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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

■ Home Experiments With Superconductors

■ A Speed Reader/Comparator for 16K to 512K EPROMs

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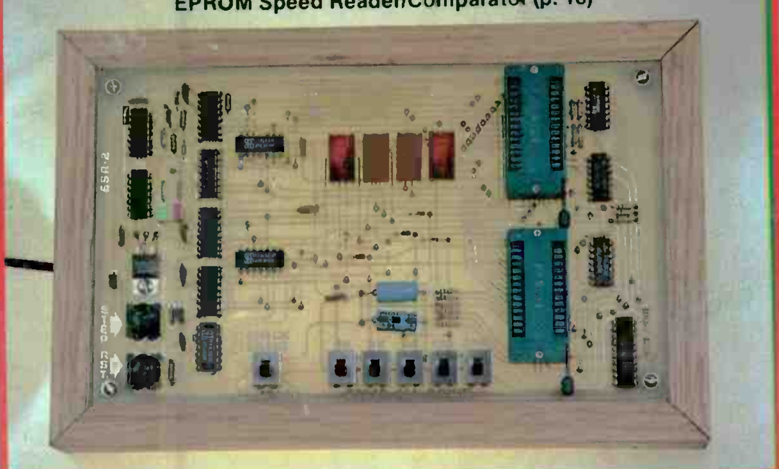
Full Construction Plans:

- ■ Make an Electronic Electric-Blanket Controller
- ■ A Visual Indicator for Incoming Telephone Calls
- ■ An In-Circuit Bipolar Transistor Tester

Plus: ■ SMD Circuit Repairing ■ A New Look at Complex Linear Mixing
■ Experimenting With Audio Circuits

EPROM Speed Reader/Comparator (p. 18)



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MODERN ELECTRONICS

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

MARCH 1988

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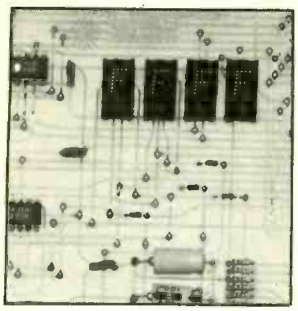

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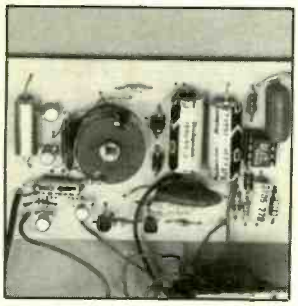

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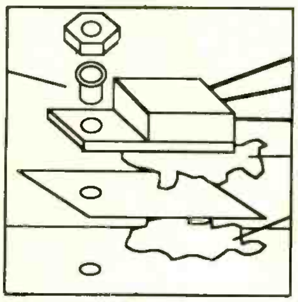

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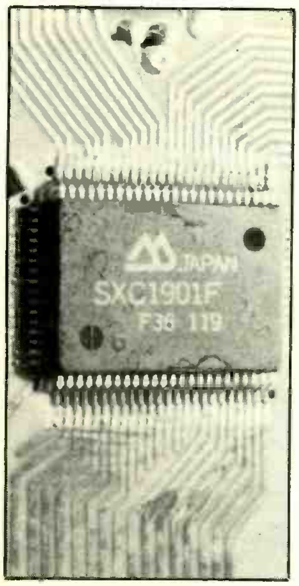

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EDITORIAL

The DAT Saga

The digital audio tape (DAT) machine saga continues into 1988 as hardware makers jockey among themselves and their record-industry opponents.

At one end, the machine makers are showing prototype models. But only consumers in Japan and Europe can buy these super-quality audio tape machines. At the other end, the U.S. record industry continues to oppose DAT machines unless they have anti-copying provisions to ensure copyright protection. It brought its case to Congress, and we're all awaiting legislation on this.

Meanwhile, the plot thickened recently. Sony, a major Japanese DAT machine manufacturer, agreed to buy the giant CBS record division. CBS, you probably know, is in the forefront of opposing digital audio tape machines that can record and developed an integrated circuit, Copycode, to prevent such recording with DAT. Which side of the coin does Sony come down on now?

At the same time, N.V. Philips, which developed the original audio cassette, and is also a major record producer (PolyGram Records) as well as a hardware manufacturer, has introduced another anti-copying scheme called "Solo." But this system does allow one to make a digital tape copy of a digital compact disc! What it does not permit is copying the tape!! This is said to foil making volume-quantities of master-quality tape.

An alternative to copying source material has always been with us, of course: Adding a tax to the tape recorder or to blank tape that would wend its way to the recording artists and record industry.

Summing up the DAT story to date, the Japanese DAT machine manufacturers are champing at the bit, awaiting Congressional action on machines that copy or cannot copy digital compact discs and tapes. The record industry is trying once again to get rewards for copyright material after losing their "case" with analog tape and video tape. And we consumers all sit here awaiting an audio tape system that can reproduce sound at least equal to that of a compact disc, which may or may not have a capacity to record near-perfect duplicates.

My feelings on all this remain the same. They are as follows: The record industry would not be earning as much money from prerecorded material as they are from prerecorded video tape sales and rentals and record sales if the video and audio machines did not have a recording facility! Simply put, I wouldn't buy a playback-only tape machine. I think much fewer would be sold, with accompanying decreases in prerecorded sales and rentals.

In fairness, though, digital audio tape machines are admittedly different. Whereas there's a generational loss of quality when standard video or audio source material is recorded, DAT copies are essentially indistinguishable from the originals. In my view, therefore, there could well be a loss of revenue for record companies in this case. As a result, it seems equitable to do something that would reward the record industry for a likely loss of some revenue as a consequence of recording DAT machines.

However, I shudder at the CBS solution: a device that prevents all recording. Everyone loses! The Philips anti-copying scheme that permits CD-to-digital tape copying, but not digital tape-to-tape is much more desirable. Be assured, however, that pirates will break the code.

My conclusion, therefore, is that there should not be anti-copying schemes at all, but a tax should be levied on blank digital audio tape. It might be untraditional, but it seems to be the neatest solution. We pay sales tax on most purchases and we pay Federal Excise Tax on some things. So why not pay a tax on blank DAT? The amount would be minuscule and we'll all come out ahead. After all, how many people will spend big bucks on a digital tape recorder that has recording hindrances?

Art Salsberg

HP Calculator Info

• Thanks for a very interesting article on the HP-28C calculator in the October 1987 issue. I will probably get one of these machines or a more programmable relative of it if HP designs it. For the time being, I will be an HP-71B and an HP-41C/CV/CX (on each) user.

Readers of your magazine who are interested in small computers such as the HP-71B or calculators like the HP-28C and HP-41 series might be interested in a new publication done in newsletter style. It is *HPX Exchange*. Articles are submitted by members and there is no compensation.

To inquire about HPX membership, send a business-sized SASE with 39 cents postage attached. I will return photocopies of the table of contents of the first two issues of the *Exchange*, pages 1 and 2 of both issues, membership application form, and one article on the machine that most interests you (specify HP-41, HP-71B or HP-28C). Or contact the editor/publisher direct at: Handheld Programming Exchange, P.O. Box 566727, Atlanta, GA 30356 (tel. 404-391-0367 evenings/weekends).

James C. Cave
P.O. Box 298
Princeton, TX 75077-0928

Project Updates

• Figures 12 and 13 of "The Versatile LM723" (February 1987) both show an npn 2N2222 (my error) where a 200-mA 2N3906 or a more robust 600-mA 2N4403 pnp transistor should be for the constant-current source. The 723 is a very robust device but it *must* be installed in a properly designed circuit. It is very prone to damage with even the slightest short circuit to any pin.

J. Daniel Gifford

• In "An FM Wireless Microphone" (January 1988), the value of C1, C2 and C7 is shown as 0.1 μF in the schematic but is stated as 0.01 μF in the Parts List.

(continued on page 59)

RADAR DETECTOR ADVANCES. Uniden's new "Uniden Talker" radar detector lets the user program a warning in his own voice (or someone else's) that's activated whenever a radar signal is detected. The X/K band device is also equipped with a conventional buzzer....Maxon's micro-size RD-XL X/K-band radar detector uses a self-contained battery to eliminate the power cord. The cordless device employs a Gallium Arsenide Field-Effect Transistor circuit.

ACTIVE LOUDSPEAKER SYSTEM. A unique remote-controlled loudspeaker system with 1,400 watts of power from ten amplifiers has been introduced by Altec Lansing. The new Model 550, which consists of a pair of speaker systems with swiveling drivers, uses a remote control panel that allows the systems' amplifiers to be adjusted ± 6 dB in 2-dB increments, with each change marked by a LED indicator. Additionally, a remote volume control adjusts the overall response curve and L/R balance can be made. Double-cabinet construction is used, with upper bass, lower midrange, upper midrange drivers and tweeter housed in separate, swiveling cabinets. Subwoofers remain stationary since their frequency is non-directional. Total harmonic distortion is said to be only 0.08% at 1 watt to rated power, from 35 Hz to 20 kHz. The amplified speaker system retails for $12,000 per pair.

CORPORATE CHANGES. Some interesting name and ownership changes were seen in 1987. The venerable General Instrument MicroElectronics name was changed to Microchip Technology Incorporated, for example....IBM announced selling off of its shares in Intel, the company that designed and produced the microprocessors for IBM's line of personal computers to date....CBS Records was sold to Sony, the latter saying that this should have little immediate effect on the current legislative DAT [digital audio tape] battle. (Wanna bet!)

BAR-CODING SKYROCKETING. The boom in bar coding continues, with 10.2% of non-using companies saying they'll be installing systems this year, according to a nationwide survey conducted by Cormier & Church, Ltd. for Texlon Corp. The current marketplace is said to be around $500-million annually, and only 18.4% of companies contacted in the survey are currently using bar coding or another form of electronic point-of-origin data gathering. The grocery business really gave birth to bar-code scanning here about 15 years ago, spreading rapidly, as supermarket shoppers know....Bar code leader INTERMEC has introduced a new bar code, CODE 49, named by its developer, Dr. David Allais, who also invented the widely-used CODE 39. The new symbology has a two-dimensional format that encodes all 128 ASCII characters and can be intermixed with and discriminated from other bar codes. The new symbology reduces the length of bar-codes to 1/16th of that encoded with the popular CODE-39 symbols.

JAPANESE TECH LANGUAGE COURSE. MIT will be starting a workshop for electrical engineers and computer scientists to learn technical aspects of the Japanese language so that they can read technical information published in Japanese. According to an MIT spokesman, Japanese counterparts often read technial English fluently and can therefore gather much information easily. The workshop (June 6 to July 29) will be limited to 20 people, with a tuition of $3,000. For more information, call MIT at 617-253-8095.

NEW

Only NRI gives you a 27" high-resolution stereo color TV you build to prepare you for today's video servicing careers.

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Now at $26 billion in annual sales, the consumer electronics industry is creating a whole new servicing, installation, and repair market. This year, TV sales alone are expected to hit 16.2 *million* units. Every day, sales of home VCRs, a product barely conceived of 10 years ago, reach 20,000 units. Every day!

And the revolution has spread to the business sector as tens of thousands of companies are purchasing expensive high-tech video equipment used for employee training, data storage, even video conferencing.

The Video Revolution Is Just Starting

Already, disc players can handle audio CDs and laser video discs. And now there are machines that will accommodate laser computer disks as well. Camcorders are becoming smaller, lighter, and more versatile . . . 8 mm video equipment produces high-resolution pictures and digital audio. By 1990 our TVs will become interactive computer terminals, giving us entertainment, information, and communications in one sophisticated video/computer/audio system.

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Can you see the opportunity? The servicing and repair market that's there already . . . and the enormous future need created by the millions upon millions of electronic devices yet to come? If you're looking for a high-potential career . . . if you'd like to get started in a field that's still wide open for the independent businessperson . . . even if you'd like to find a way to make extra money part-time, look into NRI at-home training now.

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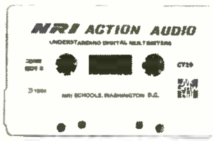
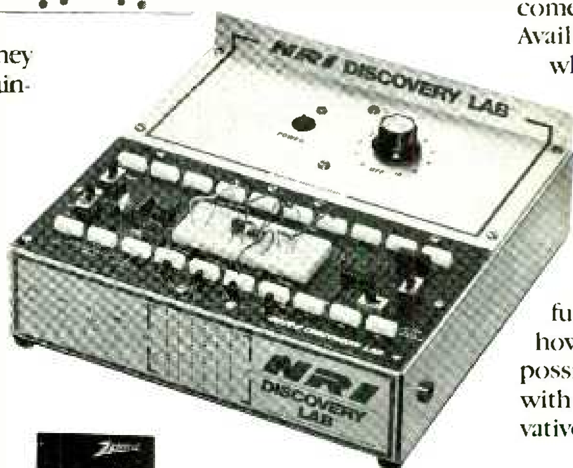
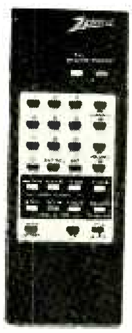
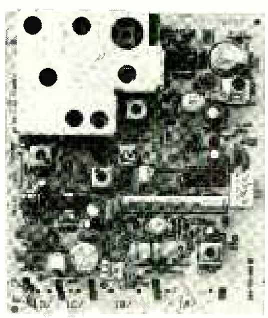
In just hours you assemble an exceptional state-of-the-art TV receiver using easy to follow, step-by-step instructions. During this assembly process, you learn to identify and work with components and circuits used in actual commercial circuitry. Then through tests, adjustments, and experiments you quickly master professional troubleshooting and bench techniques.









NRI's commitment to you goes beyond providing you with equipment appropriate to the latest technology. Of equal importance is our dedication to training techniques that let you master TV, video and audio troubleshooting and repair quickly and easily. Best of all, we ensure that in the learning process you acquire the very skills that will make you a professional service technician on the job.

NRI has purposely designed your training around equipment that has the same high-tech circuitry you'll encounter in commercial equipment. That means your training is real-world training. And *that's* unique.

Inside Your TV

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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.

Hand-Held DMMs

Two new hand-held digital multimeters that have both 3¾-digit numeric and 71-segment analog LCD displays are now available from Simpson. The "human-engineered" Models 487 and 488 DMMs feature full autoranging, 0.41-inch numeric

display digits and recessed test-lead jacks. The Model 488 is a true-rms-reading instrument on all ac voltage and current ranges: up to 750 volts ac and 10.0 amperes. Resistance ranges to 30 megohms and an audible diode/continuity test indicator are included.

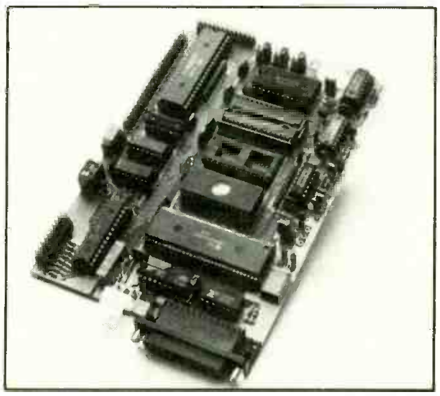
Data and peak hold for all functions and ranges aid in troubleshooting and circuit analysis. The 71-segment analog bargraph display permits accurate peak and null adjustments to be made. The 20-kHz frequency response of both models makes these instruments valuable tools in audio servicing. Overload protection, a wide temperature/humidity operating range and rugged construction assure long service from these DMMs.

Both DMMs can measure from 300 millivolts to 1,000 volts dc, 300 millivolts to 750 volts ac, 300 microamperes to 10 amperes dc and ac and 300 to 30M ohms, all full-scale. Power is provided by a single 9-volt battery. The compact instruments measure 7.28 × 3.86 × 1.85 inches and weigh about 1.1 lb. $219 for Model 487; $275 for Model 488.

CIRCLE NO. 101 ON FREE INFORMATION CARD

Microcontroller With BASIC in ROM

The Vitrax IX Microcontroller from Sintec Co. (Frenchtown, NJ) is a compact stand-alone microcontoller designed for digital-control automated analog measurement, sensor monitoring and data acquisition. Driven by a high-speed CMOS Z80-compatible processor, it is claimed to



provide features and performance most often required in industrial and commercial real-time applications. The single-board microcontroller contains a full-featured floating-point BASIC in ROM, up to 16K of EPROM-based user code and CMOS static RAM that can be expanded to 32K. Vitrax IX also features a built-in EPROM programmer to simplify code generation for autostart operation.

For ease in interfacing, the unit provides 24 bidirectional I/O lines, two full-duplex asynchronous RS-232 channels that operate at up to 18.2K baud, a Centronics parallel printer port and an optional 8-channel, 10-bit CMOS A/D converter. A real-time clock/calendar can also be added for time-dependent applications. The entire unit operates from a single 5-volt dc power supply and draws less than 150 mA. It mounts on a 6.5 × 4.5-inch printed-circuit board and is available in both factory-wired and kit forms. $139.50 in kit form; $39.50 for 8-channel, 10-bit CMOS A/D converter; $34.50 for CMOS real-time clock/calendar.

CIRCLE NO. 102 ON FREE INFORMATION CARD

Video Recording Accessories

Three new products from RCA can help videophiles make better video home movies. The Model VDC050 portable 12-volt dc light that operates on battery power or from a car's electrical system is said to insure dramatically brighter and sharper pictures. It has a special 50-watt multi-mirror lamp that maximizes light output and reduces power consumption and heat build-up. $69.95.

The Model WM002 wireless microphone is designed to capture sound at distances up to 100 feet away. It consists of two pieces: a microphone/transmitter arrangement that the person speaking carries and a small receiver that snaps onto the top of the camera. $134.95.

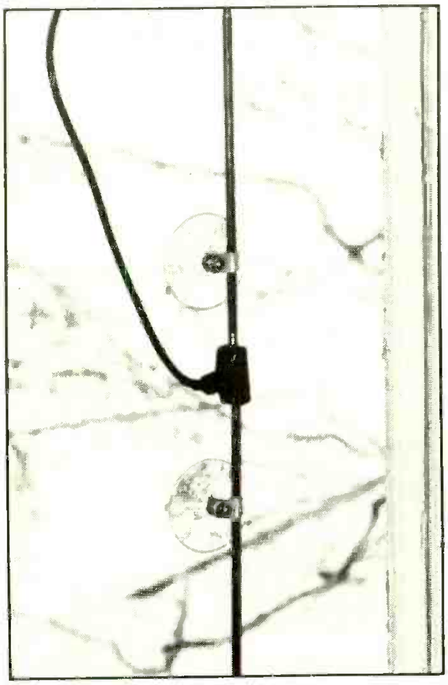
A character generator, Model CGA020, can give a "professional" touch to home video movies by adding names, dates, movie credits and other useful information to his

tapes. Characters can be displayed in four sizes and can be made to scroll off-screen, just as they do in professional moving pictures. In addition, the character generator can create "curtain" and "window" effects, and titles can be added to a tape without the need for a camera. $249.95.

