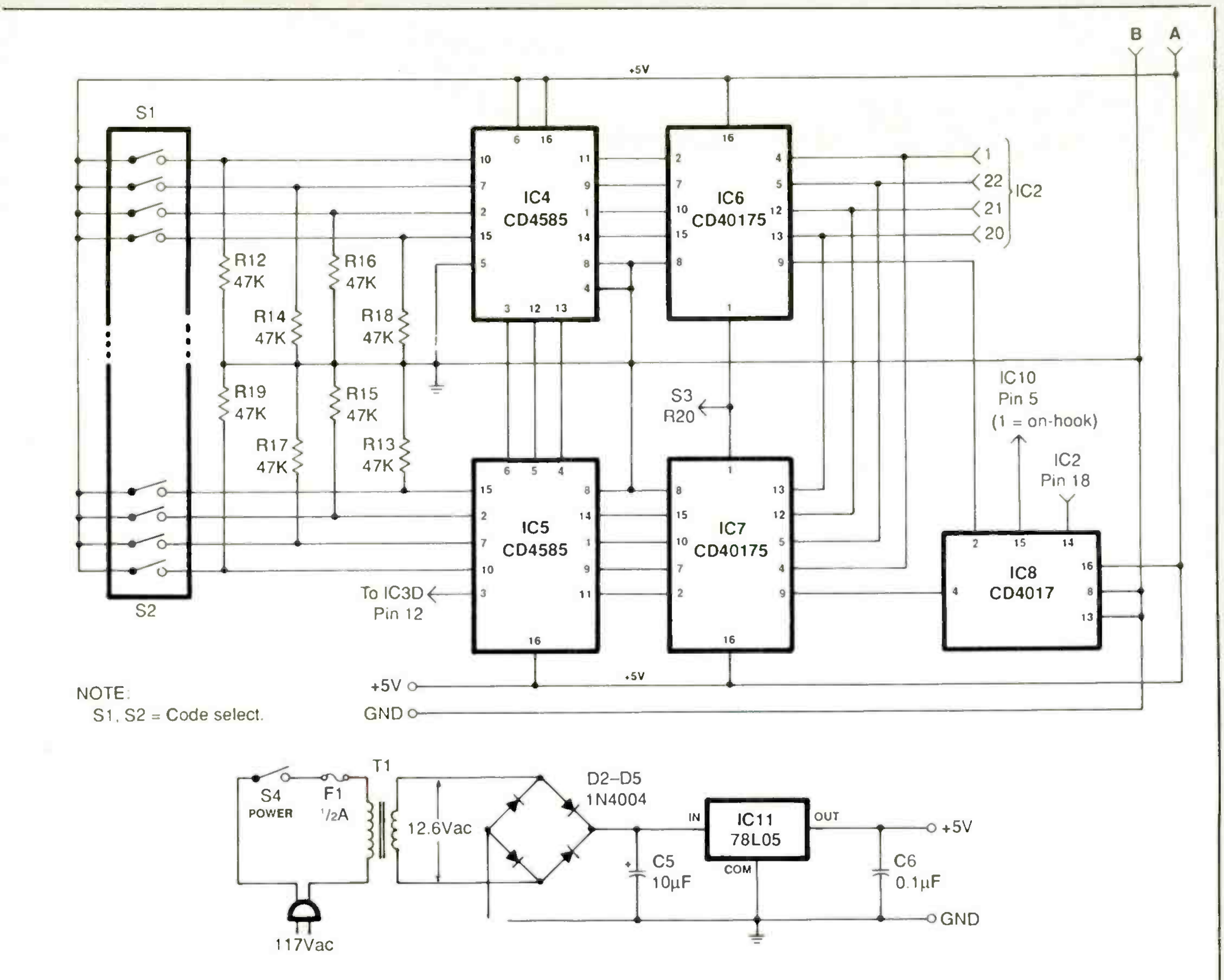


Fig. 1. Complete schematic diagram of the basic Dual-Application Telephone Security System.

ring and the caller is disconnected in about 30 seconds.

When the project is used as a remote-control device, you call your number from any telephone. The call is immediately answered by the answering machine or Answer Module. When the proper security code is keyed in, the electrical device connected to the project is activated. You can rig the system that allows one call to be used to turn on a device and a second call to turn it off.

This Security System is especially useful when you do not wish to be bothered by all kinds of undesirable calls such as people wanting to sell you this or that, which often seem to come just as you are about to enjoy dinner. It is also a handy telephone accessory when operated late at night when you do not want to take any calls except from certain people.

It is also possible to set up a two-tier system with two discrete codes, one to give access to acquaintances and the other to give access to family members. This allows you to set your security system to be activated at late nighttime hours by only your immediate family members in the event of an emergency.

About the Circuit

The complete schematic diagram of the Dual-Application Telephone Security System is shown in Fig. 1. The heart of the circuit is *IC2*, a complete dual-tone multi-frequency (DTMF) receiver chip that contains all the circuitry required to properly decode the frequencies that appear across the telephone line when any of the telephone keyboard buttons are pressed. This chip utilizes a 3.579-MHz colorburst crystal and internal divider stages.

Connected as a differential amplifier *IC1* couples to the telephone line by means of high-impedance RC networks *R1/C1* and *R2/C2*. The output of this op amp drives the analog input of DTMF receiver *IC2*, which now processes any valid Touch Tone signals on the line.

Switched-capacitor and digital fre-

Table 1. IC2 Hex Output Values

Keypad Digit	Hexadecimal Code 8	4	2	1*
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
–	1	1	0	0

* Binary values at pins 20, 21, 22 and 1, respectively

quency-measuring techniques are used in *IC2* to provide a 4-bit digital code containing hexadecimal information that identifies the digit of the telephone pushbutton pressed by the caller. A truth table that illustrates the logic levels of the hexadecimal outputs of the chip at pins 20, 21, 22 and 1 is shown in Table 1. Pin 20 represents the most-significant bit (MSB), pin 1 the least-significant bit (LSB). Chip *IC2* can detect the * and # codes of the telephone keypad. An additional "strobe" output at pin 18 of *IC2* goes high whenever a valid DTMF frequency pair is detected by this integrated circuit.

When a call is received, the telephone answering machine or optional Answer Module captures the call. A dc current then flows from the telephone line into the answering device. This current is sufficient to illuminate the LED in optoisolator *IC10*, which switches the internal phototransistor into conduction.

When the call is answered, the collector of the phototransistor inside *IC10* draws current through *R9* and goes to almost zero volt. Therefore, the logic level at pin 5 of *IC10* can be used as an on/off-hook signal. When in the on-hook standby condition, pin 5 is high. When a call is answered the logic level goes to zero, indicating that an off-hook condition exists.

Connected as an inverter, NAND gate *IC1A* provides reverse logic levels of the on- and off-hook conditions at output pin 3. Decade counter *IC8* provides a high logic level at one of its 10 outputs, depending upon the count. When the phone is on-hook, the logic 1 condition at RESET input pin 15 causes the counter to be set to zero. As a result, 0 output pin 3 is high and all other pins are low.

When the incoming call has been answered and the caller keys in the first digit of the security code, the STROBE output pin 18 of *IC2* goes high. The resulting positive edge of the pulse, fed to the clock input of *IC8*, causes the counter to advance one count to 1. In turn, this causes pin 2 of *IC8* to go high, since the counter has been advanced from 0 to a count of 1. The rising pulse waveshape at pin 2 of *IC8* is fed to the CLOCK input at pin 9 of quad type D flip-flop *IC6*.

When the caller presses the first digit of the security code, the hexadecimal data that contains the identity of the digit is contained in the 4-bit output of *IC2*, as illustrated in Figure 1. Fed to the data inputs of *IC6*, this information is latched by the rising clock pulse generated at pin 2 of *IC8*. Hence, the four bits that contain the identity of the first digit appears at the outputs of *IC6* and remains stored there.

When the second digit is keyed by the caller, the sequence just described is repeated. In this case, counter *IC8* advances from a count of 1 to a count of 2, pin 4 goes high and clocks *IC7*, and the identity if the second digit is stored in the output register of *IC7*.

Cascaded 4-bit comparators *IC4* and *IC5* compare the 8-bit digital information stored in *IC6* and *IC7* to the data contained in security code selector switches *S1* and *S2*, as chos-

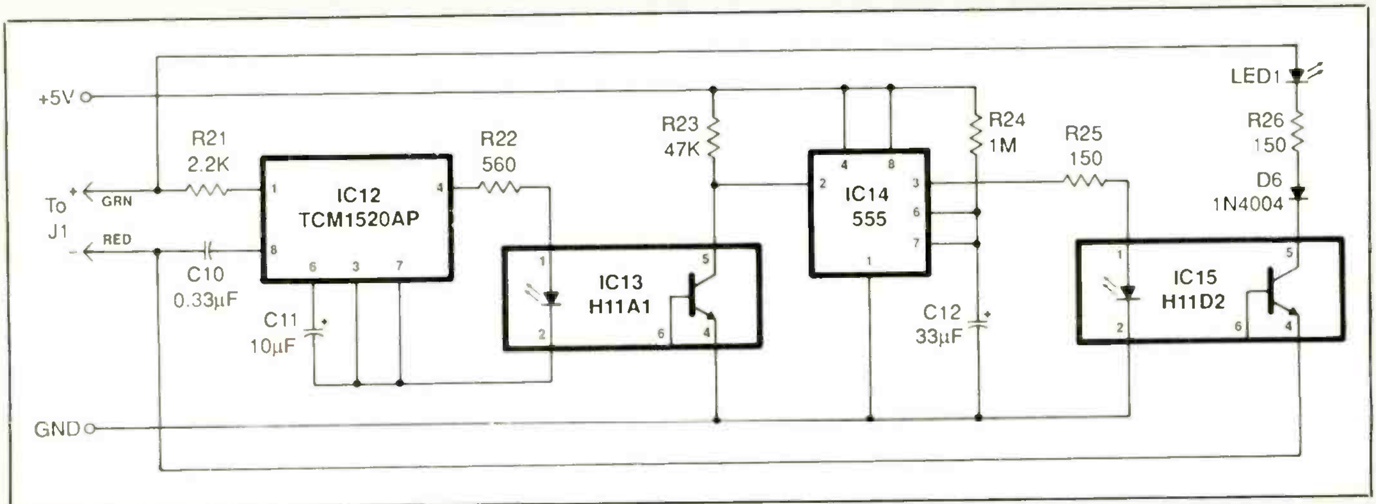


Fig. 2. Circuitry for an optional Answer Module that takes the place of a telephone answering machine.

en by you. Note that *S1* and *S2* are each composed of four positions of an eight-position DIP switch.

Each magnitude comparator has two sets of 4-bit inputs—at pins 10, 7, 2 and 15, and at pins 11, 9, 1 and 14. Thus, each magnitude comparator can compare the 4-bit digital word fed to one set of inputs with the 4-bit digital word fed to the other set and provide a high-level output at pin 3 when the two words are identical. With *IC4* and *IC5* connected in cascade, eight bits stored in *IC6* and *IC7* can be compared to the eight bits of data supplied by *S1* and *S2*.

The eight-position DIP switch that makes up *S1* and *S2* allows you to set the hexadecimal code of any pair of digits for the selected security code. When any switch position is open, the logic level to the corresponding input of *IC4* or *IC5* is zero. When a switch position is closed, the + 5-volt

PARTS LIST

Main Circuit

Semiconductors
D1 thru D5—1N4004 or silicon rectifier diode
IC1—LM358N operational amplifier
IC2—M957-20 DTMF receiver (Teltone)
IC3—CD4011B quad 2-input NAND gate
IC4,IC5—CD4585B 4-bit magnitude comparator
IC6,IC7—CD40175B quad D-type flip-flop
IC8—CD4017B Johnson decade counter
IC9—LM555CN timer
IC10—H11A1 or equivalent optical isolator
IC11—AN78L05 fixed + 5 volt regulator

Capacitors
C1,C2—0.001-μF, 300-volt ceramic disc
C3,C6—0.1-μF, 50-volt ceramic disc
C4,C9—1-μF, 10-volt electrolytic
C5—10-μF, 25-volt electrolytic
C7—47-μF, 10-volt electrolytic
C8—0.01-μF, 50-volt ceramic disc

Resistors (1/4-watt, 10% tolerance)
R1,R2—470,000 ohms
R3—220,000 ohms
R4,R5,R7,R9,R12 thru R19—47,000 ohms
R6—56,000 ohms
R8,R10—1 megohm
R11—390,000 ohms
R20—4,700 ohms

Miscellaneous
PB1—Piezoelectric buzzer (Radio Shack Cat. No. 273-060 or similar
J1,J2—Chassis-mount modular telephone jack
S1,S2—Eight-position spst DIP switch (see text)
S3—Normally-open spst pushbutton switch
S4—Spst toggle or slide switch
XTAL—3.58-MHz colorburst crystal
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure; sockets for all DIP ICs and S1/S2 assembly; modular connectors; machine hardware; hookup wire; solder; etc.

Answer Module

Semiconductors
D6—1N4004 or similar silicon rectifier diode
IC12—TCM1520AP ring detector (Texas Instruments)
IC13—H11A1 or equivalent optical isolator
IC14—LM555CN timer
IC15—H11D2 or equivalent optical isolator
LED1—2-volt, 20-mA light-emitting diode

Capacitors
C10—0.33-μF, 250-volt Mylar or paper
C11—10-μF, 50-volt electrolytic
C12—33-μF, 10-volt electrolytic

Resistors (¼-watt, 10% tolerance)
R21—2,200 ohms
R22—560 ohms
R23—47,000 ohms
R24—1 megohm
R25—150 ohms
R26—150 ohms (½-watt)

Miscellaneous
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for DIP ICs; machine hardware; hookup wire; solder; etc.

Interface Circuits

Semiconductors
D7,D8—1N4004 or similar silicon rectifier diode
IC16,IC17—MOC3011 or equivalent optical isolator
IC18—LM555CN timer
SCR1,SCR2,SCR3—MCR100-4 or similar sensitive-gate silicon-controlled rectifier
Q1—6-ampere, 200-volt triac (Radio Shack Cat. No. 276-1000 or similar—see text)
Q2—2N3904 or similar npn silicon transistor

Resistors (¼-watt, 10% tolerance)
R27,R31,R34,R38—2,200 ohms
R28,R32,R35—10,000 ohms
R29,R33—220 ohms
R30—150 ohms
R36,R37—4,700 ohms

Miscellaneous
K1,K3—5-volt dc relay with spst or spdt contacts (Radio Shack Cat. No. 275-243 or similar—see text)
K2—117-volt ac relay with 10-ampere spdt or dpdt contacts (Radio Shack Cat. No. 275-217 or similar—see text)
S5,S6,S7—Spst toggle or slide switch
S8,S9—Normally-open, momentary-action spst pushbutton switch
Machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Ready-to-wire main pc board, $19.75; Answer Module pc board, $9.75; LM358N, $1.75; M957, $18.75; CD4011, $1.75; CD4585, $3.95 each; CD40175, $3.75 each; CD4017, $1.75; AN78L05, $1.50; TCM1520AP, $6.75; optoisolators, $3.95 each (state quantity and type number); MCR-100, $1.95 each. Add $2.50 P&H per order. New Jersey residents, please add sales tax.

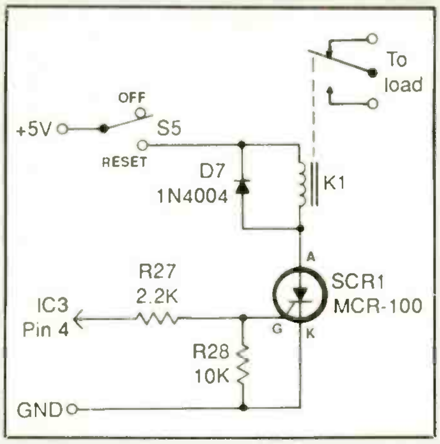


Fig. 3. A simple relay interface.

bus is connected to the input pin of the IC it is wired to and provides that pin with a logic high. Note that valid inputs are for any number from 1 to 12, which correspond to the 12 pushbuttons on the telephone keypad (0 on the keypad is 10).

With *IC4* and *IC5* connected in cascade, the "equal" output at pin 3 of *IC5* assumes a high condition only when the data inputs of the switches are identical to the data stored in *IC6* and *IC7* output registers. For all other conditions, pin 3 of *IC5* remains at logic low. A high condition at pin 3 of *IC5* means the caller has entered the correct code. This change in logic level can be used to control subsequent circuitry.

Although this project has been designed to be operational with just a two-digit security code, the basic circuitry can be easily expanded to accommodate codes containing three or more digits because *IC8* can count to 9 and provide clock pulses to one or more additional D type flip-flop circuits. Any additional digits in the security code also require magnitude comparator chips connected in cascade with *IC4* and *IC5*.

NAND gates *IC3A*, *IC3C* and *IC3D* provide a logic high at pin 4 of *IC9* only if the correct security code has been entered. For any other situation, including an on-hook condition, pin 4 of *IC9* remains at logic low.

Timer *IC9* is wired as a free-running (astable) multivibrator. When RESET pin 4 is high, the circuit oscillates at a frequency determined by the time constant of *R10*, *R11* and *C4*. This time constant is chosen to provide a 1 second on, 1 second off ringing signal.

When *IC9* is enabled, sound generated by piezoelectric buzzer *PB1* alerts you that the caller has entered the proper security code. The ring signal is automatically silenced when the call is disconnected, but a RESET switch *S3* allows you to silence it when the call is answered.

In summary, when the telephone circuit is not in use, the-on-hook logic condition detected by *IC10* causes *IC8*, *IC6* and *IC7* to be reset to zero. Pin 3 of *IC5* is held low, inhibiting *IC9* and silencing *PB1*. When a call comes in, the telephone answering machine or Answer Module captures the call. The circuit then responds to the Touch Tones generated by the caller, and the first two digits entered are stored in *IC6* and *IC7*. Should this be the correct security code, *IC9* is enabled and activates *PB1*. For any other code, the buzzer remains silent.

When the project is used as a remote-control device, the logic high generated at pin 4 of *IC3B* in response to the correct security code activates any type of slave circuitry, such as a relay, triac, etc.

Power to operate the circuit is provided by transformer *T1*, the bridge-rectifier arrangement made up of *D2* through *D5*, regulator *IC11* and capacitors *C5* and *C6*.

The schematic diagram for the optional Answer Module that can be used in place of an answering machine is shown in Fig. 2. In this circuit, *IC12* responds to the 90-volt, 20-Hz ring signal that appears across the telephone line when a call is received. This chip contains a bridge rectifier, regulated supply and control circuitry that normally presents a very high impedance to the telephone line when dormant. When a ring signal is coupled to *IC12* through *R21* and *C10*, the circuit uses the energy of the 90 volts ac to generate a regulated 5 volts dc potential between pin 4 and pins 3 and 7.

Optical isolator *IC15* operates in the same manner as *IC10* in Fig. 1. When a call is received, current generated by *IC15* causes the internal LED to turn on, causing on the internal phototransistor to conduct. The resulting negative pulse at pin 5 of *IC15* triggers the next stage.

Timer *IC14*, connected as a monostable or one-shot multivibrator, has a timing cycle of about 30 seconds,

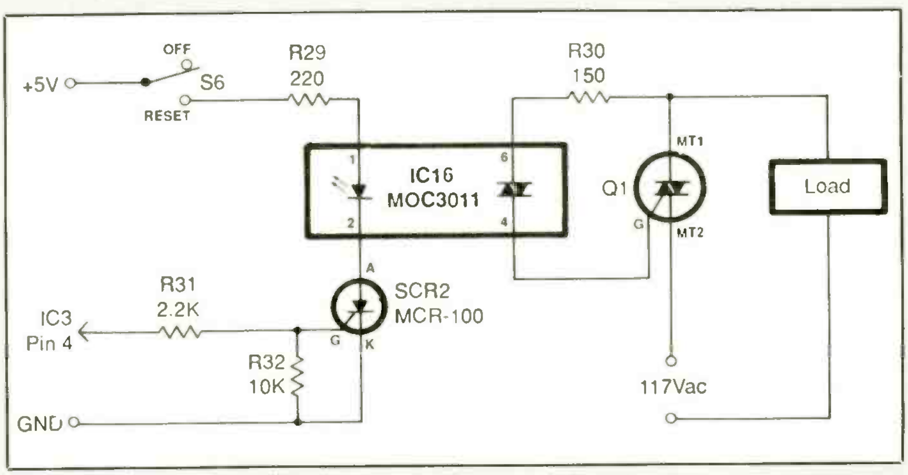


Fig. 4. A triac interface to drive an ac load in which optical isolators provide isolation from the ac power line.

determined by the values of *R24* and *C12*. When the circuit is in standby, output pin 3 of *IC14* remains low. A ring signal on the telephone line causes the output of *IC14* to go to about 3 volts, which initiates the timing cycle. At the end of the timing cycle, pin 3 returns to low.

When *IC14* is active, the output at pin 3 causes the LED inside *IC15* to turn on and cause the internal phototransistor to conduct. This essentially connects *R26* across the telephone line and, in effect, answers the call. Current from the telephone line causes *LED1* to turn on, providing visual indication that the line has been seized by the Answer Module.

The telephone line is captured during the 30-second timing cycle of *IC14* and provides sufficient time for the security system to respond to the security code if properly entered by the caller. It also allows time for you to answer the call, if so desired, which prevents automatic disconnect when *IC14* times out. If the call is not answered, the caller is disconnected at the end of the timed cycle, even if he has entered the correct security code. The timed cycle of *IC14* can be easily modified to suit your requirements by changing the value of *C12*.

The Answer Module contains two optical-isolator circuits, *IC13* and *IC15*, that provide complete isolation between the telephone line and circuitry of the project. This prevents any possible interference between the project and telephone system and ensures normal telephone performance.

Slave Circuits

When the project is to be used to remotely control electrical devices, you need some kind of interface to provide a connection between the code-recognition circuitry at pin 4 of *IC3* in Fig. 1 and the device to be controlled. There is really no limit to what you can control. The following examples are representative of what types of interfaces you can employ.

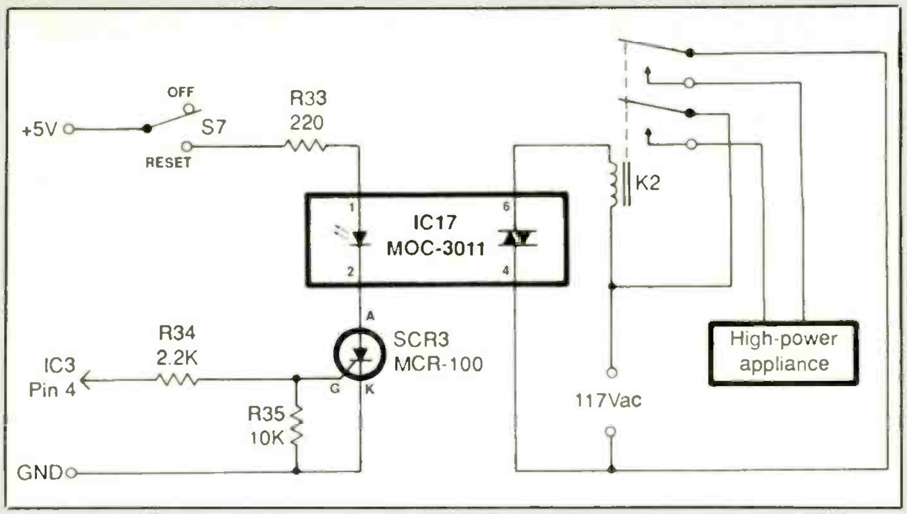


Fig. 5. High-power relay interface permits project to safely switch heavy loads like an air conditioner or heater.

Each of the slave modules we will describe is controlled by the logic output at pin 4 of *IC3B*, which changes from 0 to 1 when the correct security code is entered by you or a caller.

Each slave circuit illustrated here is powered by the 5-volt regulator in the main Security System project and requires three connections to the main circuit. Circuits that are also powered by the 117-volt ac power line contain optoisolators that maintain complete isolation between the project and power line.

The simplest of slave circuits is shown schematically in Fig. 3. Here, the coil of relay *K1* is energized in response to the positive output at pin 4 of *IC3B*. Sensitive-gate silicon-controlled rectifier *SCR1* switches on the coil of *K1* when the SCR is triggered by the positive-going output at pin 4 of NAND gate *IC3B*.

Once *SCR1* conducts, it remains

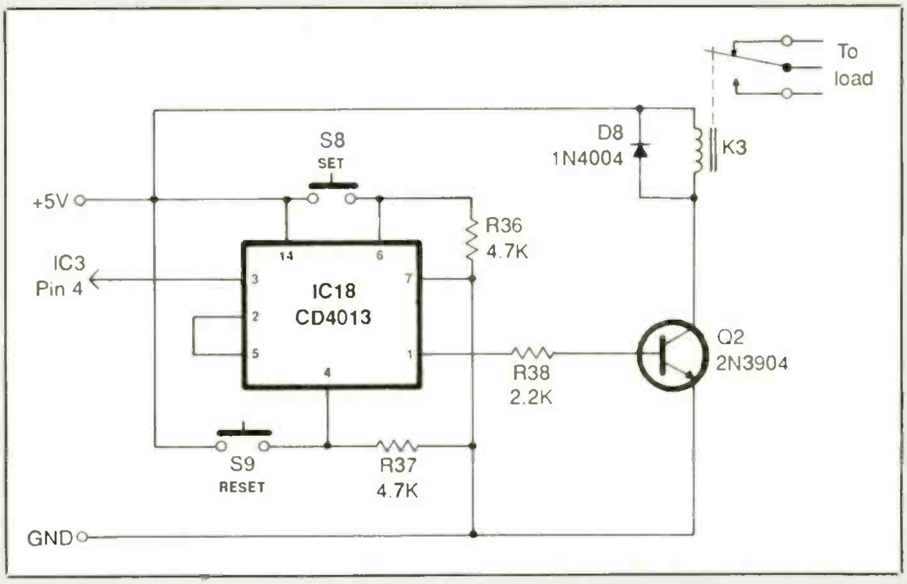


Fig. 6. Use of a flip-flop interface allows you to turn on and off a device with successive telephone calls.

latched, even though the trigger pulse is removed when the call is completed. Once triggered, the load circuit can be reset by momentarily opening *S5* to interrupt current flow through the relay coil. The coil of the relay is not committed to the 5-volt power supply in the main project. This permits relays of other voltages to be used if a power source of sufficient voltage is available.

As with all circuits that use relays to drive a load, it is important that the load current be known before selecting the specific relay to be used. Incandescent lamps draw as much as 10 times their rated current when turned on from a cold start. For such loads, it would be good practice to use a relay with a contact rating of at least five times the current draw of the lamps. Be sure to use a relay rated to switch the voltage of the load being controlled, of course.

A more elegant means of switching an ac load is illustrated in Fig. 4. In this arrangement, the relay is replaced by triac *Q3*, which now switches the current to the load. This circuit uses optical isolator *IC16* to isolate the 117-volt ac load circuit from the circuitry of the main project. Triggered by the positive logic level at pin 4 of *IC3B*, a triac inside the optical isolator is switched on by the internal LED.

Although the optical isolator used in the Fig. 4 circuit contains a triac, its load capability is not greater than 0.1 ampere. The low power triac, therefore, is used to drive a second, more powerful external triac, shown as *Q3*. As with the relay circuit in Fig. 3, power triac *Q3* must have sufficient current rating for the load. You must take into account the high surge current of incandescent lamps and induction motors when selecting a particular triac.

Using a triac to switch an ac load eliminates the wear and eventual failure of relay contacts. However, the triac has one disadvantage in that it requires a heat sink. For all but the lightest loads, the triac will dissipate a lot of heat and can fail unless a heat sink is used. (Some triacs do not have isolated tabs. For these, proper insulation, including use of heat-sink compound, is required to assure proper isolation of the heat sink from the ac power line).

The circuit shown schematically in Fig. 5 illustrates how the low power triac in an optical isolator can drive the coil of a high-power relay. The contacts of *K2*, rated at 10 amperes for the relay specified, can then be used to turn on an air conditioner, heater or other high-power appliance. This circuit eliminates the need for the heat sinking required for a power triac.

The circuit shown schematically in Fig. 6 illustrates how a "toggle" function can be implemented. This circuit permits a load to be turned on or off with the first remote telephone call, and then be turned off or on with a second call. With this arrangement, there is no limit to the number of times the load can be switched on and off. The cycle repeats indefinitely with each succeeding call.

Q output pin 1 of D type flip-flop *IC18* assumes the logic level of the data input at pin 5 when the circuit is triggered by a positive-going clock pulse fed to pin 3. The logic level inverted output (not-Q) of the chip at pin 2 is opposite that at pin 1. Since the data input of the chip is driven by the inverted output, each time the flip-flop is triggered, it must toggle, or change logic state.

The clock signal that drives *IC18* is derived from pin 4 of *IC3B* when the decoder circuit responds to the correct security code. When this occurs, the logic level at pin 1 of *IC18* turns on or off *Q5*. In turn, this sends *Q5* into conduction and energizes *K3*.

When using the Fig. 6 circuit, it is necessary to preset the output at pin 1 of *IC18* by means of SET or RESET switches *S8* and *S9* as required, since the flip-flop can assume either logic state when the circuit is first powered.

Presetting the circuit allows the desired logic level to be present at pin 1 of *IC18* so that the device to be controlled is off (or on). SET switch *S8* forces the circuit to energize the coil of *K3*, while RESET switch *S9* turns off the relay. If your requirement is always to have the load off (or on) before you leave the premises, you can delete *S8* or *S9*, as required.