CIRCLE NO. 103 ON FREE INFORMATION CARD

Instant-Mount Antenna

A new antenna that has suction cups for instant mounting on glass or any other smooth surface where drilling a hole is not possible is available from Electronic Processing, Inc. (Medford, NY). The Vak-Tenna can receive 30 to 500 MHz signals and can be used for transmitting from 50 to 250 MHz at up to 50 watts. It can



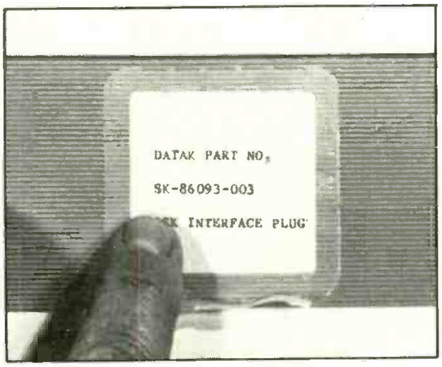
be mounted vertically or horizontally, as desired.

When mounted via its powerful suction cups, the antenna is held 1 inch from the glass to clear the frames of most windows. Its elements hinge to allow use with bay windows and at unusual angles. Two telescoping elements extend from 20 inches to 79 inches. Supplied with the antenna is a 15-ft. 50-ohm RG-58 cable. Standard connectors are PL259, BNC, Motorola and F; others are available on special order. From $29.95.

CIRCLE NO. 104 ON FREE INFORMATION CARD

Ribbon Cable Labeler

"Cabelabel" from The DATAK Corp. (N. Bergen, NJ) provides a clever approach to labeling flat ribbon cables that do not usually "take" to traditional labels. Each



Cabelabel has a white write-on area that accepts pencil, pen, typewriter or computer printer legends. A clear vinyl cover securely seals the label to the ribbon cable or other surface and protects the label from dirt, abrasion, etc. What makes Cabelabel so different is that it is made from a soft, flexible material that conforms to the corrugated cable and stretches as the cable is bent. It uses an acrylic adhesive that permanently sets over a period of several hours. The labels are designed to bear up to temperature extremes as low as -55 and as high as $+125$ degrees C, though some yellowing may occur at temperatures above 110 degrees C.

Cabelabels are available in sizes ranging from 1.8×1.8 to 1.8×0.25 inches. Label quantities vary from 36 to 108 per set, depending on size. $7.50 per set.

CIRCLE NO. 105 ON FREE INFORMATION CARD

Low-Cost PC LAN

LANtastic from Artisoft, Inc.'s (Tucson, AZ) PC local-area network system is designed for high speed. Its on-board 10-MHz coprocessor provides a transfer rate of 2M bits per second and works with a dedicated 100-ns 32K buffer RAM. The coprocessor works in parallel with the host computer's CPU to permit computing tasks and networking tasks to occur simultaneously. A Starter Kit consists of two LANtastic network adapters, 15 feet of cable, two network terminator plugs and software. Its NETBIOS software is completely implemented by the coprocessor, allowing it to run with the IBM PC Networks program, Novell's Advanced NetWare or any network operating system that uses the NETBIOS interface.

Each Kit includes a Single Server License to the LANtastic Network Operating System, LANmark™, which provides the software link between computers using LANtastic adapter cards. Users create volumes on the Server's hard disk that can be shared across the network. LANmark allows read-only, read/write and exclusive access to volumes. Se-

curity is provided by disk-access passwords. Printer spooling and electronic mail are also supported.

For most network applications, LANmark can be used instead of network software. It does not require a dedicated Server. Artisoft's optional BIT TRACY™ hardware security card can be used with LANtastic to give completely controlled access, and a DES Encryption chip can be added to encrypt volumes in the Server.

LANtastic employs bus topology

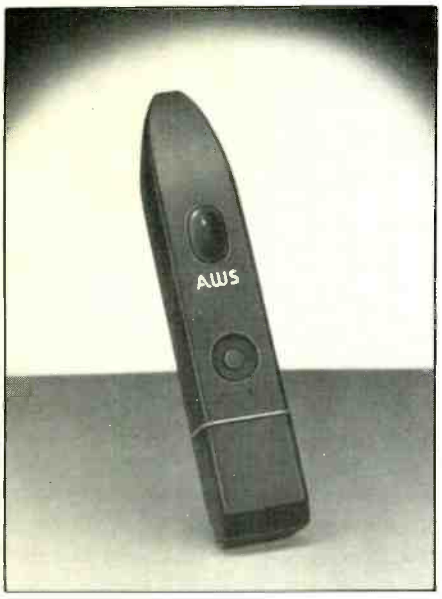
which requires no additional hardware for interconnecting 32 PCs. Multiple adapters can be installed in each PC to be used as Gateways. Male and female adapters on each adapter card provide for easy daisy-chaining, and network lengths of more than 500 feet are possible. No I/O port locations are used, so no conflict exists with existing I/O cards; and no DMA channels are used by the system.

LANtastic Starter Kit, $399; LANtastic Network Adapter, $199; BIT TRACY, $149; DES Encryption chip, $75.

CIRCLE NO. 106 ON FREE INFORMATION CARD

No-Contact Voltage Detector

A.W. Sperry's (Hauppauge, NY) new Model VH-600 "Volt Hound" test device is a no-contact voltage detector that can sense and indicate ac potentials in the range of 100 to 600 volts with reference to ground. To operate it, the user simply grasps the



Volt Hound in his hand and places its tip near a live wire. If the wire is indeed "live," an audible tone is sounded and a light turns on. The 1-ounce Volt Hound comes with two 1.5-volt button-type cells that should power it for about a year.

CIRCLE NO. 107 ON FREE INFORMATION CARD

Six-Disc CD Player

A new CD player that can play up to six compact discs has been announced by Sansui. The Model CD-X310M CD player comes with a special magazine that provides the multiple-disc play capability. Up to 32 randomly programmed selections can be distributed among the six discs in any order desired. Features include Automatic Music Program Search (AMPS) that permits you to skip to the next or previous track; Audible Manual Search for fast forward and reverse; and a Repeat function that permits repeating the track being played, all discs or all tracks programmed into memory.

A display window indicates the number of the disc being played, track number being played, elapsed time and memory. Programming can be altered at any time during operation. The easy-to-load disc magazine has six individual disc trays that pivot outward to allow the discs to be loaded label side down. Supplied are a wireless remote controller and connecting cables.

Frequency response of the player is rated at 2 Hz to 20 kHz, S/N at greater than 93 dB, harmonic distortion at 0.008 percent (at 1 kHz) and wow and flutter at unmeasurable level. The player measures 16.5"W × 13"D × 3.5"H and weighs 11.2 lbs. $400.

CIRCLE NO. 108 ON FREE INFORMATION CARD

In-Flight Headphones

Jetset is a new portable audio system for comfortable in-flight listening to movies and stereo music from Executive Travelware (Chicago, IL). It is claimed to offer a major improvement over airline-provided air-pipe headsets and can be used by wearers of in-ear hearing aids.

A patented sound pickup is made up of a pair of sensitive condenser microphone elements mounted in a specially designed seat connector. Acoustic correction baffles on the microphones filter excess hiss and sibilance from the sound. The microphones convert the acoustical signals into electronic signals that are then amplified by a patented "Airdaptor" module that drives the sup-

plied lightweight or personal-stereo headphones. Frequency response is stated as being 30 Hz to 20 kHz. Power for the module is supplied by two AAA cells. The amplifier module is short-circuit and reverse-polarity protected.

For convenience and longest battery life, power to the module automatically switches off when the headset is not plugged in. The Airdapter module is small enough to fit into a shirt pocket, measuring only 3 × 2⅜ × ½ inches. $19.95.

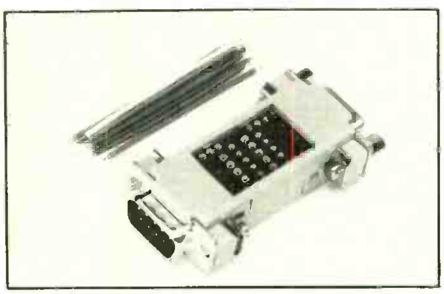
CIRCLE NO. 109 ON FREE INFORMATION CARD

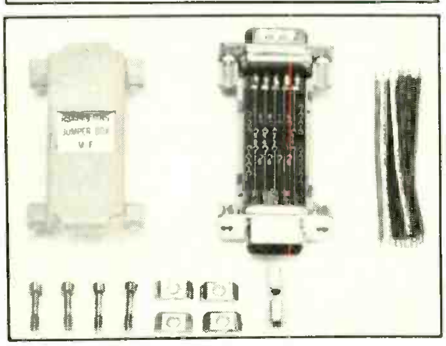
DB-9 PC Aids

Two new products from Telebyte Technology, Inc. (Greenlawn, NY) support computers that use DB-9 connectors. The Model 52 is a Jumper Box, the Model 55 a Minipatch Box.

The Model 55 Minipatch box (upper photo) is a standard breakout-box arrangement configured for 9-pin connectors and has a male and female DB-9 connector at opposite ends of its plastic enclosure. It comes with jumper wires for fast reconfiguration and has two patching areas for applications where many signals must be patched together. $16.

Users can customize interfaces between two DB-9 based devices with the Model 52 Jumper Box (lower photo). This item features a solder-masked pc board with each of the female and male connectors at opposite ends terminated in plated-through holes. Pre-stripped jumper wires are supplied for soldering into the board's holes. Once configured, the assembly is housed inside a snap-closed plastic box, after which any needed polarization hardware (supplied) is attached. $12.





CIRCLE NO. 110 ON FREE INFORMATION CARD

Battery Backup System

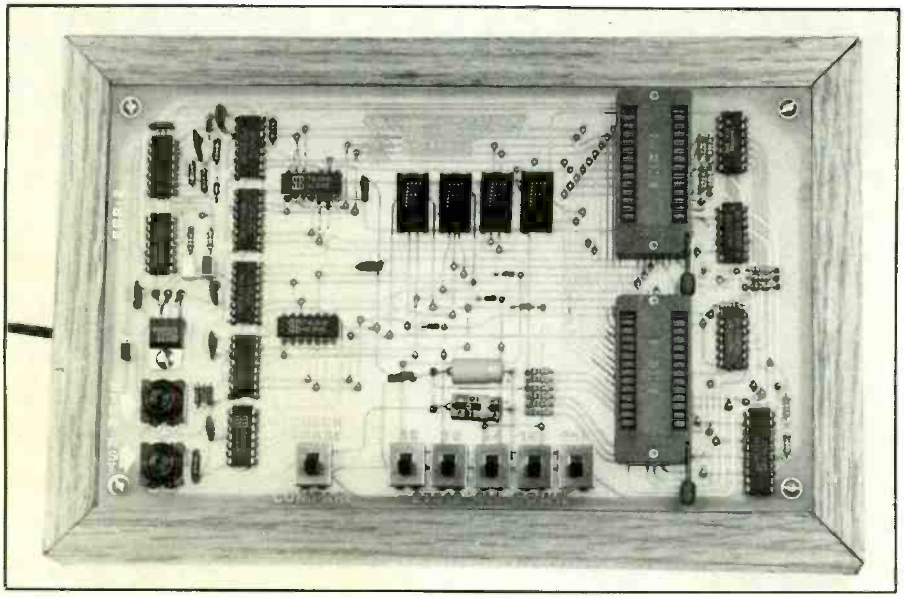
A new 325-watt battery backup system for computer and other electronics equipment users was introduced by Tripp Lite (Chicago, IL). In addition to offering protection against power failures, the Model BC-325 features full brown-out protection and a built-in filtering network that guards against transient spikes and line noise when operating on ac power.

A complete power-protection system, the Model BC-325 includes a 26-ampere-hour gel-cell battery that requires no maintenance, a regulated battery charger and an alarm with reset function. On the front panel are four grounded ac outlets, separate BATTERY POWER and LINE POWER indicators, an ALARM ON/OFF switch, a push-to-reset circuit breaker and a large POWER ON/OFF/RESET switch. The system supplies 60 minutes of emergency power at half load and 25 minutes of power on full load—enough time to allow safe shutdown of a computer or other electrical device connected to it. The battery backup system is housed in a beige cabinet with black front panel that blends into virtually any environment. $479.

CIRCLE NO. 111 ON FREE INFORMATION CARD

An EPROM Speed Reader/Comparator

Checks 16K to 512K EPROMs for complete erasure and compares a copy with an original EPROM in just seconds



By Walter W. Schopp

Getting half-way through programming an EPROM only to find that a supposedly erased one still contains unwanted data can be a frustrating and time-consuming experience. The same applies to a duplicate EPROM you have made that does not work. If you have ever been in either of these situations, you will certainly appreciate the EPROM Speed Reader to be described. This handy unit is actually two test devices in one. It not only "reads" every memory address location in any 2716 (16K) through 27512 (512K) EPROM in seconds to determine whether or not every cell has been erased, it also compares a copied EPROM against a master to check it for an accurate "take."

Our EPROM Speed Reader is a perfect accessory to the Stand-Alone EPROM Programmer featured in the February and March 1987 issues and the EPROM Eraser featured in the May 1987 issue of *Modern Electronics*. The project uses a double-sided printed-circuit board, zero-insertion-force test sockets and LED displays. You can etch and drill your own pc board (though you probably will not be able to plate-through the holes) or purchase a ready-to-wire board (see Parts List). Cost category for building this project is moderate but well worth the investment if you do a lot of erasing or/and programming of EPROMs.

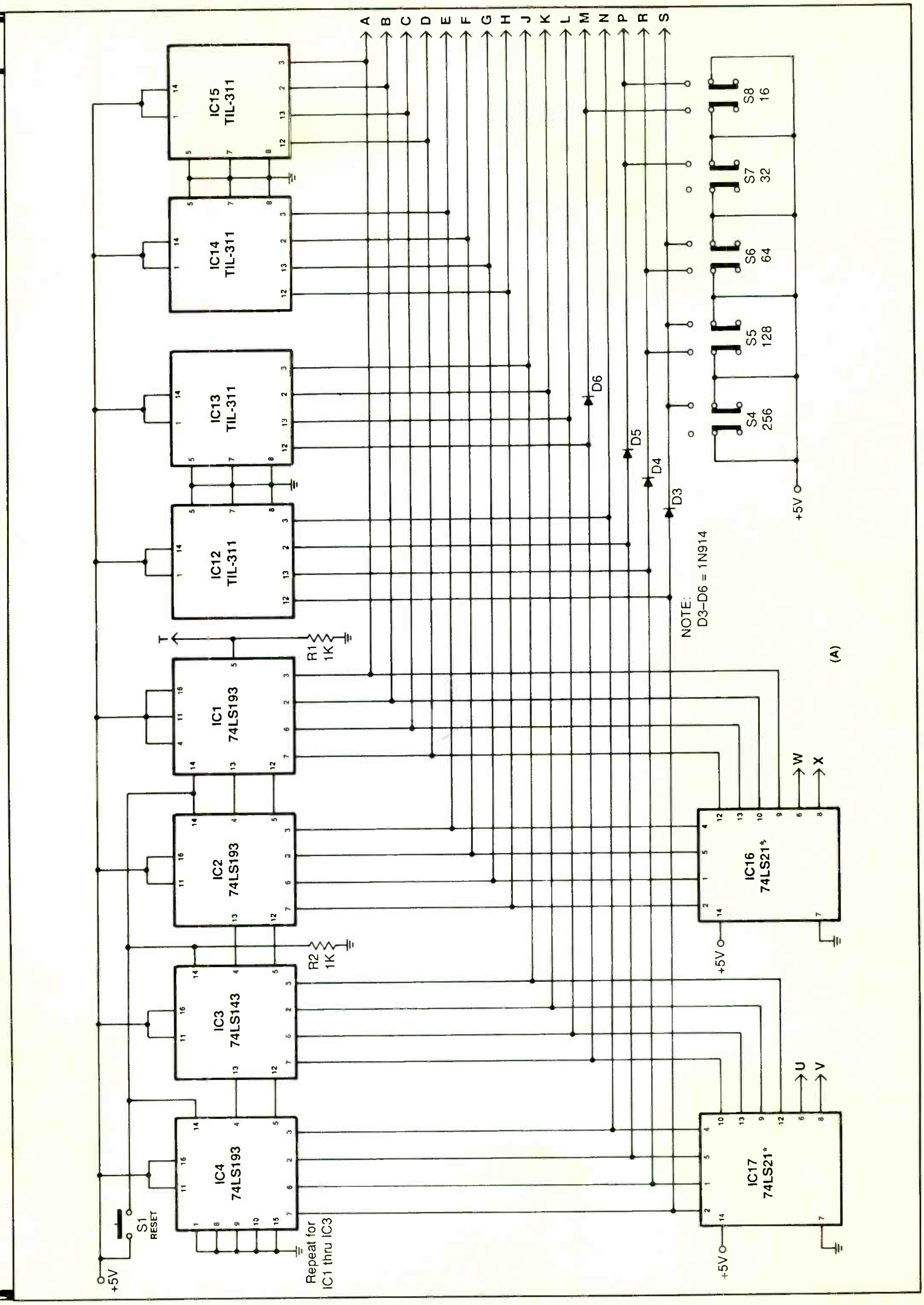
About the Circuit

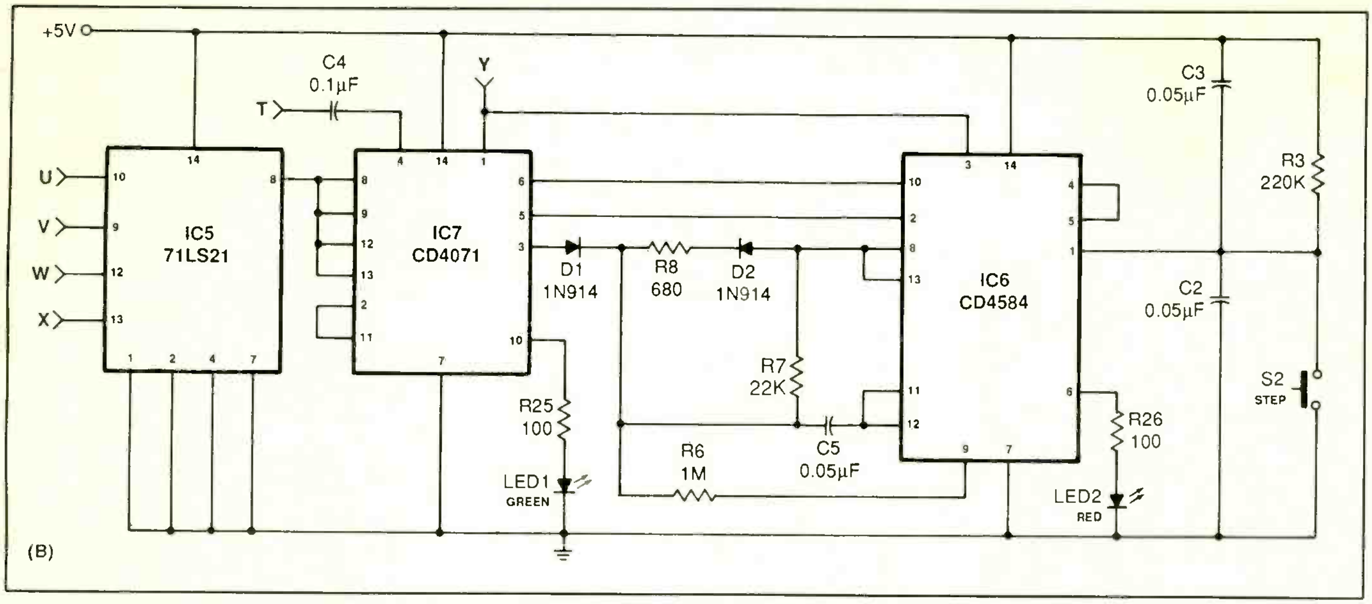
Simply by examining the pinouts of the various members of the 27XX and 27XXX family of EPROMs, you can readily see that all devices in this family are more or less pin-compatible. The differences in pinouts are confined mainly to pins 1, 2, 21, 24, 27 and 28. By switching addresses and voltages on these pins, the entire 27XX/27XXX family of EPROMs can be accommodated by a single test unit, as is done with our EPROM Speed Reader. In this project, the five switches labeled 16, 32, 64, 128 and 256 in Fig. 1(A) are used to accomplish address/voltage switching to accommodate 2716, 2732, 2764, 27128 and 27256 EPROMs. Note that, due to its large size, the main schematic diagram for the EPROM Speed Reader is shown in four parts, designated Figs. 1(A) through 1(D).

Address lines to both the master and copy EPROM are fed from the outputs of cascaded counters *IC1* through *IC4* in Fig. 1(A). The counters are driven by a square wave generator composed of two inverting buffers in the *IC6* package. The output of the generator is applied to the counter through another inverting buffer in *IC6*.

Signal inversion by the feeder inverting buffer puts the correct polar-

Fig. 1. Complete schematic diagram of project is shown here in four parts.


A B C D E F G H J K L M N P R S
IC15 TIL-311
IC14 TIL-311
IC13 TIL-311
IC12 TIL-311
IC1 74LS193
IC2 74LS193
IC3 74LS143
IC4 74LS193
IC16 74LS21*
IC17 74LS21*
R1 1K
R2 1K
T
W X
U V
S1 RESET
+5V
Repeat for IC1 thru IC3
S4 256
S5 128
S6 64
S7 32
S8 16
D3 D4 D5 D6
NOTE: D3–D6 = 1N914
(A)



ity on the input of the counter so that when the counter is stopped by an error or completion of a count sequence, it can be retriggered from STEP pushbutton switch *S2* shown in Fig. 1(B).

Timing for the square-wave generator is controlled by the RC network composed of *C1* and *R7*. If a slower or faster sweep time is desired, the values of these components can be juggled, using the formula 1/(2.2RC). Values specified for *C1* and *R7* were chosen to allow you to see the Reader in operation instead of having to wait for it to run the course of a test or compare or have everything done just as you release RESET pushbutton switch *S1* in Fig. 1(A).

Using 1N914 switching diodes *D1* and *D2* permits the generator to be stopped when a positive voltage is applied to *D1* from an OR gate in *IC7*. This OR gate allows the generator to be halted from two different sources. One of the gate's inputs is fed from the output of the comparison circuit, which supplies a positive output on detecting an error in an EPROM read operation. The other input is fed from the output of dual 4-input AND gates *IC16* and *IC17*. The outputs from these four gates are fed to 4-input NAND gate *IC5*.

PARTS LIST

Semiconductors

D1 thru D6—1N914 switching diode
LED1—Green T-1¾ light-emitting diode
LED2—Red T-1¾ light-emitting diode
IC1 thru IC4—74LS193 binary counter
IC5,IC16,IC17—74LS21 dual 4-input NAND gate
IC6—CD4584 hex Schmitt-trigger inverting buffer
IC7—CD4071 quad 2-input OR gate
IC8—CD 4068 8-input NAND gate
IC9,IC10—CD4077 quad 2-input exclusive-NOR gate
IC11—74C244 octal tri-state buffer
IC12 thru IC15—TIL311 hexadecimal decoder/driver/display
IC18—7805 +5-volt regulator (optional—see text)

Capacitors (10 WV or higher)

C1,C2,C3—0.05-µF disc
C4,C7 thru C14—0.1-µF disc
C5,C6—100-µF, 16-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1,R2—1,000 ohms
R3—220,000 ohms
R4,R5—Not assigned
R6—1 megohm
R7—22,000 ohms
R8—680 ohms
R9 thru R24—10,000 ohms
R25,R26—100 ohms

Miscellaneous

S1,S2—Spst momentary-action normally-open pushbutton switch(Digi-Key Cat. No. P9951—see Addresses below)
S3 thru S8—Dpdt pc-mount slide switch (C&K Cat. No. 1201-M2-CQE—see Addresses below)
SO1,SO2—28-pin zero-insertion-force socket (Jameco Cat. No. 228-3345—see Addresses below; also see text for option)
Printed-circuit board (see text); 6-volt dc, 300-mA plug-in power supply (see text); materials for building enclosure (see text); machine hardware; No. 6 × ½-inch woodscrews (8); hookup wire; solder; etc.

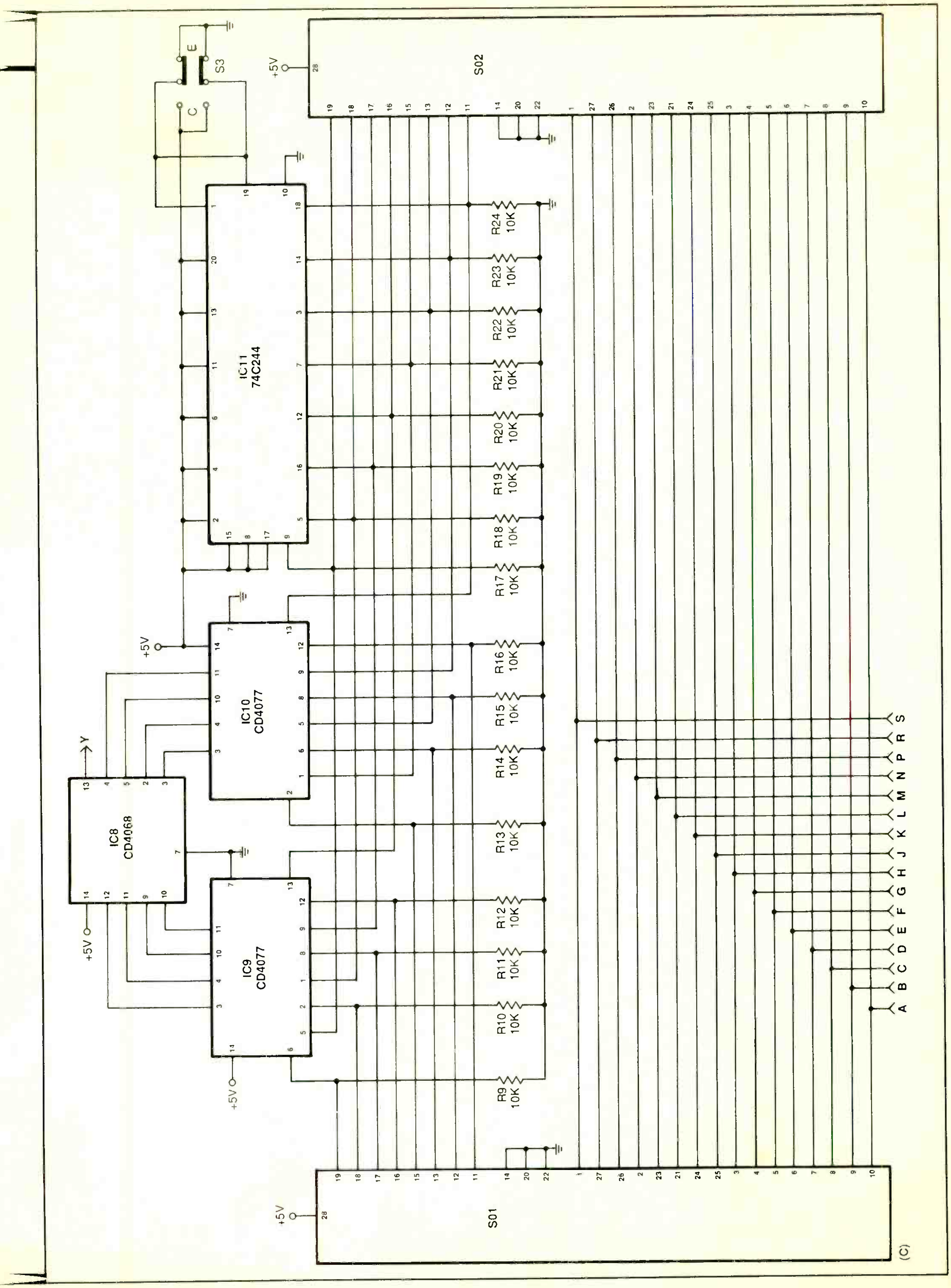
Note: A ready-to-wire, double-sided printed circuit board with plated-through holes, No. ESR-2, is available for $22.50, including P&H, from: Electronic Enterprises, 3305 Pestana Way, Livermore, CA 94550.

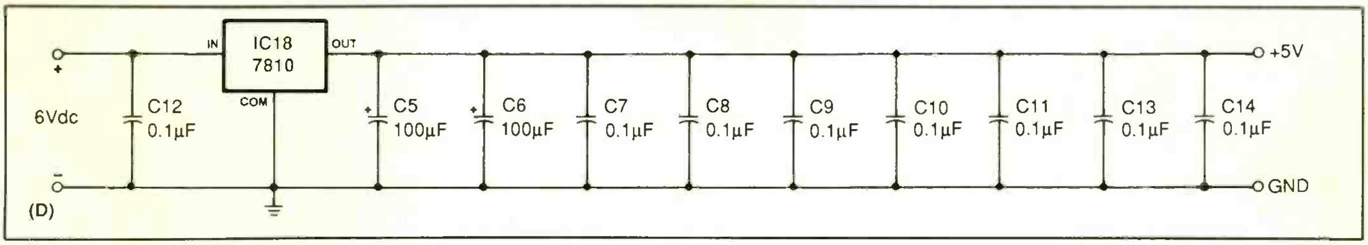
Addresses:

C&K Components
15 Riverdale Ave.
Newton, MA 02158-1082
Tel.: 617-964-6400

Digi-Key Corp.
P.O. Box 677
Thief River Falls, MN 56701
Tel.: 1-800-344-4539

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
Tel.: 415-592-8097


IC8
CD4068
IC9
CD4077
IC10
CD4077
IC11
74C244
S01
S02
S3
R9 10K
R10 10K
R11 10K
R12 10K
R13 10K
R14 10K
R15 10K
R16 10K
R17 10K
R18 10K
R19 10K
R20 10K
R21 10K
R22 10K
R23 10K
R24 10K
+5V
Y
A B C D E F G H J K L M N P R S
(C)



A positive output from *IC5* occurs when all counters, *IC12* through *IC15* indicate FFFF. This gives the counter a capacity for 65,535 counts on the address lines. When the counter makes one complete pass through all address lines, the square-wave generator stops and green light-emitting diode *LED1* lights to indicate that the pass has been completed and no errors were detected.

To accommodate 2764, 27128 and 27256 EPROMs, 28-pin zero-insertion-force (ZIF) sockets were chosen for *SO1* and *SO2*, as shown in Fig. 1(C). To check a 2716 or 2732, the EPROM must be placed in the sockets with an offset so that its pins plug into the ZIF sockets starting at pin 3 and ending at pin 26. This means that pins 1, 2, 27 and 28 of *SO1* and *SO2* will not be occupied when these 24-pin EPROMs are tested and compared. See Fig. 2 for details.

The circuit is wired so that when type select switches *S4* through *S8* in Fig. 1(A) are set to either 16 or 32, positive voltage is applied to pin 26 of *SO1* and *SO2*. This supplies the V_{CC} bus to the 2716 or 2732 EPROM, which normally require a V_{CC} potential on pin 24.

Diodes *D3* through *D6* block dc voltage from the counters and decoder/driver/display system during address line switching when *S3* through *S6* are toggled from one position to the other.

When type select switches *S3* through *S6* are set up for a 2764, 27128 or 27256 EPROM, pin 26 of both *SO1* and *SO2* becomes another address line and pin 28 is tied to the V_{CC} bus.

As the counter sweeps through the addresses, the outputs of the master and copy EPROMs are compared, address for address and output for output, by putting identical EPROM outputs on the two inputs of exclusive-NOR (XNOR) gates *IC9* and *IC10*. Since each gate in these two ICs is driven by the identical outputs of the master and copy EPROMs, if the outputs are the same, regardless if they are 1s or 0s, a positive output is present at each gate output.

There is one gate for each EPROM output. The outputs from all gates are fed into 8-input NAND gate *IC8*. With all inputs to this gate positive, indicating a proper comparison, there is a zero output from *IC8*. However, if an error is detected in the comparison, one of the outputs from the NOR gates will be negative, making one of the inputs to *IC8* negative. This will produce a positive output from *IC8*, which is fed back to the square-wave generator through *IC7*. When this occurs, the counter will stop at the address at which a mismatch was detected. The defective address can then be read off hex counters *IC12* through *IC15*.

Erasure check of an EPROM is made by putting a positive voltage on one side of all XNOR gates in *IC9* and *IC10* and comparing the outputs of the erased EPROM with this address. If the EPROM has been properly erased, all outputs should be at logic 1 at all addresses. Hence, any address output that shows a 0 indicates that that bit location has not been erased and will be detected as an error. Positive voltage is applied to *SO2* when *S3* is set to E (check erase).

The EPROM to be checked for erasure is placed in *SO1*. The positive voltage is applied to *SO2* through octal tri-state noninverting buffer *IC11*. When a positive voltage is applied to pins 1 and 19, the outputs of the buffer float and the positive voltages at the inputs of the buffers is not present on the outputs. Grounding pins 1 and 19 turns on the buffers and the positive voltage at the buffer inputs is present at the buffer outputs. This applies the positive voltage to one side of all XNOR gates in *IC9* and *IC10*.

When an error signal is detected, the generator stops and the red light-emitting diode *LED2* turns on. This indicates that the counter has stopped at the defective address and the defective address can be read off the displays on *IC12* through *IC15*.

When the counter goes to its maximum count of FFFF, green *LED1* turns on and the counter stops, indicating that the addresses have all been checked and that no errors were detected.

Power for the circuit is supplied by a standard 6-volt dc plug-in power supply rated to deliver at least 300 milliamperes. The power supply schematic diagram is shown in Fig. 1(D). The incoming 6 volts dc is regulated down to the 5 volts dc required by the circuit by +5-volt regulator *IC18*. The 5-volt dc output from *IC18* is smoothed and stabilized by filter capacitors *C5* and *C6*. The remaining capacitors, identified as *C7* through *C14*, are bypass devices used to keep noise off the V_{CC} bus.

Construction

Every part of the EPROM Speed Reader, except the 6-volt dc power supply, mounts directly on a single circuit board. Because of the great number of interconnecting runs required to assemble the circuit, a printed-circuit board is recommended. If you wish, though, you can build the circuit on perforated board that has holes on 0.1-inch centers, using Wire Wrap hardware. However, make certain that you mark off each wire run as you make it on the schematic diagram or a photocopy of it to avoid wiring errors.

Notice in the actual-size etching-and-drilling guides for the project in Fig. 3 that a double-sided printed-circuit board is needed for the project. Ideally, this board should have plated-through holes, which are beyond the means of the typical home builder to make. You can still home-fabricate the pc board, though, by avoiding the use of molded IC sockets and carefully bridging conductors that must continue from one side of the board to the other with lengths of *solid* bare hookup wire.

If you prefer not to fabricate your own board, you can purchase a board with plated-through holes from the source given in the Note at the end of the Parts List.

Before you begin to plug components into a home-fabricated pc board, install the bridging wires as follows. Locate and mark the locations for all wires. These are shown in Fig. 4 as heavy black dots on the top view of the board. There are 96 such dots.

Next, place the board on a sheet of corrugated cardboard on your work surface, component side up, and plug one end of the bare solid wire into one of the marked holes and push until the wire penetrates the cardboard by about 1/16 inch. Solder the wire to the copper pad on the top of the board and clip it close to the board's surface. Repeat for all remaining marked locations. Make sure as you solder these pads and those for the IC sockets that you do not create solder bridges to nearby pads or copper-trace runs.

After soldering the bridging wires to all 96 pads on the component side, flip over the board and solder the wire stubs to the pads on that side. Work quickly, heating the wires and pads only long enough to flow the solder and make good mechanical and electrical connections. Again, clip any excessive-length wires close to the board's surface. When you have done this, use an ohmmeter set to its lowest range or an audible continuity tester to ascertain that all bridging wires are properly soldered to the conductive pattern on both sides of the board. Touch the meter or tester probes to the copper traces —*not* the soldered connections.

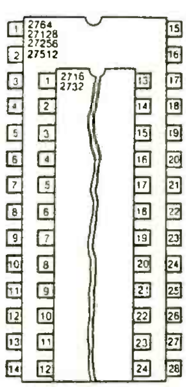
Double check all bridging wire locations against Fig. 4. It is easy to mistake a component hole for a bridging hole.

Regardless of whether you are using a home-fabricated board or the commercial plated-through-hole version, it is a good idea to use sockets for all ICs except voltage regulator *IC18*. If your board does not have plated-through holes, you cannot use standard molded sockets. Instead, use Molex Soldercon® socket strips, which give you soldering access on both sides of the board.

Divide the Soldercon strips into the number needed for each IC. Without removing the metal strip along the tops of the strips, plug one strip into each IC location as shown in Fig. 4 and solder to the pads on *both* sides of the board. Use a fine-pointed soldering iron and only enough solder to make good connections. Work carefully to avoid creating solder bridges to nearby pads and conductors.