Coming Next Month

We have discussed in detail here operation of the elements that make up a complete Dual-Application Telephone Security System. Next month in the conclusion of this article, we will focus on building the system, checking it out and installing and using it. ME

Home Security Porch Light Controller

This accessory automatically turns on and off an outside light shortly after a doorbell is rung to deter burglars

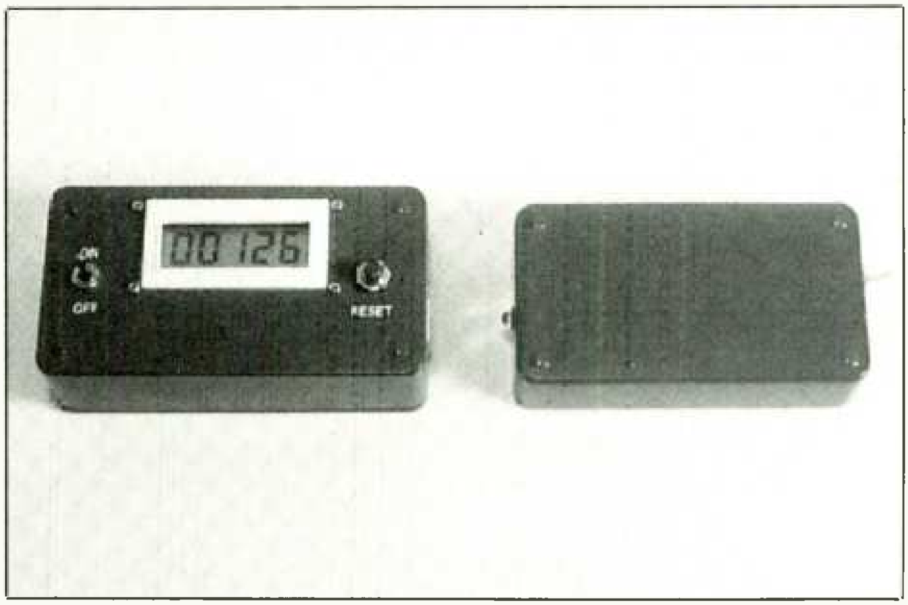
By Emerson J. Huff

A burglar usually checks to see if someone is home before attempting an illegal entry. He often does this by ringing his victim's doorbell. If no one answers, he feels the coast is clear. The Home Security Porch Light Controller described here can deter a burglar by automatically turning on your porch light a few seconds after someone rings your doorbell.

When your doorbell button is pressed, the bell rings in the usual manner and triggers a count-down circuit that controls power to your porch light. At the end of the 5-second countdown cycle, the porch light automatically comes on, giving the impression that someone inside your house has turned on the light. About 2 minutes later, the light automatically extinguishes.

This security device also allows you to control your porch light with your doorbell button whenever you enter and leave your home at night. Upon entry, it gives you 2 minutes of light to find the keyhole in the lock on your front door. When you go out, it also gives 2 minutes of light for you to see where you're going.

You can use an existing ac-powered porch light with this Controller. Optionally, you can install a separate ac-powered porch light dedicated exclusively for security purposes. Finally, you can have the system control a low-voltage porch light like those used on motor homes and RVs.



About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the circuitry that provides automatic control of the porch light. This is basically an astable multivibrator circuit built around the 555 timer chip shown as *IC1*. The circuit provides separate countdown timing periods.

Pressing the doorbell connected across the input network composed of *D3* and *C4* causes power from the doorbell circuit to energize relay *K1*. When this occurs, dc power from the V + rail of the circuit is applied to the trigger of silicon-controlled rectifier *SCR1*, which conducts and completes the powering circuit through the lower set of normally-closed contacts of *K2* for *IC1*.

Once powered, *IC1* begins counting down. At the end of the countdown cycle, which is about 5 seconds, the output at pin 3 of *IC1* goes low and activates relay *K2*. The contacts of this relay then assume their alternate position. At this time, the upper contact set closes the power circuit to the porch light, which turns on the latter. The timing circuit senses no pause in V + while the relay contacts are changing state.

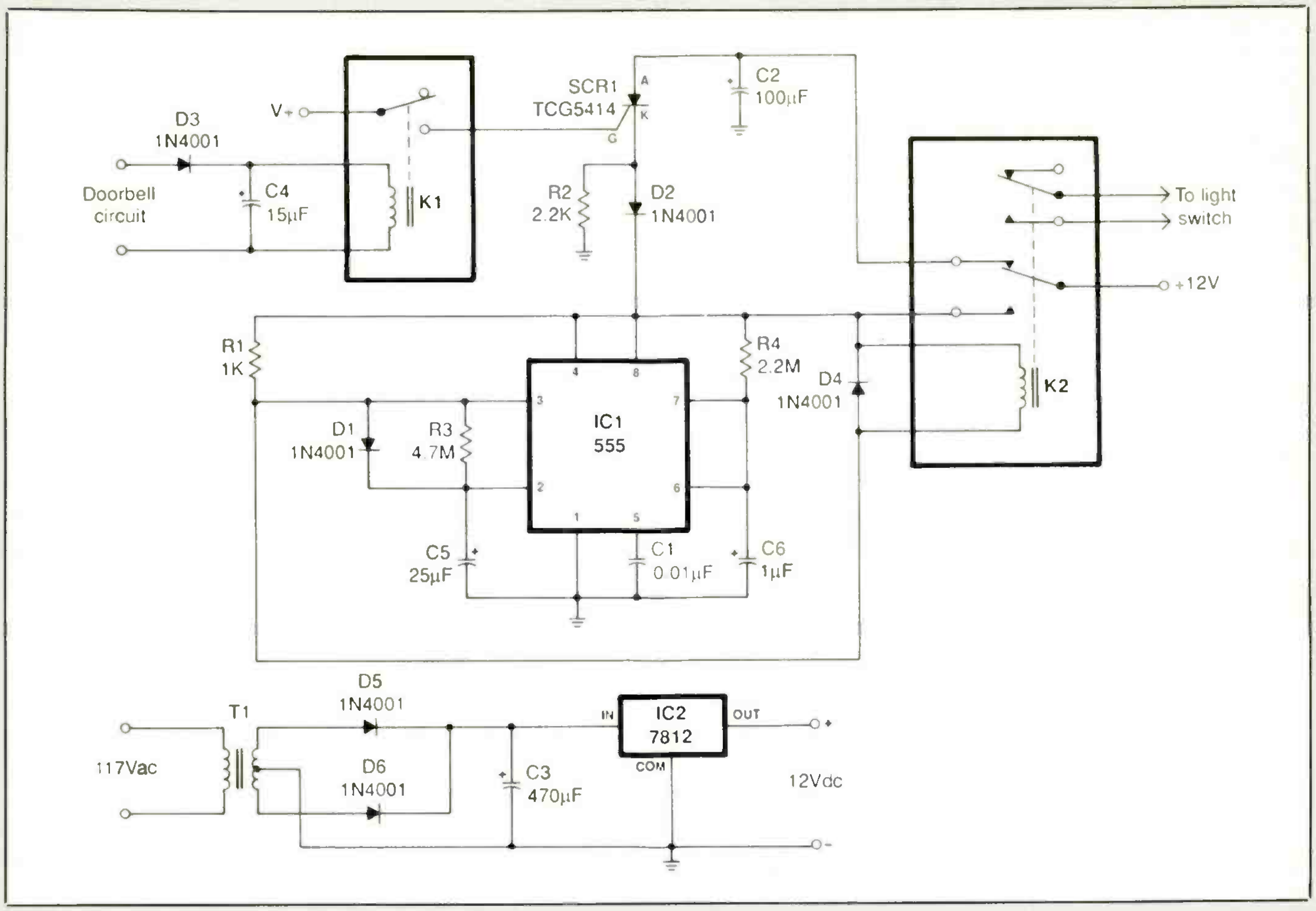


Fig. 1. Schematic diagram of timer-control circuit for automatic porch light.

Timer *IC1* continues to count down for about 2 minutes longer before the output at pin 3 goes high once again, ending the timing cycle. This low-to-high transition deenergizes *K2*, which disconnects V+ from the coil of this relay. As a result, the upper contacts break the power circuit to extinguish the porch light.

Timing periods can be changed to your preference. To make whatever changes needed, use different values for the components in the RC timing networks made up of *R3/C4* and *R4/C5*, using the formula T = RC.

Construction

Components for most of the project's circuitry should be mounted and wired together on a circuit board. You can design and fabricate a printed-circuit if you wish, though the circuitry is simple enough that you can use perforated board that has holes on 0.1-inch centers and suitable push-in terminals. Also use push-in terminals for connection to off-the-board components.

Wire the circuit-board assembly as shown in the actual-size illustrations given in Fig. 2. Use a socket for *IC1*. Make sure all polarized components and the 555 are properly oriented before soldering their leads and pins.

Keep in mind that a number of components mount off the circuit-board assembly, as shown in Fig. 3. These include voltage regulator *IC2*, power transformer *T1*, relay *K2*, diode *D4*, filter capacitor *C3* and rectifier diodes *D5* and *D6*. As shown in the wiring diagram in Fig. 3, the last three components mount on a five-lug terminal strip, to which are made the connections from the ac line, primary and secondary windings of *T1* and the +12-volt dc output line from the power supply.

The entire circuit is designed to fit inside a standard 6/6/4 electrical pull box, with all components and the circuit-board assembly mounted on an aluminum plate. Details of the layout and interconnections are shown in Fig. 3. Machine the cover plate as needed to mount the various elements in place.

Mount the power transformer and five-lug terminal strip in their respective locations. Then wire *C3*, *D5* and *D6* to the indicated lugs of the ter-

PARTS LIST

Semiconductors
D1 thru D6—1N4001 or similar silicon rectifier diode
IC1—LM555 timer
IC2—7812 fixed + 12-volt regulator
SCR1—TCG5414 or equivalent silicon-controlled rectifier

Capacitors (24 WV)
C1—0.01-μF Mylar
C2—100-μF electrolytic
C3—470-μF electrolytic
C4—15-μF electrolytic
C5—25-μF electrolytic*
C6—1-μF electrolytic*

Resistors (½-watt, 10% tolerance)
R1—1,000 ohms
R2—2,200 ohms
R3—4.7 megohms*
R4—2.2 megohms*

Miscellaneous
K1—Miniature spdt 12-volt dc relay (Colectro No. D1-974 or equivalent)
K2—Miniature dpdt 12-volt dc relay with 3- to 5-ampere contacts and 150- to 160-ohm coil and flat terminals (Radio Shack Cat. No. 275-206, includes socket, or Master No. GM dpdt or equivalent)
T1—24-volt center-tapped, 50-mA power transformer
Printed-circuit board or perforated board with holes on 0.1" centers and suitable push-in solder posts (see text); Master No. N-18 relay socket with screw-type terminals; socket for IC1; Romex or BX connectors as required (see text); 12-volt porch-light fixture and 12-volt, 1.5-ampere power transformer (optional—see text); three-conductor Romex or BX cable; 6/6/4 pull box with 1/2" knockouts; 4"-square junction box; 4"-square 16-gauge aluminum plate; rubber grommets; spacers; machine hardware; hookup wire; solder; etc.

*Adjust values of these components to suit timing needs, as detailed in text.
Note: Master Electronic Controls is located at 1220 Olympic Blvd., Santa Monica, CA 90404 (query Dan Berry). A low-voltage mobile porch light suitable for control with this project can be purchased from K-Mart (specify Item No. 390-s).

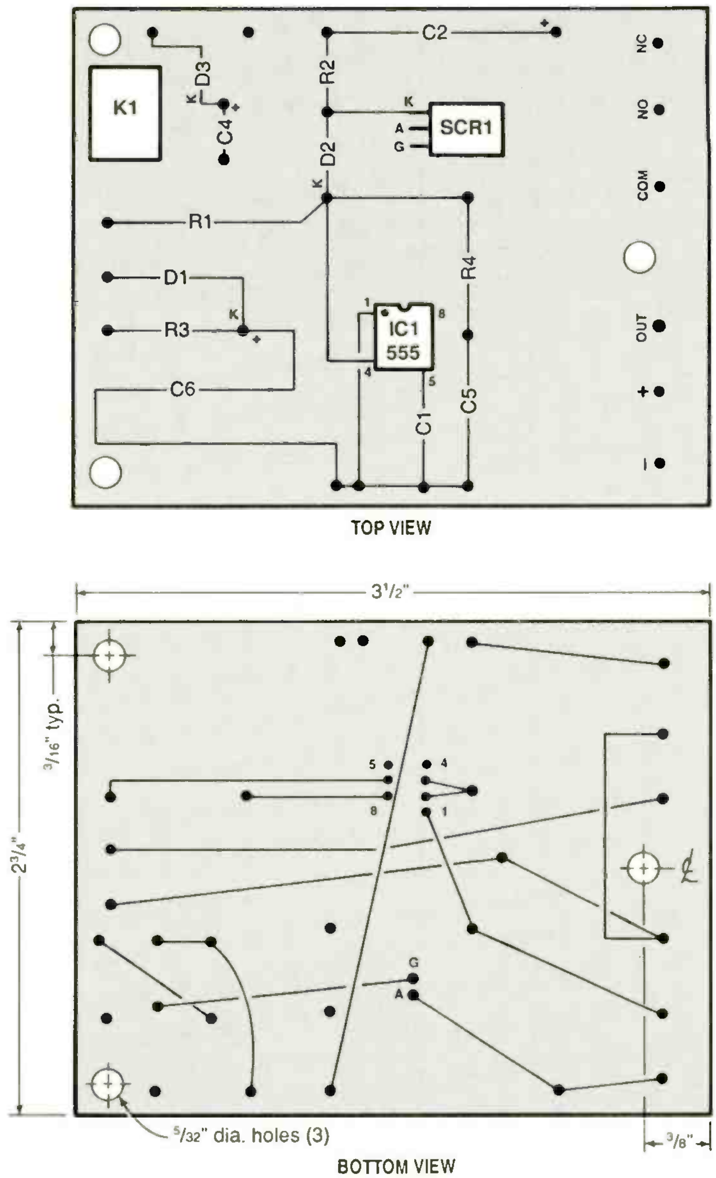


Fig. 2. Most components mount on a small printed-circuit or perforated board. Wire them together point-to-point or convert this wiring guide to a pc layout.

minal strip. Observe polarity for all three components. Do *not* solder any connection until directed to do so. (Note that none of the lugs of the terminal strip are connected to the tabs used for mounting purposes.)

Crimp and solder one secondary lead of *T1* to the indicated upper lug of the terminal strip in Fig. 3. Plug the secondary center-tap lead of the transformer into the hole of either mounting tab on the terminal strip and solder into place. Strip ¼ inch of insulation from both ends of three 3-inch-long stranded hookup wires. Tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. (Do this for all wiring used in the project.)

Crimp one end of one wire and one

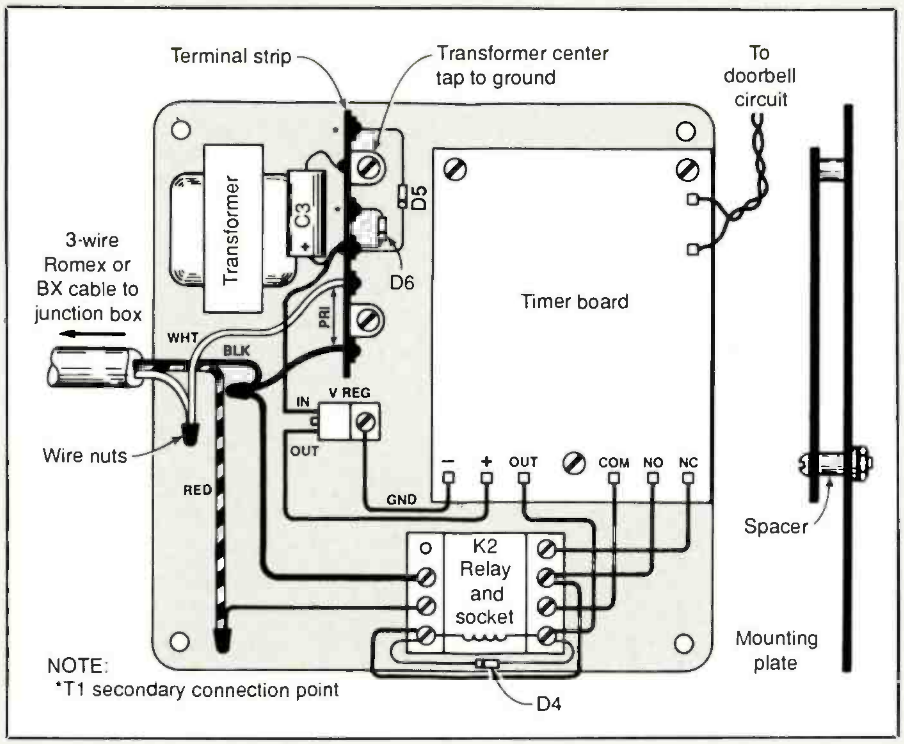


Fig. 3. Wiring diagram for off-the-board components and connections to doorbell and control circuits.

primary lead of *T1* to the second to lowest lug of the terminal strip. Do the same for another wire and the other primary lead to the bottom-most lug. Crimp one end of the remaining wire to the lug to which the + lead of *C3* and cathode leads of *D5* and *D6* are connected and solder them.

Mount relay *K2* in the location shown with machine hardware. Then mount the circuit-board assembly in place with ½-inch spacers and 4-40 × ¾-inch machine screws, lockwashers and nuts. Prepare nine 3-inch-long hookup wires as described above. Then solder one end of six of these wires to the push-in solder terminals located along the lower edge of the circuit-board assembly. Crimp or solder a spade or ring-type lug to the free end of the wire coming from the – (left-most) terminal on the board.

Clip the center (COM) lead from voltage regulator *IC2*. Secure the regulator directly to the aluminum plate in the indicated location with suitable machine hardware, sandwiching the wire with the spade or ring lug between screw head and tab on the regulator. (The metal plate serves as the heat sink for the regulator.) Crimp and solder the wire coming from the + (second from left) terminal on the board to the OUT pin of the regulator and the free end of the wire coming from the *C3/D5/D6* lug of the terminal strip to the IN pin of the regulator. Bend both regulator pins upward enough so that they are well clear of the metal plate.

Finish wiring the circuit by connecting the free ends of the remaining wires coming from the circuit-board assembly and the remaining three wires to the indicated points on the relay *K2* socket. Do not forget to wire diode *D4* into place as shown.

Connections to the doorbell circuit and three-conductor electrical wiring that goes to the porch light will be made later during final installation.

Installation

If you are using an existing or fitting an additional porch light to control, be aware that you will be dealing with potentially lethal 117-volt ac line power. Therefore, exercise extreme caution when making line-level connections. Always work on such lines with the fuse pulled or circuit breaker open to make the line electrically dead. If you do not know what you are doing, have a qualified electrician make the hookups.

Keep in mind that all ac line-level installations must conform to local electrical codes. In most areas, you can do the work yourself, as long as you obtain a homeowner's permit to do so. In other areas, you might be required to have a qualified electrician do the installation.

There are advantages to using an existing porch light with this Controller. Such a light is already in place and does not require fixture installation and running of electrical wiring to it. It is also capable of giving a great deal more light than is possible with separate low-voltage lights.

When planning to use this project to control an existing porch light, check the location of the existing light switch and routing of the wiring to the light. Since you will be wiring the Controller to the existing light switch with the Controller, you will have to add a 4-inch-square junction box into which the Controller's circuitry fits.

An alternative to an existing porch light is to install a second ac-line-powered porch light that is dedicated to doorbell control. The advantage of going this route is that you retain normal control over your existing porch light. Disadvantages are that you must install a new fixture and run a cable from an ac source to the Controller and then to the new porch-light fixture.

Whichever ac-line-level approach you use, you must wire a junction box as shown in Fig. 4. Note here the

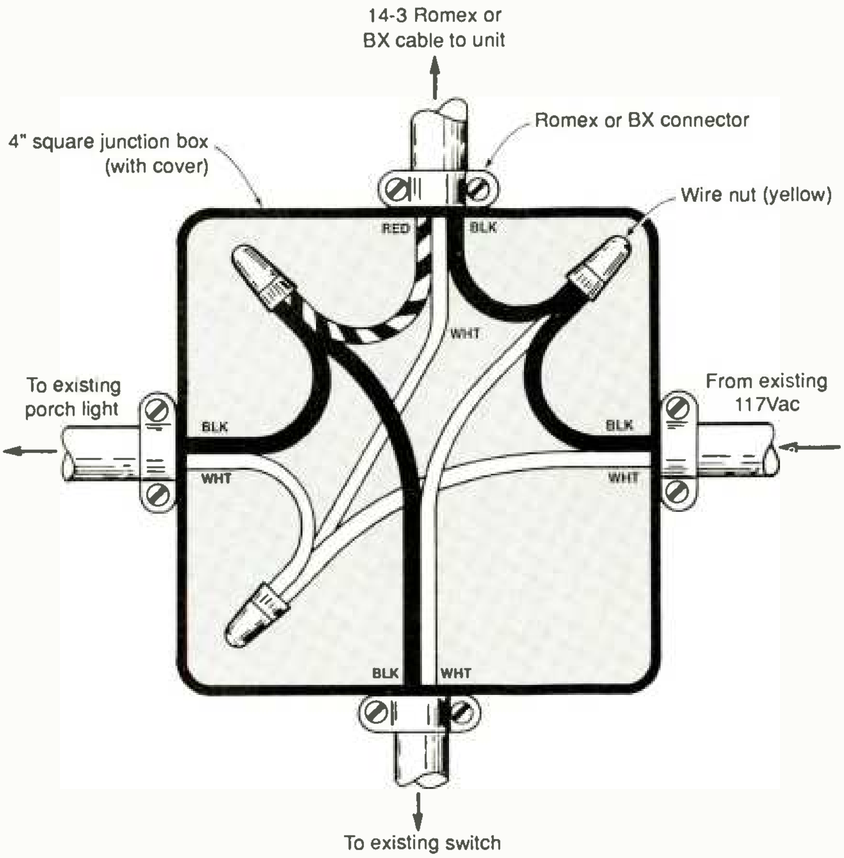


Fig. 4. Junction box wiring details for an existing ac-powered porch light.

use of Romex or BX electrical cable. Depending on the electrical codes in your particular area, you *must* use the appropriate type of electrical cable. You must also use the appropriate couplers for the specific type of cable being used.

Make sure when you make any ac line-level connections that you tie the Romex or BX cable conductors and whatever conductors are used for feeding line power into the project with appropriate wire nuts, as shown in both Fig. 3 and Fig. 4. Do *not* make soldered connections.

Your third choice of controlled porch light is a low-voltage unit like those used in RVs. One disadvantage of using such a fixture is that you must install the fixture and route the electrical line from scratch. Another is that the light from it is generally low in level. Typically, such fixtures operate at 12 volts and draw 1.44 amperes of current to deliver about 18 watts of light. This is not very much light, but it should be adequate to fool a potential burglar.

With a low-voltage light, you are not dealing with potentially lethal 117-volt ac line potential, other than to replace the existing doorbell transformer with a more-powerful unit that will safely power the light fixture. The existing doorbell transformer simply does not output enough current to power the light fixture. The load on the replacement transformer is not additive. The doorbell and light fixture will rarely be on at the same time; so, a 1.5-ampere transformer is more than adequate to handle the load.

Wiring for the doorbell circuit is shown schematically in Fig. 5. With this arrangement, you make two sim-

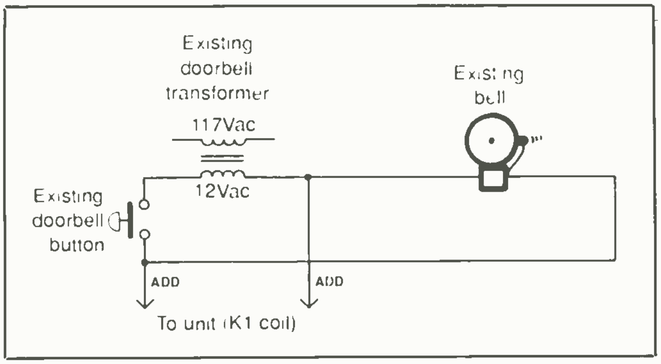
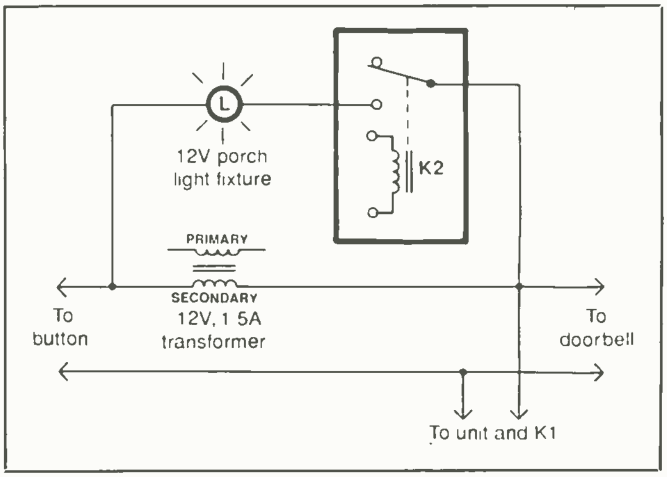


Fig. 5. Details for connecting project to doorbell circuit.

Fig. 6. Wiring details for using a 12-volt porch light.



ple connections between the existing doorbell circuit and the TO DOORBELL CIRCUIT points on the circuit-board assembly (see Fig. 1 and Fig. 3). Use ordinary twisted-pair bell wire for these connections.

Figure 6 shows the wiring arrangement to use when controlling a 12-volt porch light fixture. Before attempting to remove the existing transformer, make sure the ac line feeding power to it is electrically dead. Restore power to the new circuit after wiring the replacement transformer into the circuit.

Before doing getting to work, plan your installation carefully. All cable runs should be as short and direct as possible. Do not make cable runs too sharp. If you are using Romex, make certain that you do not damage the tough insulation on the cable by drawing it across sharp corners, especially if the corners are metal. Also, when you are securing the Romex cable to the junction boxes, avoid excessive pinching of the insulation.

When integrating the Controller into your porch-lighting and doorbell systems, carefully check every step you complete against the Figures in this article. When you are done and before you restore ac line power to the circuit, double and triple check all wiring. This cannot be overstressed.

Once the Controller has been installed and you have restored ac line power, check out its operation. Press and release your front doorbell button. The doorbell should sound as usual. About 5 seconds later, the porch light should turn on and remain on until the Controller's circuit times out and the light extinguishes. Of course, these two times may be different if you chose to change the values of the components in the RC time-constant networks.

If you do not obtain the proper responses from the circuit, disable ac power to the Controller and doorbell and porch-light circuits and troubleshoot your work. **ME**

Wide-Coverage Water Detector Sensor

Lets you monitor for the presence of water over a wide area instead of at just one point in a basement or other area subject to flooding

By Brad Thompson

Water may be one of Nature's necessitaries, but it can cause expensive damage if it appears unwanted in a basement or other storage area. Though a commercial water detector can be used to sense the presence of water in such areas, their sensors usually limit monitoring to a single point. Hence, to monitor a large area requires an array of such detectors or an extended sensor element. In this article, we'll show you how to build an electronic water detector that uses a linear sensor element that can provide virtually unlimited coverage with a single detector unit.

Our Water Detector uses a reliable moisture sensor that, oddly enough, is available from agricultural supplies outlets as electrical fence tape that replaces the wires commonly used to keep livestock in pastures. Its woven ribbon construction traps moisture, and its flexibility eases installation. Costing only pennies per foot, this tape is inexpensive enough to discard if it becomes contaminated or damaged.

About the Circuit

Before we get into our discussion of the actual circuitry used in this project, it is important to lay the groundwork with a discussion of water sensors and how they are used most effectively.

Most inexpensive electronic water detectors apply direct current (dc) to their sensing contacts. However, electromigration and electrolysis effects can result in damage to the contacts, even if they're not immersed in water. Trace amounts of salts found in room dust can dissolve in atmospheric moisture that condenses upon a water sensor's electrodes to form a conductive solution. With direct current applied to the electrodes, molecules of metal migrate between the electrodes and create microscopic conductive paths that eventually reduce resistance between the electrodes and trigger false alarms.

Additionally, fully immersing a dc sensor's electrodes in water causes electrochemical corrosion and plating effects that can permanently damage the electrodes. Applying ac to a sensor's electrodes prevents electroplating and corrosion because any chemical reactions that occur during the positive half of the ac cycle reverse during the negative half-cycle.

While an ac power source is as close as your nearest 117-volt ac wall outlet, this raw ac would create a lethal shock hazard if you were to directly apply the line voltage to a water sensor. The Waterline sensor generates its own isolated, low-power ac and uses dc power to reduce shock hazards and allow operation from a battery supply, which is a bonus for rural residents and recreational vehicle owners.

Shown in Fig. 1 is the complete

Electrical Characteristics of Tap Water

Tap water is not electrically inert unless it is purified in a laboratory. Water samples taken from a household tap contain varying amounts of dissolved minerals that affect both drinkability and electrical conductivity. The project described in the main article essentially makes a go/no-go conductivity measurement. It sounds an alert when electrically conductive water reaches the sensor tape.

If you attempt to measure the resistance of common drinking water using a battery-powered ohmmeter, you will notice that the reading changes with the depth to which the probes are plunged. Scientists define the *resistivity* of water by measuring the resistance of a sample between electrodes of a fixed size and distance apart. One common resistivity unit is the *ohm-centimeter* and is defined in terms of $(R \times A)/D$, where R is resistance in ohms, A is electrode area and D is distance between electrodes.

The Table shown elsewhere in this article lists typical values of resistivity for various kinds of water. It includes some values for conductors and insulators to serve as a means of comparison.

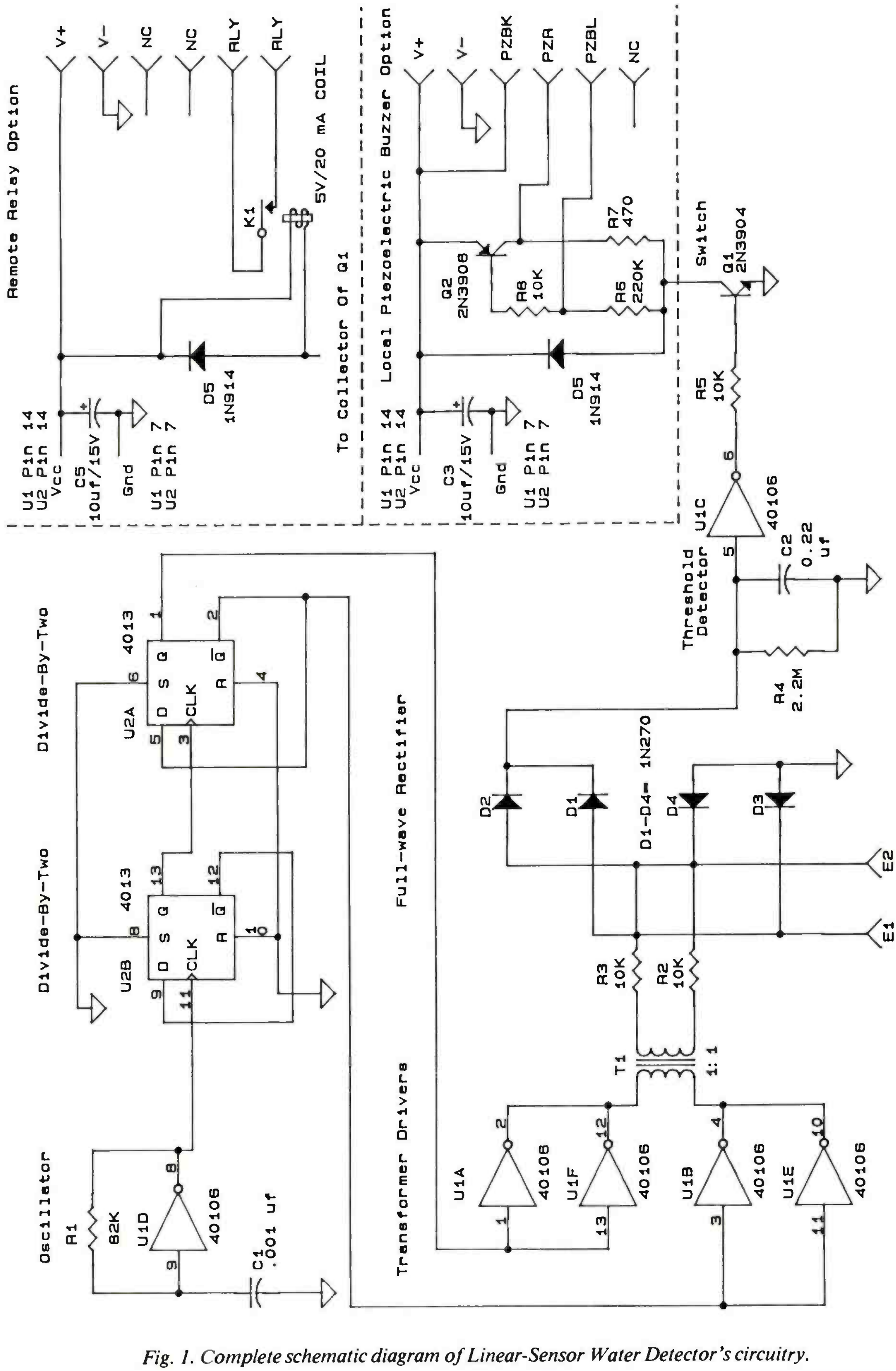


Fig. 1. Complete schematic diagram of Linear-Sensor Water Detector's circuitry.

PARTS LIST

Semiconductors
D1 thru D4—1N270 or similar germanium signal diode (see text)
D5—1N914 or similar silicon signal diode
Q1—2N3904 or equivalent high-beta small-signal npn silicon transistor
Q2—2N3906 or equivalent high-beta small-signal pnp silicon transistor
U1—CD40106BE or MM74C14N CMOS hex Schmitt trigger
U2—CD4013BE CMOS dual D-type flip-flop

Capacitors
C1—0.001-μF, 50-volt plastic with 0.3-inch lead spacing
C2—0.22-μF, 50-volt plastic with 0.3-inch lead spacing
C3—10-μF, 16-volt axial-lead electrolytic or tantalum

Resistors (¼-watt, 5% tolerance)
R1—82,000 ohms
R2,R3,R5,R8—10,000 ohms
R4—2.2 megohms
R6—220,000 ohms
R7—470 ohms
R9—2,200 ohms

Miscellaneous
K1—Reed relay with spst contacts with 5-volt dc, 20-mA coil (Radio Shack Cat. No. 275-232 or similar)
PB1—Fixed-frequency dc piezoelectric buzzer with three leads (Radio Shack Cat. No. 273-064 or similar)
SW1—Normally-open, momentary-contact spst pushbutton switch
T1—Audio coupling transformer with 1:1 turns ratio and 600- to 10,000-ohm impedance (Radio Shack Cat. No. 273-1374, Mouser Electronics Cat. No. 42TM018. Cut off center-tap lead of Mouser transformer, if used)
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (see text); four-position spring-action terminal board (Radio Shack Cat. No. 274-622 or similar); Baygard HV or equivalent sensor tape; 6-volt manganese-alkaline battery (see text); optional remotely located piezoelectric buzzer (Radio Shack Cat. No. 273-066 or equivalent—see text); spacers; machine hardware; hookup wire; solder; etc.

Note: A 10-foot sample of sensor tape is available for $4 postpaid from: Brad Thompson, GMT Interface Products, Suite 233, 56-A Main St., Maynard, MA 01754. Mouser Electronics is located at: P.O. Box 699, Mansfield, TX 76063.

schematic diagram and functional blocks that make up the project's circuitry, including a remote relay option, which we will explain later. As you can see, this circuit design makes use of only a few discrete components and two inexpensive CMOS logic circuits—the *U1* hex Schmitt trigger and *U2* dual D-type flip-flop.

Together with *R1* and *C1*, *U1D* make up a relaxation oscillator. The output frequency of this simple oscillator arrangement can vary widely, due to component tolerances and variations in output voltage from the power supply. For example, even though the components are functionally identical, substituting a 74C14 for a CD40106 for *U1* decreases the oscillator's frequency from about 18 kHz to 6 kHz because the internal trigger voltage thresholds of the two IC devices differ.

In addition, the output of the oscillator isn't a symmetrical square wave and, hence, has a net dc component. If the output from the oscillator were used to directly drive *T1*, the unbalanced dc component contained in the asymmetrical signal would saturate the transformer's core and decrease circuit efficiency.

Though keeping the oscillator's frequency within the audio range results in most efficient operation of *T1*, absolute frequency isn't critical. By dividing the oscillator frequency by four, the signal "seen" by *T1* is limited to a 1.5-kHz to 6-kHz range and, as a bonus, generates a symmetrical square wave to drive *T1*.

Stages *U2B* and *U2A* of the CD4013 dual D-type flip-flop divide the oscillator's output signal frequency by four and produce a square wave that drives parallel-connected sections *U1A/U1F* and *U1B/U1E*, respectively. In turn, these stages drive the primary winding of *T1*.

Like most digital CMOS devices, each of the outputs of *U1* consists of a pair of MOS transistors connected in "totem-pole" arrangement. The upper transistor sources current to the load from the V+ power-supply rail, while the lower transistor sinks current from the load to the ground rail. Two CMOS inverters driven 180 degrees out-of-phase with each other form an "H-bridge" driver in which the primary of *T1* serves as the crossbar of the "H" and one inverter sources current as the opposite inverter sinks current from the load.

Connecting inverters in parallel boosts the current-driving and current-sinking capabilities of the circuit. The parallel connection works successfully because all inverters in a single device are well-matched. Built-in clamping diodes protect each of the outputs of *U1* against voltage spikes that exceed the positive supply potential or go below ground.

Transformer *T1*'s symmetrical ac output drives water-sensing electrodes *E1* and *E2* via current-limiting resistors *R2* and *R3*. Under dry conditions, the resistance across the sensing electrodes is relatively high and the transformer's full ac voltage appears at the input of a full-wave bridge rectifier made up of *D1* through *D4*. The rectified ac is smoothed to dc by *C2* and sent to threshold detector *U1C*, which holds its output at pin 6 at logic "low." Resistors *R2* and *R3* control sensitivity. Increasing the values of these two elements increases the sensitivity of the detector circuit.

Water that reaches electrodes *E1* and *E2* results in a low-resistance shunt path being formed across *R2* and *R3*. This causes an ac voltage drop that decreases the rectifier's dc output applied to pin 5 of *U1C*.

When the dc potential at pin 5 of *U1C* falls below approximately 33 percent of the power-supply potential, the output at pin 6 of *U1C* switches from logic "low" to logic "high" and applies current to the base of *Q1*. When this transistor conducts, it applies power to piezoelectric buzzer driver *Q2*. This causes an audible alarm to sound.

Resistor *R1* and capacitor *C1* set the frequency of oscillator *U1A*. Increasing the values of either of these two components has the effect of lowering the operating frequency of the oscillator. For best results, the value of *R1* should be kept to between 10,000 and 100,000 ohms. Also, it is best to use a plastic, ceramic or mica-dielectric capacitor for *C1*.

Although the Parts List specifies germanium diodes for *D1* through *D4*, you can use such conventional silicon signal diodes types as the 1N914 or 1N4148, for example, if you decrease the values of *R2* and *R3* to compensate for the higher forward voltage drops of silicon diodes. Hot-carrier signal diodes also work well and require no resistor changes.

Though most users will require only an audible warning of encroaching water, you can replace the piezoelectric buzzer with a relay and use its contacts to drive a conventional bell or klaxon-type horn to generate a louder warning or to apply power through a larger relay to the motor of an electric pump that will then remove the water from the affected location. Bear in mind, though, that the relay draws approximately 20 milliamperes more current than does the piezoelectric buzzer when the alarm activates. Details for the relay circuitry are shown at the upper-right in Fig. 1.

In standby mode, the project draws approximately 1 milliampere of current at 6 volts. When activated and sounding the buzzer, the circuit draws approximately 6 milliamperes. Under standby conditions, projected life for a battery made up of four manganese-alkaline D cells is about 450 days, or 15 months. For longer life, use a 6-volt manganese-alkaline battery, which yields approximately 20 months of service.

When battery potential drops to about 2 volts, the sensor will activate the piezoelectric buzzer to signal that battery replacement is needed. Closing PRESS TO TEST switch *SW1* connects 2,200-ohm resistor *R9* across the Detector's input to simulate a "wet" sensor (see Fig. 5).

You can also operate the project from a UL-approved plug-in wall-type dc power supply or battery eliminator. Bear in mind, however, that the output voltage of some plug-in supplies is poorly regulated for low-current loads. Hence, you should measure the loaded supply voltage to ensure that it falls in the nominal 5-to-6-volt dc range.

The piezoelectric buzzer-based version of the project operates at supply potentials of up to 15 volts dc maximum, but greater voltages increase current consumption and can over-stress the transformer driver sections of *U1*. Also, you may have to change the values of *R2* and *R3* to adjust the sensitivity of the circuit at higher voltages.

Construction

Owing to the fact that there is nothing critical about component layout or conductor runs, you can assemble this project on either a printed-circuit board or perforated board using suitable Wire Wrap or soldering hardware. In describing assembly in this article, we will assume pc wiring.

Fabricate your printed-circuit board using the actual-size etching-and-drilling guide shown in Fig. 2. After etching the board is complete, drill all holes, including the mounting holes shown in each corner.

Figures 3 and 4 illustrate two different methods of wiring the pc board. The one in Fig. 3 is for the

Resistivities of Common Substances

Material	Resistivity*	Comments
Plate Glass	2×10^{13}	Insulator
Polyurethane	2×10^{11}	Insulator
Pure Water	2×10^{7}	Chemically Pure
Distilled Water	5×10^{4}	Well-Distilled
Mine Water	5×10^{3}	Mine Drainage
Ground Water	10^{3} to 10^{5}	Drinkable
Sea Water	2×10^{1}	Normal Salinity
Ethyl Alcohol	2×10^{4}	Not Diluted
Olive Oil	5×10^{6}	
Petroleum Oil	2×10^{10}	
Aluminum	2.6×10^{-6}	Conductor
Copper	1.7×10^{-6}	Conductor
Germanium	8.9×10^{-2}	Semiconductor
Soil	4×10^{-3} to 2.5×10^{4}	Mix of clay, sand and gravel

*Resistivity is expressed in terms of ohm-centimeters

Sources: Smithsonian Physical Tables, Ninth Edition, 1969, Smithsonian Institution Press, Washington, DC
Earth Resistances by G.F. Tagg, First Edition, 1964, Pitman Publishing Corp., New York, NY

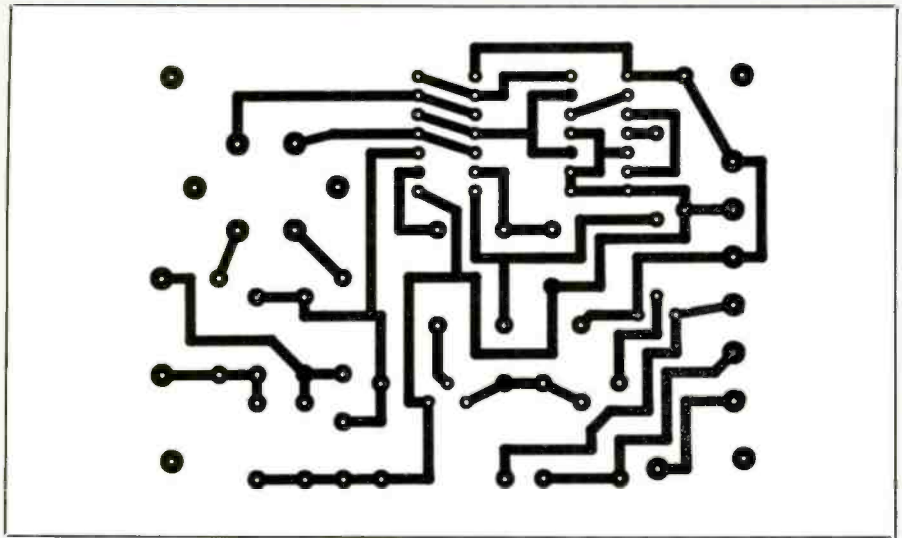


Fig. 2. Actual-size etching-and-drilling guide for fabricating printed-circuit board for project.

basic project with the piezoelectric buzzer located local to the project itself. The one in Fig. 4 is for wiring the project so that a relay switches power on and off to a remotely located buzzer, klaxon horn or to a second relay whose contacts feed ac line power to an automatically operated water pump.

Once you decide on the version of the project you will be building, orient the blank pc board in front of you as shown in either Fig. 3 or Fig. 4. Begin populating the board by installing and soldering into place the sockets for *IC1* and *IC2*. Do *not* plug the ICs into the sockets until after you have conducted voltage checks and are certain that the project is properly wired.

Continue wiring the board by installing and soldering into place any wire jumpers specified (one in Fig. 3, three in Fig. 4). These jumpers are labeled with "JU" prefixes in both cases. Use bare solid hookup wire for the jumpers.

Next, install and solder into place the various resistors, then the capacitors and diodes. Make certain that the diodes and electrolytic or tantalum capacitor *C3* are properly polarized before soldering any leads into place on the bottom of the board. If you are wiring the Fig. 4 version of the project, note that JU2 and JU3 *replace* resistors *R7* and *R8*, respectively, in Fig. 3. Also, eliminate *R6* altogether in this version.

Making absolutely certain that you properly base them, wire transistors *Q1* and *Q2* into the Fig. 3 circuit. If you are assembling the Fig. 4 version, install only *Q1* and replace *Q2* with the coil leads of the relay, as shown. Then plug the relay's contacts into the two holes labeled RLY and solder into place.

Install the audio coupling transformer in the T1 location. Plug its leads into the color-coded holes provided for them in the board and solder them into place.

Strip ¼ inch of insulation from both ends of four 5-inch-long hookup wires, preferably with color-coded insulation. If you are using stranded wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder.

Plug one end of these wires into the holes labeled E1, E2, V+ and V− in Fig. 3 and solder all four connections. Plug the free ends of the black-, red- and blue-insulated leads from the piezoelectric buzzer into the holes in the circuit-board assembly labeled PZBK, PZR and PZBL holes, respectively, and solder into place.

If you are wiring the Fig. 4 version, prepare the same number of 5-inch-long wires. Also prepare in the same manner two 8-inch- and one 3-inch-long wires. Twist together one end of one 5-inch and the 3-inch wires and then lightly tin the bundle with solder. Do the same with the other 8-inch and another 5-inch wire.

Plug the bundle with the 3-inch wire in it into the hole labeled V+ and solder into place. Similarly, plug the other bundle into the hole labeled V− and solder it into place. If necessary, slightly enlarge the holes to accommodate the double-thickness bundles. Route the free end of the 3-inch wire to the indicated RLY hole and solder it into place.

Plug one end of the remaining 8-inch wire into the other RLY hole and solder it into place. Then plug one end of the remaining two 5-inch wires into the holes labeled E1 and E2 and solder into place.

Now turn over whichever version of the circuit-board assembly you wired and inspect it. If you discover any questionable solder connections, reflow solder on them and add solder if needed to assure mechanically and electrically solid connections. If you missed any connections, solder them now. Also, check for solder bridges, especially between the closely spaced IC pads. If you locate any, remove them with desoldering braid or a vacuum-type desoldering tool.

Select a suitable enclosure for your project. This can be of any construction, but make sure it is large enough to accommodate the circuit-board assembly and whatever else will be contained inside it and on its panels. For example, you need a much larger enclosure for the Fig. 3 version, which includes a bulky battery, than you need for the Fig. 4 version.

Machine the enclosure as needed.

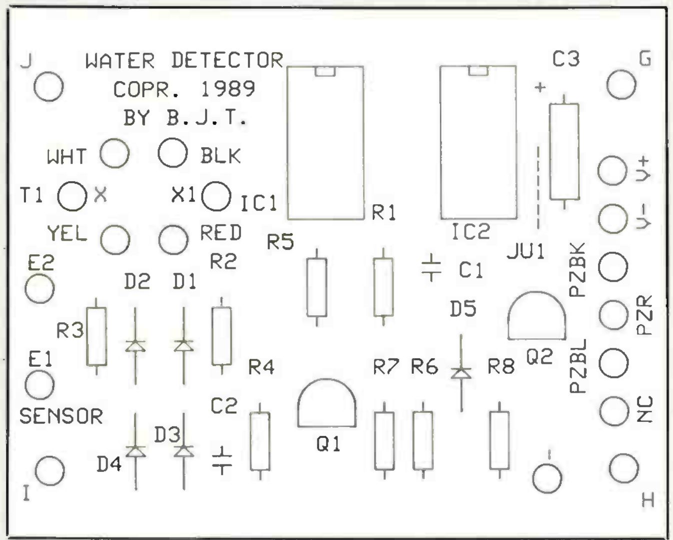


Fig. 3. Wiring guide for basic version of project's pc board.

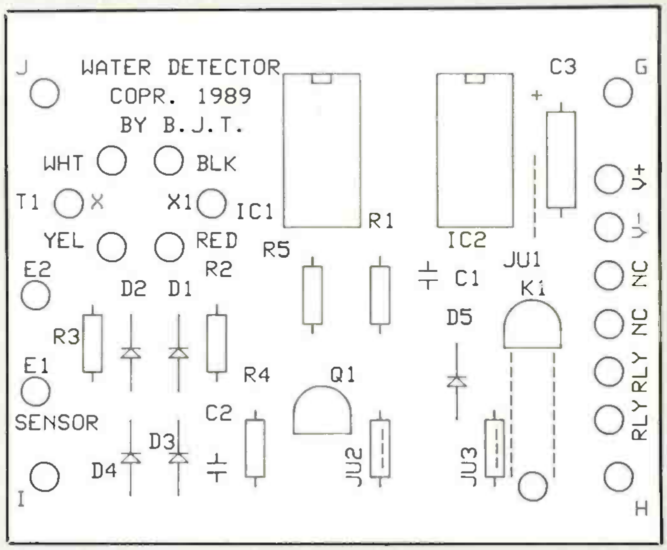


Fig. 4. Wiring guide for optional remotely located buzzer version.

That is, drill mounting holes in the floor panel for the circuit-board assembly and battery holder, the latter if used. Also drill through the front panel a mounting hole for PUSH TO TEST switch *SW1* and a mounting hole for the piezoelectric buzzer in the top panel. Finally, you must cut a slot in which to mount a four-position spring-type terminal board in the rear panel. After machining the enclosure, deburr all sharp edges made in metal.

Mount the battery holder into place using suitable machine hardware. (Note: You need a four-cell holder for D-size cells. If you use a lantern battery, make some arrangement to secure it in place to prevent it from moving around.) Then mount the circuit-board assembly into place, using ½-inch spacers and 4-40 or 6-32 × ¾-inch machine screws, nuts and lockwashers. Mount the switch in its hole and the terminal board in its slot.

Crimp one lead of the *R9* resistor to the lug of the terminal board nearest the switch. Crimp the free end of the wire coming from hole E2 to the same terminal board and solder the connection. If necessary, use insulated hookup wire to lengthen the other lead of the resistor to make it long enough to reach the near lug of the switch. Crimp and solder this wire to the switch lug.

Next, prepare another hookup wire to bridge from the next lug of the terminal board to the other lug of the switch. Crimp the wire to the switch lug and solder the connection. Locate the free end of the wire coming from the E1 hole in the circuit board assembly and crimp and solder this wire and the free end of the wire coming from the switch to the indicated terminal-board lug (see either drawing in Fig. 5).

Observing proper polarity, crimp and solder the free ends of the V+ and V− wires coming from the circuit-board assembly to the lugs on the battery holder, or terminate them at the appropriate terminals of the lantern battery, if used. If you built the Fig. 4 version of the project, route the free ends of the V− and indicated RLY wires to the indicated lugs of the terminal board. Making sure to observe which wire goes where, crimp and solder the wires to the lugs.

For the Fig. 3 version, use suitable hardware, silicone adhesive or fast-set epoxy cement to secure the piezoelectric buzzer to the top panel of the enclosure. Also, you might want to consider placing an spst slide or toggle switch between the positive (+) lead of the battery and indicated circuit-board assembly hole to allow you to turn on and off power.

If you opted for ac powering of the project, eliminate the battery. Instead, drill another hole in the rear panel of the enclosure to accommodate a jack that matches the plug on the end of the cable coming from the plug-in wall-type power supply. Mount the jack in the hole and connect and solder the V+ and V− wires to the lugs of the jack. Make certain you observe proper polarity.

Checkout

With the ICs still not installed in their sockets, power up the project. That is, make the connections to the battery (and set the POWER switch to "on") or plug the ac-operated dc power supply into the jack on the rear of the enclosure and plug the supply into a convenient ac outlet.

To perform voltage checks, you

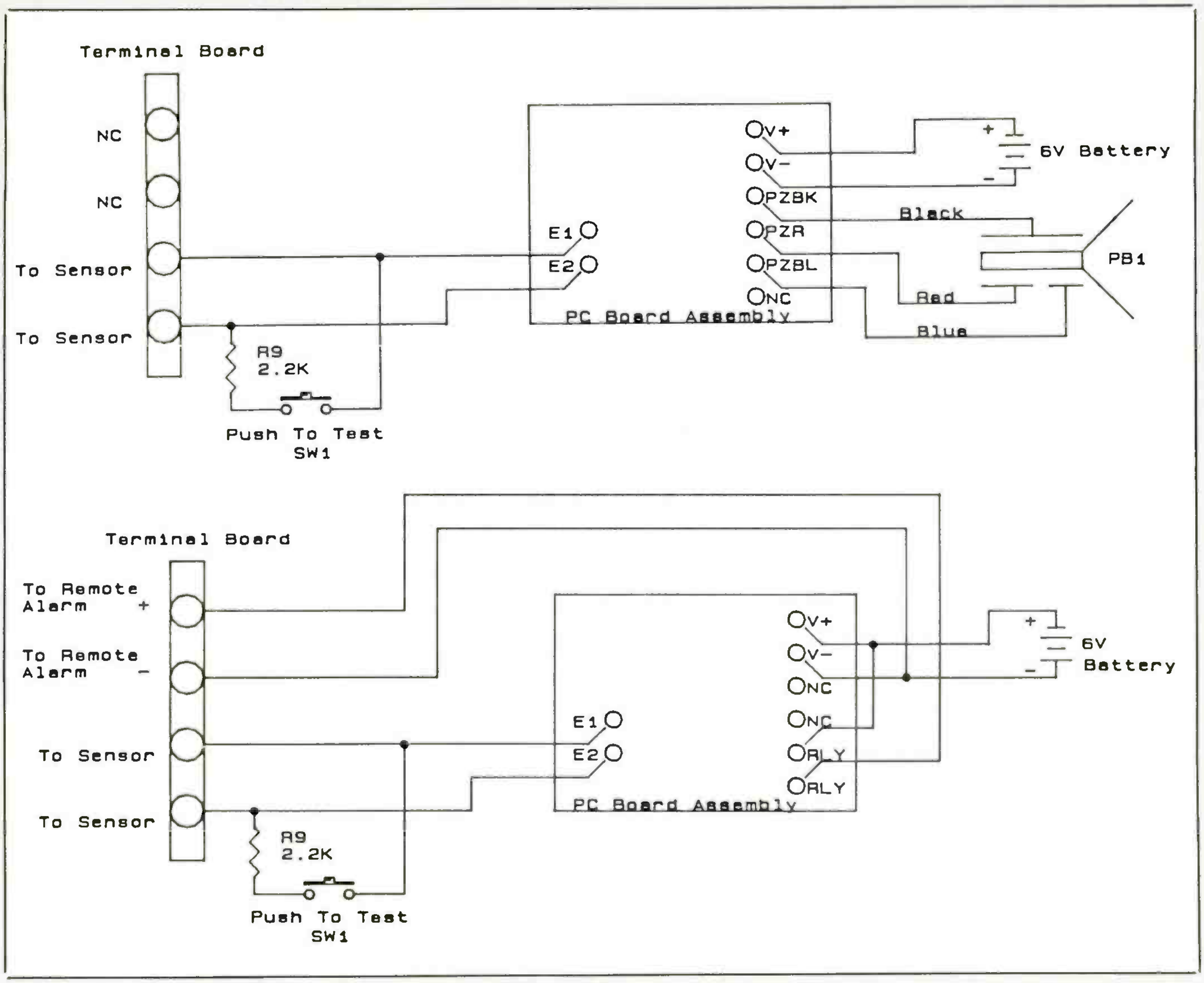


Fig. 5. Wiring details for local piezoelectric buzzer (upper) and remote relay (lower) versions of project. Note that both versions show battery powering, which can be replaced with a plug-in wall-type dc power supply.

need a dc voltmeter or a multimeter set to the dc-volts function. Clip the common lead of the meter to a convenient point that is at circuit ground. The ground lead of *C1* or *C2* will do fine. Then touch the tip of the "hot" probe to the receptacle for pin 14 of each IC socket in turn. You should observe a meter reading in both cases of approximately +6 volts. If not, power down the circuit and rectify the problem before proceeding.

Once you are certain that the project has been properly wired, power it down and install the ICs in their respective sockets. Practice safe handling procedures for these two CMOS devices. Also, make sure that each IC is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets as you push them home.

Use a dry-transfer lettering kit or tape labeler to apply identifying legends near the terminals of the terminal board. If you use dry-transfer lettering, protect the terminal board with masking tape and spray two or more light coats of clear acrylic to protect the legends. Allow each coat to dry before spraying on the next.

Now prepare the sensor tape. Before doing this, however, you must be aware that the tape has a characteristic capacitance of about 24 picofarads per foot. This limits its maximum length to less than 100 feet, which should be more than sufficient for most applications. With this in mind, cut the tape to the length needed. Then carefully separate about 2 inches of alternate wire conductors from the bundle by routing them in different directions. That is, bend all odd-numbered conductors toward you and all even-numbered conductors away from you. This will keep the tape from shorting out. Use an ohmmeter to check your progress during this operation.

Tightly twist together all wires in each bundle. At this point, you can simply tin with solder each bundle of wires. Connect each bundle to the project via the TO SENSOR contacts on the terminal board.

Installation

Bear in mind that resistors *R2* and *R3* limit the current applied to the water-sensing tape and, thus, determine the sensor's sensitivity when water forms a conductive path across the electrodes. When the tape is dry, full ac voltage reaches the *D1* through *D4* bridge rectifier. In most parts of the country, fresh ground water or potable tap water contains enough resistance to add up to between 1,000 and 3,000 ohms across the electrodes of the sensing tape.

Water contacting the tape forms a voltage divider with *R2* and *R3*. As has been detailed above, detection potential for *U1C* is approximately 33 percent of the power-supply voltage. Hence, to use the sensor with a high-resistance liquid, such as distilled water, you can increase the values of these two resistors to increase the project's sensitivity. If you increase the values of these two resistors to 100,000 ohms each, skin resistance will activate the alarm when you touch the electrodes.

You can also reduce the values of *R2* and *R3*, but power consumption will increase commensurately when the electrodes in the sensor tape are shunted because the lower circuit resistance more heavily loads down the transformer.

Use only plastic tape to install the sensor cable in the selected location. Do *not* use metallic staples, screws or nails to secure the tape in place. These will only short-circuit the sensor tape and defeat the purpose of the project.

If you built the Fig. 4 version of the circuit-board assembly and plan to use it to activate an external relay to sound a remote klaxon horn or turn on a water pump, do *not* pass ac line current through the contacts of the relay on the board. To do so will present a dangerous shock hazard, not to mention that the high current drawn by the load may fuse the relay's contacts permanently closed.

When installation is complete, power up the project. If at this point the alarm sounds continuously, there is something wrong with circuit wiring, or the electrodes in the tape sensor are shorted together.

To check for proper circuit operation, use an oscilloscope or logic probe to check for the presence of a square wave at the transformer's primary by monitoring pins 10 and 12 of *U1*. If the dc potential at pin 5 of *U1* is low, test *D1* through *D4* for excessive leakage current. Replace any diode that shows excessive leakage.

Check for a square wave of one-quarter of the oscillator frequency at pin 1 of *U2* and one-half the oscillator frequency at pin 13 of *U2*. Finally, check the oscillator output at pin 8 of *U1* (note that checking the oscillator output at this pin with a ×1 scope probe may load down the circuit and change the frequency of the oscillator).

If no oscilloscope is available, you can use an audio signal tracer to follow the oscillator signal through the divider chain.

Once your Wide-Coverage Water Detector Alarm is operating as it should, turn it on and leave it powered continuously. Now, whenever you hear the alarm sound, you will know it is time to take remedial action to prevent water damage to your home and persuasions. If you incorporated a water pump, this will automatically turn on and attempt to keep the protected area from flooding.