You can plug in and solder into place the remaining Soldercon strips for the ICs in the same manner. However, if you have old ICs, it would be better to use them to make sure the second strip in each case is properly aligned with the first. To do this, plug the second strip into its holes in the board and then plug the IC into the receptacle ends of the Soldercons and carefully solder the pins to the copper pads on the bottom of

Pin	2716	2732	Pin	2764	28128	27256	28512
			28	V_{cc}	V_{cc}	V_{cc}	V_{cc}
			27	PG/M	PG/M	A14	A14
24	V_{cc}	V_{cc}	26	N.C.	A13	A13	A13
23	A8	A8	25	A8	A8	A8	A8
22	A9	A9	24	A9	A9	A9	A9
21	V_{pp}	A11	23	A11	A11	A11	A11
20	$\overline{OE}$	$\overline{OE}$	22	$\overline{OE}$	$\overline{OE}$	$\overline{OE}$	$\overline{OE}$
19	A10	A10	21	A10	A10	A10	A10
18	$\overline{CE}$	$\overline{CE}$	20	$\overline{CE}$	$\overline{CE}$	$\overline{CE}$	$\overline{CE}$
17	O7	O7	19	O7	O7	O7	O7
16	O6	O6	18	O6	O6	O6	O6
15	O5	O5	17	O5	O5	O5	O5
14	O4	O4	16	O4	O4	O4	O4
13	O3	O3	15	O3	O3	O3	O3



17512	27256	27128	2764	Pin	2732	2716	Pin
A15	V_{pp}	V_{pp}	V_{pp}	1			
A12	A12	A12	A12	2			
A7	A7	A7	A7	3	A7	A7	1
A6	A6	A6	A6	4	A6	A6	2
A5	A5	A5	A5	5	A5	A5	3
A4	A4	A4	A4	6	A4	A4	4
A3	A3	A3	A3	7	A3	A3	5
A2	A2	A2	A2	8	A2	A2	6
A1	A1	A1	A1	9	A1	A1	7
A0	A0	A0	A0	10	A0	A0	8
O0	O0	O0	O0	11	O0	O0	9
O1	O1	O1	O1	12	O1	O1	10
O2	O2	O2	O2	13	O2	O2	11
GND	GND	GND	GND	14	GND	GND	12

Fig. 2. Connection details for various members of 27XX/XXX family of EPROMs to test sockets and pin address and output identifications.

the board. This done, remove the IC and set it aside. Flex the metal connecting strip on both rows of Soldercons until it parts from the receptacle pins. Then replace the IC and solder the Soldercons to the pads on the component side of the board. Repeat with the remaining strips.

You will notice that no holes are provided for pins 6, 9 and 11 of *IC12* through *IC15*. Therefore, no Soldercons (or socket pins) must be installed in these locations. The best way to handle this is to plug the pins of an ordinary 14-pin IC into two strips of seven Soldercons, flex away the metal connecting strips and remove the Soldercons from pins 6, 9 and 11. Then plug the Soldercons into the holes in the board and solder them to the pads on the bottom of the board, remove and set aside the IC and solder the Soldercons to the pads on the top of the board. (If you are installing the sockets on a board with plated-through holes, simply clip pins 6, 9 and 11 from each of four 14-pin sockets.)

For *SO1* and *SO2* you have two options. You can use Wire Wrap sockets that can be spaced far enough above the surface of the board to provide soldering access. Alternatively, you can use solder-tail sockets that plug into parallel rows of Soldercons as you did for the ICs. If you use Wire Wrap sockets, place a rectangle of single-ply corrugated cardboard under the sockets to raise them enough to provide soldering access on the component side of the board. The cardboard "shim" should be ¼ inch narrower than the distance between the rows of pins on the socket and long enough to fit under both sockets and to protrude about ½ inch from the pin 14/15 end of *SO2*.

With the shim in place, tack solder the four corner pins of both sockets to the pads on the component side of the board. Flip over the board and solder the pins to the pads on the bottom of the board. If desired, clip

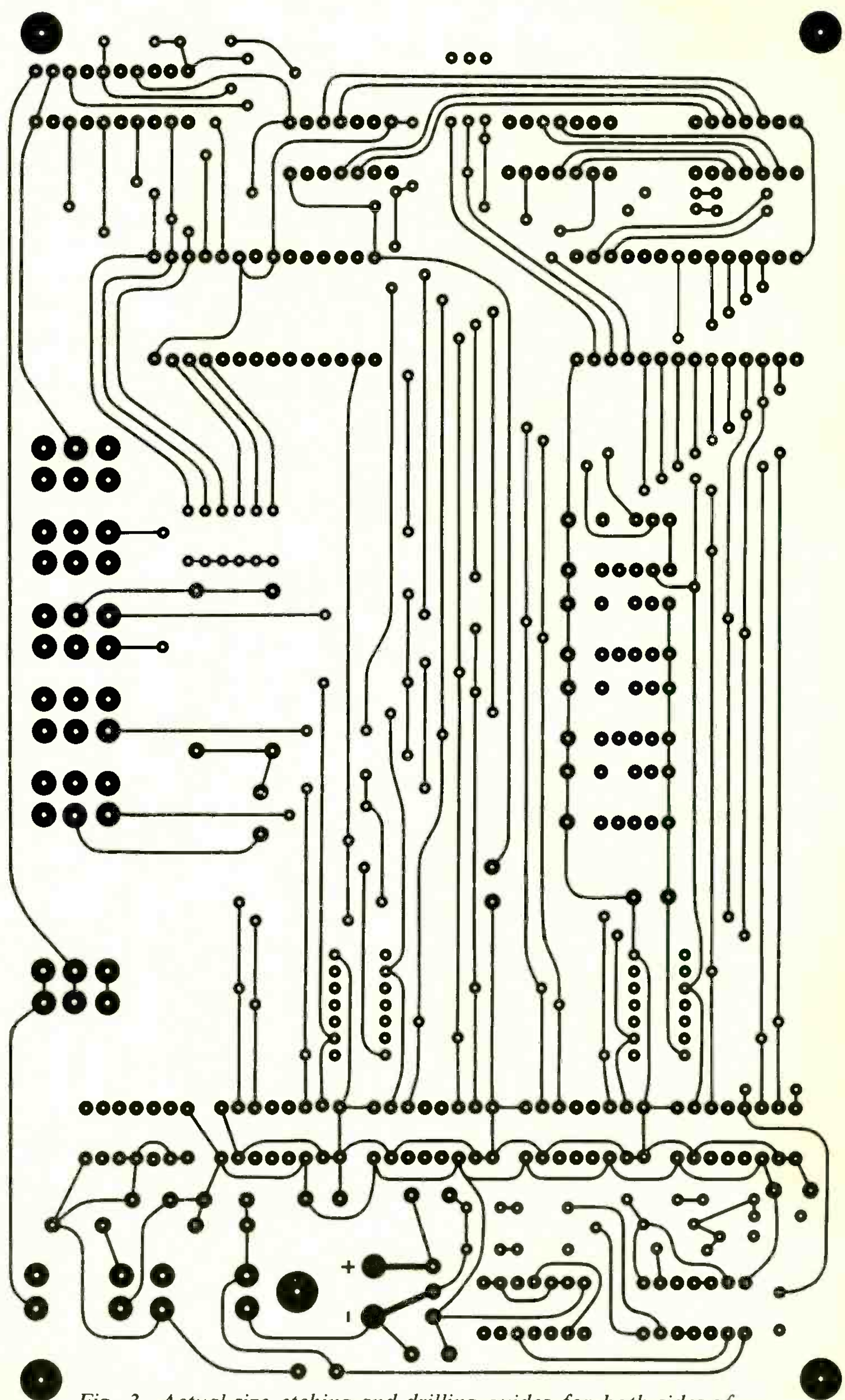
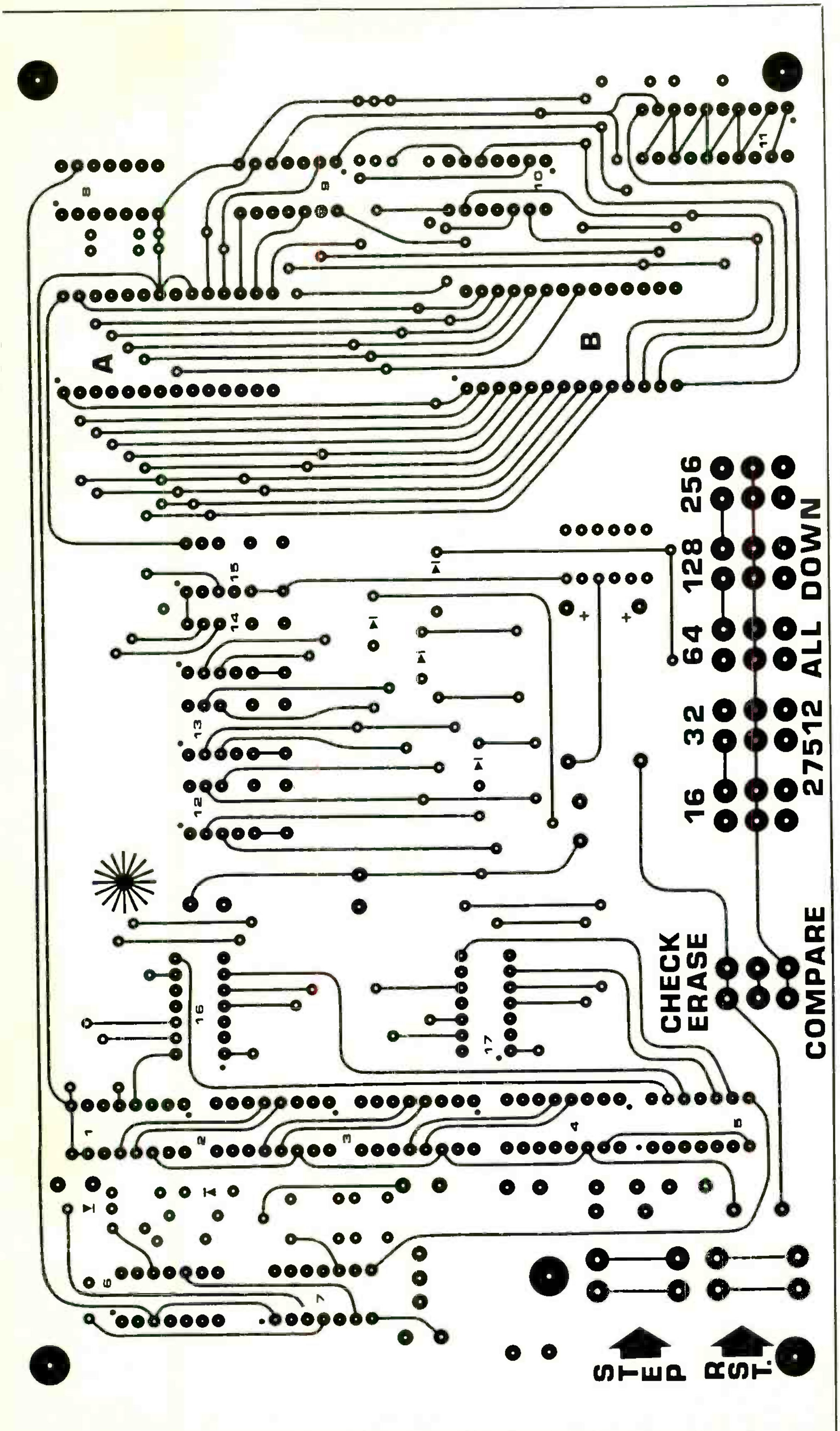


Fig. 3. Actual-size etching-and-drilling guides for both sides of printed-circuit board needed for project.

each pin close to the board's surface. Then flip over the board once again and carefully solder the remaining pins to the pads on the component side of the board. You can leave the cardboard shim in place if you wish or gently but firmly pull it from under the sockets. If you run into any snags, compress the cardboard with the blade of a screwdriver through the slots in the tops of the sockets.



Now mount the resistors in their respective locations, soldering their leads to the pads on both sides of the board. Do the same for the diodes, making sure you properly orient them. Then install and solder into place in the same manner the capacitors, making sure you properly polarize *C5* and *C6*.

Plug the lugs of the switches into the holes in the board in their respective locations and solder the lugs first to the pads on the *component* side of the board and then to the pads on the bottom of the board. It may be necessary to have only a small fraction of an inch of lug protruding through the holes in the bottom of the board to accomplish soldering to the pads on the component side. If you cannot get soldering access with your switches, try to find switches that do provide such access, either with longer lugs or pins that exit from the sides of the switches. In the *S4* through *S8* group, install *S6*, then *S5* and *S7* and end with *S4* and *S8*

Bend the pins of voltage regulator *IC18* at a 90-degree angle toward the rear of the IC. Plug the pins of the regulator into the holes in the board and secure the IC to the board with a 4-40 × ¼-inch machine screw, lockwasher and nut. Solder the pins to the pads on both sides of the board.

Plug the leads of *LED1* and *LED2* into their respective holes in the board (make sure they are properly polarized) and push the LEDs down until the bottoms of their plastic cases are about ¼ inch from the surface of the board. Carefully solder the leads to the pads on the component side of the board. Flip over the board and solder the leads to the pads on the bottom of the board. Clip away any excess lead lengths.

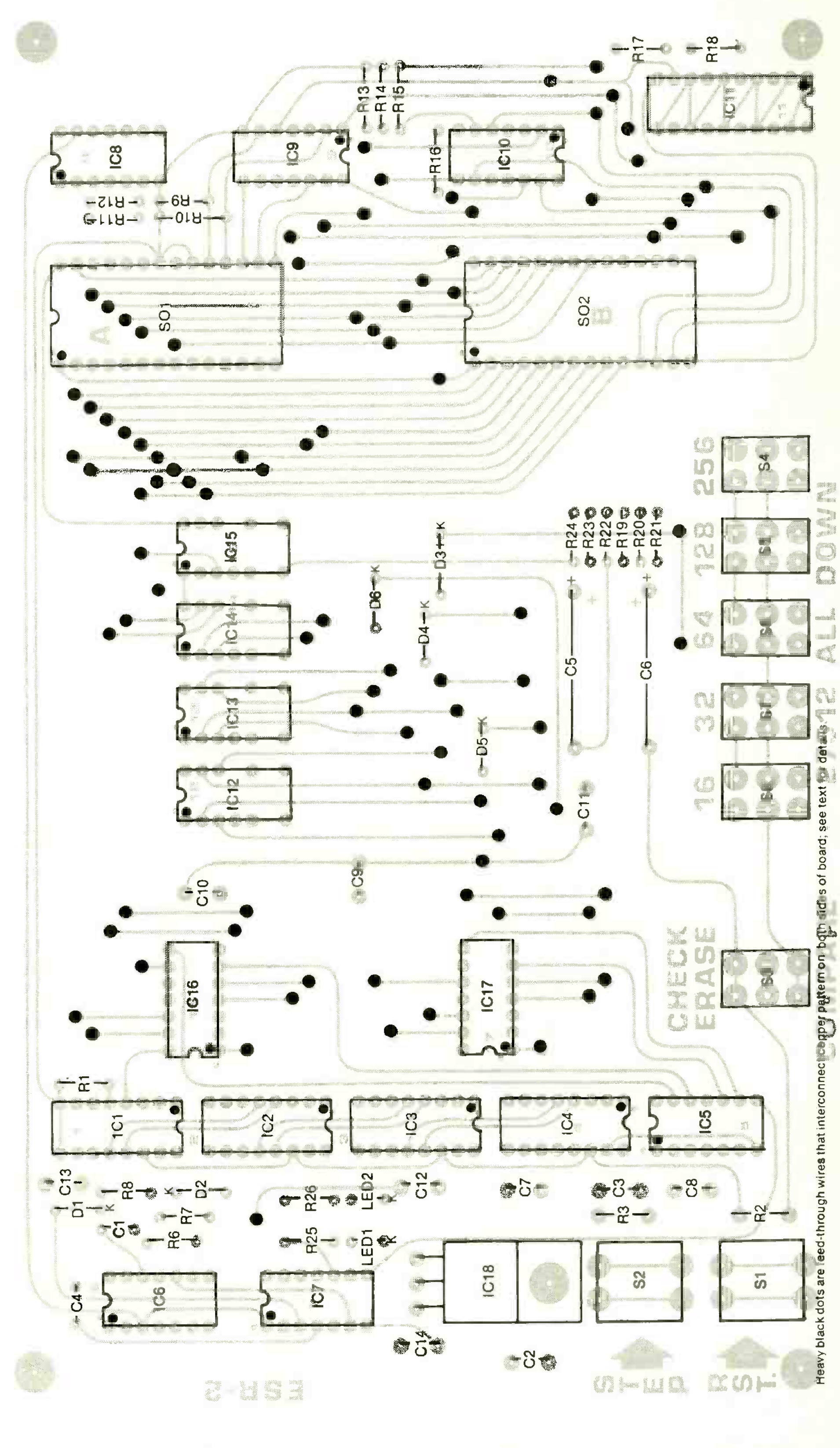
Perhaps the easiest method of housing the EPROM Speed Reader is to mount it in a wood frame made from 1 × 2-inch pine cut to length to make a box just large enough into which to drop the circuit-board assembly. Hence, the inner dimensions of the box should be 8½ inches wide by 5⅛ inches deep. You can either butt- or miter-join the corners of the frame. Use a 1 × 1-inch pine cleat at each corner, recessed about 1/16 inch from the top and about ¼ inch from the bottom to allow the circuit-board assembly and a sheet of Masonite to be dropped into place on top and bottom, respectively.

Decide on whether you want to be able to plug the 6-volt dc power supply into the project for use and unplug it when not in use or you want a permanent hookup arrangement. If the former, you need a mating jack for the plug on the end of the supply's feeder cord. If the latter, cut off and discard the plug on the end of the cord, separate the conductors by about 1 inch and trim ¼ inch of insulation from each conductor. Twist together the fine wires in each conductor and tin with solder.

Drill an entry hole for the cord from the 6-volt dc power supply in the rear wall of the enclosure frame. If you plan on using a plug/unplug arrangement with a power jack, make the hole large enough to accommodate the jack mounted on a piece of sheet metal or thin plastic. Otherwise, make the hole only large enough to pass through the cord and tie a knot in the cord about 4 inches from the prepared end inside the box.

Making sure that the bare conductor wires do not touch each other, plug the power supply into an ac outlet and use a dc voltmeter set to read 10 volts or so full-scale to determine the polarity of the supply's conductors. Mark the +5-volt conductor

Fig. 4. Component installation guide for pc board.



for easy reference. Disconnect the supply from the ac outlet. Then connect and solder the +5-volt conductor directly to the + pad and the unidentified conductor to the − pad on the board.

When using the plug/unplug arrangement, interconnect the power jack with the board with color-coded hookup wires.

If you wish, you can even combine the EPROM Speed Reader in the same enclosure used for the Stand-Alone EPROM Programmer featured in the February and March 1987 issues of *Modern Electronics*, rather than build a separate enclosure for it. This would probably be a more convenient way to go, since the two units are generally used together. If you go this route, the regulated 5 volts dc from the EPROM Programmer can be used to power the EPROM Speed Reader and voltage regulator *IC18* can be omitted from the latter.

At this point, the only integrated circuit that should be installed on the board should be regulator *IC18*. Do *not* install the other ICs in their sockets until after you have completed initial voltage checks.

Checkout & Use

Before you plug any IC into its socket, you must perform a preliminary voltage check, especially if you Wire Wrapped the project, to ascertain that the circuit has been correctly wired and that all points in the +5-volt bus are indeed connected to the bus if you used a pc board with no plated-through holes. For this step, all you need is a dc voltmeter or a multimeter set to read dc on a range that will easily accommodate the maximum +6 volts that should appear in the circuit.