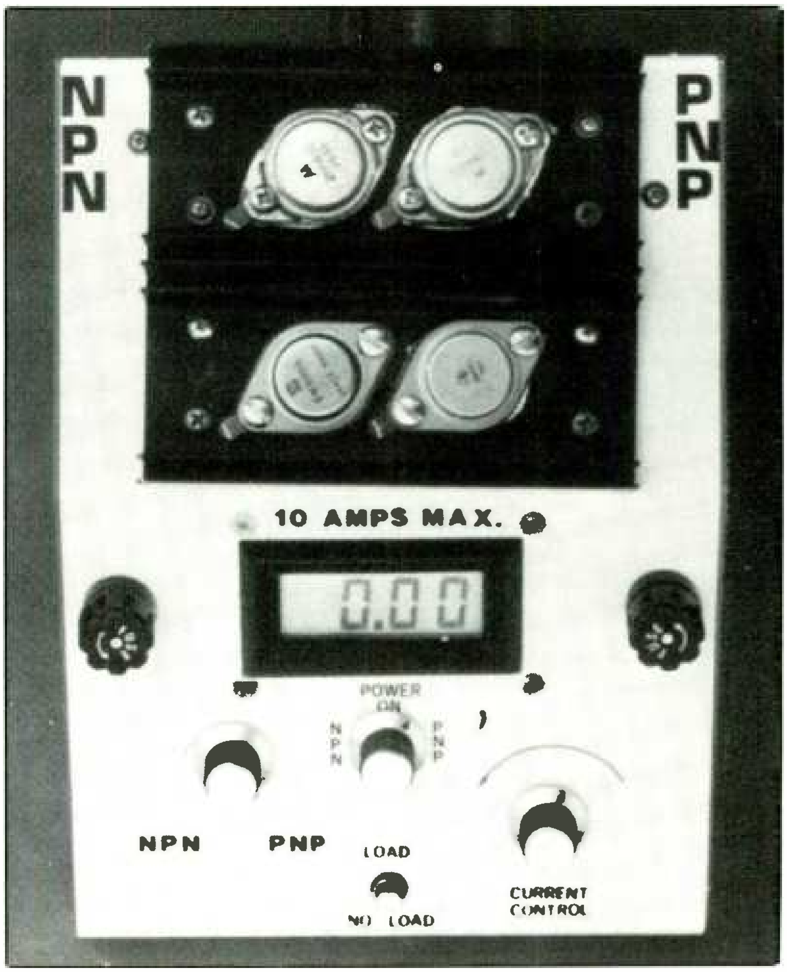
Variable-Load Box & Power-Transistor Tester

Lets you check the regulation and set current limits of your dc power supply. Also checks the operating condition of npn and pnp bipolar power transistors.

By David H. Bevel

If you test and repair electronic equipment or do serious experimenting, a device for checking the regulation of your dc power supply and condition of power bipolar transistors can be very handy to have on your testbench. When available as a commercial product, such a specialty device is likely to be very expensive. However, you can build the Variable-Load Box/Power-Transistor Tester described here at relatively low cost.

This accessory does double duty as a variable load for low-voltage dc power supplies and for testing both npn and pnp bipolar power transistors. As a variable load, it lets you check your dc power supply's output for proper voltage regulation at the specified current. "Device Under Test" (DUT) sockets allow you to test bipolar power transistors. Operated in this mode, the project uses the test transistor as the power supply load and operates as a go/no-go indicator of the dc current-handling ability of the transistor.



About the Circuit

Shown in Fig. 1 is the schematic diagram of the basic circuitry used for the Variable-Load Box/Power-Transistor Tester. The power supply connects to the input of this accessory via color-coded binding posts. A single-ended positive (+) output supply connects to the project via *BP1* (+) and *BP3* (GND). A single-ended negative (−) supply connects to the project via *BP2* (−) and *BP3* (GND). A bipolar supply connects via all three binding posts, in the proper polarities.

When LOAD control *R2* is varied, it changes the voltage that appears at the base of bias transistor *Q1* or *Q2*. Which of these two transistors is the recipient of this voltage depends on the setting of NPN/PNP switch section *S1B*. If NPN is selected, *Q1* is the recipient, and vice-versa.

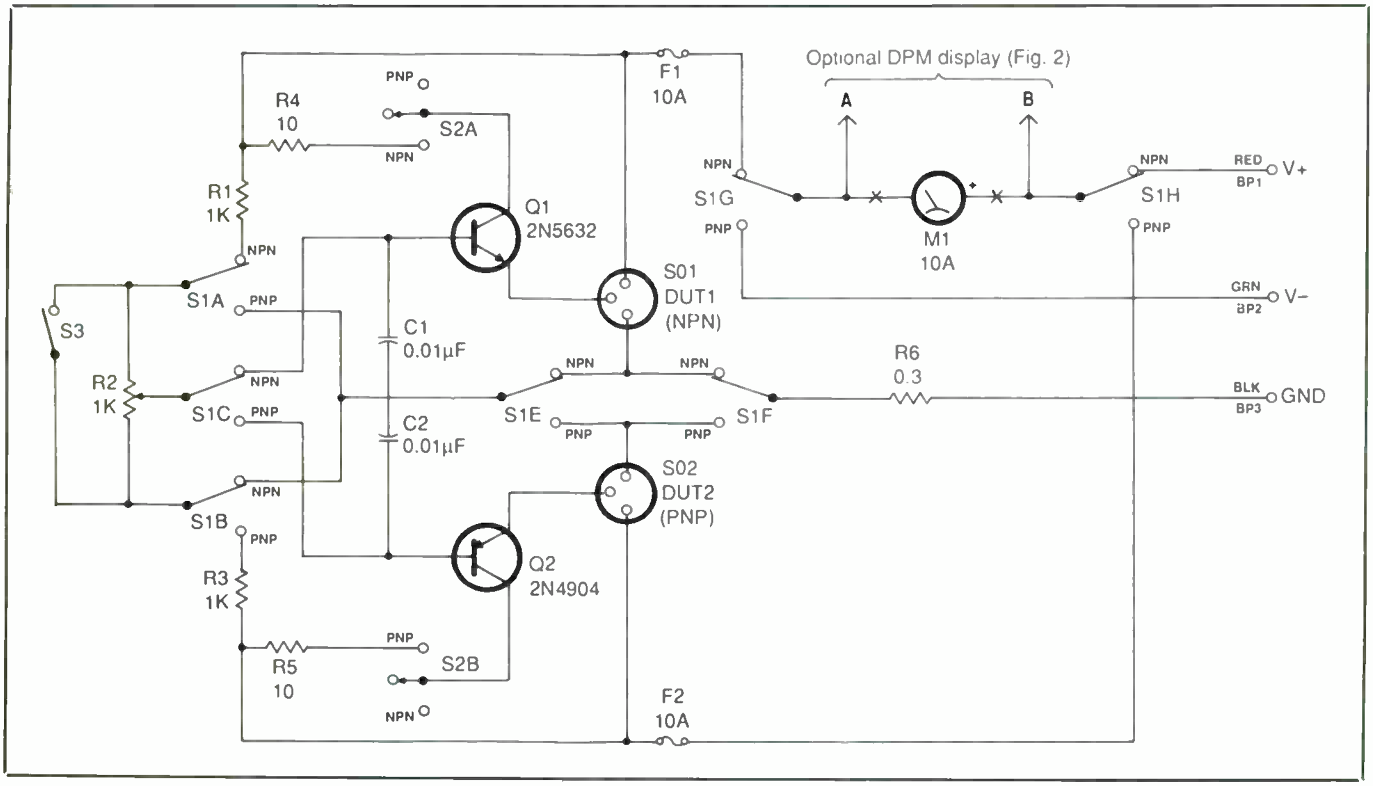


Fig. 1. Complete schematic diagram of basic Variable-Load Box/Power-Transistor Tester.

Any increase in the drive voltage to the base of the selected transistor results in an increase in the transistor's forward bias. Conversely, any decrease in base drive voltage results in a decrease in forward bias. Whether increase or decrease, the result causes a shift in the voltage ratio across the bias transistor and load resistor for the selected transistor (*R4* or *R5*). This varies the base bias of the transistor plugged into DUT1 or DUT2 socket *SO1* or *SO2*, whose internal resistance is increased or decreased. The magnitude of the load placed on the external power supply is changed accordingly.

At 5 volts, current is limited to about 3 amperes. At 15 volts, the output current should approach or even exceed 10 amperes. To increase the current-sink capability of the circuit, the values of *R1* and *R3* can be decreased, or these resistors can be removed altogether from the circuit. If you do remove these resistors, keep in mind the power rating of *R2* and

PARTS LIST

Semiconductors

IC1*—ICL7106CPL LCD panel-meter decoder/driver (Intersil)
Q1—2N5632 or similar silicon npn power transistor
Q2—2N4904 or similar silicon pnp power transistor

Capacitors

C1,C2,C4*—0.01-µF ceramic disc
C3*—100-pF ceramic disc
C5*—0.047-µF Mylar or ceramic disc
C6*—0.22-µF Mylar or ceramic disc
C7*—25-µf, 25-volt electrolytic

Resistors (5% tolerance)

R1,R3—1,000 ohms, 2 watts
R4,R5—10 ohms, 10 watts
R6—0.3 ohm, 50 watts
R7*—0.1 ohm, 1 watt, 5% tolerance
R8*—100,000 ohms
R10*—24,000 ohms
R11*—470,000 ohms
R12,R13*—1 megohm
R2—1,000-ohm linear-taper panel-mount potentiometer
R9*—20,000-ohm pc-mount trimmer potentiometer

Miscellaneous

B1*—9-volt battery
BP1,BP2 BP3—Five-way binding post (one each red, green and black—see text)
F1,F2—10-ampere slow-blow fuse
M1—10-ampere dc panel-mount ammeter (see text)
S1—8pdt switch
S2—Dp3t switch
S3—Spst toggle or slide switch
SO1,SO2—Power-transistor socket (see text)
Four-decade LCD module with 2-volt full-scale range (see text)*; printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text)*; socket for IC1*; suitable enclosure (see text); transistor heat sink; bayonet-type fuse holders (2); snap connector for B1*; control knobs for S1, S2 and R2; dry-transfer lettering kit and clear acrylic spray; machine hardware; hookup wire; solder; etc.

*Components for optional digital panel metering system; see text.

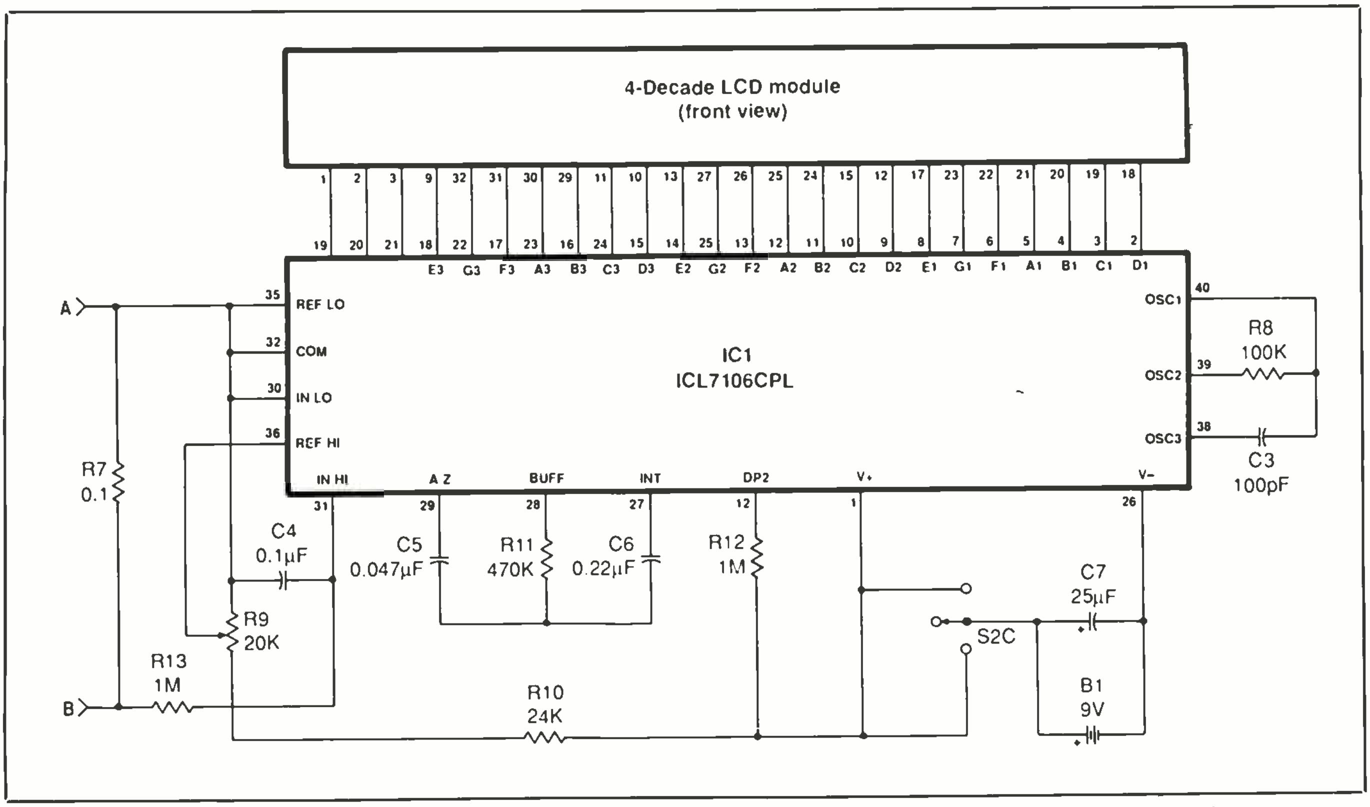


Fig. 2. An optional digital numeric display circuit that can be used in place of analog meter movement shown in basic circuit. This circuit connects to main project via two leads that bridge points A and B in both circuits with each other. Eliminate analog meter movement from basic circuit when using this optional metering system.

all other passive components in the circuit when using the project at higher voltages.

The circuitry shown is easy to modify to suit particular needs. For example, you could replace the single fixed values shown for *R1* and *R3* with several different values for each leg of the circuit and a multiple-position switch to select from among the various values. Of course, to be able to do this, the values selected for both legs should be the *same*.

Another thing you might want to keep in mind when using a power supply that has a 12-volt or greater output is to current-limit the supply to no more than 10 amperes if it is capable of delivering more than this. This is to obviate "pegging" the pointer on ammeter *M1*. Alternatively, you can substitute another analog metering system for the 10-ampere movement specified. A better alternative is to replace the analog metering system with the optional digital metering scheme shown schematically in Fig. 2. This digital system has a 20-ampere range, which should be more than sufficient for all but a very few power-supply applications.

As you can see in Fig. 2, the optional digital metering system is basically a simple arrangement. It consists of a specialized integrated circuit that converts the analog input applied across points A and B into a binary-coded signal that can be directly displayed on the three-decade LCD display. This circuit is powered by its own 9-volt battery, *B1*, which is switched in and out of the circuit via switch section *S2C*.

Construction

Unless you are planning on using this project for testing power supplies only, you must plan on incorporating transistor test sockets for *SO1* and *SO2*. The best type to use is molded into a single body that has a mounting hole in the middle, such as RCA's No. KH3403 or Keystone Electronics' Nos. 4513 through 4516.

The mounting hole in the socket may have to be countersunk, along with the mounting hole drilled in the enclosure to ensure that the mounting screw is flush with the surface of the enclosure. This allows the heat sink to lie flat on the surface of the enclosure and obviates interference by the hardware.

When mounting the DUT sockets in place, be sure to use an insulating washer between sockets and retaining nuts if there is any possibility of the nuts making contact with the metal surface of the sockets. This metal surface is connected to the socket contact for the collector of any transistor under test.

In selecting an enclosure and heat sink, a point to remember is the amount of sustained current you plan on using. If a large sustained current is planned upon, a large heat sink and a muffin cooling fan are probably in order and should be incorporated into the project. These, as well as the project circuitry, will dictate the size and shape of enclosure you will have to use.

As you can see in the interior view of the finished project, all components of the basic circuitry mount directly on the panels of the enclosure, without need for a circuit board. Of course, if you decide to incorporate the digital display in place of the analog meter movement, you will have to assemble the circuitry for this on a circuit board.

If you wish, you can design and fabricate a printed-circuit board on which to mount the various components that make up the optional digital display system. Otherwise, use any small piece of perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware to assemble and wire together the components for the circuit. Also, whichever means you use, plan on using a socket for *IC1*.

Just about any ready-to-use LCD panel meter that is set up to give a 2-volt full-scale readout can be used for the digital-display system.

Plan your component layout carefully before machining the enclosure that will house the project. A typical layout for a sloping-panel "instrument" enclosure is shown in the lead photo. The view shown is from directly above the project. The three color-coded binding posts are mounted on the rear panel; the power-transistor heat-sink/socket assembly is on the flat top panel; and the optional digital display, fuse holders and operating controls are on the sloping "front" panel.

Once you have the layout planned, machine the enclosure as needed. If you have decided to use the optional digital panel meter, make the rectangular slot for mounting it in place just large enough to permit the plastic bezel that surrounds the LCD window to pass through. A nibbling tool comes in handy for this operation.

When you have finished machining the enclosure and testing the various components for proper fit, deburr all holes and the LCD display slot to remove sharp edges. Then spray paint the enclosure, if needed. When the paint has completely dried, label the panels with appropriate legends, using a dry-transfer lettering kit. Protect the legends with two or more light coats of clear spray acrylic. Allow each coat to dry before spraying on the next.

Mount the various components in their respective locations. Make absolutely certain that output binding posts *BP1* and *BP2*, which connect to the "hot" voltage outputs of the power supply with which the project is to be used, do not electrically contact the metal of the enclosure. Use the fiber hardware supplied with the binding posts to assure this.

Wire the optional digital display circuit into the main circuit. This requires only two connections to be made. Connect a wire from point A

(Continued on page 80)

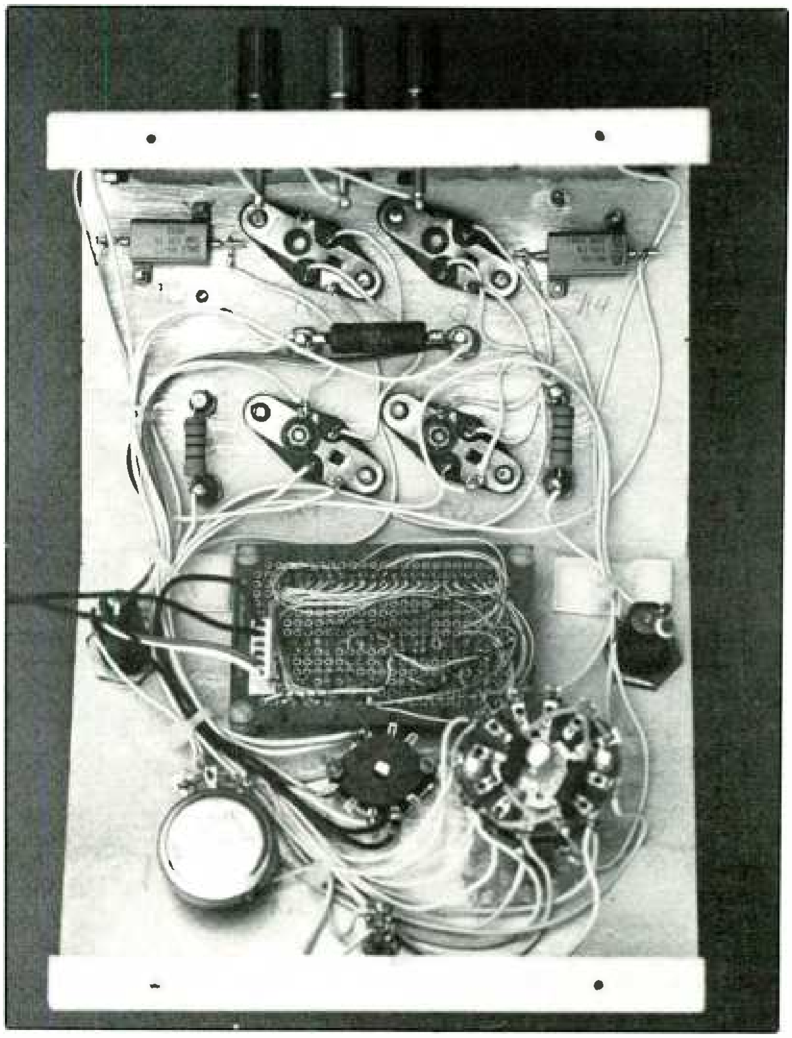


Fig. 3. Interior view of of wired project, including installation of optional digital metering circuitry.

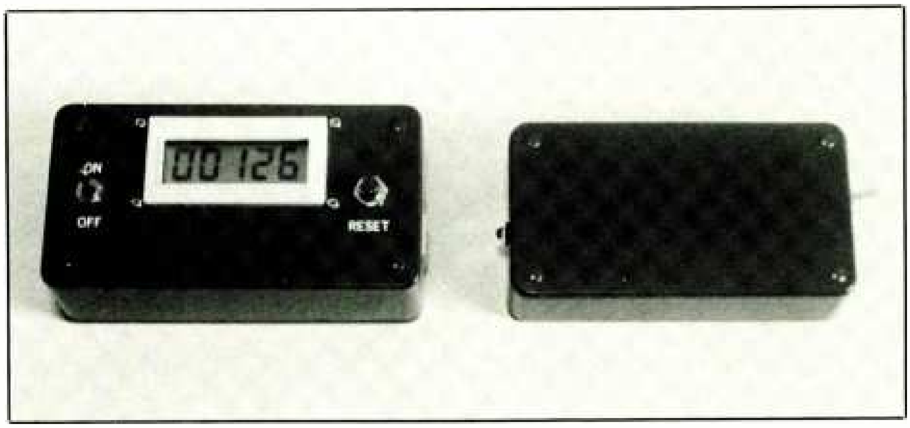
An Infrared-Detector Event Counter

Multiple-application project tallies the number of events it detects and displays the running total on a digital numeric display

By Jan Axelson

An event counter is a device that counts how many times something occurs. An example is the odometer in a car, which counts how many miles the car has traveled; another is a turnstile with a counter that keeps track of how many people have passed through it. An event counter might also count objects passing by on a factory conveyer belt. No matter what the application, all event counters include a means for detecting the desired occurrences, a counter to tally them and a means for displaying the results.

In this article, we describe an event counter that counts the number of objects that pass through an infrared beam. Each time something passes between the transmitting and receiving elements and interrupts the beam, an event is counted. You can use this Event Counter for any of a number of applications. Because the infrared beam is invisible, it can be used unobtrusively.



About the Circuit

Shown in Fig. 1 is the complete schematic diagram for the Event Counter's transmitter circuitry. This circuit is powered by *B1* and *B2*, two 1.5-volt cells in series. Low-power TLC555 timer *IC1* is configured as a 40,000-Hz oscillator. This oscillator controls infrared-emitting diode *IRED1*.

When pin 3 of *IC1* goes low, transistor *Q1* switches on, turning on *IRED1*. Conversely, when pin 3 goes high, *Q1* is cut off and *IRED1* ceases transmitting IR energy. Charging of *C1* through *R1* and *R2* determines how long pin 3 is high during each oscillation period, and discharging of *C1* through *R2* determines how long pin 3 is low.

The value of *R2* is chosen so that *IRED1* is on for about 2 microseconds in each cycle. Potentiometer *R1* is adjusted so that *IRED1* is off for 23 microseconds of each cycle. Thus, the total period is 25 microseconds. By pulsing on *IRED1* only briefly, battery power is conserved while providing a strong transmitted signal.

Resistor *R4* limits the current through *IRED1* to about 140 milliamperes. Because *IRED1* is on for just a small portion of each cycle, average current drain is well below the maximum allowable average current for a typical IR-emitting diode. Base current for *Q1* is limited by *R3*, and *C2* is recommended for power-supply decoupling.

A way is now needed to detect the IR beam and count how many times it is interrupted. Shown in Fig. 2 is a wiring diagram for the Event Counter's receiver, count and display sections. As you can see, most of the receiver circuitry is contained inside module *MOD1*. This integrated module contains all the circuitry needed to detect the IR beam. A second module, shown as *MOD2* contains the circuitry that counts the number of times the beam is interrupted and shows a running count of that number in its digital display.

Battery cells *B3* through *B6* power the receiver circuit. Half of dpst switch *S2* connects *B6* to *MOD2*, which requires just 1.5 volts. The other half of *S2* connects *B3* through *B6* to the circuitry in *MOD1*.

Module *MOD1* is a GP1U52X infrared receiver/demodulator and is available from Radio Shack (Cat. No. 276-137). The module was described in Forrest Mims' "Electronic Notebook" column in the February, 1989 *Modern Electronics*.

Conveniently, the GP1U52X contains an optical filter, photodiode, preamplifier, limiter, bandpass filter, demodulator, integrator and comparator in one package. If you were to attempt to build all of this circuitry using op amps and other components, you would be tackling a major project in itself.

A PIN photodiode with peak sensitivity in the near-infrared range (980 nanometers) is used as the detecting element built into *MOD1*. Infrared energy striking this element causes the photodiode to develop a current that is used to drive the input of the module.

To prevent the photodiode from responding to signals outside the IR band, an optical filter blocks visible light. Additionally, a bandpass filter rejects signals that are not oscillating at or near 40 kHz. This helps to prevent the module from responding to "stray" IR energy that is not at the 40-kHz frequency of the signal generated by the transmitter.

Just three connections are required for *MOD1*: an output at pin 1, a +5-volt input at pin 2 and a ground input at pin 3. Its 5-volt supply is regulated by 5.1-volt zener diode *D1*. Battery *B3* through *B6* applies 6 volts to the series combination of *R5* and *D1*, with avalanche current holding the potential across *D1* at about 5 volts. Current limiting for the zener diode is provided by *R5*.

Pin 1 of *MOD1* responds to the presence of IR energy oscillating at a frequency of about 40 kHz. This pin is low when such a signal is detected. At all other times, it is high.

Module *MOD2* is an integrated counting module, also available from Radio Shack (Cat. No. 277-302) that contains a five-decade liquid-crystal display, counter circuit and battery holder. Solder pads along the top of the module permit easy connection to GROUND, RESET, COUNT, +1.5 VOLTS and TONE OUTPUT. An AA cell clips directly into a holder on the back of the module. Alternatively, you can wire another 1.5-volt source to pins 1 and 4. With an average current drain of the module of just 4 microamperes, the single AA cell should last a very long time.

The displayed count increments each time pin 3 of *MOD2* goes high. In Fig. 2, the count is controlled by pin 1 of *MOD1*, with transistor *Q2*

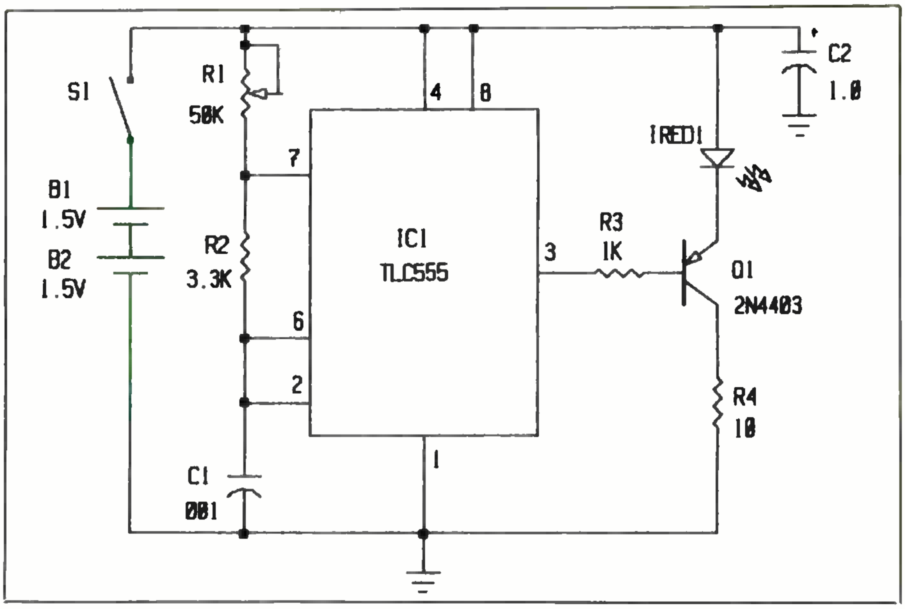


Fig. 1. Complete schematic diagram of the Event Counter's transmitter.

PARTS LIST

Semiconductors
D1—5.1-volt zener diode
IC1—TLC555 or equivalent low-power timer (see text)
IRED1—Infrared-emitting diode
Q1—2N4403 or similar general-purpose pnp transistor
Q2—2N2222 or similar general-purpose npn transistor

Resistors (¼-watt, 5% tolerance)
R2—3,300 ohms
R3—1,000 ohms
R4—10 ohms
R5—33 ohms
R1—50,000-ohm pc-mount potentiometer

Capacitors
C1—0.001-µF, 15-volt polyester or other timing capacitor
C2—1.0-µF, 15-volt tantalum

Miscellaneous
B1 thru B6—1.5-volt cell (AAA, AA, C or D—see text)
MOD1—GP1U52X infrared receiver/demodulator module (Radio Shack Cat. No. 276-137 or similar—see text)
MOD2—Electronic LCD counting module (Radio Shack Cat. No. 277-302 or similar—see text)
S1—Spst toggle or slide switch
S2—Dpst toggle or slide switch
S3—Normally-open momentary-contact spst pushbutton switch
Suitable enclosures; battery holders; panel-mount LED holder; eight-pin socket for IC1; printed-circuit board (or perforated board with holes on 0.1-inch centers, suitable Wire-Wrap or soldering hardware—see text); lettering kit (see text); machine hardware; hookup wire; solder; etc.