Clip the meter's common lead to circuit ground at the negative (−) lead of either *C5* or *C6*. Plug the 6-volt dc power supply into an ac outlet (and its output cable into the jack on the rear of the enclosure if this is the arrangement you opted for). Now touch the meter's "hot" probe to pin 16 of all 16-pin ICs, pin 14 of all 14-pin ICs, pin 20 of *IC11* and pin OUT of *IC18*. The readings in all cases should be the same +5 volts. Touching the hot probe to pin IN of *IC18* should yield a reading of approximately +6 volts. If you do not obtain the proper reading in any case, power down the circuit and correct the problem before proceeding.

Once you are satisfied the project is wired properly, disconnect it from the ac line and wait a few minutes to allow *C5* and *C6* to discharge. Then, referring back to Fig. 4, install the ICs in their respective sockets. Make sure each is properly oriented and that no pins overhang the socket or fold under between IC and socket as you push each home. Also, since these are CMOS devices, handle them with the same precautions as you would any other MOS device to avoid inflicting damage to them from static electricity.

To use the EPROM Speed Reader to compare the data programmed into a master and a copy EPROM, plug the two EPROMs to be compared into either socket. It does not make any difference which socket is used for which EPROM, but make sure you properly install the EPROMs, both as regards to orientation and offset, if any. That is, if you are comparing 2716s or 2732s that have only 24 pins, place them in the sockets so that the upper two receptacles on both sides of both sockets are unoccupied.

Set *S3* to C (compare) and *S4* through *S8* according to the type of EPROMs being compared. Only one of these switches should be in the up position: *S8* for 2716s, *S7* for 2732s, *S6* for 2764s, *S5* for 27128s or *S4* for 28256s. All other switches should be in the down "off" position. The only exception to this rule is that when comparing or checking 27512 EPROMs, *all* switches must be in the off position.

Keep in mind that there is no way that an EPROM can be reprogrammed or erased by the EPROM Speed Reader. Always begin a read/compare operation with the counter reset to zero by pressing and releasing RESET switch *S1*. Counting begins as soon as *S1* is released.

When or if the counter stops counting as a result of a detected error in the comparison, the error can be recorded and the counter can be single stepped to the next address by pressing and releasing STEP switch *S2*. If no error is present at this address, the counter will resume counting until it detects another error or the count is complete. As mentioned earlier, a detected error stops the counter and turns on the red LED. If no error is detected, the counter will sweep from start to finish, stop counting and light the green LED. The whole process takes only a few seconds.

To check erasure of an EPROM, simply plug the erased device into *SO1* and set *S3* to E (check erase). Set *S4* through *S8* according to the type of EPROM being tested and reset the counter by pressing and releasing *S1*. The procedure for checking erasure is the same as for comparing EPROMs except that you compare the erased EPROM with all 1s on one side of XNOR gates *IC9* and *IC10*. The results will pop up in seconds.

If an error is detected, the red LED will turn on. If the counter runs through the complete range of addresses with no detected error, the green LED will light.

If you do a lot of programming of supposedly erased EPROMs, our EPROM Speed Reader will save you a lot of time and frustration. Its dual-function operation perfectly complements whatever programmer you are using, whether it is the one for which the project was built or a commercial unit. With this project, you will know if an erased EPROM is fully erased *before* you attempt to reprogram it and if a copy is the same as the original. **ME**

Mixing Frequencies: A New Look

Photos help explain complex linear mixing to amateur radio operators and others

By John Wannamaker

One of the easiest ways to grasp a complex linear mixing situation is through a good illustration. Ink drawings that are particularly well presented help explain simpler results, but anything that involves manually summing many cycles of several frequencies has simply been too tedious a task to render by hand. Now we have photographs that offer more insight than can be explained with the proverbial 10,000 words. Some of these appear in print here for the first time, and all are accompanied by an explanation and comments to appeal to readers of various technical backgrounds.

If you currently have or have ever had difficulty understanding AM radio and sidebands, the material presented here may be just what you need to clear up any confusion in this area. Even experienced single-sideband operators may discover something new or clear up some point.

To create these photos, summing (linear mixing) was done with an operational amplifier. A special device was used to generate up to four sine waves simultaneously, each with independently adjustable frequency, amplitude and phase shift. Frequencies of the four oscillators I used were in the low audio range, but they can be reasonably projected upward to represent what happens at radio frequencies.

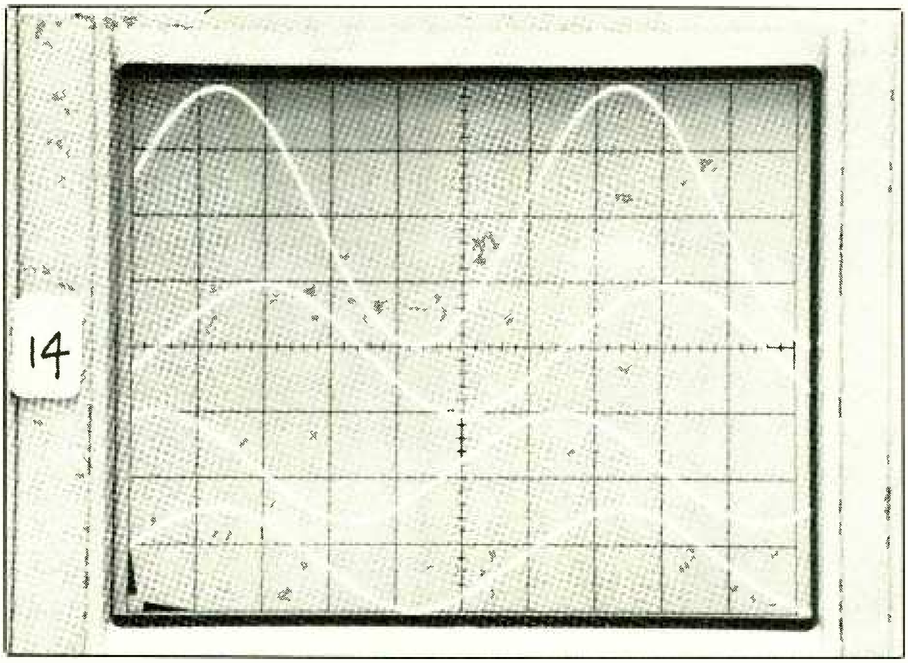


Fig. 1. Three sinusoidal waveforms (bottom) sum into a resultant waveform (top) of identical frequency.

Sine Waves Only

Figure 1 illustrates something that can be done only with sine waves. Here three sinusoidal waves of the same frequency (bottom trace), differing in amplitude and phase relationship, are summed to produce a sine wave (top trace) of the identical frequency. The only time the output could be otherwise is when the inputs sum to zero by precisely canceling each other out.

Summing of sine waves with different frequencies results in a complex waveform. Figure 2 shows how a fundamental frequency and its third, fifth and seventh harmonics combine (top trace) to begin formation of a square wave. In theory, the perfect square wave contains an infinite number of odd harmonics. (Apologies to readers who notice here that the fifth harmonic's amplitude is too low. Final press time was reached before it could be corrected for publication.) The slight variation in lateral symmetry of the resultant is due to a bit of distortion of the fundamental frequency.

In Fig. 3, a ramp can be seen taking shape. This ramp is composed of a fundamental frequency and its second, third and fourth harmonics. All harmonics, both odd and even, would are required to form a ramp waveform. Incidentally, this "recipe" must also specify amplitudes and phase relationships, properties that could change the shape if not selected correctly.

The heart of waveform analysis is this: If sine waves can be combined to form other waveshapes, then other waveshapes, no matter how they are generated, can be thought of as specific combinations of sine waves. This theory is supported by the photos in Figs. 2 and 3.

Anything that causes even the slightest distortion in an otherwise pure sine wave must by that very act create one or more additional frequencies. This is known as "harmonic distortion," where two frequencies are mixed nonlinearly. Amplitude modulation, where fairly large amounts of power are involved, is an example of this. AM creates sum and difference frequencies that become the upper and lower sidebands, respectively.

Figure 4 shows an often-used com-

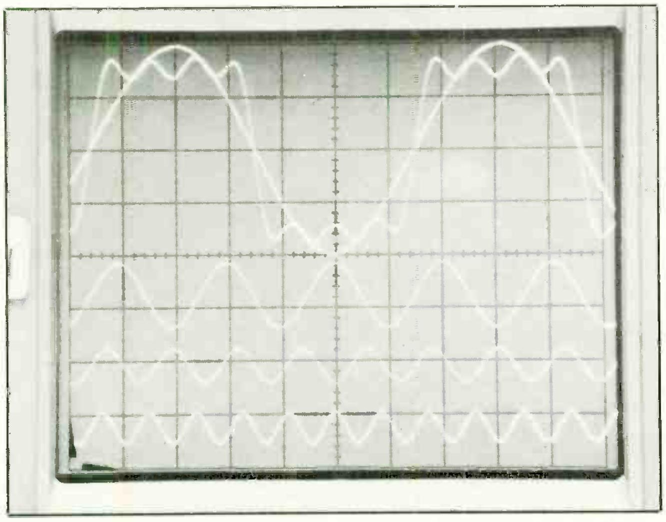


Fig. 2. Making of a square wave involves addition of fundamental frequency with odd harmonics. Third, fifth and seventh harmonics shown here are on the way toward making a square wave.

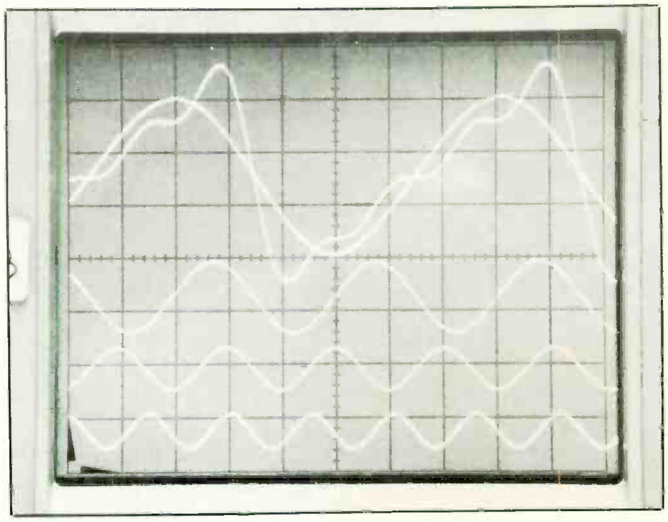


Fig. 3. Adding fundamental frequency and all harmonics produces a ramp waveform. Second, third and fourth harmonics shown here are on the way toward making a sawtooth-like ramp waveform.

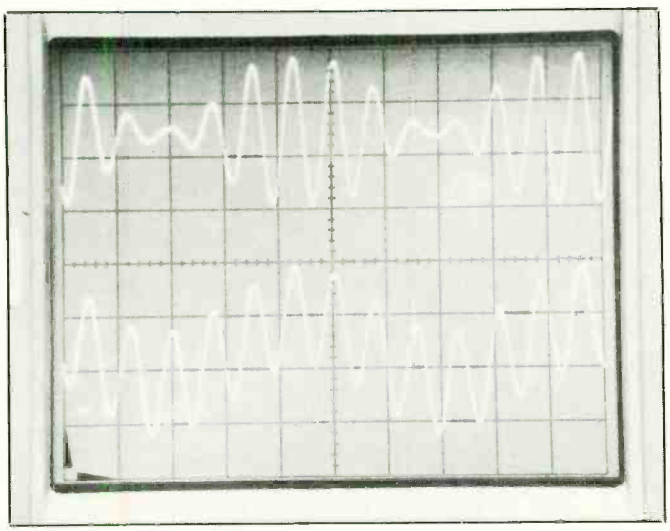


Fig. 4. Waveforms typically shown to represent heterodyning (top) and linear mixing (bottom).

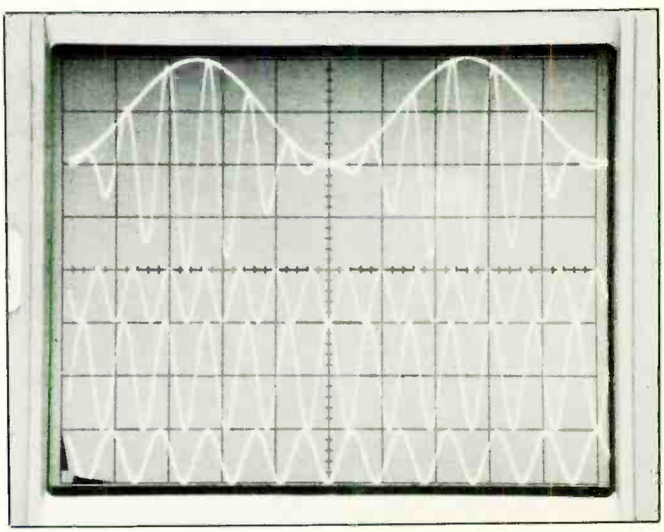


Fig. 5. Simulated carrier and sidebands mixed to reconstruct a nonexistent modulated waveform.

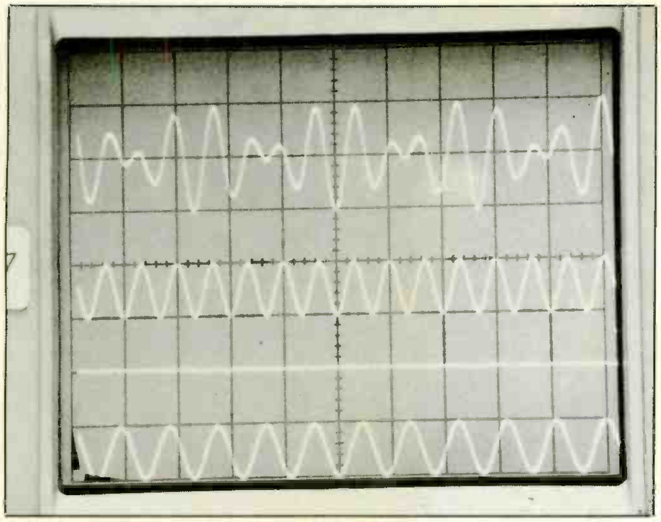


Fig. 6. With carrier reduced to zero, sideband reacts with sideband and introduces a frequency that is twice that of the true audio component.

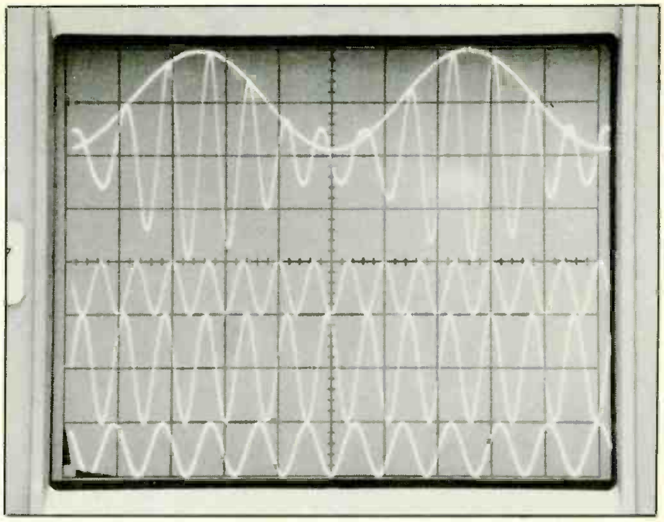


Fig. 7. This photo illustrates the effect on the modulation envelope when the carrier has been shifted in phase by approximately 30 degrees.

parison between linear mixing (bottom trace) and nonlinear mixing or heterodyning (top trace). In this case, linear mixing even looks easy to analyze.

If the highest frequency is filtered out, only the lowest remains and vice-versa. However, the modulated waveform needs some explanation. This waveform is the result of *linearly* mixing the component frequencies at the output of a nonlinear (heterodyning) circuit, and not even quite that because the lowest frequency component—call it the audio—is not included. Its effects can be seen, but it is not part of the summed values. Simple visual examination reveals that it is not possible to tell that sum and difference frequencies play any part in the waveform's shape.

Figure 5 shows a lower sideband (bottom trace), a carrier and an upper sideband as each might be separately received as an incoming signal. The receiving antenna acts as the linear mixer that sums these tuned-in frequencies (top trace). Collectively, they "recreate" a modulated envelope that never actually existed, since separate oscillators were used to generate them.

The audio that outlines the upper

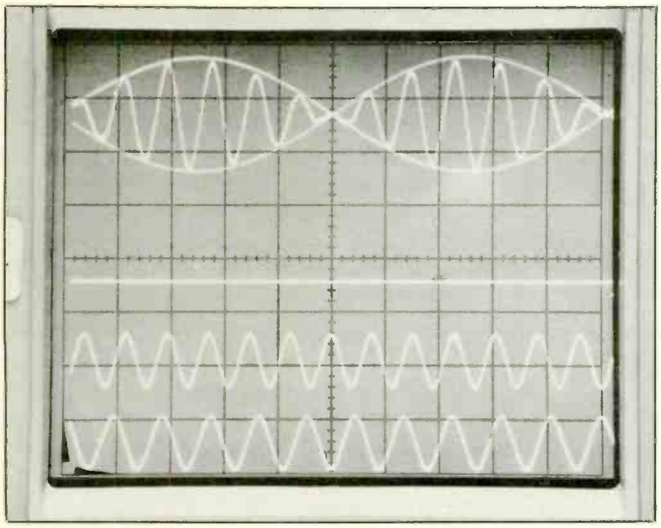


Fig. 8. Shown here is what the antenna presents to the receiver from a single-sideband reduced-carrier transmission (equal amplitudes).

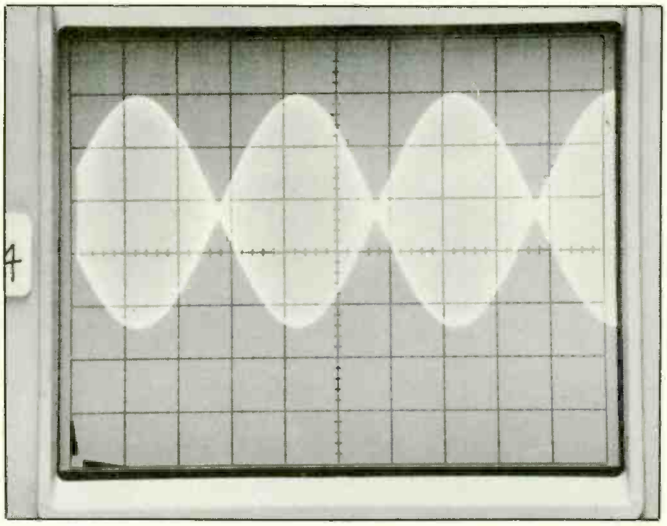


Fig. 9. Frequencies of 600 kHz and 602 kHz are shown here received with equal strengths; the results are similar to those illustrated in Fig. 8.

modulation envelope shown in Fig. 5 has been added for purposes of clarity. Although linearly mixed, each component frequency would be heterodyned with a receiver's local oscillator to produce its own intermediate frequency (i-f) . . . and combine linearly.

The following observations are worth making at this point:

(1) Carrier and sidebands do not vary in their peak-to-peak amplitudes and are true CW signals as long as the same modulation continues.

(2) While the phase relationship between the three signals is constantly changing, there is a repetitive pattern to this change that occurs at the frequency of the audio component.

(3) Both sidebands are in-phase with the carrier to form the modulated peaks, and both sidebands are out-of-phase with the carrier to form the valleys.

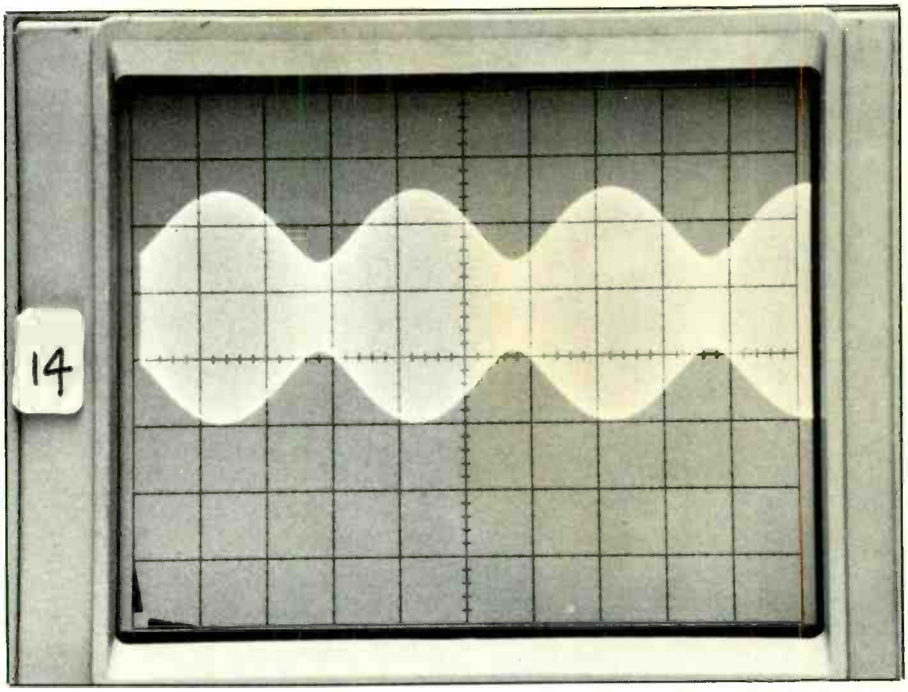


Fig. 10. Improved single-sideband envelope, where carrier has twice the amplitude of the sideband.

Nonsinusoidal Factors

When the carrier is completely eliminated, the receiving antenna has only the sidebands with which to work and combines them into the shape shown in Fig. 6. This modulation envelope has variations at twice the frequency of the true audio component, which can be seen for reference in Fig. 5. Not so noticeable here is the fact that the variations are not sinusoidal, the relatively few "r-f" cycles not being able to outline the shape clearly. (The single sideband photo shown in Fig. 9 gives a better idea of the pulsating waveform.)

When a signal that is equivalent in frequency and phase to the original carrier is inserted by the receiver, a modulation envelope more like the original is created when it combines with the sidebands. If its amplitude is insufficient, some of the second harmonic shown in Fig. 6 is revealed. If its amplitude is twice that of either sideband, a 100-percent modulated envelope will appear. If its amplitude is greater than this, something less than 100 percent modulation is recreated, but any detected audio would be essentially the same in peak value as under 100-percent modulation.

What happens to the recreated modulation envelope if a reintroduced carrier is shifted approximately 30 degrees from its proper phase is illustrated in Fig. 7. This apparent "filling in" of the envelope valleys continues to increase with phase shifts up to 90 degrees and the beat note between sidebands begins to become apparent. With a 90-degree shift, what would otherwise have been 100-percent modulation appears to be less than 20-percent modulation, and distortion is severe.

When a conventional receiver is receiving a single sideband with reduced carrier, both of the same amplitude, the signal illustrated in Fig. 8 is the best reconstruction that the receiver can manage. It is easy to confuse what the true audio component should be when examining this photo. Ideally, it would be the same as the audio shown in Figs. 5 and 7.

By covering the entire bottom half of the modulated signal, the true shape of the demodulated audio is revealed. What would be the negative peak of a sine wave is a very sharp peak, indeed. The recovered audio would (and did) look very much like the output of an unfiltered full-wave rectifier. What appears to be and actually is two overlapping sinusoidal waves are exactly one-half of the true frequency of the audio. This is not something that can be recovered, nor would it be desirable to recover it when voice or music is being transmitted.

Results shown in Fig. 8 seemed to be so very bad that they were double checked by actually transmitting and receiving CW signals of 600 and 602 kHz. The signals were followed through an old vacuum-tube receiver as they were "superheterodyned" in-

(Continued on page 90)

Experimenting With Audio Circuits

Using op-amps to build a variety of professional audio circuits to suit different requirements

By Joseph J. Carr

Perennial favorites with electronics experimenters and hobbyists, audio projects are both useful and well-behaved. Though vhf radio circuits and home computers may require special expertise to build successfully, even a newcomer to electronics can quickly assemble almost any audio circuit and have it work the first time out. In this article, we will discuss some of the types of audio circuits that have become popular over the years. Perhaps one or more of these circuits will fill a specific need you have.

Because most easily built audio projects are based on the ubiquitous operational amplifier, we will discuss a little op amp theory preliminary to getting into the projects portion of this article.

Setting the Stage

Shown in Fig. 1 are the schematic representations of the classical inverting and noninverting op-amp configurations that are in common usage. In Fig. 1(A) is the inverting follower amplifier configuration, while in Fig. 1(B) we see the noninverting amplifier configuration. Output from the Fig. 1(A) circuit is exactly the opposite of the input (inverted 180 degrees). Conversely, the Fig. 1(B) circuit's output is the same as its input signal (no inversion). In either case, the output can be lower or higher in amplitude than the input signal or the same amplitude as the input signal, depending on the values selected for *R1* and *R2*.

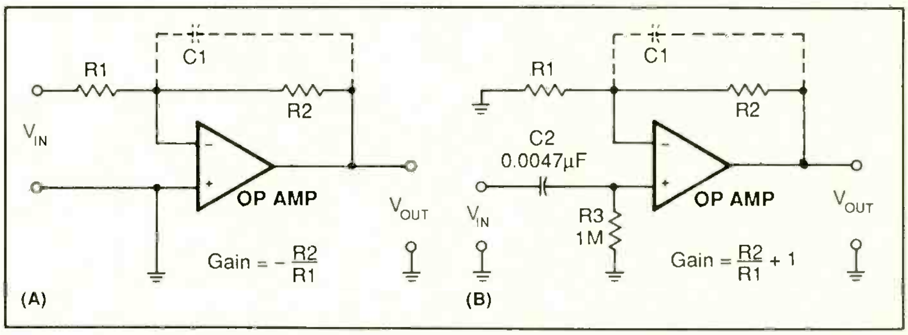


Fig. 1. Inverting follower (A) and noninverting follower (B) op-amp circuit configurations.

Gain of the Fig. 1(A) inverting amplifier is merely the ratio of feedback resistor *R2* to input resistor *R1* and is derived from the formula Gain = −(R2/R1). The minus sign in the equation simply means that a 180-degree inversion has taken place. The value of input resistor *R1* is usually kept at a minimum of 10 times the output impedance of the signal source to minimize loading effects.

For most low-impedance sources (low-impedance microphones, other amplifiers, etc.), the value of *R1* should be 10k ohms or more. For high-impedance sources, *R1*'s value should be at least 10 times the source's impedance. For example, a microphone specified to have a 50k-ohm impedance would require a value for *R1* of 50k ohms × 10 = 500k ohms.

Figure 1(B)'s noninverting amplifier uses the noninverting (+) input of the operational amplifier and has an input impedance equal to the value of input resistor *R3*. In this example, the input impedance of the amplifier is 1 megohm. Gain of this configuration is given by the formula Gain = (R2/R1) + 1.

In both circuits in Fig. 1, optional capacitor *C1* across the *R2* feedback resistor tailors the upper end −3-dB point in the frequency response of the circuit. For example, if you wish to design an amplifier for use as a microphone preamplifier in a communications system, you would want to limit the frequency response from a lower limit of 300 Hz to an upper limit of 3 kHz. These are the frequencies at which gain drops off by 3 dB below the center band's gain.

Capacitor *C1* sets the upper −3-dB point, while capacitor *C2* in Fig. 1(B) sets the lower −3-dB point. In both cases, the required values of the capacitors are calculated from the respective desired −3-dB frequencies and associated resistances. The formula for calculating these capacitances is C = 10⁶/(6.28FR), where *C* is in microfarads, *F* is the required −3-dB frequency and *R* is the value of the associated resistance (*R2* or *R3* in this circuit).

In Fig. 1(B), 0.0047-microfarad capacitor *C2* is shown associated with 1-megohm resistor *R3*. If you plug these values into the equation, you will find that this combination of values gives a lower −3-dB frequency of 34 Hz.

Suppose, as an example, you have a feedback resistor—*R2* in Figs. 1(A) and 1(B)—of 220k ohms. What value of shunting capacitor *C1* will yield a 3-kHz upper −3-dB point in the frequency-response curve? You would solve for this value as follows:

$C = 1{,}000{,}000/(6.28R2F)$
$C = 10^6/(6.28 \times 220{,}000 \times 3{,}000)$
$C = 0.000240$ microfarad

As you can see the final required capacitance value needed would be 240 picofarads.

Power Supply Considerations

Operational amplifiers and other linear ICs frequently require a dual-polarity dc power supply to operate properly. The V+ supply must be positive and the V− supply must be negative with respect to circuit ground or common. In most audio projects, these supplies will be +6 and −6 volts to +15 and −15 volts dc. In other applications, supply potentials down to 1.5 and up to 22 volts are used. Keep in mind, however, that special types of devices are needed for operation at potentials below and above the ±6- to ±15-volt range.

Shown in Fig. 2 are the classical methods of connecting a bipolar power supply to an operational amplifier. Decoupling and bypassing shown on the dc power-supply lines is common to most audio linear IC devices, not just op amps. Each power-supply line is bypassed by two capacitors: a 4.7-microfarad electrolytic (usually tantalum) and a 0.1-microfarad Mylar or other type. The higher-value electrolytic provides low-frequency decoupling, while the lower-value capacitor provides high-frequency decoupling.

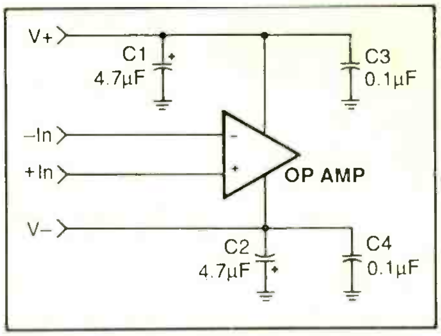


Fig. 2. Details of bipolar power-supply connections to typical op amp with high- and low-frequency decoupler/bypass capacitors.

At this point, you might be wondering why two capacitors are used for decoupling/bypassing, especially when a high and a low value capacitor are connected in parallel with each other. The reason for using both capacitors is that electrolytics are almost useless at higher frequencies. Hence, at frequencies where a high-value electrolytic capacitor would be virtually useless, the low-value capacitor comes into play.

For maximum effectiveness, these capacitors should be mounted as close as possible to the body of the IC they are to serve. If space limitations require a tradeoff, place the 0.1-microfarad capacitors closer to the IC than the electrolytics, but do not allow any capacitor to be positioned too far from the IC or its effect will be virtually useless.

Audio Mixers

An audio mixer is a circuit that combines audio signals from two or more inputs into a single-channel output. Application examples for mixers include multiple microphone public-address systems, multiple guitar systems and radio-station console service where inputs from tape players, record players and two or more microphones are combined into a single line that goes to the transmitter's modulator input.

Shown in Fig. 3 is an example of a simple audio mixer in which an op amp is used for combining signals from three separate sources. The audio input lines are identified as AF1, AF2 and AF3. Each source is applied to the inverting (−) input of the op amp, and each "sees" gains of R4/R1, R4/R2 and R4/R3, respectively. Because all resistors have values of 100k ohms, the gains for all three channels are 1 or unity.

Gain on any given channel can be customized to the requirements of each source simply by using the appropriate value of resistance in each case. Gain of any given channel will be 100k ohms/R, where *R* is the value of input resistance *R1*, *R2* or *R3*, depending on the channel to be customized. When calculating values to use, however, be careful to avoid reducing the input resistance to a

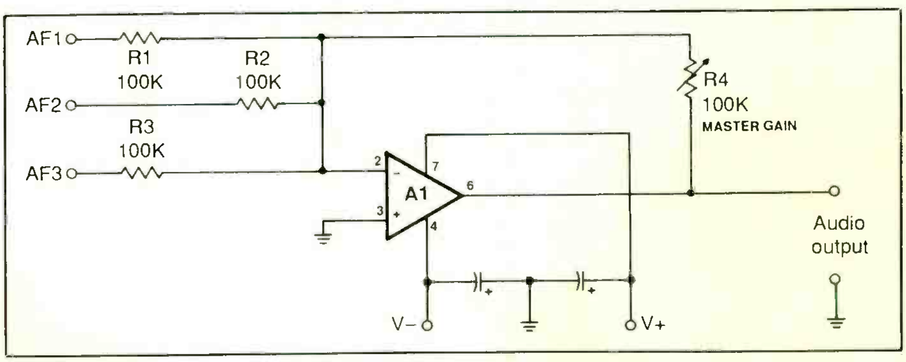


Fig. 3. Simple audio mixer circuit.

value that is too low to prevent loading the signal source.

If the signal source is another operational-amplifier preamp (or other voltage amplifier), input resistance can be reduced to several thousand ohms without causing problems. However, if the source is a high-impedance phono cartridge or some similar device, use a minimum of 50k ohms for the resistor's value.

In some cases, it might be beneficial to increase the value of the feedback resistor to 1 megohm or so to make the corresponding input resistances greater for any given gain. Keep in mind that the input impedance seen by any single channel is the value of the input resistance.

Master gain control *R4* is used as the feedback resistor in the Fig. 3 circuit. By using a potentiometer here, feedback resistance can be varied from 0 to 100k ohms. If no control over gain is required, *R4* would be a fixed-value resistor.

If an application calls for a one-time set-and-forget gain adjustment (as might be the case in radio station applications), make *R4* a trimmer potentiometer. Otherwise, the feedback potentiometer should be a panel-mounted unit that is adjusted via a standard control knob.

Almost any good operational-amplifier integrated circuit that has a gain bandwidth (GBW) that is sufficient for your proposed application can be used in the mixer circuit shown in Fig. 3. Because gain is unity, and GBW of more than 20 kHz will suffice, all op amps except those in the 741 family will suffice in communications applications.

An improved audio mixer circuit design is shown schematically in Fig. 4. This one is based upon the RCA CA3048 amplifier array IC, which provides approximately 20 dB of gain for each channel. The CA3048 is a 16-pin DIP IC that contains four independent ac amplifiers. Offering a gain of 53 dB with a typical GBW of 300 kHz, the CA3048 has a 90k-ohm input impedance and 1k-ohm output impedance. It produces a maximum low-distortion output signal of 2 volts rms and can accommodate inputs of up to 0.5 volt rms.

Each dc power supply can be up to 16 volts. Notice that there are two V+ and two ground pins on the CA3048. These multiple connections reduce internal coupling between amplifiers. The two V+ pins and two ground pins tie together externally as shown. The V+ pins are bypassed with two capacitors, *C5* and *C6* for high- and low-frequency bypassing, respectively. These capacitors must be mounted as close as possible to the body of the IC, with *C5* taking precedence over *C6*, since high-frequencies are more critical.

RC network *R3/C2* from the output to ground stabilizes the amplifier and prevents oscillation. Like the power supply bypass/decoupling capacitors, these components must be mounted as close as possible to the body of the IC.

Only one channel is shown in detail in Fig. 4; each of the other three channels is identicai and all are joined together with the circuitry shown at the input side of *C4* as shown. Each channel has its own *R1* level control, which also provides a high input impedance for the mixer.

600-Ohm Audio Circuits

Professional audio applications generally use a 600-ohm balanced line between the devices in a system. As an example, a remote preamplifier will have a 600-ohm balanced output and will connect to the next stage through a three-conductor line. Such a system uses two "hot" lines and a ground line to provide interstage connections.

An amplifier with a 600-ohm balanced output is called a line-driver amplifier, while an amplifier with a 600-ohm balanced input is a line receiver. Of course, some amplifiers function as both line drivers and line receivers.

Shown in Fig. 5 is the schematic diagram of a line receiver amplifier built around an LM301 op amp operated with unity gain input via the noninverting input terminal. Input to the circuit is through line transformer *T1*. If *T1*'s turns ratio is other than 1:1, "gain" is essentially the

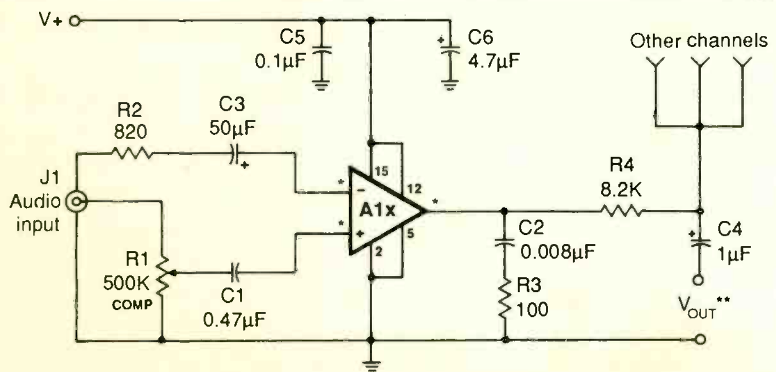


Fig. 4. Improved audio mixer circuit.

X = A, B, C or D

AMPLIFIER	–INPUT	+INPUT	OUTPUT
A	3	4	1
B	7	8	6
C	10	9	11
D	14	13	16

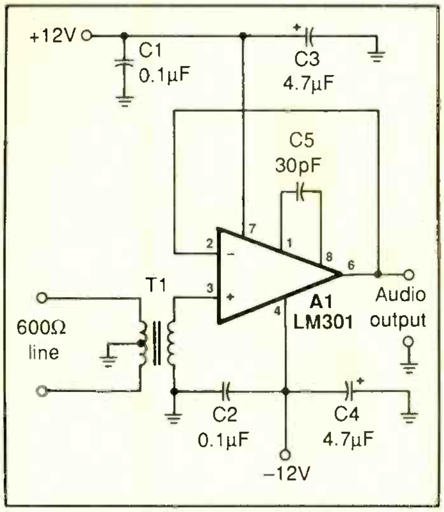


Fig. 5. A 600-ohm line receiver amplifier circuit.

turns ratio of the transformer. Suppose, for example, a 600-ohm input, 10k-ohm output transformer is selected. This transformer will have a secondary/primary impedance ratio of approximately 17:1. Turns ratio is the square root of 17, or about 4.1. This means that the voltage applied to the input of the op amp in this case would be 4.1 times greater than would be the case if a 600-ohm 1:1 line transformer had been used.