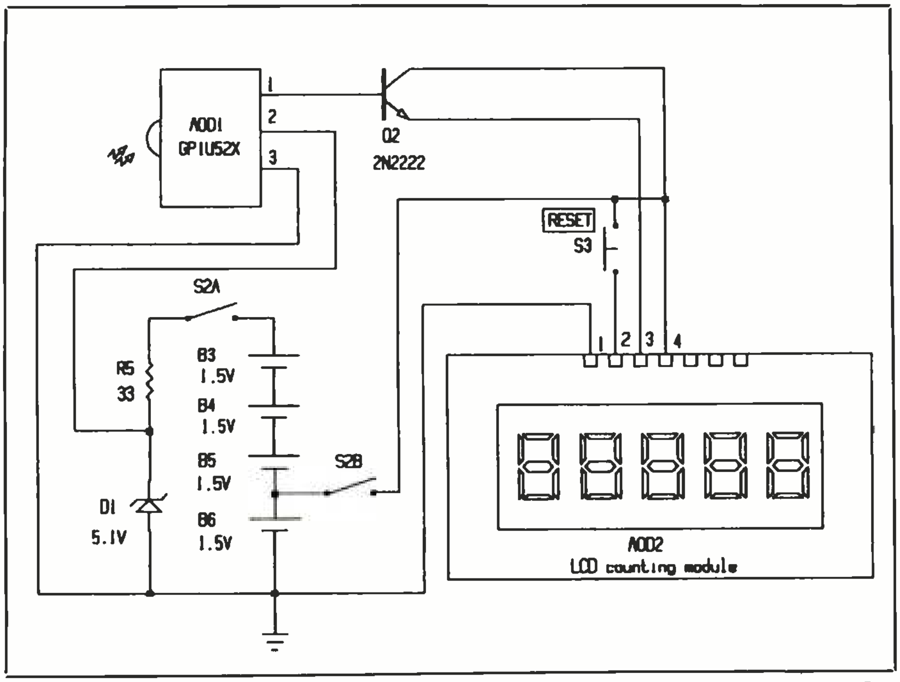


Fig. 2. Wiring diagram for the Event Counter's receiver and counter system. Circuitry appears to be very simple because MOD1 *and* MOD2 *are pre-assembled modules containing all circuitry required to perform the given functions.*

providing an interface between the two modules. When pin 1 of *MOD1* is low, *Q2* is held in cutoff and pin 3 of *MOD2* has no voltage applied to it. When pin 1 of *MOD1* is high, *Q2* switches on, which provides a low-resistance path between pin 3 of *MOD2* and 1.5 volts.

To set up the Event Counter for operation, the transmitter and receiver units must be positioned so that the beam from *IRED1* in the transmitter strikes the detecting diode on *MOD2* in the receiver. When *MOD1* detects the beam, its pin 1 goes low and remains in that state until something interrupts the beam. When this occurs, pin 1 of *MOD1* goes high and causes the display to increment one count. When the beam path is restored, pin 1 of *MOD2* goes low again and waits for the next beam interruption. Pressing momentary-action switch *S3* resets the count to all zeros.

As an aside, counting module *MOD2* is useful for many projects besides this one. For a simple, manually operated counter, eliminate *MOD1*, *B3* through *B5*, *Q2*, *R5* and *D1* in Fig. 2, and connect a normally-open pushbutton switch across pins 3 and 4 of *MOD2*. Alternatively, use a magnetic or other type of switch to trigger the count. To hear a "beep" tone each time an event is counted, connect a speaker across pins 5 and 1 of *MOD2*.

Construction

There is nothing critical about component layout or conductor runs. Therefore, you can use any wiring technique that suits you to wire together the two circuits. If you wish, you can lay out and fabricate a printed-circuit board for the transmitter circuit. Alternatively, you can use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware. For the receiver, you have the option of mounting the very few discrete components on a small perforated board or a multiple-lug terminal strip.

This project requires two enclosures—one for the transmitter and the other for the receiver. Modules *MOD1* and *MOD2* are available from Radio Shack (see Parts List). Other sources may offer similar modules that can be used in circuits similar to the ones described here. All other components are readily available. A low-power TLC555 timer is specified for *IC1* in the transmitter module. You can substitute another low-power timer chip, such as the XR-L555, but do not use a bipolar 555 because it requires a minimum supply of 4.5 volts. Also, use a socket for *IC1* when assembling the transmitter circuit.

You can use AAA, AA, C or D cells for *B1* through *B6* in both circuits. Of course, the larger cells provide longer operating life, but require more enclosure room. Smaller cells will deliver a respectively long life if they are used.

Items that mount directly on the enclosures include *IRED1*, *MOD1*, *MOD2* and *S1* through *S3*. As you plan placement of *IRED1* and *MOD1*, align them so that *IRED1* and the round "eye" of *MOD1* are at the same height when the enclosures are in their normal orientations, as shown in Fig. 3. Exact height is not critical, but the same for both elements is.

Do *not* use the battery holder on *MOD2* in the receiver for *B6*. This holder does not provide a means for turning off the module. Instead, use a single holder for *B6* and wire it in series with holders for *B3*, *B4* and *B5*, or solder a wire that taps off the positive (+) terminal of *B6* from a four-cell holder for *B3*, *B4* and *B5*. Note that *B6* is the last cell in the series arrangement; its negative (−) terminal connects directly to ground.

In Fig. 4(A) and (B) are shown the insides of completed transmitter and receiver units, respectively. Begin construction of these by cutting two small pieces of perforated circuit board (or use a home-fabricated pc

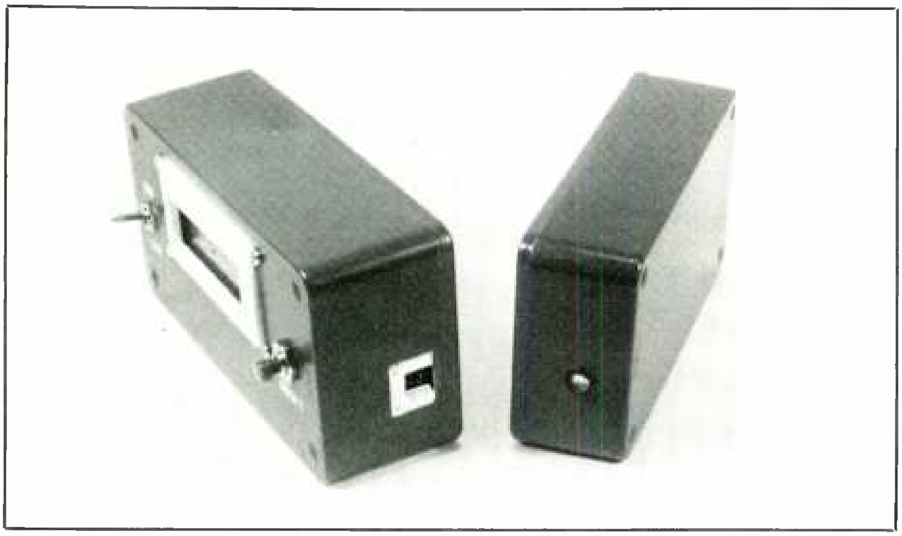


Fig. 3. An infrared-emitting diode on the transmitter beams infrared energy to the receiver's infrared detector.

board for the transmitter unit), one for *IC1* and its associated circuitry in the transmitter, and the other for *R5*, *D1* and *Q2* in the receiver.

Using Fig. 1 as a guide, wire the transmitter circuitry. Before installing potentiometer *R1*, use an ohmmeter to adjust it for about 30,000 ohms between the center and either outer lugs. Wire these lugs to pins 7 and 8 of *IC1*. Then wire the third lug to the wiper lug of the pot.

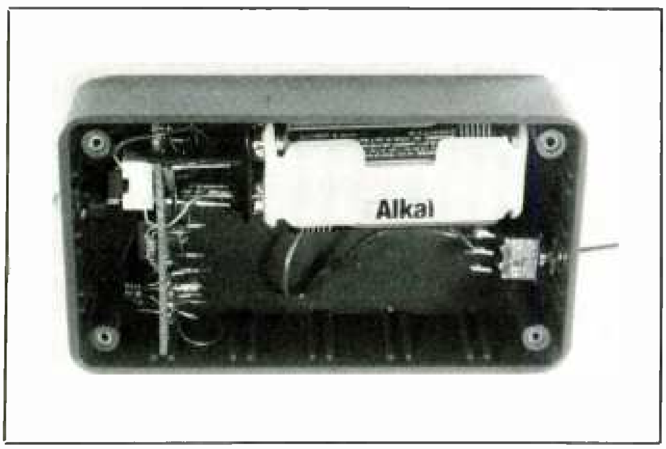
Mount *IRED1* and *S1* directly on the enclosure and wire them to the circuit-board assembly using short lengths of insulated hookup wire with ¼ inch of insulation stripped from each end. Wire the battery holder for *B1* and *B2* to *S1* and ground on the circuit-board assembly.

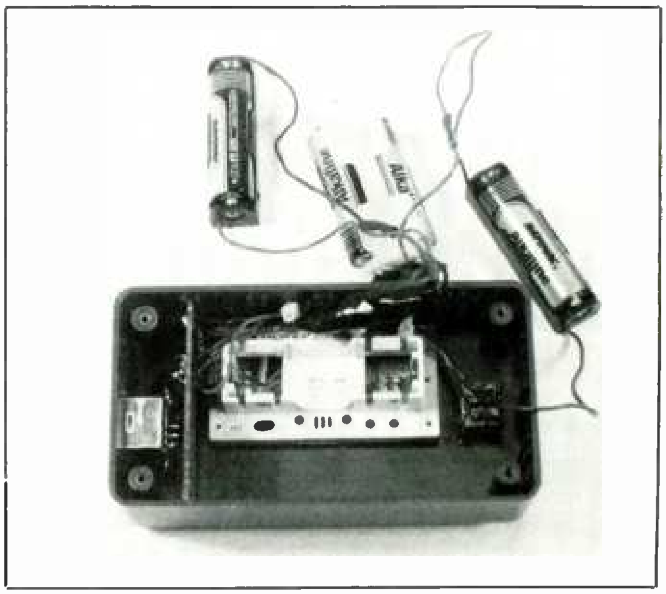
To wire to *MOD2*, remove the four small mounting screws on its front. Carefully lift off the back of the module to expose a set of seven solder pads along the top of the circuit board. Cut four short lengths of hookup wire, strip ⅛ inch of insulation from one end and ¼ inch from the other end of each. Solder the ends from which ⅛ inch of insulation has been removed to pads 1 through 4 on the module. Pad 1 is the right-most when the module is face down. (This is the pad nearest the most-significant digit on the display.) When you are finished, replace the back of the module and reinstall the screws.

On the receiver unit's circuit board, insert *R5*, *D1* and *Q2*, and wire the circuitry as shown in Fig. 2. Use the wires you soldered to *MOD*2 to make the connections. Then use short lengths of hookup wire to make the connections to *MOD1*, both halves of *S2*, *S3* and the battery holder(s).

Prepare the transmitter's enclosure by making holes for mounting the clip for *IRED1* and *S1*. The receiver's enclosure requires holes for *MOD1*, *MOD2*, *S2* and *S3*. The rectangular slot for *MOD1* can be made by drilling a ⅜-inch hole and then using a nibbling tool to enlarge this to the appropriate size. The module slides into its hole with its detecting diode facing out, so that the face of

Fig. 4. (A) A small circuit board accommodates most of the transmitter's components, with the IR-emitting diode mounting directly on the enclosure. (B) Counting module and IR receiver mount on the receiver's enclosure.





the module is flush with the outside of the enclosure. From there, you can use clear fast-setting epoxy cement to secure the module in place later on when you are directed to do so.

To install *MOD2*, cut a rectangular slot just large enough for the raised display panel to fit through. The nibbling tool comes in handy for this operation as well. Then drill four small holes to match the locations of this module's mounting screws. Install *MOD2* by again removing its four screws, inserting the module from the inside of the enclosure into its prepared opening, and reinstalling the screws through the enclosure into the module. Also, drill the mounting holes for *S2* and *S3*.

Label *S1* on the transmitter and *S2* on the receiver with the legends ON and OFF and *S3*, also on the transmitter, with the legend RESET. Use a dry-transfer lettering kit, and protect the legends with two or more light coats of transparent spray acrylic (remove or cover *MOD1* and *MOD2* while spraying). If you use self-adhering plastic tape labels, there is no need to protect the legends.

When the acrylic spray has completely dried, install the circuit board assembly in the transmitter enclosure. Then mount the clip for *IRED1* and *S1* and insert *B1* and *B2* in the battery holder. Wrap the battery holder in nonconductive foam plastic to hold and cushion it inside the enclosure. Install the circuit-board assembly (or terminal strip) inside the receiver enclosure. Then mount *S2*, *S3*, *MOD2* (if it is not already installed) and *MOD1* in place.

You can now cement *MOD1* into place by applying a bead of epoxy cement inside the enclosure where this module meets the wall of the enclosure. When the epoxy has fully set, install *B3* through *B6* in their holders and insert their holders, cushioning them as needed.

Checkout & Use

Before use, the transmitter must be adjusted for an output frequency of 40 kHz at pin 3 of *IC1*. If you have a frequency counter or an oscilloscope, use it to measure the frequency and adjust the setting of *R1* until the signal monitored at pin 3 of *IC1* is at 40 kHz on the counter or displays a 25-microsecond period on the oscilloscope.

If you do not have access to a frequency counter or oscilloscope, adjust the frequency by the trial-and-error method with the aid of a voltmeter. With both enclosures open, set the transmitter and receiver a couple of feet apart, with *IRED1* aimed at the face of *MOD1*. Turn on both units and measure the voltage from the emitter of *Q2* to ground.

If necessary, adjust the setting of *R1* until the measured voltage goes low, indicating that a signal is being detected. Continue adjusting *R1* until the voltage goes high (1.5 volts), indicating that no signal is detected. Then adjust the pot to about the middle of the range for which the voltage is low. The measured value of *R1* at this point should be approximately 30,000 ohms, with some variation caused by differences in the values of *R2* and *C1*.

Now, each time you block the infrared beam from *MOD1*, the count in *MOD2* should increment. Pressing *S3* should reset the displayed count to zero. If you experience any problems with your circuits, power down and carefully check over your wiring against Fig. 1 and Fig. 2.

When your Event Counter is functioning as it should, move the transmitter and receiver farther apart to determine how well the counter functions over greater distances. With careful aiming, interruptions of the IR beam should result in positive counting over distances of 10 feet or more. If you adjusted the transmitter's frequency by trial and error, you may discover that fine-tuning *R1* with the transmitter and receiver farther apart will yield greater range.

You also can experiment with increasing the range by using a smaller value for *IRED1* current-limiting resistor *R4*. Doing this increases the power of the transmitted beam, though the tradeoff will be faster battery depletion. Alternatively, for an Event Counter that operates over a short distance, you can get by with a larger value for *R4* and correspondingly longer battery life.

As you experiment with your Event Counter, keep in mind these characteristics of counting module *MOD2*: Maximum count frequency is 7 Hz, which means that if more than seven objects pass through the beam per second, not all may be counted. Also, debouncing circuitry in *MOD2* helps to keep the counter from responding to brief stray signals detected by *MOD1* while the beam is blocked. **ME**

Designing Oscillators

A primer on designing sine-wave audio oscillators

By Joseph J. Carr

Oscillators are commonly used in all types of electronic circuits to accomplish different things. In analog circuits, the sine-wave oscillator dominates. It is important, therefore, that you gain a thorough grounding in designing sine-wave oscillators. In this article, our focus is on audio-frequency oscillators in which resistive/capacitive elements are used as the frequency-determining devices.

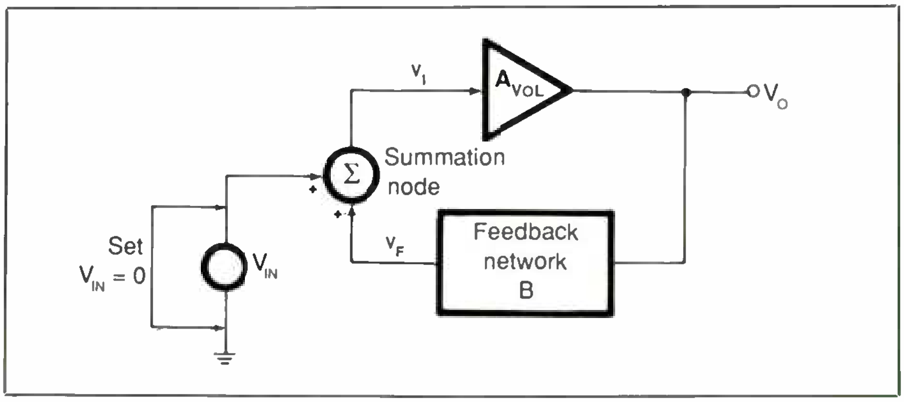


Fig. 1. Elements of a basic feedback oscillator.

Basic Theory

A feedback oscillator, such as the one diagrammed in Fig. 1, consists of an amplifier that has an open-loop gain of A_{vol} and a feedback network with gain function B. This is called a "feedback" oscillator because the output signal from the amplifier is fed back to the input of the amplifier via some type of network.

Figure 2 is a block diagram model of the basic feedback oscillator. It bears more than a superficial resemblance to a feedback amplifier. A feedback oscillator is simply an amplifier in which special conditions prevail. These conditions are commonly referred to as "Barkhausen's criteria for oscillation" and are stated as follows: (1) Feedback voltage V_F must be in-phase (360 degrees) with input voltage V_{in}; and (2) Loop gain BA_{vol} must be at least unity (1) or greater.

The first of the Barkhausen criteria means that the total phase shift from the input to the output of the amplifier, around the feedback loop, must be 360 degrees or an integer (N) multiple of 360 degrees.

Any of many different devices can be used as the amplifier. In some circuits, the active element is a common-emitter bipolar npn or pnp transistor. In other circuits, it is a junction field-effect transistor (JFET) or metal-oxide semiconductor field-effect transistor (MOSFET). In older equipment, the active element was a vacuum tube. In the most up-to-date of circuits, this device is most often an integrated-circuit operational amplifier or other linear IC amplifier.

An inverting type of amplifier is the most frequently encountered. Its output is out-of-phase with its input by 180 degrees. As a result, to obtain the 360-degree phase shift required to initiate and sustain oscillation, an additional phase shift of 180 degrees must be accomplished in the feedback loop. This phase shift must be at only the frequency of oscillation. If the network is designed to produce this phase shift at only one frequency, the oscillator produces a sine-wave output at that frequency.

Before considering specific sine-wave oscillator circuits, it is useful to more closely examine Fig. 1. Several things can be deduced about this circuit. The first is that

$$LV_i = V_{in} + V_F \quad [1]$$

Rearranging Equation [1], you get

$$V_{in} = V_i - V_F \quad [2]$$

Another thing that can be deduced from the Fig. 1 circuit is that

$$V_F = BV_o \quad [3]$$

$$V_o = V_oA_{vol} \quad [4]$$

Continuing, the transfer function, or gain, abbreviated A_v is:

$$A_v = V_iA_{vol} \quad [5]$$

Substituting Equations [2] and [4] into Equation [5], you get

$$A_v = V_iA_{vol}/(V_i - V_{F)} \quad [6]$$

Then, from Equation [3], $V_F = BV_o$. Hence,

$$A_v = V_iA_{vol}/(V_i - BV_o) \quad [7]$$

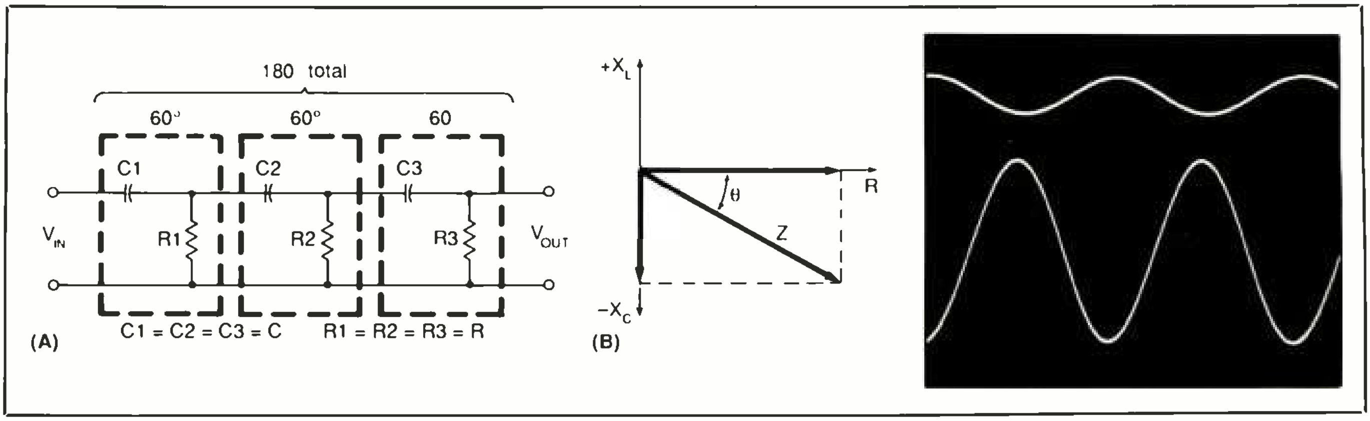


Fig. 2. Configuration of a three-stage RC network (A) for the RC phase-shift oscillator; the diagrammed phase-shift (B) shown as a function of resistance; and capacitance and an oscilloscope display (C) of the input and output waveforms.

However, Equation [4] shows that $V_o = V_iA_{vol}$. So Equation [7] can now be written as

$$A_v = A_{VOl}/(1 - BA_{vol}) \quad [8]$$

Dividing both numerator and denominator by V_i, you obtain

$$A = A_{vol}/(1 - BA_{vol}) \quad [9]$$

Equation [9] serves for both feedback amplifiers and oscillators. However, in the special case of an oscillator in which $V_{in} = 0$, V_o approaches infinity. Therefore, it is implied that the denominator of Equation [9] must also be zero:

$$1 - B_{vol} = 0 \quad [10]$$

Thus, for feedback oscillation,

$$BA_{vol} = 1 \quad [11]$$

Because BA_{vol} is the open-loop gain of the amplifier and feedback network, Equation [11] meets Barkhausen's second criterion.

Sine-Wave Oscillators

As their name implies, sine-wave oscillators generate a signal that is sinusoidal in shape. Such a signal is ideally very pure. When perfect, this signal's Fourier spectrum contains only the fundamental frequency and no harmonics. Indeed, it is the presence of harmonics that gives a nonsinusoidal waveform its characteristic shape.

The active element in circuits described in this article is an operational amplifier. However, any linear amplifier will work in place of the op amp. The one circuit that illustrates the principles most clearly is the RC phase-shift oscillator. Therefore, we begin our discussion with this circuit.

Stability in an oscillator circuit can refer to several different phenomena. Usually the first thing that comes to mind is frequency stability. This refers to the ability of the oscillator to remain on the design frequency over a period of time. Several different factors affect frequency stability. The most important are temperature and power-supply voltage variations.

Amplitude stability is another factor. Because sine-wave oscillators do not operate in the saturated mode (if they did, the output signal waveform would be an approximate square wave), it is possible for minor variations in circuit gain to affect the amplitude of the output signal. Again, the factors most often cited for any problem in this area include variations in temperature and supply voltage.

Variations in supply voltage are usually overcome by use of a regulated power supply for the circuit. Compensation for temperature variations is best achieved through either use of a temperature-compensated design or maintaining a constant operating temperature.

Some variable sine-wave oscillators may exhibit amplitude variations in the output signal when the operating frequency is changed. In these, either a self-compensation element is used or an automatic level control circuit is used.

Yet another form of stability refers to the purity of the output signal. If an oscillator circuit exhibits spurious oscillations, these will be superimposed on the output signal. As with any circuit that contains an op amp or any other high-gain linear amplifier, it is necessary to properly decouple the lines that provide dc power to the circuit. It may also be necessary to frequency-compensate the circuit.

RC Phase-Shift Oscillator Circuit

A three-stage cascade resistor-capacitor network, such as shown in Fig. 2(A), is the basis of the RC phase-shift oscillator. An RC network exhibits a phase shift, as shown in Fig. 2(B), that is a function of resistance R and capacitive reactance X_C. Because X_C is inversely proportional to frequency ($1/2\pi FC$), the resulting phase angle is a function of frequency.

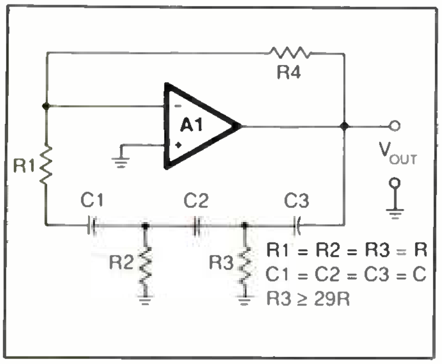


Fig. 3. Circuit details for an op-amp RC phase-shift oscillator.

Your goal in designing an RC phase-shift oscillator should be to create a 180-degree phase shift between the input and output of the network at the desired frequency of oscillation. Conventional practice is to make each RC leg in the network identical to obtain a 60-degree phase shift. The result will be the required 180-degree phase shift. This approach is not a requirement as long as the network you do use provides the required 180-degree phase shift.

One reason for using identical stages in the phase-shift network is that it is possible for designs that are not identical to operate at more than one frequency for which the additive phase shift will be 180 degrees. In a case like this, undesirable multi-modal oscillations can result.

Shown in Fig. 2(C) are the input and output waveforms of an RC network in which three stages of 10,000 ohms and 0.01 microfarads were used with an input frequency of 650 Hz. Note the 180-degree phase shift in the lower trace, and keep in mind that the vertical input scale factors for these two traces are different.

Peak-to-peak amplitude of the upper trace in Fig. 2(C) is 78.8 volts, while peak-to-peak amplitude of the lower trace is 0.268 volt, or $1/29$ of the input level. This attenuation factor is important in oscillator design because it establishes the minimum gain requirement in the amplifier.

An operational-amplifier RC phase-shift oscillator circuit design is shown in Fig. 3. Here, the cascade phase-shift network composed of *R1*, *R2*, *R3*, *C1*, *C2* and *C3* provides 180 degrees of phase shift at a specific frequency. Due to its configuration as an inverting follower, the amplifier provides another 180 degrees of phase shift. Total phase shift, therefore, is 360 degrees at the frequency for which the RC network provides 180 degrees of phase shift.

Frequency of oscillation for the Fig. 3 circuit is given by the formula:

$$f = 1/(2\pi RC) \quad [12]$$

where *f* is frequency in Hertz; *R* is resistance in ohms and *C* is capacitance in Farads. It is common practice to combine the constants in Equation [12] to arrive at the simplified expression:

$$f = 1/15.39RC \quad [13]$$

Because the required frequency of oscillation is usually determined by the application to which the oscillator is put, it is necessary to select an RC time constant to force the oscillator to operate as needed. Also, because capacitors come in fewer standard values than do resistors, it is usually the practice to select an arbitrary trial value of capacitance and then select the resistance that will cause the oscillator to produce the correct frequency with the value of capacitance chosen.

To make the calculations simpler, it is prudent to express the equation in a way that permits specifying capacitance *C* in microfarads. Equation [13] is sometimes rewritten as:

$$R = 1{,}000{,}000/(15.39C_{\mu F}f) \quad [14]$$

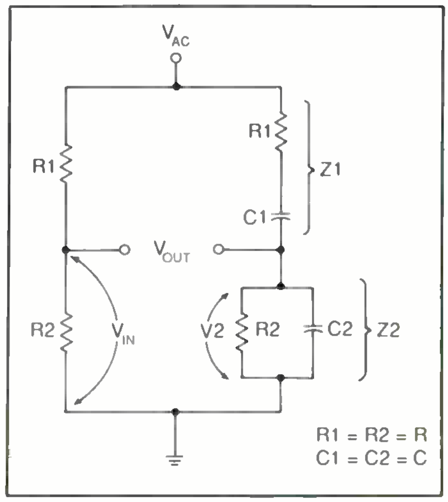
Attenuation through the feedback network must be compensated for by the amplifier if loop gain is to be unity or greater. At the frequency of oscillation, attenuation is $1/29$. Because loop gain must be unity, the gain of amplifier *A1* must be at least 29 to satisfy AB = 1. For the inverting-follower shown, R1 = R and A_v = R4/R1. Therefore, R4 must be 29R to meet Barkhausen's criterion for loop gain.

Wein-Bridge Oscillator

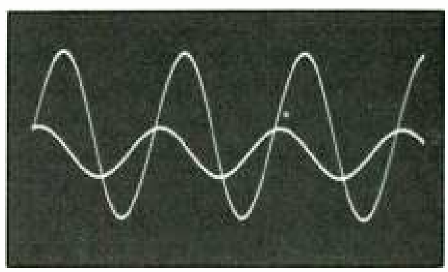
The Wein-bridge oscillator arrangement shown in Fig. 4(A) is like several other well-known bridge circuits in that it consists of four impedance arms. The arms consisting of *R1* and *R2* make up a resistive voltage divider that produces a V1 potential of

$$V1 = V_{ac}R2/(R1 + R2) \quad [15]$$

The two remaining arms consisting



(A)



(B)

Fig. 4. Frequency-determining RC elements (A) of a Wein-bridge oscillator and oscilloscope display (B) in which V_{ac} and V2 for the circuit in (A) are shown superimposed on each other.

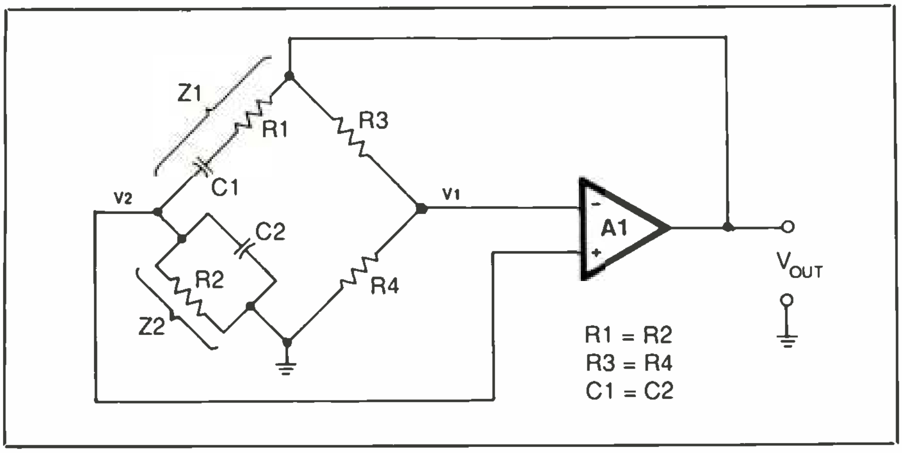


Fig. 5. A typical Wein-bridge oscillator circuit configuration.