Like most op-amp circuits, the Fig. 5 circuit requires a dual-polarity dc power supply feeding its V+ and V− terminals. These power supplies can typically provide between +6 and +15 volts. Each supply line must be decoupled by high- and low-frequency bypass capacitors *C1* and *C3* with the same considerations as in the Fig. 4 circuit.

Output from the Fig. 5 circuit is an ordinary single-ended voltage, as is the case in other op-amp circuits. Hence, the output will typically have a very low impedance. It is possible to get away with a 600-ohm 1:1 transformer if the natural output impedance of the op amp is on the order of 50 ohms or so. A general rule of thumb in this regard is that the primary impedance of any transformer selected should be 10 times the natural output impedance of the device for best voltage transformation.

Another way to make a 600-ohm line-input amplifier is to use the simple differential dc circuit shown in Fig. 6. Make sure that input resistors *R5* and *R6* have values of 300 ohms, though. (Note: A 270-ohm value is shown for these resistors because this is the closest standard value that can be easily obtained from most sources. In most cases, derating the values to 270 ohms will have no discernible effect on circuit performance.)

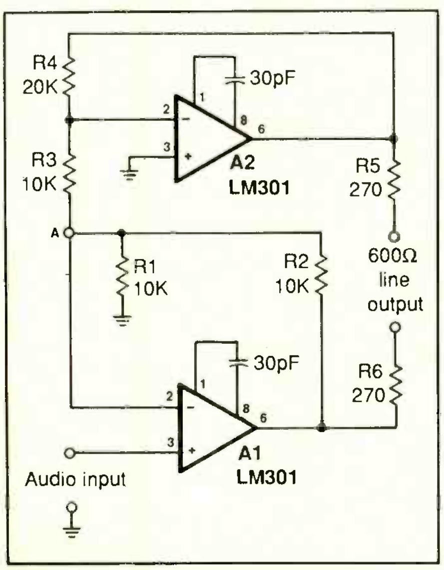


Fig. 6. A 600-ohm line driver amplifier circuit.

Figure 6 shows a line driver based on a pair of ordinary operational amplifiers, with power connections deleted but all pinouts the same as in Fig. 5. The output circuitry is balanced because it is made from two single-ended op amps that are driven 180 degrees out-of-phase with each other. The low output impedance of the operational amplifier plus the 270-ohm series resistances make the balanced output impedance a total of approximately 600 ohms.

The Fig. 6 circuit is a good example of clever usage of one property of the ideal op amp. Applying a voltage to one input causes the same voltage to appear at the other input. In this case, the audio input signal voltage applied to the noninverting input of amplifier *A1* also appears at the inverting input of the same amplifier. Thus, V_{in} appears at both inputs and point A, which allows point A to feed the other half of the balanced circuit made up of amplifier *A2*.

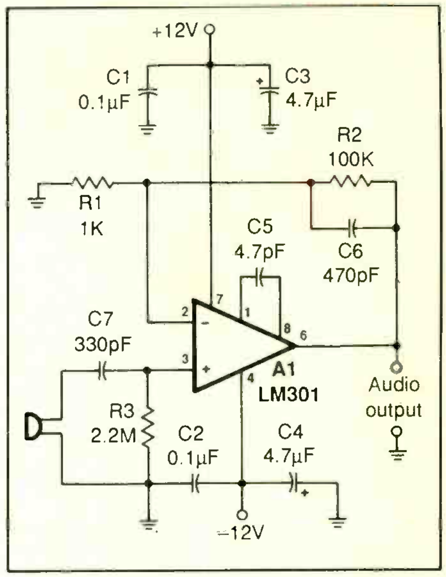


Fig. 7. Simple microphone preamplifier circuit suitable for use in communications and restricted-frequency-response PA applications.

Because *A1* is a noninverting gain-of-2 circuit and *A2* is an inverting gain-of-2 circuit, the two sides of the circuit are 180 degrees out-of-phase with each other. This is the condition required of the two "balanced" output lines.

Preamplifier Circuits

A preamplifier is an audio amplifier that gives some initial amplification to the signal before passing it to another circuit for additional amplification and processing. For example, a microphone has a low-level output of several millivolts to 0.2 volt. A preamplifier typically boosts this low-level signal to between 100 millivolts and 1 volt before applying it to the input of a power amplifier that drives a loudspeaker or the input of a transmitter's modulator.

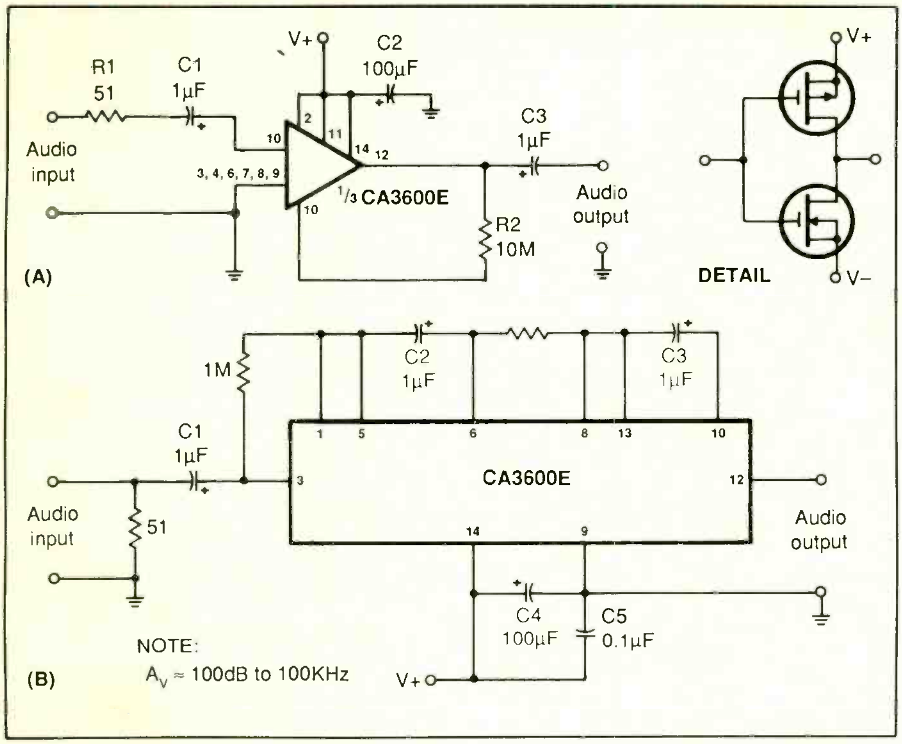


Fig. 8. Single- (A) and multiple-stage (B) general-purpose preamplifier circuits suitable for use in hi-fi applications.

A schematic diagram of a simple microphone preamplifier is shown in Fig. 7. This circuit is suitable for PA and communications use but not for high-fidelity applications because of its narrow bandwidth. Built around a common LM301 op amp wired in a noninverting follower configuration and using the values shown for input and feedback resistors *R1* and *R2*, the circuit has a gain of 101.

A microphone is capacitively coupled to the noninverting input of the op amp. To keep the op amp's input bias currents from charging *C7* and thereby latching up the op amp, 2.2-megohm resistor *R3* is placed between the op amp's noninverting input and circuit ground.

This circuit can be made less complicated if a dynamic microphone is used to drive it. This type of microphone uses a high- or low-impedance coil that is permanently connected into the circuit. In this arrangement, *R3* and *C7* are omitted and the microphone is connected between pin 3 of *A1* and circuit ground. If you anticipate having to disconnect the microphone from the circuit, however, keep *R3* in the circuit to prevent the op amp's output from saturating at or near V+ when the noninverting input is left open.

Frequency response of this circuit is tailored by *C5* and *C6*. With the values shown for these capacitors, the upper −3-dB point in the response curve will be slightly beyond 3 kHz and will roll off at about 6 dB/octave beyond this frequency.

Two general-purpose preamplifiers based on RCA's CA3600E IC are shown schematically in Fig. 8. The CA3600E is a complementary COS/MOS transistor array device. Single- and multiple-stage designs are shown in Fig. 8(A) and (B), respectively. The internal transistor array equivalent for one transistor pair is shown in the inset in Fig. 8(A). This design

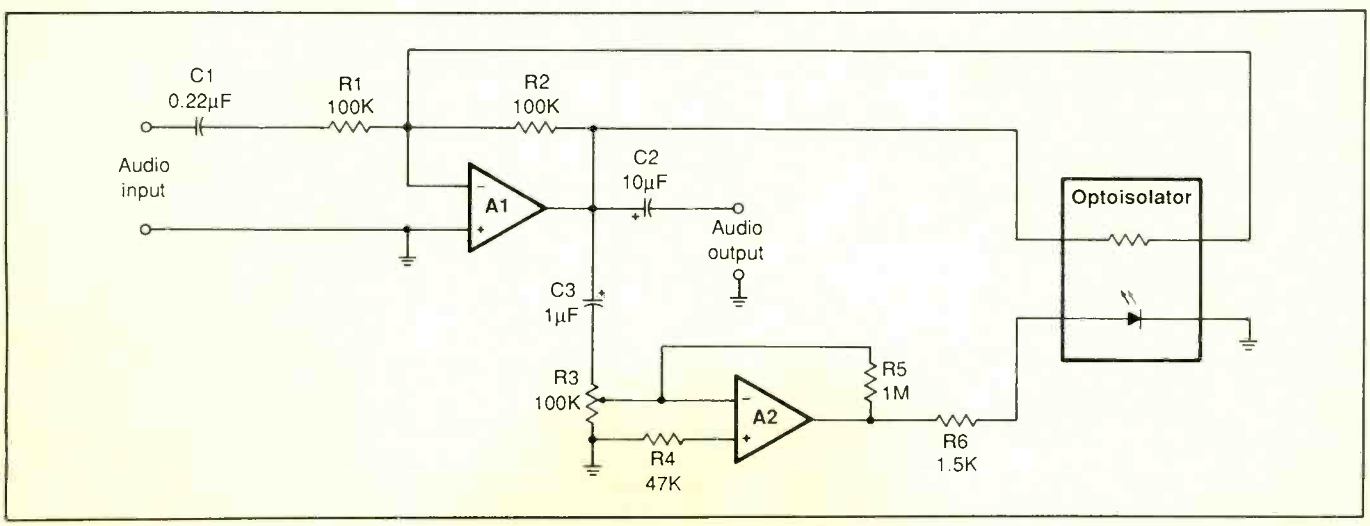


Fig. 9. A typical compression amplifier circuit.

is capable of up to 30 dB of gain at a V+ of 15 volts dc, slightly more at lower potentials but only at a sacrifice of the 1-MHz −3-dB point in the response curve.

Figure 8(B)'s multi-stage design is capable of gains up to 100 dB at frequencies up to 1 MHz, assuming a 10-volt dc supply (gain drops to 80 dB when a +15-volt supply is used). This gain and frequency response are very useful in audio and other applications. However, it must be approached with caution when you actually build the circuit. Be sure to keep the power supply decoupling capacitors as close as possible to the body of the IC.

Unless a preamplifier stage with a higher impedance is provided, the 50-ohm input impedance of the Fig. 8(B) circuit takes this amplifier out of the audio-amplifier category because audio amplifiers expect to "see" higher impedances.

Compression Amplifier

An amplifier that reduces its gain on input signal peaks and increases gain in signal valleys is known as a "compression" amplifier. Such a circuit is usually used by electronic musicians and broadcasters to raise the average power in the signal without creating appreciable distortion. Shown in Fig. 9 is the schematic diagram of a typical compression amplifier circuit.

Amplifier *A1* is any good audio op amp, such as the LM301 (see earlier circuits for power supply and compensation details). Circuit gain is set by input resistor *R1* and a feedback resistance composed of *R2* and the optocoupler's output resistor element. Resistance of the optocoupler is set by the intensity of the light-emitting diode's brightness, which is, in turn, set by the amplitude of the signal fed to the LED from *A2*.

Because the output signal from *A2* is proportional to the output signal from *A1*, overall gain reduces itself, or compresses. Any high-resistance output device, such as those from Clairex, or an H11A1 optocoupler that uses a JFET for the resistance element can be used in this circuit.

Assembly Notes

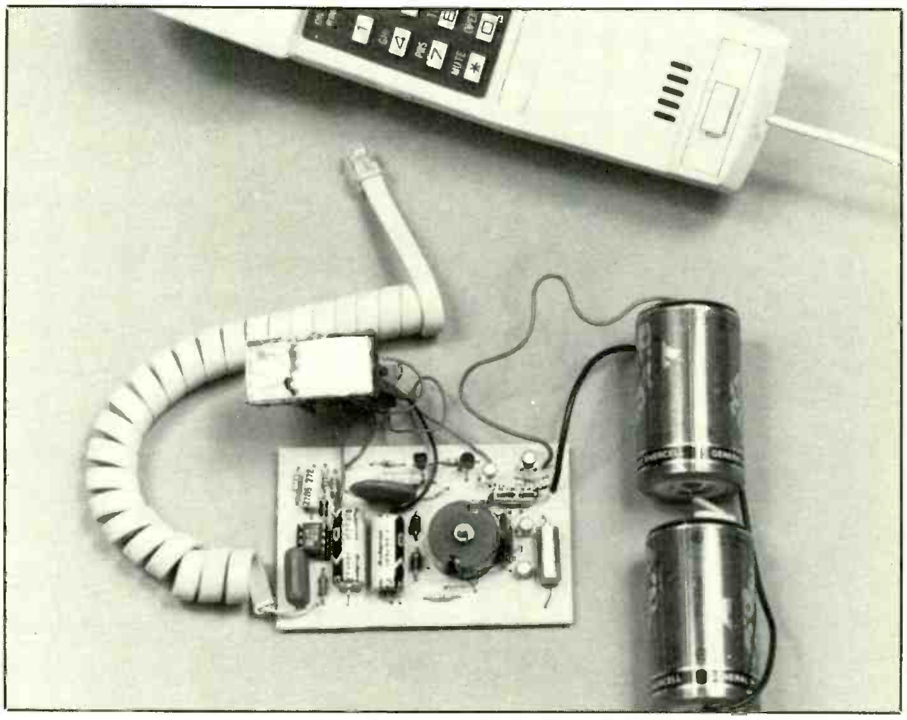
Any one or all of the circuits discussed here can be quickly and easily assembled using any of a variety of wiring techniques. If all you want to do is experiment, you can build the circuits on a solderless breadboarding block. For more permanent circuitry, you can mount and wire the components on small printed-circuit boards of your own design or perforated board with holes on 0.1-inch centers and suitable hardware.

There is nothing really critical about layout of the components in any of these circuits. However, to be on the safe side, always keep inputs and outputs as far apart as possible. It is also a good idea to use a socket for any integrated circuit used in a given circuit. ME

Automatic Telephone Flasher

Add-on accessory gives you visual indication of an incoming telephone call

By Anthony J. Caristi



Have you ever missed an important call because you didn't hear your telephone ring? Perhaps you were listening to music at high volume through headphones, or you or a member of your household is hearing impaired. For situations like these, a visible alerter like the Automatic Telephone Flasher to be described provides a practical solution. The Flasher can be used in conjunction with your instrument's "bell" or alone simply by switching off the latter.

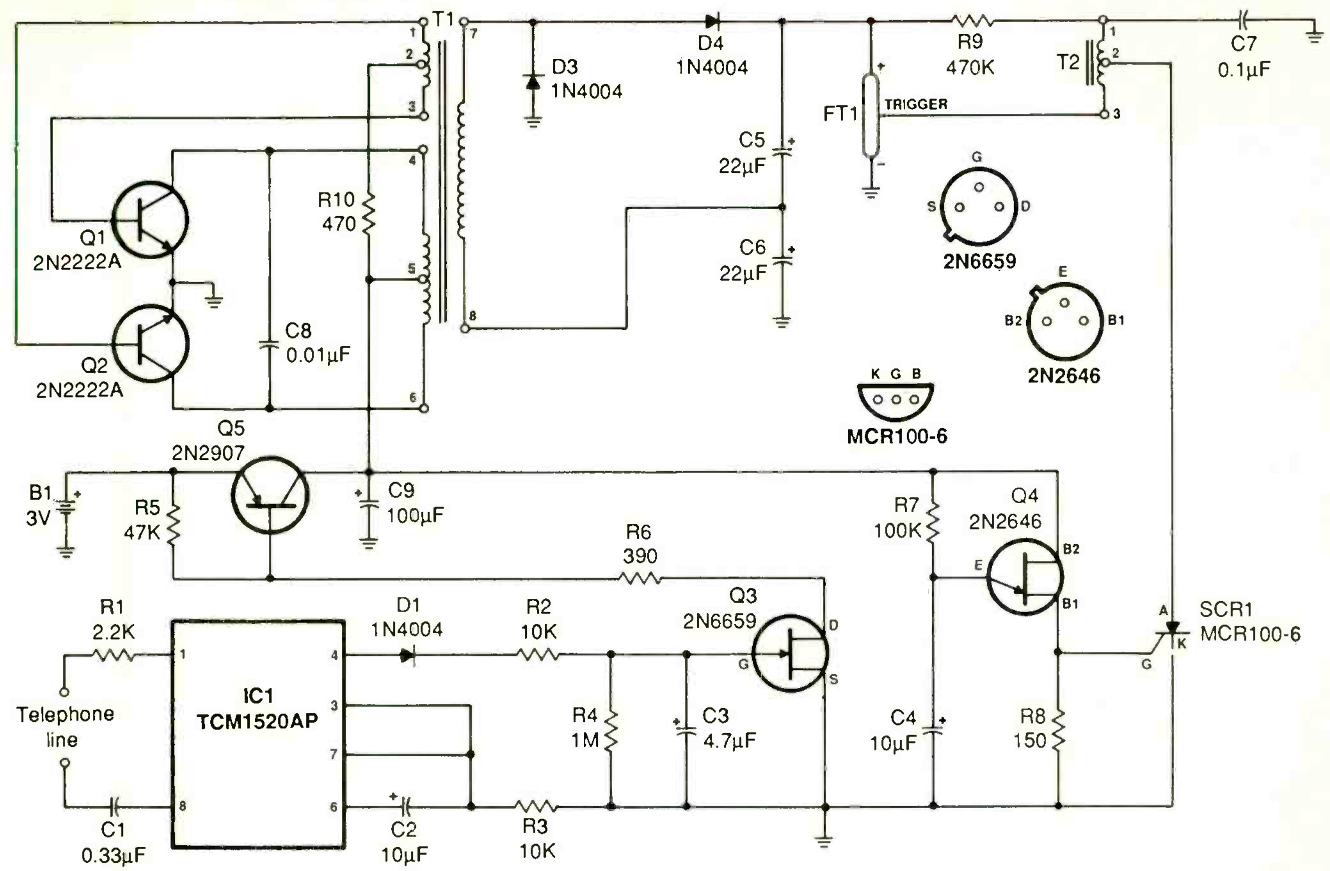
Completely self-contained in its own enclosure, the Automatic Telephone Flasher uses a pulsed photoflash unit as the alerting device. The project connects to the telephone line only to sense the ring signal generated by an incoming call. Because the ring signal has very little energy, two standard D cells power the project's flashtube circuitry and are called on to deliver power to the circuit only when the ring signal is present on the line. Hence, battery life is extremely long—up to a year or more, depending on the number of calls you receive in a year.