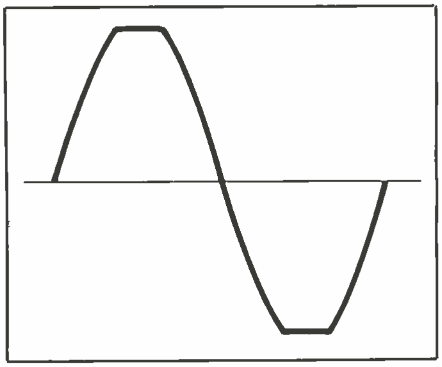


Fig. 6. Waveform shows flattened-peak result for a Weinbridge oscillator with gain slightly greater than required for stable oscillation.

of *Z1* and *Z2* are composed of complex RC networks that each contain one capacitor and one resistor. Impedance *Z1* is a series RC network, while impedance *Z2* is a parallel RC network. The voltage and phase shift produced by the *Z1/Z2* divider are functions of the R and C values and applied frequency.

Figure 4(B) shows V_{ac} superimposed on V2. Note here that $V2 = V_{ac}/3$ and that V2 and V_{ac} are in-phase with each other.

In Fig. 5 is shown the circuit for the complete Wein-bridge oscillator. The resistive voltage divider supplies V1 to the inverting (–) input, while V2 is applied to the noninverting (+)

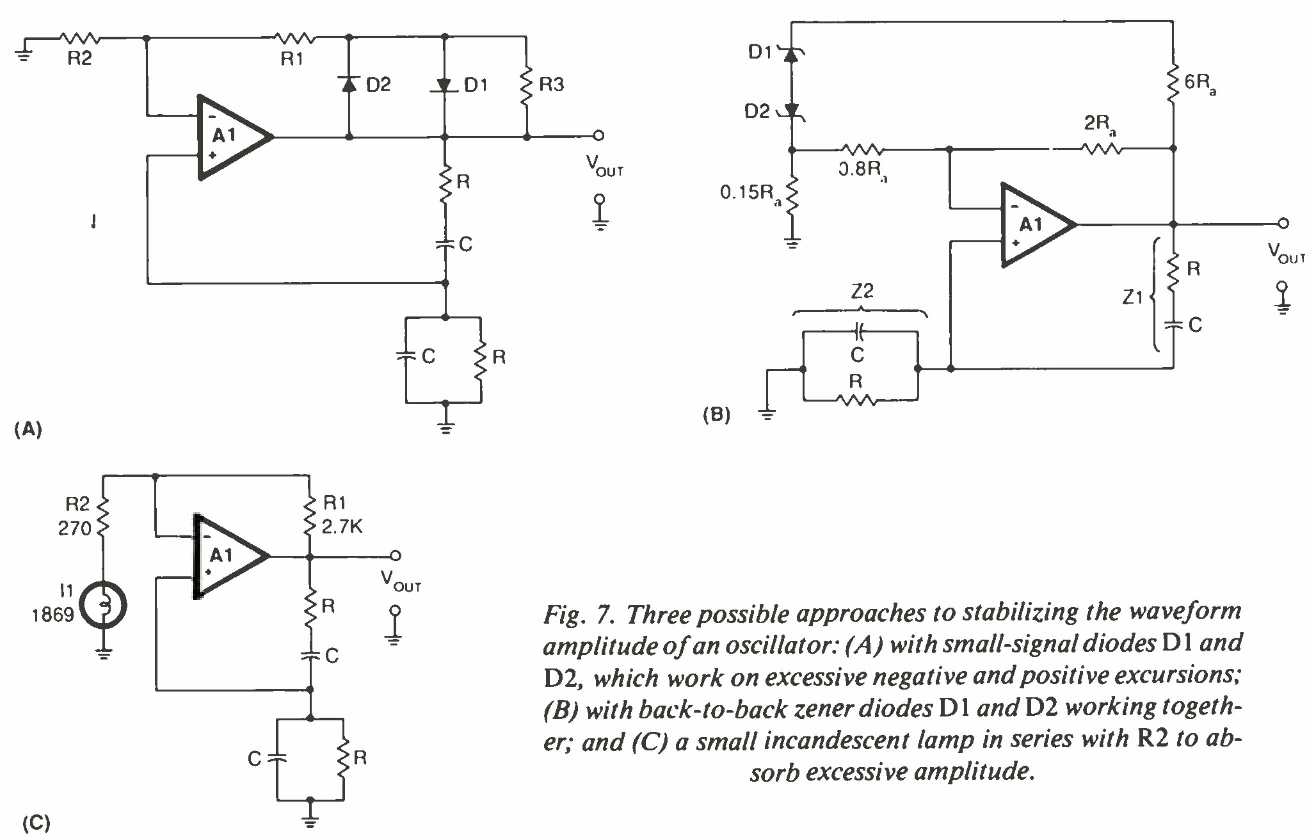


Fig. 7. Three possible approaches to stabilizing the waveform amplitude of an oscillator: (A) with small-signal diodes D1 *and* D2*, which work on excessive negative and positive excursions; (B) with back-to-back zener diodes* D1 *and* D2 *working together; and (C) a small incandescent lamp in series with* R2 *to absorb excessive amplitude.*

input of the amplifier element. The bridge signal source is the output of amplifier *A1*. With the ac signal applied to the + input, the gain the circuit sees is calculated from:

$A_v = (R3/R4) + 1$ [16]

and the ac feedback applied to the + input is:

$B = Z2/(Z1 + Z2)$ [17]

At resonance, B = 1/3. Therefore, as shown,

$V2 = V_o/3$ [18]

Because $A_v = V_o/V2$ by definition, satisfying Barkhausen's loop gain criterion $(-A_vB = 1)$ requires that $A_v = V_o/V2 = 3$. Using this result,

$A_v = (R3/R4) + 1$ [19]

Stated another way,

$R3 = 2R4$ [20]

If R1 = R2 = R and C1 = C2 = C, the resonant frequency of the Wein bridge is calculated using the formula:

$f = 1/(2\pi RC)$ [21]

For the standard Wein-bridge oscillator in which R1 = R2, C1 = C2 and R3 = 2R4, a sine-wave output will result in frequency f.

Under operating conditions, a Wein-bridge oscillator circuit tends to want oscillations to build up without limit when the gain of the amplifier used is high. Shown in Fig. 6 is what happens to the output signal when the gain is only slightly above that required for stable oscillation. Some slipping begins to appear on the waveform peaks. At even greater gain, clipping becomes more severe and eventually results in a sine wave that resembles a square waveform.

Shown in Fig. 7 are several methods that can be used to stabilize the amplitude of the waveform of the Wein-bridge oscillator. The one shown in (A) uses small signal diodes, such as the commonly available 1N914 or 1N4148 devices. At low signal amplitudes, the diodes are not sufficiently biased. Hence, the gain of the circuit is:

$A_v = [(R1 + R3)/R2] + 1$ [22]

As output signal voltage decreases, however, the diodes become forward-biased. With the arrangement shown, *D1* is forward-biased on negative peaks and *D2* is forward-biased on positive peaks of the signal.

Because *D1* and *D2* are shunted across *R3*, total resistance *R3'* is less than that of *R3*. Using Equation [22], you can determine that reducing the value of *R3* to *R3'* reduces circuit gain, making the circuit self-limiting.

Another method of stabilizing the Wein-bridge circuit is shown in Fig. 7(B). Here, a pair of back-to-back zener diodes limit circuit gain. With the resistor ratios shown, overall gain is limited to slightly greater than unity so that the circuit will oscillate. Peak output voltage from this circuit is set by the zener voltages of *D1* and *D2*. These voltages should be equal to assure low-distortion operation of the oscillator circuit.

The final method of stabilization, shown in Fig. 7(C), has a small incandescent lamp connected in series with *R2*. With this arrangement, when the amplitude of the output signal tries to increase above a certain level, the lamp draws more current. This causes the gain of the amplifier to reduce. The lamp-stabilized circuit is perhaps the most popular approach for obtaining stable output, though a thermistor is sometimes used in place of the lamp.

High-Power Infrared Light-Emitting Diodes

By Forrest M. Mims, III

High-power near-infrared-emitting diodes have been available since the mid-1960s. The major differences between today's high-power near-IR emitters and early devices are lower prices, a change in wavelength, and improved fabrication methods. In this column, I'll survey some of the basics of near-infrared LEDs and then present a high-current LED pulser circuit you may want to try. First, though, a personal anecdote that will help explain my high interest in infrared LEDs.

The Texas Connection

In 1966, I read about an amazing new semiconductor diode that emitted near-infrared light when forward biased. The diode was manufactured by Texas Instruments. The new diode so captivated my imagination that I soon conceived of a method for making a miniature guidance device for the blind that would use one of the new light-emitting diodes (LEDs) as an optical source.

The LED would be modulated by a simple transistor oscillator. Its optical power would be collimated into a narrow beam by a simple lensing arrangement. Nearby objects illuminated by the pulsating beam would reflect a portion of it back to a solar cell installed below the LED. The output from the solar cell would be amplified by a modified hearing aid amplifier and coupled to the user's ear by means of a small phone. Intensity of the tone emitted by the phone would provide a crude indication of the distance to nearby objects.

In the spring of 1966, I hitchhiked from Texas A&M University to Texas Instruments in Dallas and met Dr. Edwin Bonin, one of the scientists responsible for the design of TI's new LEDs. I explained my idea for a travel aid for the blind, and Dr. Bonin gave me three of the expensive ($365) near-IR emitters. Within a week, I managed to transform the idea for a travel aid for the blind into a working device not much larger than a package of chewing gum. I later tested the device with more than 20 blind adults and children.

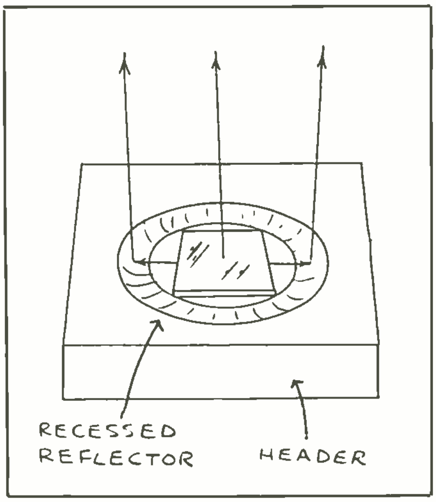


Fig. 1. LED chip installed in reflective header.

This anecdote is my way of acknowledging the role that light-emitting diodes have played in my career as a circuit designer and electronics writer. Even though hundreds of varieties of visible and near-IR LEDs are now readily available, I often think back to that hitchhiking trip to Texas Instruments when I solder one into a circuit.

High-Power Near-IR-Emitting Diodes

The pn junction region of a light-emitting diode is a very efficient photon generator. Indeed, in the early 1960s, scientists at Texas Instruments found that the junction of a gallium-arsenide (GaAs) near-IR emitting diodes emitted 88 photons for every 100 electrons that crossed the junction. This corresponds to an astonishingly high internal quantum efficiency of 88 percent.

Unfortunately, only a fraction of the photons emitted at the junction exit the surface of the chip. Also, some of those that do are blocked by the header on which the chip is mounted and the electrode that makes electrical contact with the chip's upper side. Therefore, the power conversion or output efficiency of a LED is considerably less than 88 percent.

Some of the radiation generated at the junction is absorbed by the diode itself. Some is blocked by the header on which the diode is mounted and the electrode on the diode's upper side. Too, radiation that arrives at the surface of the diode at more than the critical angle is reflected back inside the diode and lost.

The critical angle problem is so important it's worth exploring in more detail. Air has an index of refraction of 1 (or 1.0003, when compared to a vacuum). The index of refraction of diamond is 2.42. GaAs, which has an index of refraction of 3.5, is one of the few materials with a refractive index greater than that of diamond. This means that light rays originating inside a GaAs crystal that strike the interface of the surface of the crystal and the surrounding air at an angle more than about 16 degrees are reflected back inside the crystal. This phenomenon is known as total internal reflection.

Several clever methods have been developed to reduce the index of refraction mismatch between the surface of a GaAs crystal and air. One is to apply an etchant that dissolves a thin layer of GaAs and leaves behind a roughened surface. Another is to coat the surface of the crystal with an anti-reflection layer. Such coatings, however, are fragile and difficult to apply when contacts are present.

Texas Instruments improved the external efficiency of its high-power near-IR emitters by grinding and polishing the upper surface of the diodes into a dome shape. Since the surface of the diode is curved, radiation emitted within the diode always arrives at the GaAs-air interface within the critical 16 degrees. In theory, this method could improve the efficiency of a domed diode over a similar flat diode by a factor of as much as 26. In practice, however, the additional thickness of the GaAs required to permit the formation of a dome gives an improvement of around 10.

Manufacture of dome-shaped diodes is a time-consuming and expensive procedure. Furthermore, domed diodes require more GaAs material than do flat diodes. Because of these drawbacks, most light- and near-IR-emitting diodes are encapsulated in an index-matching epoxy. The index of refraction of typical encapsulants ranges from 1.4 to 1.8. While not nearly a perfect match to the 3.5 index of refraction of GaAs, this provides a much better match than air.

Consider a gallium-phosphide (GaP) LED that emits green light and has a critical angle of 17.7 degrees. Encapsulating such a diode in epoxy with a refractive index of 1.66 increases the critical angle to 30.3 degrees and permits some 2.5 times more light to be emitted by the diode.

So far I haven't mentioned the fate of light emitted from the edges of a LED chip. In the early days, all or most of this radiation was lost if the chip was installed inside a metal header. Today, most LED chips are installed inside tiny reflectors formed in the header, as shown in Fig. 1. The reflector captures emission from the edges of the chip, which can be rather substantial, and reflects it outward.

Heterojunction Technology

The earliest LEDs and semiconductor diode lasers were made using homojunction technology in which a diode was made from a single semiconductor, such as gallium-arsenide (GaAs). In the late 1960s, it was learned that very high efficiency near-infrared LEDs and diode lasers could be made using heterojunction technology. In this technology, a diode is formed from a sandwich of semiconductors that have slightly different electrical and optical properties. The multiple layers of semiconductor that form a heterojunction increase the diode's light-emission efficiency by confining the electrons that cross the junction to a very thin region. Since the outer layers of the heterojunction sandwich are much more transparent to the light emitted at the junction than are the p and n regions of two-layer homojunction diodes, more of the light generated at the junction escapes.

The first LEDs to benefit from heterojunction technology were near-infrared devices. The new diodes emitted two or more times the power of homojunction devices. Heterojunction devices made possible the first laser diodes capable of continuous operation at room temperature and the first visible-light laser diodes. Indeed, virtually all laser diodes made since the early 1970s use heterojunction technology.

In the early 1980s, heterojunction technology was applied to visible LEDs. The eventual result, the aluminum-gallium-arsenide (AlGaAs) super-bright red LED, will be the subject of a future column.

IR LED Characteristics

The voltage across the pn junction of any diode must exceed a threshold value before the diode begins to conduct. For silicon diodes, this turn-on or forward voltage is around 0.6 volt. For visible LEDs, the forward voltage ranges from approximately 2.1 to 2.8 volts for GaP green LEDs to 1.75 to 2.5 volts for AlGaAs red emitters. The forward voltage for near-infrared emitters ranges from around 1.5 volts for GaAs devices that emit at 940 nm to around 1.75 volts for AlGaAs diodes that emit at 880 nm.

The optical power of the light emitted by a LED is determined by the device's forward current. Since excessive current can cause destructive heating, it is very important to limit the forward current to a safe value.

The most important high-power IR LEDs are AlGaAs devices that emit a peak wavelength of 880 nanometers and GaAs:Si LEDs that emit a peak wavelength of 940 nanometers. Shown in Fig. 2 is a spectral graph that compares wavelengths emitted by both types of LEDs.

GaAs:Si LEDs were the first high-power LEDs, and they are still widely used. But AlGaAs LEDS offer several major advantages.

A typical GaAs:Si LED will emit around 5 milliwatts at a forward bias of 100 milliamperes. A typical AlGaAs LED will emit twice as much power for the same forward bias. Another advantage of AlGaAs LEDs is much faster rise and fall times. For example, the typical risetime of an AlGaAs LED is 0.5 microsecond, while that of a GaAs:Si LED is 1.5 microseconds. Respective falls times are 0.25 and 0.55 microsecond.

Another advantage is that emission of

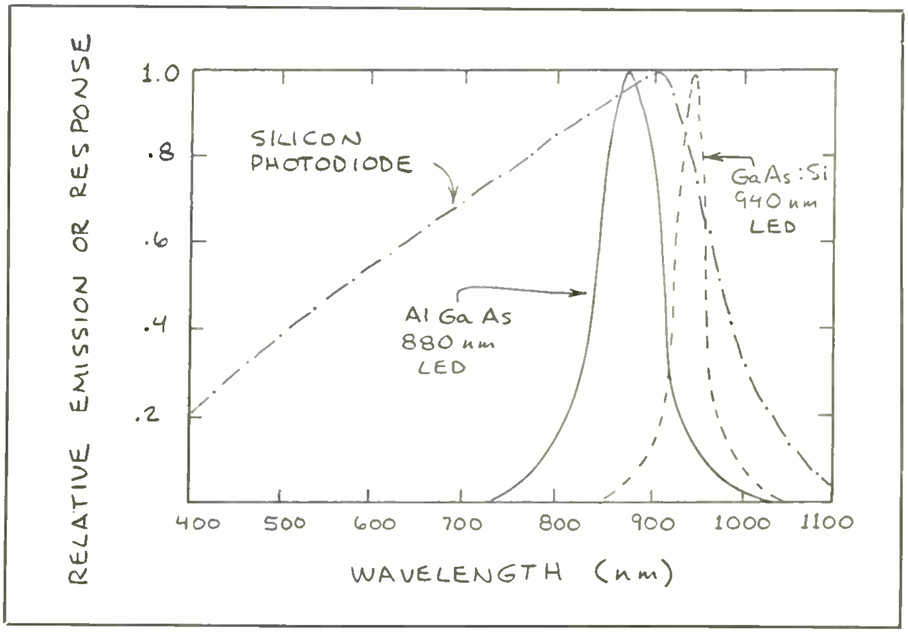


Fig. 2. Spectral emission of GaAs:Si and AlGaAs LEDs.

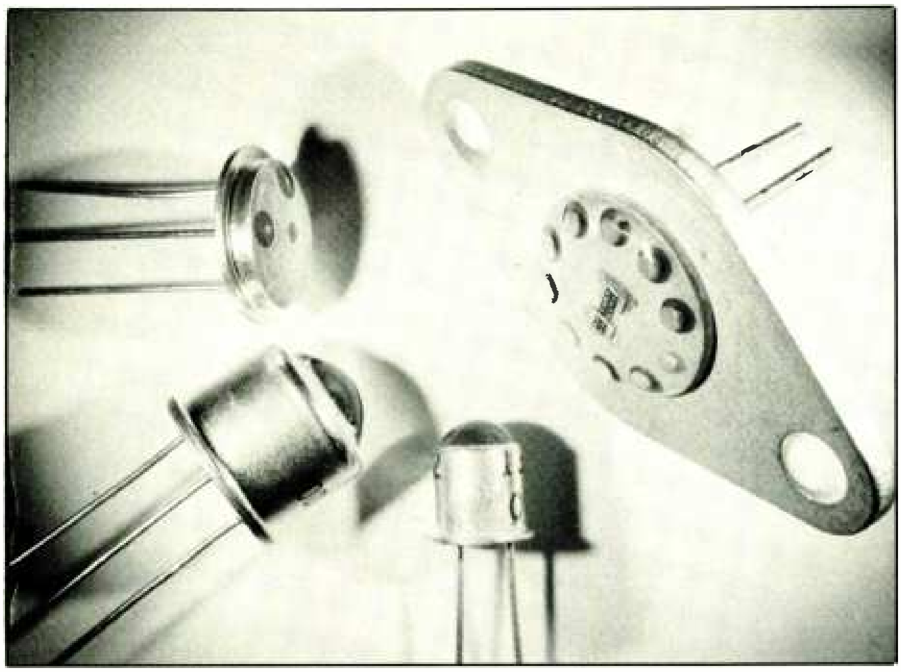


Fig. 3. High-power infrared LEDs made by Opto Diode Corp.

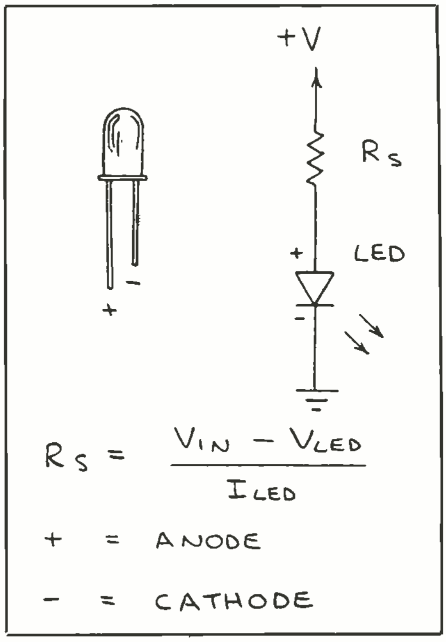


Fig. 4. Basic LED current-limited drive circuit configuration.

an 880-nm LED is closer to the peak sensitivity of silicon phototransistors and photodiodes. This often provides a free power bonus when an 880-nm LED is substituted for a 940-nm LED.

Still another advantage of 880-nm LEDs is that their emission falls within an atmospheric window that is unaffected by water vapor. With 940-nm LEDs, on the other hand, emitted radiation is heavily absorbed by water vapor. I have used this characteristic to make an atmospheric water-vapor sensor, a topic about which I will write at a later date. But because of their susceptibility to water-vapor absorption, I probably would not use a 940-nm LED for an outdoor lightwave communication system.

GaAs:Si LEDs do have an advantage if a totally invisible IR source is required since the emission from AlGaAs LEDs is visible as a dim red glow when such diodes are viewed along their axis of emission at night or in a dark room.

High-Power IR LEDs

In Fig. 3 is shown a common TO-46 880-nm LED, along with three high power near-IR-emitting diodes made by Opto Diode Corp. (750 Mitchell Rd., Newbury Park, CA 91320). The large TO-66 diode is the OD-663, which features a series arrangement of three individual chips on a single header and is described below.

The common LED in Fig. 3 is the small TO-46 device with a glass lens. It will emit 5 milliwatts when forward biased at 50 milliamperes. The slightly larger TO-39 glass-lensed diode next to it also emits 5 mW at 50 mA. The difference is that the larger diode can be forward biased at 500 mA, a level at which it emits a typical power of 50 mW. This diode emits 600 mW when driven with 10-ampere pulses each with a duration of 10 microseconds or less!

Next to the OD-50L is a flat-shaped OD-100 LED, which is installed on a TO-39 header and coated with a thin dome of epoxy. Since there is no metal can to obstruct some of the radiation emitted by the chip, the OD-100 emits twice as much radiation as the OD-50L. At 500 mA forward bias, it emits 100 mW. When driven with 10-ampere, 10-microsecond pulses, it emits an incredible 1.3 watts, a level of power ordinarily associated with pulsed diode lasers.

Keep in mind that this amazing power level is accompanied by a considerably broader beam than that emitted by the OD-50L. Beam divergence of the OD-50L at the half-power points is a fairly narrow 10 degrees. Beam width of the OD-100 is around 150 degrees.

By now, you may be wondering why the OD-50L and OD-100 emit so much more power than the ordinary 880-nm LED shown in Fig. 3. The most important reason is the better heat sinking provided by the larger TO-39 headers used by these two devices. Also, four bonding wires are used to make electrical contact with the upper side of the chip in both the OD-50L and OD-100. Besides lowering the resistance path for the drive current, the additional wires help soak up and divert away heat dissipated within the chip. Finally, both the OD-50L and OD-100 must be used with a good external heat sink when operated at high currents.

All that's necessary to operate a LED continuously is a suitable series resistor to keep the current within the LED's ratings. Fig. 4 shows a basic current-limiting circuit for a LED, along with the formula that permits you to calculate the value of the series resistor.

If you exceed the LED's maximum current rating, you will shorten its life or even destroy it. High-power LEDs usually require a heat sink when they are operated above a specified current level.

Pulsed High-Current Infrared LED Driver

LEDs can be operated at much higher currents than permitted for continuous operation if the current is applied in the form of brief (0.1- to 100-microsecond) pulses. For example, the powerful Opto Diode OD-50L can be driven with 10-ampere pulses as long as pulse duration does not exceed 10 microseconds and rate does not exceed 100 Hz. At 10 amperes, the OD-50L emits 600 milliwatts.

So why would you want to pulse a LED with a very high current? One reason is that the very-high power level of a pulsed LED is well suited for use in long-distance intrusion alarms and other kinds of detection systems. Another important use for pulsed high-power LEDs is long-distance signaling and telemetry. For example, replace *R1* with a suitable variable-resistance temperature sensor, such as a thermistor, and you have a long-range optical telemetry system that can send a temperature-modulated signal over hundreds or even thousands of feet.

To obtain brief flashes of high radiant power from an infrared LED, you need a low-impedance switch capable of applying as much as 10 volts or more across the LED. One method is to charge a capacitor to the necessary voltage and then switch it across the LED; another is to simply switch a current on and off.

I have designed and built many capacitive discharge pulsed high-current drivers for single-heterostructure (SH) laser diodes. These diodes typically require a drive current of 10 to 15 amperes with a maximum pulse width of 100 to 200 nanoseconds. To achieve these very fast, high-current pulses requires the use of a 0.01- or 0.02-microfarad capacitor charged to 100 volts or more and a low-impedance switch.

Prior to the arrival of the power MOSFET, the best way to switch a charged capacitor across a laser diode was by means of an SCR or a bipolar transistor operated in its avalanche mode. The ultra-low on-resistance available with some power MOSFETs provides a much simpler and more efficient means for current switching.

Figure 5 shows the circuitry of a high-current driver in which a common 555 timer is operated as an oscillator that sends a train of pulses to the gate of a MOSFET via a CMOS inverter. The inverter is necessary to change the negative pulses from the 555 into positive pulses. Note that three inverters in the 74C04 are connected in parallel to provide a very clean switching pulse to the gate of the MOSFET, which causes it to switch on with a slightly lower on-resistance. You can connect all six inverters in parallel if you wish. Be sure to tie the unused inputs to ground.

Pulse repetition rate of the circuit is controlled by *R1*. Pulse duration is controlled by *C1*. Typical pulse durations produced by a range of capacitance values are as follows:

C1 (μF)	Pulse Duration (μs)
0.0047	0.85
0.001	1.7
0.005	6.0
0.01	10.0
0.047	40.0
0.1	88.0

Though these are the values I measured, they are affected by the tolerances of the capacitors you use. Therefore, consider them as only approximate values. Also, make sure the capacitor is rated for the power supply voltage.

The MOSFET is in a series circuit with the LED and an optional series resistor (*R3*) that permits you to determine both duration and amplitude of the current pulses through the LED. You can omit *R3* if you don't plan to measure the current through the LED.

Any power MOSFET that will switch the power supply voltage will work in this circuit. For best results, use a MOSFET

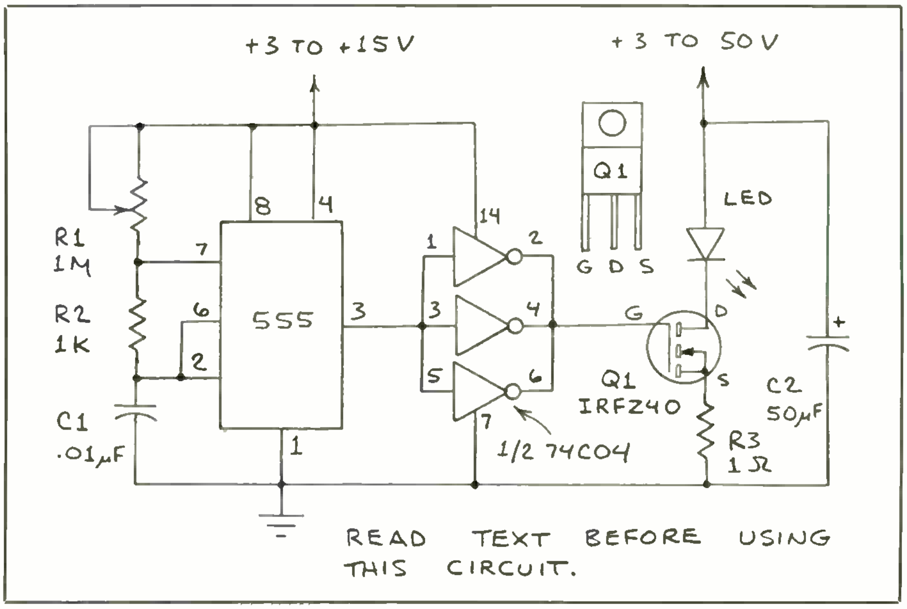


Fig. 5. MOSFET high-current LED pulse drive circuit.

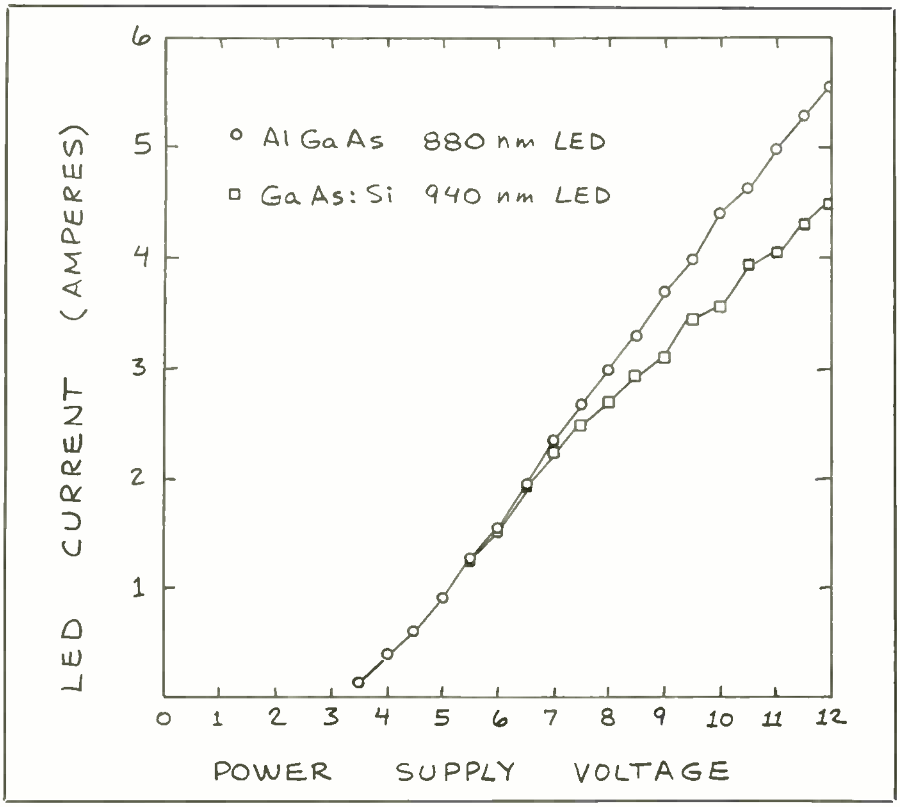


Fig. 6. LED current produced by MOSFET LED pulse drive circuit.

with an on resistance of less than 1 ohm to provide the highest possible current through the LED. The IRF-511, available from Radio Shack for $1.99, has an on resistance of 0.6 ohm and will switch 60 volts. For absolutely highest current, do as I did and use a more expensive IRFZ40 with an on resistance of only 0.028 ohm. The IRFZ40 is available from Digi-Key (P.O. Box 677, Thief River Falls, MN 56701-0677) for $6.12.

Note that the circuit shows two positive power supply connections. This permits you to connect a fairly high voltage to the MOSFET section of the circuit to provide very high current pulses. Figure 6 shows the current through an AlGaAs LED and a GaAs:Si LED for a range of voltages when both power-supply connections are connected to the same supply. If the pulse portion of the circuit is operated at 10 volts and the MOSFET section at 20 volts, the circuit will deliver a string of hefty 10-ampere pulses to an AlGaAs LED.

Be sure to think through your objectives before using this circuit. Otherwise, you might damage the LED you plan to operate. Is the pulse repetition rate set too high for the allowable duty cycle of the LED? Will the battery or batteries you plan to use provide sufficient current to drive the LED? If the LED and 555 are powered by the same battery, will the oscillator stop oscillating should the battery voltage fall substantially when the MOSFET is switched on? Will you exceed the peak current rating of the LED you plan to operate? If so, should you insert a current-limiting resistor (at *R3*) or reduce the power supply voltage.

These questions are best answered with the help of an oscilloscope and an adjustable power supply. Begin by using a 1-ohm resistor for *R3*. Do *not* use a wire-wound resistor since it will act like an inductor and slow down the current pulses and cause ringing. If you can't find a 1-ohm resistor, make one by connecting ten 10-ohm resistors in parallel.

Next, connect the oscilloscope across the 1-ohm resistor and apply power to the circuit. You should observe a clean 10-microsecond pulse with relatively fast rise and fall times. If the corners of the pulse exhibit ringing, shorten the length of the connections between *Q1*, the LED and the positive supply. If the top of the pulse is sloped downward, flatten it by increasing the value of *C2*.

According to Ohm's law, when *R3* is 1 ohm, the amplitude of the pulse in volts equals the current through series resistor *R3*. Therefore, if your scope shows an amplitude of 100 millivolts and you're using a standard 10 × probe, the amplitude is (0.100 × 10)/1 or 1 ampere.

If the LED is connected to a variable power supply, you can immediately see the effect on the pulses when the voltage is varied. This is how I acquired the data plotted on the graph in Fig. 6. Keep in mind that the current will increase if you later remove the 1-ohm resistor.

This is only one way to monitor the current pulse through the LED. If you know the on resistance of *Q1*, you can monitor the current by connecting the scope across the drain and source of *Q1*. You might also want to monitor the optical output pulse by pointing the LED at a solar cell or photodiode connected to the scope's second channel. You can then see if increasing the LED's drive current produces a proportional increase in output power. As long as you don't exceed the recommended duty cycle and pulse duration, it should. Otherwise, heating effects will limit the power emitted by the diode. Incidentally, a small-area photodiode will provide a much faster response time than a solar cell.

Viewing Radiation From an IR LED

If you've spent much time working with high-power IR LEDs, you know the frustration of not being able to see the invisible beams emitted by these devices. It's very difficult to align focusing lenses and to determine the shape of the projected beam pattern when the radiation is invisible.

A special phosphor-coated card provides one way to convert the near-infrared emitted by such diodes into a pattern of visible light. The card is first charged by placing it near a white light source. Room lighting is then darkened, and the card is placed in the path of the beam from an IR LED. A glowing orange or green pattern then reveals the cross-section of the invisible beam. Phosphor cards are available from various sources, among them, Edmund Scientific (101 E. Gloucester Pike, Barrington, NJ 08007-1380) and others.

The 880-nm emission from a high-power IR LED is visible as a dull red glow. The human eye has very limited sensitivity at 880 nm, but, as you can see by referring to Fig. 2, an AlGaAs infrared LED has some emission at a wavelength as low as 750 nm. Therefore, most of the red sensation is probably caused by the diode's low wavelength emission.

Don't be fooled by the feeble nature of this red glow or the dim orange pattern on a phosphor card; the radiation from a high-power IR LED would make a most impressive sight if it could be visualized. One way to appreciate the brilliant emission from such a diode is to view it through an infrared image converter or a television camera that responds well to near-infrared.

Infrared image converters are very expensive. A good alternative is a home video camera since many such cameras will respond to a near-IR beam. Indeed, the large Opto Diode OD-663 emitter in the TO-66 package shown in Fig. 3 is designed primarily as an invisible infrared illuminator for night-vision goggles and CCD television cameras.

The OD-663 includes three chips connected in series. At 300 mA, the OD-663 has a typical emission of 170 mW. The device emits more than a watt when driven by 5-ampere, 10-microsecond current pulses. Like the OD-100, the OD-663 has an epoxy dome instead of a glass lens and, thus, emits a very broad beam.

Figure 7 is a macrophotograph that shows the three AlGaAs chips installed on the OD-663's header. The two outer chips are mounted on top of miniature ceramic substrates to insulate their bases from the header. The top side of each of the two ceramic substrates is plated with gold to provide a conductive surface. Four electrode wires are bonded to the upper side of each chip. The electrodes are connected between the individual chips, the header and the header's elec-

(Continued on page 80)

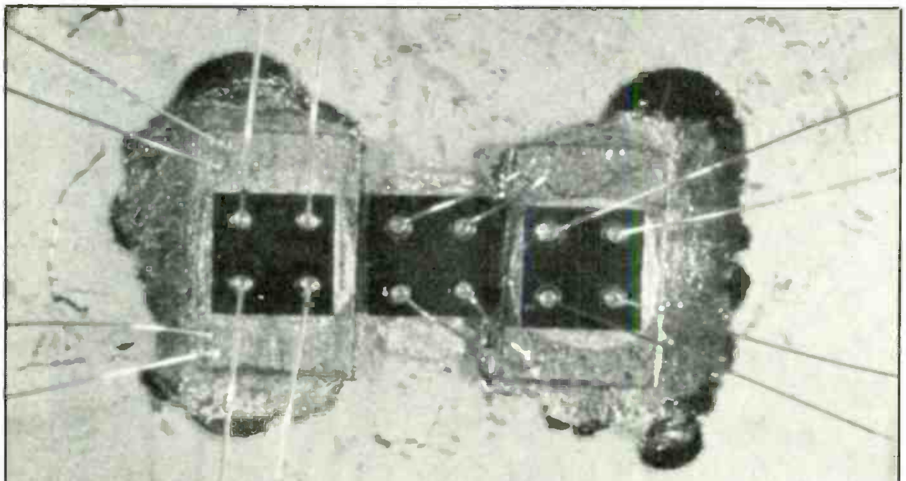


Fig. 7. Macrophotograph of three LED chips of OD-663 high-power IR emitter.

BOOKS

Essential Circuits Reference Guide. *By John Marcus & Charles Weston. (McGraw-Hill. Soft cover. 531 pages. $29.95.)*

Traditionally, books like this one have been very popular because they are a time-saving resource that eliminates the need to reinvent the wheel every time a circuit must be designed. Like most such books, this 8-1/2 × 11-inch volume offers hundreds of ready-to-apply circuits and ideas. It is also arranged like an encyclopedia in that categories are presented in alphabetical order, starting with A for Antenna Circuits and finishing with Z for Zero-Voltage Detector Circuits. This simplifies look-up of a given type of circuit. If a specific circuit type is needed, a comprehensive index is provided at the back of the book for locating it.

Containing more than 1,600 circuit schematics, this book has something for just about every application short of full-blown computer and microwave specialties. Every schematic is fully annotated with component number and value, and each is accompanied by a short caption that tells something about the circuit and the source from which it was obtained. Represented in the line-up are circuits for audio control, converting dc to dc, active and passive filtering, all sorts of quantity measuring, metal detection, multiplexing, optoelectronics, oscillation, pulse generation, and much more.

Adding value to the contents of this book are a list of commonly used abbreviations, along with their meanings, semiconductor symbols used throughout the book, and complete addresses of the sources from which the various circuit schematics were obtained. All in all, this is a valuable reference resource. Engineers and experimenters will come to depend heavily on its contents to save them many hours of circuit design time.

Learning Electronics: Theory and Experiments With Computer-Aided Instruction for the Apple; Learning Electronics: Theory and Experiments with Computer-Aided Instruction for the IBM. *By R. Jesse Phagan & Bill Spaulding. (Tab Books Inc. Soft cover. 329 pages. $16.95 each.)*

These two books bring tutorial technology into the modern era and may very well provide an added incentive for learning electronics to a wider segment of the reading/computing public. Both books have identical text and illustrations, differing only in the programs they provide to satisfy the computer-aided portions. They are larger than the usual pocket-book size, with dimensions that exceed 9 by 11 inches.

Though it might appear from a quick glance at their titles that these books are useless without access to an Apple or IBM or compatible computer, this is not the case. But for the programs that make electronics a bit easier to learn, both books are classical texts on the fundamentals of the technology. Thus, they can be used in a traditional go-it-alone learning experience.

These books deal strictly with fundamentals of electronics—not complex or very sophisticated circuitry. Topic coverage includes: dc circuit components, using an ohmmeter, oscilloscope familiarization, dc circuit analysis, magnetism and inductance, sine-wave analysis, transformers, capacitors and time constants, ac circuits, and resonance. Separate discussions on the job market, electrical safety, shop math and engineering notation and basic hand tools and soldering are also provided. Coverage of each topic is quite complete and consists of easy-to-follow text and appropriate schematics and drawings, and references to use of specific included computer programs where helpful.

All chapters begin with a statement of objectives and an outline and most conclude with a quiz. Separate "midterm" and "final" exams are provided for the reader to check his progress. Answers to all exam questions are given in an appendix at the back of each book. Another appendix gives complete program listings, written in BASIC, for the computer-aided portion of the books. Each is assigned a figure number so that where it is used can quickly be located in the body of the books. These programs can be keyed into a computer by hand (a laborious process that is prone to keying errors) or can optionally be purchased on floppy disk from Tab Books for a nominal cost ($25). The programs provide a sense of interaction that is lacking in just plain reading of normally dry technical text and, thus, can spur one on to continue studying longer than would normally be the case.

NEW LITERATURE

Parts Catalog. A new catalog that lists and describes electronic and computer-related components and parts at below OEM prices is available from American Design Components. Illustrated with photos and drawings, the 36-page, two-color catalog lists such discrete components and integrated circuits, transistors, diodes, LEDs, crystals, fans, batteries, switches and more. It also lists power supply assemblies and such computer-related items as disk drives, video monitors, add-in boards, and complete computers for the hobbyist and industry. For a free copy, write to: American Design Components, 815 Fairview Ave., Dept. ME, Fairview, NJ 07022.

Test Accessories Catalog. The new 138-page catalog of Electronic Test Accessories from Pomona Electronics highlights five new product groups. These include IC test clips, low-cost coaxial cable assemblies and a new family of DMM test-lead kits. Ten major product categories are accessed through an easy-to-use index. These include the company's most popular selection of jumpers and cables, boxes, plugs and jacks, connectors, adapters, single-point test clips and static-control devices. Helpful selection guides are provided for user convenience. For a free copy, write to: ITT Pomona Electronics, 1500 E. Ninth St., P.O. Box 2767, Dept. ME, Pomona, CA 91769.

Equipment Catalog. A new catalog from RAG Electronics lists reconditioned and new test equipment for electronics use. Listed are test equipment from name-brand manufacturers like Hewlett-Packard, Tektronix, Fluke and 12 others. The listings cover a wide variety of oscilloscopes, spectrum analyzers, DMMs, power supplies, signal sources, environmental chambers and more. Technical descriptions are given for each product listed and many are accompanied by a photo in this 16-page, two-color catalog. For a copy, write to RAG Electronics, Inc., 21418 Parthenia St., Dept. ME, Canoga Park, CA 91304-1597.

Interconnection Products Catalog. More than 3,500 items are listed and described in the 1990 edition of the Interconnection Products Catalog from L-com Data Products. The 100-page catalog details a full line of components and accessories for electronics, computer and communications markets. Featured is an extensive line of more than 1,200 ready-made coaxial and data cables, connectors, peripheral-sharing devices, baluns, IEEE-488 cables and accessories, patch panels and line testers. Full product descriptions include prices up to moderate quantities. New products listed in this edition include modular and IBM Token Ring wiring aids, an automatic and manual matrix switch, Wang-type surge protectors, a new series of coaxial switches specifically made for panel mounting and Macintosh networking kits. For a copy of the catalog, write to: L-com Inc., 1755 Osgood St., Dept. ME, N. Andover, MA 01845.

Product Line Catalog. Contained within the latest 74-page product line catalog from Jameco are listings and full descriptions for a wide range of items ranging from computer kits and IBM/Apple-compatible peripherals to individual integrated circuits. Among the new items that have been added to this 1989 catalog are 16- and 20-MHz AMI 80386 motherboards and the new NEAT (New Enhanced AT) motherboard. A welcome feature is a two-page insert of TTL and microprocessor pinout data. For a free copy, write to: Jameco Electronics, Shoreway Rd., Dept. ME, Belmont, CA 94002.

Interface/Monitoring Equipment Catalog. A colorful 21-page catalog from B&B Electronics provides an instant reference and guide to the RS-232 interface and monitoring equipment manufactured by the company. Among the items listed are RS-232 converters, switches, jumper boxes, data splitters, adapters, modem security devices, multiplexers, smart switches, Breakout II software, cable assemblies, surge protectors, technical publications, etc. The listings for converters for industrial enclosures include: a four-channel RS-232-to-RS-422/485 converter. RS-232-to-current-loop converter and new industrial converter power supplies. For a copy of Cat. No. 12-1990, write to: B&B Electronics Mfg. Co., 4000P Baker Rd., P.O. Box 1040 (Dept. ME), Ottawa, IL 61350.

A Replacement Battery, Hand-Held Scanner and Trackball

By Ted Needleman

As usual, the pile of interesting computer goodies has been threatening to overwhelm my small office area here at home; so this month I'd better cover some of smaller items. That way, I can clear a path to my PC.

Recently, I received a short paper from Rupp Corporation entitled "Why Do Batteries Fail More Often Than They Should in IBM ATs and Clones?" As many of you know, the IBM AT pioneered the use of a small area of RAM, backed up by a battery, to hold the PC's configuration data. Usually using CMOS (low-power) RAMs, this configuration table contains information about how much RAM the machine contains and how it is distributed (DOS, Expanded, and Extended memory), the system time and date, the type of display adapter the system contains and what type of disk drives (both floppy and hard) are installed. The use of this approach lets you set and change configurations without having to continually open up the machine and play with DIP switches. The setup routine can, instead, be accessed through a combination of keys on the keyboard, in many cases Ctrl, Alt and Esc pressed at the same time.

This is one of those approaches that sounds elegant in theory, but in the real world hasn't worked very well. As long as the battery puts out a certain level of voltage, all is well. But when this voltage drops below that required to maintain the CMOS RAM, your configuration information goes to "data heaven," and with it goes your ability to boot from the hard disk.

Hopefully, you've got the disk type written down somewhere, because without this obscure drive type number (which, by the way, does not usually have anything to do with the manufacturer's part number), the PC has no way of knowing anything about the drive, including how many cylinders and heads it contains. Some diagnostic packages can give you this information. More often though, you'll have to copy down the manufacturer's drive type and call the technical support number for either the vendor from whom you bought your PC or the manufacturer of the drive.

Rupp Corp.'s bAT Pak self-recharging battery for IBM AT and compatible computers plugs into a standard disk-drive power connector and the external battery connector on the motherboard. Its rated life is 10 years.

Having been through this several times before I smartened up enough to copy the configuration data on the systems I work with onto large address labels stuck to the bottom of each PC, I can vouch that the battery will almost always pick the most inopportune time to give up the ghost.

Rupp's paper, cheerfully sent to you if you ask for it, explains that the voltage-sensing network in many PCs, which is supposed to switch from the battery to the PC's own power supply when the system is powered up, often doesn't work. The result is that the backup battery is drained even when the system is in use. In fact, according to the company's analysis, you may even be draining your battery faster when the system is turned on than when it's off.

I don't know if Rupp's analysis of the situation is correct. But I do have enough experience in replacing batteries to know what a royal pain it is to do. Different vendors use different types of batteries, and it's almost a given that your local computer store will have every type except the one you need at the moment.

If your PC uses a rechargeable battery pack, you won't face this problem, and I envy you. For the rest of us, Rupp's "bAT Pak" is a good solution for eliminating the configuration backup-battery problem. "bAT Pak" is a rechargeable lead-acid battery that installs in place of whatever your system currently uses. Attach it to a spare power connector from your power supply, and plug it into the battery connector on the system's motherboard. Then forget about ever having to change the battery in your system.

"bAT Pak" attaches to the power supply with a Velcro strip, so it can be easily removed if necessary to get at the motherboard. The power connector is carried through "bAT Pak," so you don't lose the ability to add other drives if your PC's power supply doesn't have several extra connectors. The instruction manual for this is a single sheet of paper, which is more than sufficient to describe the task. Once you've taken the cover off the PC, the whole operation takes about a minute to complete.

For $39.95, I'm sold on "bAT Pak." The price seems a bit steep at first, until you price the most common replacement batteries, which often go for between $20 and $30. Factor in the bother of having to find a dealer with the one you need, having to configure your system every time you use it until you make the replacement, and having to open up the system to replace a battery, and the $40 price tag on Rupp's battery suddenly becomes the bargain it is. If you're a serious PC user, and your system doesn't have a rechargeable battery in it, you're a good candidate for Rupp's "bAT Pak."

While I'm on the topic of batteries, I should mention that it's come to my attention that the term Ni-Cad, referring to Nickel-Cadmium batteries, and its derivative spellings, is a registered trademark of Saft, which obtained the rights from Gould Battery, the original copyright holder. If I've used the term generically in the past (and I'm sure I have), I apologize. Companies, such as Saft, have every right to protect their trademarks from becoming generic terms, and as a writer I understand the importance of protecting copyrighted material.

Hand-held Scanner

Over the past 18 months or so, I've looked at about a half-dozen hand-held image scanners. These inexpensive little devices are terrific for grabbing images from magazines and photos to use in desktop published newsletters, catalogs and fliers. To a large extent, they have all been very similar, differing mostly in the software they provide. The A4 AS-8000P scanner I recently received from ECA C&C Products is in the same category as The Complete PC's and Logitec's hand-scanners. It even looks pretty much the same, like a mouse with a large snout containing the scan window. Like the others, it offers a choice of resolutions (from 100 to 400 dots per inch in 100-dpi increments) and a choice of line art or three dither patterns for half-tone emulations.

It also offers some unusual features, such as very well done paint and OCR software, software-controlled interrupt and DMA address configuration, and a user-controllable scan width, at a reasonable price of $350.

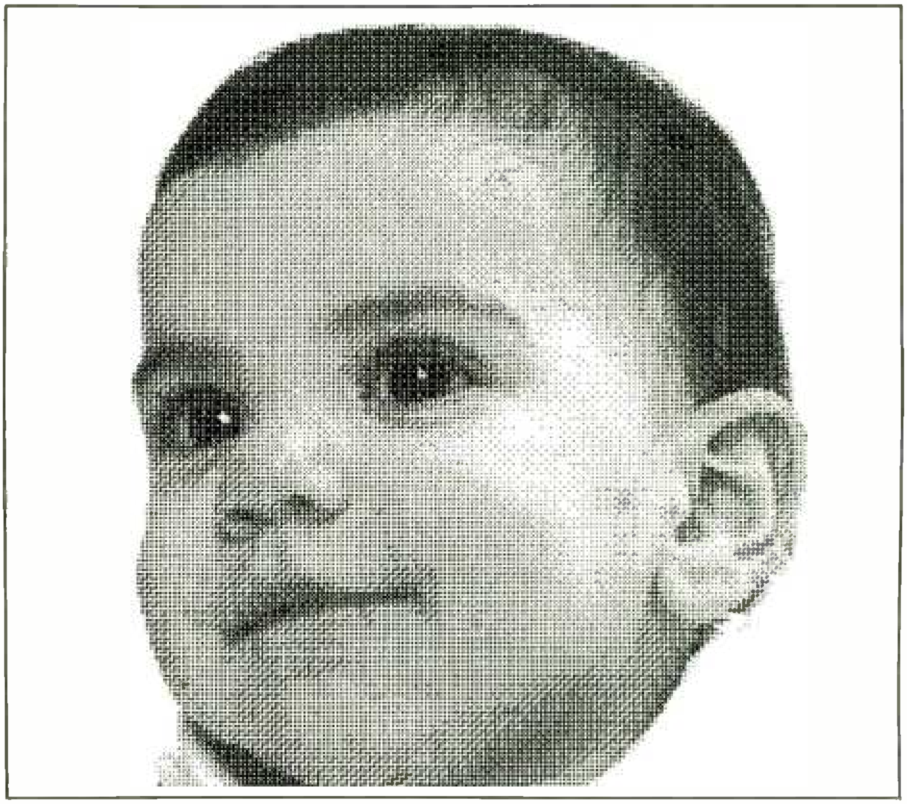
I've covered installation of these scanners in past columns, so I'm not going to describe it in detail here. There is a half-size interface card that installs in any eight-bit slot in a PC, and installing the software is a simple matter of creating new directories for the paint and OCR software and copying the files from floppies into the proper directories. The scanner requires 640K RAM; MS-DOS 3.1 (or higher); a hard disk; Hercules, EGA, or VGA graphics; and a mouse to operate.

Once the software has been put on the hard disk, you're ready to use the scanner. If you need to reconfigure the DMA channel or printer, you can do this from within both the Image72 (paint) program or the A4 OCR software by selecting the scan icon and choosing the CONFIGURE box from the menu that pops up. The interface card does contain a jumper for this, but it can be overridden by the software selection process if you find that it has to be changed after you've closed up the PC's case.

Each of the two software packages that accompanies the scanner is at least as good as those available with other hand-held scanning units. Image72 offers all of the features of other paint programs, including color display if supported by your PC. The OCR package provides trainable OCR and is very similar in both features and operation to the CAT Reader package I described a few columns back. In training mode, it presents you with characters or character pairs it doesn't recognize, asks you to define them from the keyboard, and incorporates the definitions into future text conversions.

As with almost all OCR software I've looked at, you have to do a fair amount of training to get anywhere near the 98% accuracy rate the vendor claims possible for the hardware/software combination. And keep in mind that even with 98% accuracy, there will still be a fair amount of errors in even a single page. This is the problem with most OCR and just has to be accepted with the present level of affordable technology.

I like the A4 scanner and its accompanying software a lot. There are two places where it falls down a bit, though. The first is in the documentation. Although it is generally well done, it lacks an index and is a bit vague in places. For example, when scanning the photo of my daughter, which is reproduced elsewhere in this column, I continually received three beeps when trying to save the image. I had to really hunt around the man-



A laser-printed image of author's daughter captured with ECA C&C Products A4 AS-8000P hand-held scanner.

PC CAPERS...

ual to find out that this meant the captured image was too large to fit in the buffer, where it must first be moved before you can save it to disk. And I had to do more hunting and reading to find that the only way around this was to lower the resolution or scan a smaller area.

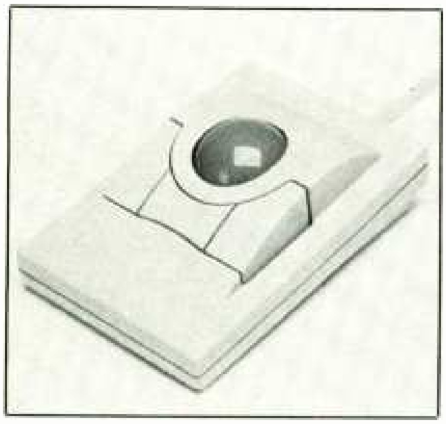
Another example of this concerns the mouse driver. The Image72 paint program requires that a mouse be installed. The documentation tells you to load the mouse driver supplied with your mouse before starting the software. Yet both packages come with a universal mouse driver. I found this out by reading the OCR software manual before using the paint package. I loaded this universal driver and it worked perfectly with the Mouse Systems trackball I was using.

This brings me to my second criticism. The A4 Image72 package has a pre-defined image buffer of 64K, regardless of how much RAM you may have in your PC. With 3 megabytes of RAM in my system, I find it really annoying that I had to lower the scan resolution to 200 dpi to capture a standard-size photograph. Perhaps the vendor will enhance this in the next release of the software.

All things considered, though, I like the A4 scanner package very much. It has both image-capture and OCR capabilities, and the software is written in assembler, so that both software packages operate very quickly. It also has exceptional image merge capabilities, which let you scan pictures larger than the 4.1-inch scan head. You can even adjust the scan width, in the Image72 software, if you need to scan only a 2- or 1.5-inch swath. Finally, the software can save images in a large variety of formats.

The image of my daughter Karin was saved in .PCX format, and printed using Z-Soft's PC Paintbrush. I could have printed it directly from the Image72 software, but I wanted to verify that the .PCX format was transportable. Other images were saved in .TIF format and imported into PageMaker. Image72 offers nine formats, so you should be able to use the images with whatever software you happen to have.

At $350, the A4 AS-8000P is slightly



Mouse Systems' new PC Trackball is available in both serial and bus versions and is compatible with any software that supports the Microsoft serial mouse without having to change an installed driver.

more expensive than other hand scanners. If you think you might need OCR, though, it's less expensive than buying someone else's scanner and adding an OCR package to it. And even if you don't need OCR, the Image72 features mentioned above make it a leader in the hand-scanner marketplace.

Mouse Systems Trackball

The A4 scanner previously discussed requires a mouse to operate. As I had just received a trackball from Mouse Systems, I thought that I would try it out instead. Trackballs are garnering a great amount of interest but actually pre-date mice. First used for military and high-end graphics applications, they're almost mechanically identical to mice, except that the roller ball is on the top of the unit. Instead of moving the entire unit around, as with a mouse, you move the roller ball with your fingertips to position the cursor on the screen. This offers all the mouse advantages but doesn't require a great deal of empty space on your desk the way a mouse usually does.

Mouse Systems is best know for its high-quality optical mice. In the past several years, however, the company has also produced some fine mechanical mice, and the PC Trackball is of similar quality. It has three large buttons, with the center button underneath the ball, and takes up a scant 5.5 by 4 inches of desk space. The accompanying software includes drivers and utilities, as well as IMSI's "The Magician" presentation graphics software package.

Available in both serial (the version reviewed) and bus models, PC Trackball can also be used with any software that supports the Microsoft serial mouse without having to change an installed driver. Just to verify this, when I tried it with a copy of PageMaker that had been used with a Microsoft mouse, the PC trackball worked fine.

The documentation and utilities that come with the PC Trackball are generic to Mouse Systems products. By this I mean that the same manuals and disks come with the company's optical and mechanical mice, as well as the Trackball. There are three or four pages on each of the separate products. Otherwise, everything works the same whether you're using a mouse or the trackball.

I've used a Mouse Systems optical mouse on one of my PCs for years, and I love it. I'm a bit ambivalent about the trackball, however. For one thing, the ball seems a bit smaller than others I've seen, and I wasn't able to obtain the same accuracy with it as with the mice I'm used to using. Perhaps this just takes time, and accuracy will improve with further practice.

For another thing, placement of the center button below the ball makes the trackball somewhat awkward to use. While I don't use this center button often, it might be a little easier to get at if it was above, rather than below, the ball.

I'm going to be taking a look at a few other trackballs in upcoming months, so I'll reserve my final judgment about the Mouse Systems unit until I have something to compare it with. In the interim, if you're thinking about a trackball, be sure to look at the Mouse Systems one. It appears to be well made, and at $119.95 for the serial version and $139.95 for the bus version, it's certainly priced in line with similar quality mice. ME

Products Mentioned

bAT Pak
Rupp Corp.
835 Madison Ave.
New York, NY 10021
212-517-7775

A4 AS-8000P Hand-Scanner
ECA C&C Products, Inc.
38 Rte. 46 East
Lodi, NJ 07644
201-478-0507

PC Trackball
Mouse Systems, Inc.
47505 Seabridge Dr.
Fremont, CA 94538
415-656-1117

Designing a Buck-Boost Voltage Regulator

By Joseph Desposito

In this month's column, we focus on voltage regulators. First we'll explain how a new device from Linear Technology can be used in the design of a buck-boost type regulator. This regulator circuit is just one of many designs included in a collection of switching-regulator circuits you can obtain from the company. We'll finish up with new regulators from a variety of other sources.

Switching Regulators

Linear Technology Corp. (1630 McCarthy Blvd., Milpitas, CA 95035) announced a new switching regulator, the LT1172, and an eight-pin plastic mini-DIP (0.3-inch wide) version of its popular LT1072. The LT1172 is a 1.25-ampere switching regulator that can be synchronized with a system clock in the range of 48 kHz to 100 kHz. Multiple LT1172 circuits can be synchronized for higher output current. The new LT1072 package reduces system space requirements and enables machine insertion of the device in printed-circuit boards. A synchronizing feature in its circuits allows multiple LT1072s to be synchronized with a system clock in the range of 48 kHz to 70 kHz.

Both devices operate over a range of 3 to 60 volts and include a 1.25-A switch on the chip. These chips are intended for designers who need switching regulators on their boards, but are unfamiliar with switching regulator applications. Linear Technology provides designers with complete design manuals and field application support.

The LT1172 and LT1072 use an adaptive anti-saturation switch drive to allow a wide range of load currents with low saturation voltage and high efficiency. Like the earlier LT1070 and LT1071 members of Linear's switch-mode regulator family, the devices operate in all standard switching configurations. To minimize application problems, all oscillator, control and protection circuitry has been included on the chip.

Circuitry for producing a fully isolated flyback regulator is also built into the chip; it needs no opto-couplers or extra transformer windings. An externally activated shutdown mode incorporated in the chip reduces total supply current to a typical value of 50 microamperes for standby operation.

Like the LT1072, the LT1172 is available in an 8-pin mini DIP package. Both devices are also available in five-lead TO-3 metal-can and TO-220 plastic packages. Pricing for the devices in the eight-pin mini-DIP package is $2.45 in quantities of 100 and up.

An applications note on using switching regulators in power-supply and other kinds of circuit design is available free from Linear Technology. It contains schematics for more than 80 designs for

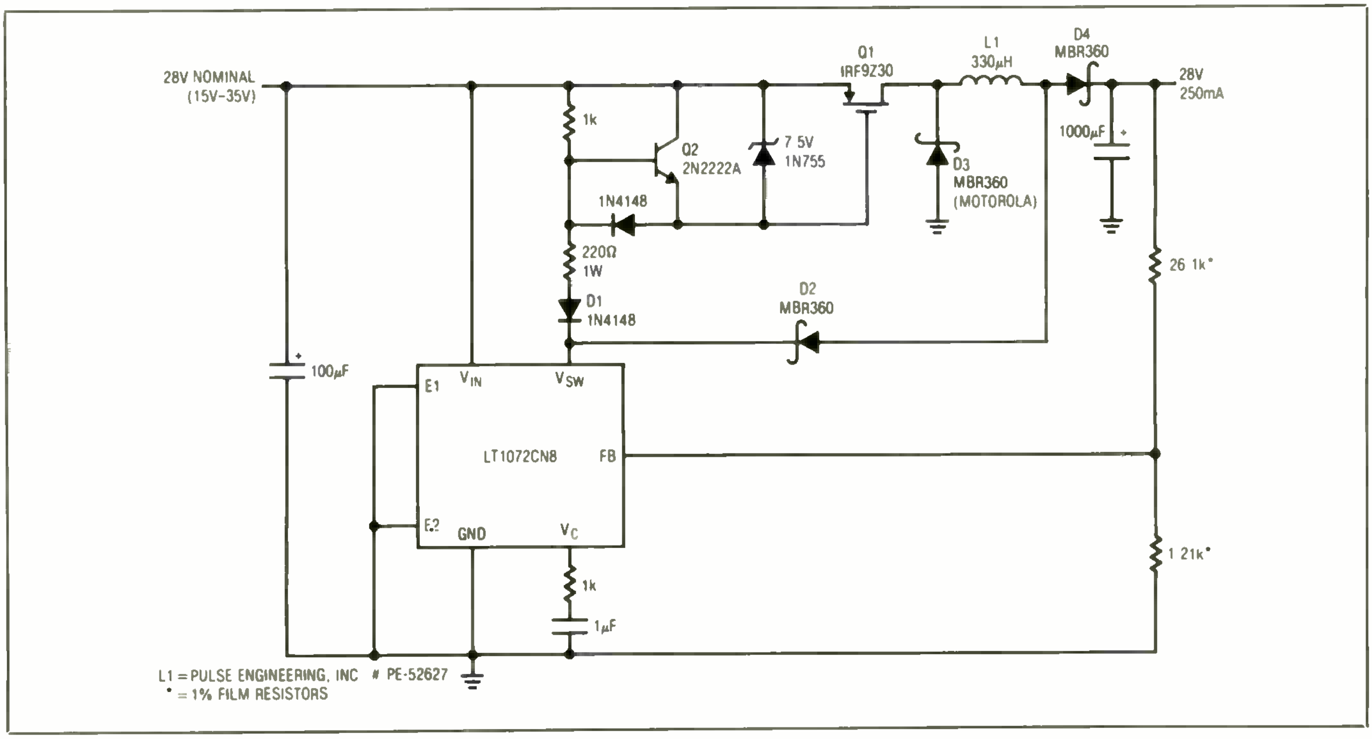


Fig. 1. An example of a positive buck-boost converter (15 to 35 volts to 28 volts) circuit built around Linear Technology's LT1072CN8 switching regulator.

battery-based switching power supplies, positive boost converters, buck converters, forward converters, high-voltage converters, multi-output regulators and converters, off-line switching regulators, pre-regulators, and dc-to-dc converters for general-purpose and telecommunications applications.

The applications note, titled "AN30: Switching Regulator Circuit Collection," is available free from the company by calling a toll-free telephone number: 1-800-637-5545.

One of the circuits in the collection is a positive buck-boost converter (15 to 35 V to 28 V). The buck-boost topology is useful in circuits whose input voltage can be either lower or higher than the output voltage. The design shown in Fig. 1 uses a single inductor in place of the transformer typically used in such designs.

In this circuit, the gate-source voltage is clamped so that it won't exceed the device's ±20-V rating. When VSW is on, pass transistor *Q1* saturates and the gate voltage is clamped by the zener diode. Since the inductor is within one diode drop (*D2*) above ground, the voltage drop across the inductor—except for *Q1*'s V_{BE} drop and saturation losses—is now equal to the input voltage. Diode *D1* is reverse-biased, and it prevents the output capacitor from discharging into the chip's VSW pin.

When the VSW pin is off, *Q1* and *D2* cease to conduct. Because the current in the inductor continues to flow, *D3* and *D4* become forward-biased, allowing the inductor energy to transfer into the load. Diode *D2* prevents transistor *Q1* from staying on when the circuit is operating in the buck mode. On the other hand, *D1* blocks current flow into the gate-drive circuit when the converter is operating in boost mode.

Single Cell 3- or 5-Volt Converters

Maxim Integrated Products (120 San Gabriel Dr., Sunnyvale, CA 94086) introduced the new MAX654-8 dc-to-dc converters that offer a simple, compact solution to the problem of generating a regulated +5 or +3 V from a low input voltage source, such as a single-cell battery. The MAX654/6/7 feature a guaranteed 1.15-V startup, and continue to function as the input drops under 1 V. The new family of converters can supply up to 450 mA (MAX658) of output current with a minimum of external components, achieving typical conversion efficiency of up to 75%.

A number of features are included in each device to minimize external components in battery-powered applications. These include: an 80-μA quiescent current standby mode in which the 5-V output can still supply low currents; a battery comparator output that goes low when the input battery voltage drops below 1.15 V; a control input that permits either standby or high-power mode to be activated by a switch or logic level; and a power-ready output that goes high when the 5-V output has reached its proper output level after power-up or termination of standby. A typical operating circuit for the MAX654 is shown in Fig. 2.

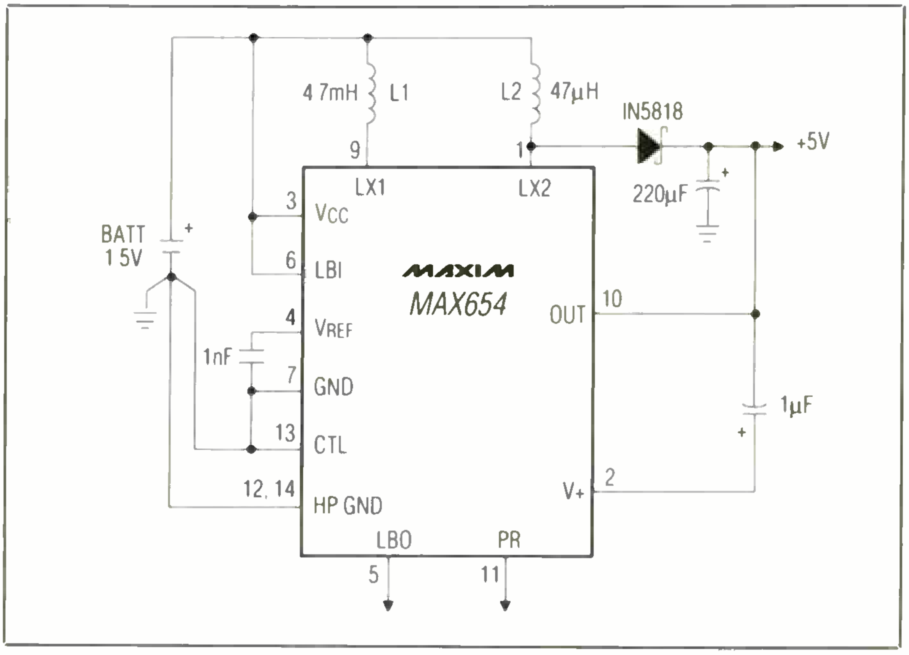


Fig. 2. A typical operating circuit for the MAX654 from Maxim Integrated Products.

Applications include battery-powered portable equipment, pagers, radios, telephones, remote sensing devices and all hand-held equipment where size and efficiency are key parameters. Maxim offers the MAX654-8 in 14-pin plastic DIP, narrow SO and CERDIP packages. Prices start at $3.34 in quantities of 1,000 and up for commercial-grade devices in 14-pin plastic DIP packages.

Low-Dropout Regulator

National Semiconductor Corp.'s (2900 Semiconductor Dr., P.O. Box 58090, Santa Clara, CA 95052) new low-dropout voltage regulator, the LM2936, uses less than 14 μA quiescent current at 100-μA standby loads. It's specifically designed for battery-operated fixed 5-V systems. Dropout performance is guaranteed to be 400 mV at 50 mA, with an output tolerance of ±2% over line, load and temperature.

Like its predecessors, the LP295X family, the LM2936 contains on-chip short circuit protection and a thermal shutdown feature. But unlike its predecessors, the new chip includes a loaddump circuit that protects the regulator from transients up to 60 V, shutting down the regulator when 30 V is reached. In addition, the regulator has protection for reverse-voltage transients up to −50 V. Both features are important in harsh automotive and industrial environments.

An on-board reverse battery-protection feature protects the voltage regulator from accidental switching of the terminal leads on the battery. Due to these new features, the LM2936 has a maximum output current of only 50 mA (versus 100 mA for the LP295X family). However, no external circuitry is needed.

The LM2936 is available in a TO-92 package that is pin-compatible with older 5-V regulators. It is priced at 69 cents in quantities of 100.

Voltage Regulation ICs From Samsung

A family of precise, versatile, monolithic IC voltage regulation devices that simplify the design of system power supplies is now available from Samsung Semiconductor (3725 North First St., San Jose, CA 95134). The devices include a switching regulator, a series of programmable precision references, and two types of regulating pulse-width modulators (PWM).

The switching regulator, the KA78S40, is essentially a flexible monolithic subsystem that contains all the active building blocks needed to implement a switching regulator system. The device can be used to implement step-up, step-down or inverting switching regulators.

The KA78S40 has its own on-chip temperature-compensated voltage reference, a voltage comparator, an independent high-gain operational amplifier, a controllable oscillator and a high-current, high-voltage output. The chip can provide an output current of up to 1.5 A without external transistors. The output is adjustable from 1.3 to 40 V.

The KA431 series of programmable precision references are three-terminal adjustable regulators with guaranteed thermal stability over either of two temperature ranges. Output voltage can be set to any value between the reference voltage—approximately 2.5 V—and 36 V with two external resistors.

The devices have a low dynamic output impedance, typically 0.2 ohm. Active output circuitry provides a very sharp turn-on characteristic, making the devices good replacements for zener diodes. Sink current capability ranges from 1.0 mA to 100 mA. The devices have an equivalent full-range temperature coefficient of 50 ppm/°C. They're temperature compensated for operation over their full rated operating temperature range.

The two regulating pulse-width modulators, the KA3524 and KA7500, contain all control circuitry needed to implement switching regulators of either polarity, transformer coupled dc-to-dc converters, tranformerless polarity converters, voltage doublers and other power-control applications.

Each device is a monolithic IC that contains an internal regulator that provides a stable 5-V reference supply trimmed to 1%. The reference is capable of supplying as much as 50 mA to external circuitry. Each device also contains error amplifiers, a phase-splitting flip-flop, an output control circuit, a PWM comparator and an oscillator with master or slave operating capability.

The KA7500 differs form the KA3524 in that it has a dead-time comparator and an uncommitted output transistor that can source or sink as much as 200 mA. The device also offers output control for either push-pull or single-ended operation. In addition, the KA7500's duty cycle can be varied via a dead-time control line into the on-chip, dead-time comparator.

Complete PWM control circuitry is contained on the chip. Also, internal circuitry prohibits appearance of a double pulse at either output. The KA7500 can be operated over a wide switching frequency range of 1 kHz to 300 kHz. The KA3524 and KA7500 operate from a wide range of supply voltages—from 10 to 40 V—over an operating temperature range of 0°C to + +70°C.

The switching regulator and pulse-width modulators come in a 16-pin DIP package. The programmable reference is available in two types of packages—TO-92 and an eight-pin DIP—and in two temperature ranges, 0°C to 70°C and −40°C to +85°C. When ordered in quantities exceeding 100, the KA78S40CN switching regulator is priced at $1.47, the KA432 is 53 cents, and the KA3524 and KA7500 are $1.09 each. ME

Getting Organized With Agenda

Lotus Development's Personal Information Management software helps to cope with today's constant flow of details that have to be acted upon at a future time

By Art Salsberg

Most of us face a constant barrage of small bits of information that we have to follow up on. For busy managers, administrators and supervisors this is especially challenging.

Perhaps you're an electronics service manager, for example, and you have to schedule equipment repairs in and outside the shop, keep track of maintenance schedules, dispatch technicians, assign replacement help to cover for someone who's ill, set up appointments with suppliers, and so on. There's just so much you can do with small notes here and there, jottings on pads, voluminous notes in a notebook, and so on. What do you do when changes have to be made, when you want an overview of a certain time period or the most important assignments to be done, or you'd like to separate TV receiver repairs and VCR repairs, prioritize service work to be done, etc.?

Personal computers and appropriate software can play an effective role in organizing and retrieving such information, and give you an overview of what's to be acted upon down the short and long roads. With few exceptions, most such software programs fall short in areas. Some can only be effective with very diligent work, while others can only present efficient views of what's to be done for limited numbers and categories before a jumble of notes become confusing. Lotus's "Agenda" is an exception. It's the pioneer program in what is called "Personal Information Manager" (PIM) application software. No word-processor, outliner, clip note, or fetch software programs can match this type of program for heavy-duty organizational capability, and quick use.

Agenda is a powerful program, and as such, it might intimidate the new user at first blush. For $395 (list) it comes with a set of four 5.25" floppy disks and, for alternative installation, two 3.5" disks; and a three-ring-binder User's Guide and a second similar binder with three booklets.

You need an IBM computer or true compatible, 640K of RAM, MS-DOS 2.0 or higher, and a hard disk. You'll certainly require the latter since Agenda files will use roughly 1.5 megabytes. The program isn't copy protected in a full sense, but it writes code to one of your disks when you first install it and requires using the install program to make backups or copies. In addition, two pop-up accessory programs that take up at least 65K of RAM may be installed to add to the versatility of information collection, as will be shown later. (If you're using OS/2 as your operating system, you'll require 1.5 megabytes of RAM instead of the 640K cited above for MS-DOS.)

This latest version of Agenda includes a new starter application called "Activities Planner." It contains activities commonly used by most people, illustrating a variety of Views that will speed learning how to use the program. Additionally, Version 1.01 protects files from loss or damage due to power interruption and has a database recovery utility built in should the unimaginable ever happen to your data. (An update kit for owners of the earlier Agenda version is available for $15. This update was provided free for a limited period of time.)

Using Agenda

This is one of those programs you just can't effectively use without reading some of the information presented in Agenda's fine manuals, especially the chapter, "Thirty Minutes with Agenda." You'll get a fast look at all the basics. Moreover, I'd heartily suggest that you go through the automated demonstration disk that's provided. Additionally, an Agenda Tutorial gives you step-by-step instructions, and an Agenda Sample Applications illustrates a variety of ways in which to use the program on the job.

These recommendations aren't made because Agenda is ultra-complex, but just that it allows you to do so many things that you must have a practice run-through to prepare you to use the program advantageously. In this sense, it's not like a powerful word processor program that permits you to merrily use a tiny fraction of its functions without touching on its full strength. On the other hand, it's much simpler to use Agenda "full strength" because operating requirements are much more limited than typical heavy-weight word processor or database programs.

Actually, what you're doing with Agenda is akin to creating a special database that's entered and massaged in an altogether different manner. Throw in some beautifully working artificial intelligence and you'll have some idea of what Agenda is all about.

The people at Lotus Development sure knew what they were doing when they developed this program. With Agenda, you can enter whatever you wish in an unstructured manner, sort, retrieve, automatically cross reference. In essence, you work with it in a sort of free form manner. Function key assignments simplify the entire process.

You might compare a standard database program's "records" with Agenda's "items." Unlike a database, though, you don't have to set up any structure. Just type away with free-form text, using a couple of words or about four lines (350 characters). Just as if you're using an ordinary word processor. This might be words such as "Check out Martin's VCR after lunch" or "Phone Howard tomorrow to be sure he's at home." You can also attach a note to any item that can be as long as about 10 pages.

Any time you wish you can assign items

Hardware Personal Info Organizer

While a host of personal information management software is on the market, from ones with a limited scope to superweights like Agenda reviewed here, they all share one limitation: You can't easily tuck any of them into your pocket for quick referral.

Take heart, however, because a bevy of carry-along hardware products are also available to help you jog your memory. Some, like Sharp's "Wizard" and Casio's "Boss," are the heavyweights among portable hardware designed for this purpose. A new one, that I'd call "Mighty Mite," is SelecTronics' "Datastor 1000c." The size of a modestly thickened credit card, this $40 product is a marvelous databank that can be easily carried around to recall names, numbers, addresses, memos and appointments. It also recalls time (you can choose a 12- or 24-hour format), date, day and displays running seconds on its two-line LCD display.

In addition to the foregoing functions, it performs as a 12-digit four-banger calculator with memory, percentage and currency-exchange-rate calculations. Datastor is topped by a nice alarm feature that will beep for 20 seconds when the alarm time is reached. Moreover, it allows you to store a message along with the alarm that will be displayed. Up to 100 characters can be stored per alarm message, with the first 12 characters shown. There's a scroll button to see the rest of the message. Among other features is a secret three-digit file number code, which performs like a computer software's security password.

Powered by a 3-volt lithium battery, it also contains a backup duplicate so that your data will remain intact if you change the main battery. Memory space is 10K, with a storage capacity of up to

to "categories," which are similar to a database's fields. If you set a few categories manually, Agenda will start assigning items to categories *automatically*. You can also name sub-categories. For example, you could set up a category as Jobs and a sub-category as Names. Or another sub-category as Serviceman. You can choose virtually any number of categories you wish to. Furthermore, you can add synonyms so that Robert and Bob or just plain B are interpreted the same by the program.

The delightful part of all this is that it's so easy to work with Agenda once you get the thing down pat. The program can be set to use its artificial intelligence to suit you. You can set it so that it enters items in their proper categories from among a bevy of them automatically or set it so that it has to give you the final okay to place the items. The strength of the automatic function can be varied by you, too. It even evaluates dates when the specific one isn't given, such as typing ". . . tomorrow" or ". . . next Friday," and automatically enters the specific date into a related "When" category.

Finally, Agenda has a "View" function. This allows you to see whatever is stored in memory, permitting you to filter things the way to wish to see them; horizontally, vertically, both, any item, any category, mixtures, and what have you, including narrower or wider columns with automatic wrap-around. In

100 characters and 64 digits for each record put into memory. The device shuts off automatically after 7 seconds to conserve battery energy if you forget to press the OFF button.

Datastor's raised tablet-like soft key tablets are small. However, taking care, they were easy to use, responded well and had sufficient spacing for my fingers to work them without error. This is no easy task, since the face squeezes in all the letters of the alphabet and 0 to 9 numerals, as well as a group of command keys, such as STORE, RECALL, SCROLL, etc. Although the LCD display isn't backlighted, characters displayed are large and very black against the background, making the display comfortable to read.

The Datastor 1000c certainly packs a lot of useful functions into a remarkably compact design at a modest price that the "street" in many areas will doubtlessly discount. One can always wish for more memory capacity, but the Datastor 1000c contains enough to make it through the week, unless you plan to fill it up with *all* your phonebook numbers. One feature not mentioned, by the way, is a "Decision Maker." This bit of frivolity activates the display with a random "Decision-Yes," "Decision-No" or "Decision-Maybe" message should you be torn between deciding something one way or another. With the "Maybe" message, I guess it's better than flipping a coin.

For those of you who aren't familiar with SelecTronics, the company merged recently with Microlytics, which produces some very fine computer software, such as the search and retrieval program "Gofer," and a host of other compact portable products. Selectronics also includes "The Electronic Bible" and "Wordfinder" in its product line, as well as other Datastor models. One such pocket model includes an RS-232 port to send its notes and whatever to a personal computer or vice-versa. It works its miracles of miniaturized databank products with the aid of a Xerox license to use the big X's impressive data-compression technology.

You don't have to be a disorganized person to make good use of Datastor, of course. It's a product that will serve admirably for all of us, combining great utility, carry-along ease and low cost. In sum, it's not just a gimmick device, but a highly useful tool for just about everyone. Oh, yes, it automatically arranges names in alphabetical order whenever you key in a new one.

effect, it's a magic genie at your fingertips for information retrieval at its best.

You can add, delete, modify, copy, print with page layout choices and headers, move, sort, get help screens, change screen colors, rename, add or change a password, automatically save matter choosing an interval from 1 to 60 minutes, create macros, import, transfer, and more. Two pop-up accessories are also provided to either capture text from another software application and paste it into an item or note in Agenda or transfer up to 10 items at a time to a structured file and them import them to the Agenda database.

Like Lotus 1-2-3, you move a highlight bar on the top of the screen display's menu to select the function you want. Function-key assignments toggled for display at the bottom of the screen simplify operations, with the same common use of F1 for Help. Unlike 1-2-3's slash-line key to access the menu, however, Function key F10 is used. In addition to macros to speed up work, there are also keys you can assign to provide "accelerated" performance.

Conclusions

Agenda 1.01 is a truly impressive program that fills an important need. Its shortcomings are few, while its strengths are many and great. Among the former is a quirky requirement that a /b/ has to be placed at the beginning and end of a header that you want to boldface instead of simply typing Y or N when given a choice. Aside from such minor quibbles, the only negative I can observe relates to any powerful program: it requires a lot of memory and disk space, and it takes more time than simple programs to become familiar with the in's and out's of Agenda.

Agenda's strength, however, becomes apparent when you constantly have lots of scraps of information you want to organize for quick, easy retrieval. Chief among them is the program's ability to link different files. You can assemble a bunch of information from different files in a flash, say, all the Panasonic VCRs scheduled for repair in a forthcoming week. Or all the customers living in a certain area. I especially like Agenda's artificial intelligence capability. No longer does one have to repeat typing related information in different files since the program does it for you automatically.

Lotus Development's Agenda isn't for everyone, of course. It's exceptionally appropriate for anyone who works with a lot of short items, not with extensive documents. If the former is your lot, as it is for so many of us, then Agenda will indeed make you a much more efficient person, releasing a lot of time you can put to use for other responsibilities. Stick with the program for a while to get the hang of it, and I'm confident you'll agree that Agenda is a winner among its kind.

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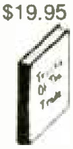

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NEW PRODUCTS ••• (from page 14)

Model 7300-ESD, features a static-dissipating handle. A third version, the Model 7300-AK, is available as an adapter kit for existing Endeco Model 510-3 irons.

CIRCLE NO. 85 ON FREE INFORMATION CARD

Ni-Cd Recycler

R F Tronics (Agawam, MA) claims to have solved the "memory" problem in nickel-cadmium battery packs with its series of Cad-Cyclers. This new device helps to restore a battery

pack to its full ampere-hour capacity by properly discharging it to a precise recommended level. Full capacity is usually restored in three charge/discharge cycles. Repeated use of Cad-Cycler is said to help prevent memory from forming in a battery pack and maximize the life span and number of charge/discharge cycles that a battery was designed to produce.

These hand-held Cad-Cyclers are all solid-state in design and are powered by the battery being discharged. They feature: red flashing MIN and green MAX LEDs; reverse-polarity protection; convenient screw-type terminals on battery and charger ends for use with any desired connectors; CHARGE/DISCHARGE selector switch; beeper that signals end of discharge (less than 5-mA drain). Designed to be used with existing battery chargers, the Cad-Cycler series is said to convert any charger into a battery cycler.

Discharging is automatically halted as battery voltage drops to within 0.1 volt of the designed 1.1-volt per cell stop level. Five models currently make up the line. The Models CC-4, CC-5 and CC-8 discharge at a 500-mA rate, while the Models CC-6 and CC-7 discharge at a 600-mA rate. Each model is color coded for easy identification.

CIRCLE NO. 86 ON FREE INFORMATION CARD

Stereo Headphones

Audio-Technica's Model SG800CD Sound Guard™ stereo headphones provide separate volume controls for the left and right channels. This feature makes it possible for the user to adjust channel balance and sound level for optimum listening without having to reset amplifier or receiver controls. Also built into the headphone system is a stereo/mono switch.

Closed-back earcups in the Model SG800CD block external sound. The ear seal is created by soft vinyl earpads. A double headband system and pivoting earpieces assure proper fit and fatigue-free listening.

Technical Specifications: frequency response, 20 Hz to 20 kHz; sensitivity, 100 dB at 1 mW, 1 kHz;

matching impedance, 4 to 16 ohms; weight without cord, 6.4 ounces; cord length, 6 feet. The single-entry cable supplied with the phones is terminated in a mini-plug plug for compatibility with home, portable and personal stereo systems. A ¼" adapter plug included for use with home systems that require this.

CIRCLE NO. 87 ON FREE INFORMATION CARD

CIRCLE NO. 61 ON FREE INFORMATION CARD

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Variable Load *(from page 43)*

in the main circuit to point A on the display circuit-board assembly and repeat with another wire between points B in both circuits.

An interior view of the finished prototype of the project is shown in Fig. 4.

Checkout

To use your Variable-Load Box/Power Transistor Tester, first set to the NO LOAD position and CURRENT CONTROL *R2* to its fully counter-clockwise position. For a positive power supply or an npn transistor, set two-position switch *S1* to the NPN position (use the alternate position of *S1* for a negative supply or pnp transistor). Then set three-position switch *S2* to the *same* position selected for *S1*.

Connect your power supply to the project via the appropriate binding posts and turn on the power. Set *S3* to the LOAD position. Now slowly rotate the knob on CURRENT CONTROL *R2* as you observe either the analog meter movement or digital panel meter. The current should steadily increase until the control reaches its fully-clockwise position. Repeat this test with the switches set to their alternate positions and the polarity of the power supply reversed. You should notice that at lower voltages, the response of *R2* is not as immediate as it is in the 12-to-15-volt range.

If the project does not yield the correct responses or it blows fuses, begin troubleshooting it by making certain that connections to the transistors have been properly made, that the collectors are not short-circuited to the enclosure or heat sink on which they are mounted and that you installed the transistors in their correct sockets. Next, trace your wiring to the switches. Make sure you have not reversed the connections with relation to the legends on the enclosure. Do not put your project into service until you have corrected any problems encountered during checkout.

ELECTRONICS NOTEBOOK...

(from page 61)

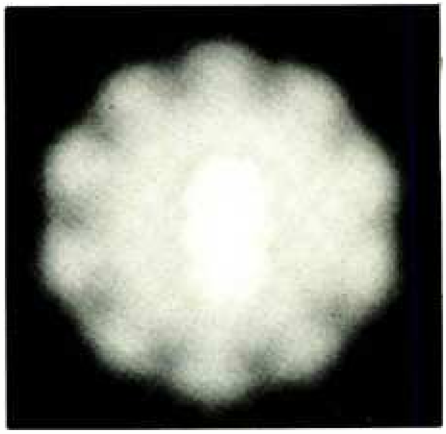

Fig. 8. A forward-biased OD-663 as viewed through an infrared image converter tube.

trodes to provide a series path through the three diodes.

Figure 8 is a photo of the screen of an infrared image converter tube that I placed directly over the forward biased OD-663 shown in Fig. 7. The image converter was focused on the three chips of the OD-663 and the camera lens was focused on the image converter's phosphor screen. Unfortunately, the photo doesn't begin to capture the brilliant appearance of the OD-663 when viewed through an image converter.

While a CCD color video camera I tried did detect the emission from the OD-663 and other high-power 880-nm LEDs, it wasn't nearly as sensitive as my old single-stage IR image converter. This is probably due to the filtration necessary to give color sensitivity to the CCD array. A monochrome CCD camera should work much better, particularly since the peak emission wavelength of AlGaAs LEDs is a close match to the peak spectral response of silicon.

Going Further

In a subsequent column we'll take a close look at high-power red LEDs. Meanwhile, you may want to assemble a lightwave receiver to detect the pulses from the system described above. I've described various kinds of lightwave receivers in this column and elsewhere. See, for example, my *Engineer's Mini-Notebooks* "Optoelectronics" and "Communications Projects" from Radio Shack. **ME**