About the Circuit

As shown in the complete schematic diagram of the project in Fig. 1, the telephone flasher consists of two major sections—a telephone ring-signal detector and a dc-to-dc converter power supply that generates a high voltage required to trigger a xenon flashtube. These two sections are coupled to each other by an electronic switch made up of n-channel enhancement-mode field-effect transistor *Q3* and silicon bipolar transistor *Q6*.

Telephone ring detector *IC1* and its associated components are used to detect the ring signal when it appears on the telephone line from the phone company when a caller attempts to get through. Included in *IC1* is a bridge rectifier, 5-volt regulator and transient suppression circuitry that prevents damage to the integrated circuit and false operation that might otherwise occur if a large transient voltage appears across the telephone line.

Drive for *IC1* is provided directly from the 90-volt, 20-Hz ring signal that appears across the line to announce an incoming call. During standby, *IC1* presents a very high impedance to the telephone line. Also, this chip in no way affects incoming and outgoing calls. Its only purpose is to generate a regulated output voltage at pin 4 in response to the ring signal. Capacitor *C2* stores the energy of the signal to power the regulator circuit so that it produces a 5-volt dc output between pins 4 and 7 of the integrated circuit.



PARTS LIST

Semiconductors

D1,D2,D3—1N4004 or equivalent 400 PIV silicon diode
IC1—TCM1520AP telephone ring detector (Texas Instruments)
Q1,Q2—2N2222A or similar npn silicon transistor
Q3—2N6659 or equivalent n-channel enhancement-mode field-effect transistor
Q4—2N2646 unijunction transistor
Q5—2N2907 pnp silicon transistor
SCR1—MCR 100-6 silicon-controlled rectifier (Motorola)

Capacitors

C1—0.33-µF, 250-volt Mylar
C2,C4—10-µF, 50-volt electrolytic
C3—4.7-µF, 25-volt electrolytic
C5,C6—22-µF, 150-volt electrolytic
C7—0.1-µF, 500-volt ceramic disc
C8—0.01-µF, 250-volt ceramic disc
C9—100-µF, 10-volt electrolytic

Resistors (¼-watt, 10% tolerance)

R1—2,200 ohms
R2,R3—10,000 ohms
R4—1 megohm
R5—47,000 ohms
R6—390 ohms
R7—100,000 ohms
R8—150 ohms
R9—470,000 ohms
R10—470 ohms

Miscellaneous

B1—Two 1.5-volt high-energy or alkaline D cells in series (see text)
FT1—250-volt Xenon flashtube (Radio Shack Cat. No. 272-1145 or similar—see text)
T1—Hand-wound transformer (requires TDK pot core and bobbin No. H5AP2213Z52H or similar and Nos. 30 and 36 enameled wire—see text)
T2—Trigger transformer with 300-volt primary and 6,000-volt secondary (Triad No. PL-10 or similar)
Printed-circuit or perforated board with holes on 0.1″ centers and suitable solder or Wire Wrap hardware (see text); socket for IC1; double D-cell holder for B1; standard telephone cord with modular connector at one end; thin tape; suitable enclosure (see text); machine hardware; hookup wire; solder; etc.

Note: The following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Pc board, $7.75; pot core and bobbin, $8.75; 2N2222A, 2N6659 and MCR 100-6, $2.25 each; 2N2646 and 2N2907, $3.00 each; and TCM1520AP, $3.95. Add $1 P&H. New Jersey residents, please add state sales tax.

Fig. 1. Complete schematic diagram of automatic telephone flasher.

Since its gate-to-source voltage is zero, *Q3* remains in cutoff during standby. The resistance between the drain and source is virtually infinite, which prevents any base current from flowing in *Q5*. As a result, *Q5* is also in cutoff, meaning that no current can flow from battery *B1* to the rest of the circuit.

When a ring signal appears across the telephone line, the 5-volt dc output from *IC1* biases *Q3* into conduction. The resulting low resistance now between *Q3*'s drain and source causes *Q5* to switch on at full saturation. This powers the circuit and allows the dc-to-dc converter to oscillate and trigger xenon flashtube *FT1*.

Since the time constant of *Q3*'s gate circuit, controlled by the values of *R4* and *C3*, is about 5 seconds, the forward bias on *Q3* is sustained during the 4-second interval between telephone ring pulses so that *FT1* continues to flash.

When the ring signal ceases, the bias on *Q3* decays to zero, which cuts off both this transistor and *Q5*. When this occurs, *FT1* extinguishes.

About 250 volts is needed to trigger the flashtube. This high voltage is provided by the dc-to-dc converter power supply composed of bipolar transistors *Q1* and *Q2*, transformer *T1* and the associated components. These components make up an oscillator circuit that operates at a frequency of 3 to 4 kHz. The collectors of the two transistors are connected in push-pull fashion to alternately drive each half of *T1*'s primary with the battery voltage.

The bases of *Q1* and *Q2* are driven by the feedback winding to assure that the dc-to-dc converter will oscillate as it should. Each transistor alternately conducts and is cut off, causing the transformer's primary to be driven by a 10-volt peak-to-peak square wave. The step-up turns ratio of the secondary winding produces a high ac voltage at pins 7 and 8 of *T1* that is used to drive a full-wave voltage doubler. The doubler charges *C5* and *C6* to about 125 volts each. Since these capacitors are connected in series with each other, the sum of the voltages—about 250 volts—is used to trigger the gas inside the flashtube to ionize and, in so doing, emit a bright flash of light.

Although *FT1* is connected across the output of the power supply, it does not conduct current and flash until it is triggered by a very-high-voltage pulse fed to its trigger electrode. This electrode is simply a wire that wraps around the flashtube near its middle.

To generate the very-high-voltage spike (it is almost 6,000 volts) needed to trigger the flashtube into operation, a second, trigger, transformer (*T2* in Fig. 1) is used. This circuit is very much like that used in the typical capacitive-discharge (CD) electronic ignition system used in motor vehicles.

Unijunction transistor *Q4* and its associated components make up a relaxation oscillator that operates at a frequency of about 1 Hz. Timing capacitor *C4* is charged by current through *R7*. When the charge reaches about 1.5 volts, *Q4* suddenly conducts and dumps the charge stored in *C4* into emitter resistor *R8*. When this occurs, the voltage produced across *R8* is sufficient to trigger silicon-controlled rectifier *SCR1* into conduction.

During the time *C4* charges to 1.5 volts, *C7* is charged to about 250 volts through *R9* and the high-voltage supply. When *SCR1* is suddenly triggered into conduction, the energy stored in *C7* flows into the primary of *T2*. Step-up action causes the approximately 6,000-volt output at the secondary of *T2* to be be presented to *FT1*'s trigger electrode, causing the flashtube to conduct and the energy stored in *C5* and *C6* to be converted into heat and light.

Although the energy in a single flash of *FT1* is dissipated in about

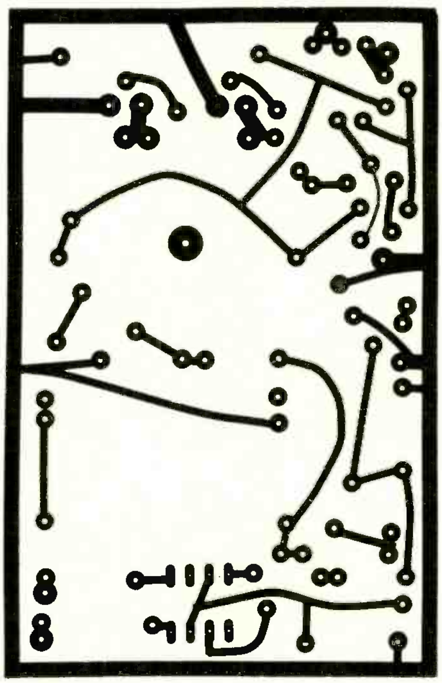


Fig. 2. Actual-size etching-and-drilling guide for project's printed-circuit board.

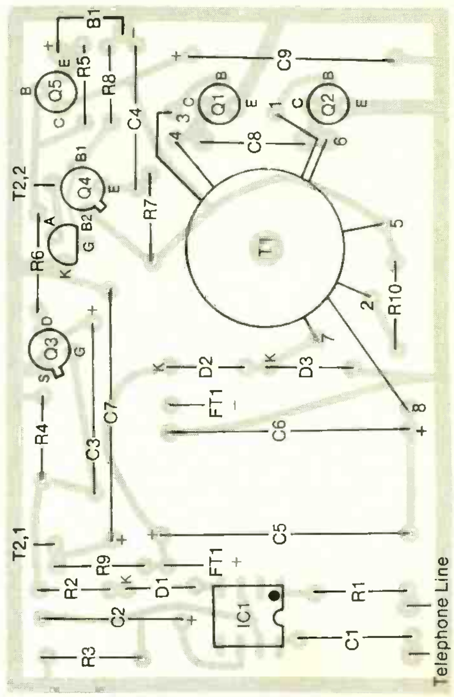


Fig. 3. Wiring guide for pc board. Use this as rough layout guide if you wire project on perforated board.

0.001 second, the flash produces enough light—similar to that of a photoflash used with cameras—to be easily seen. As *FT1* flashes, *C5*, *C6* and *C7* quickly recharge to await the next pulse from *C4*. The cycle repeats as long as the ring signal is present on the telephone line.

Although trigger transformer *T2* produces an output of about 6,000 volts, no potential shock hazard exists because there is no power (current) behind this very-high voltage. However, it is always a good idea to respect any high voltage, whether from *T1* or *T2*, since you will get an electrical shock if you place any part of your body in contact with the circuitry.

Construction

As shown in the lead photo, the entire circuit, with the exception of the battery and flashtube, can be wired on a small single-sided printed-circuit board that measures only 3.5 × 2.25 inches. Since there is nothing critical about either wiring or component location, you can assemble the circuit on a similar-size perforated board that has holes on 0.1-inch centers and use suitable soldering or Wire Wrap hardware to make wiring interconnections. Just be sure that the secondary of *T1* and the primary of *T2* do not cross over the low-voltage circuits of the transistors and related components. If you do not heed this advice, the circuit can fail should a voltage breakdown occur between the high-voltage supply and the sensitive low-voltage components. The advantage of using a printed-circuit board is that it precludes such a breakdown.

You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2, or you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. Once the board is ready, refer to Fig. 3 and mount and solder into place a socket in the *IC1* location. Do *not* install *IC1* in its socket until after preliminary checks have been made.

Install and solder into place the resistors, diodes and capacitors. Then do the same for the transistors (except *Q3* and *Q5*, which will also be installed after preliminary checks have been made) and *SCR1*. Observe polarity with the diodes and electrolytic capacitors and basing for the transistors and silicon-controlled rectifier. (Note: If you wire the project on perforated board, use the layout shown in Fig. 3 as a rough guide to component placement and orientation.)

The flashtube and trigger transformer *T2* can be obtained from the sources given in the Parts List. Alternatively, you can salvage these items from an old camera photoflash unit. Wire these components to the circuit board as indicated in Figs. 1 and 3; observe polarity for the flashtube.

Since this project contains voltages that are not normally encountered in modern solid-state circuits, be sure to follow the voltage ratings of the components indicated in the Parts List when selecting them. Do *not* use components with voltage ratings less than those indicated. If you do, one or more of the components is likely to break down. If this occurs, the circuit will not operate and other components are likely to be damaged.

Use a standard telephone cord that is terminated in a modular plug to make connection to the telephone line. This is both an FCC requirement for telephone accessories and a convenience that will let you move the project to another telephone if you desire to do so. Since the circuit is ac coupled to the telephone line through *C1*, you need not be concerned with polarity. Connections are made to the red and green conductors of the telephone line; the black and yellow conductors are not used and can be disregarded.

Switching transformer *T1* must be hand wound by you. This is not as difficult a task as you might imagine. In addition to the pot core/bobbin assembly specified in the Parts List, you will need a small quantity of No. 30 and 36 enameled (so-called "magnet") wire and some thin insulating tape. Mylar tape will do nicely. It is mandatory that you perform the winding procedure exactly as follows to ensure proper phasing of the primary and feedback windings.

Start with the feedback winding, identified by terminals 1, 2 and 3 in Fig. 1. Use No. 30 enameled wire for this winding. Wind a total of 10 turns of this wire on the bobbin, making a center tap at the fifth turn. Starting with a 36-inch length of wire, wind five turns around the bobbin, leaving a 4-inch-long "leader." Bring the wire out of the bobbin, at one of the openings provided, fold the wire over into a 4-inch U shape wind five more turns on the bobbin in the *same* direction as you wound the first five turns. Secure the feedback winding in place on the bobbin with a single layer of tape to insulate it from the next winding. Allowing about a 4-inch leader at the end of the wire, clip off any excess. Use masking tape to label the start, center tap and end of this winding with the numbers 1, 2 and 3, respectively.

Next, wind the transformer's primary turns in bifilar fashion to achieve the tightest possible coupling between the two halves of the winding to minimize voltage spikes that will appear at the collectors of *Q1* and *Q2*. Use two 30-inch lengths of No. 30 enameled wire for this winding. Label the same ends of these two wires 4 and 5. Place these two ends together and, leaving a 4-inch leader in both cases, wind nine turns around the bobbin in the *same* direction as the feedback winding was wound. Secure this winding with a layer of tape. Clip all but 4 inches from what remains of these wires.

Use an ohmmeter set to a low-ohms range or a continuity tester to identify the unmarked ends of the primary. Label the wire that gives continuity with the end labeled 4 with a 5. The other wire then gets a label with a 6 on it.

The secondary winding of the transformer simply consists of 250 turns of No. 36 enameled wire wound in either direction. When you have finished winding the wire onto the bobbin, secure it in place with a couple of layers of tape. Then trim the leads to about 4 inches in length and label them with the numbers 7 and 8.

Assemble the bobbin inside the pot core halves, being careful to avoid getting any dirt or other foreign debris on the polished surfaces of the core. Use tape to secure the two halves of the pot core together. Then carefully scrape away about ¼ inch of enamel insulation from the ends of all transformer leads, including the center of the U loop on the center tap of the feedback coil, after first clipping open the center of the U. Tin each lead end with a thin layer of solder.

Mount the transformer on the circuit-board assembly in the location shown in Fig. 3. Use a No. 6 machine screw and nut and a plastic or fiber washer if you have one. Be very careful to avoid over-tightening the hardware or you will crack the very brittle ferrite pot core, rendering it useless.

Plug the transformer's leads into the appropriate holes in the pc board and solder into place. Remember that there will be *two* leads that go into holes 2 and 5. Be very careful to connect the transformer's leads into the circuit properly; a wiring error at this stage will result in an inoperative circuit.

You can install the entire project in a suitable plastic or metal enclosure. Mount the flashtube so that it will be readily seen when it flashes. If you use a clear plastic enclosure, you can locate the flashtube inside it.

Since power for the circuit is provided by two 1.5-volt D cells in series with each other to provide 3 volts, it is best to use heavy-duty or alkaline cells for longest operating life. This battery is called upon to deliver current only when the telephone rings; hence, its service life can approach that of its shelf life. Just keep in mind that the circuit is designed to give a flash rate of about once per second. When you notice that the frequency of flashes is much less than this, it is time to replace the cells with fresh ones.

Checkout & Use

It is best to check operation of the dc-to-dc converter section first. Make sure that *IC1*, *Q3* and *Q5* are *not* installed on the circuit-board assembly. Use a bench-type dc power supply set to deliver 2.5 volts or two C or D cells in series as a power source. Current drawn from the source will be in the 100- to 300-mA range.

Use a dc voltmeter or a multimeter set to dc volts to measure the output voltage from the dc-to-dc converter circuit. The meter must have an input resistance of 1 megohm or more and be set to measure at least 300 volts. Be very careful not to touch any of the wiring during and after the test because high voltage will be present in the circuit.

Before powering the circuit, connect the meter's "hot" probe to the positive (+) side of *C6* and common probe to the negative (−) side of *C6*. Then connect the dc power source across *C9*, again observing polarity. You may now hear a faint 3- or 4-kHz tone as the circuit oscillates, and the voltmeter's reading should slowly rise toward 250 volts. As the flashtube fires, the indicated voltage should suddenly drop toward zero and begin to rise toward 250 volts. This charge/discharge cycle should continue to repeat about once each second for as long as power is applied to the circuit.

Once you obtain the proper indications, disconnect the power source from the circuit and use a low-value, say, 1,000-ohm, resistor to carefully discharge *C5* and *C6* by temporarily bridging each capacitor's leads. Be careful to avoid touching the resistor's leads!

If you do not obtain a dc voltage reading on the meter, the circuit is probably not oscillating as it should. Disconnect the power source from the circuit and check the basings of *Q1* and *Q2* and the orientations of *D3*, *C5* and *C6* against Fig. 3. If all seems to be okay, the 1 and 3 feedback leads of *T1* may be incorrectly phased. Transpose these two leads and try again. If this does not work, return the leads to their original holes, and carefully review the transformer winding instructions to ascertain that you have properly performed the procedure.

If you obtain 250 volts or more but the flashtube fails to fire, *Q4* may not be oscillating. In this case, check the orientation of *C4* and basing of *Q4*. Connect the voltmeter across *C4* and ascertain that the reading indicated slowly rises to about 1.5 volts, then suddenly drops to near zero and repeats about once per second.

If *Q4* is oscillating, check the wiring of *T2* and *SCR1*. If possible, try using another flashtube. Do not proceed to final assembly until you have cleared up any problems encountered during checkout.

When you are finished with checkout, disconnect the power source from the project and once again carefully discharge *C5* and *C6* with the bridging resistor. Then plug *IC1* into its socket, making sure to properly orient it as shown in Fig. 3 and that no pins overhang the socket or fold under between socket and IC. Install and solder into place *Q3* and *Q4*, checking for proper basing before soldering the leads of these transistors to the copper pads on the bottom of the board.

Place two D-size cells in a two-cell holder and wire them in series with each other. Then wire this "battery" into the circuit as shown in Figs. 1

and 3. With the cells connected into the circuit as shown, there should be no project activity.

For your final test, plug the modular connector at the end of the project's cord into a telephone jack (use a duplex adapter if only one jack is present at the telephone box) along with your existing telephone instrument. Have a friend place a call to your number. When the telephone rings, the flashtube should fire at a rate of about once per second, even during the 4-second interval between rings. When you pick up your phone's handset to answer the call, flashing should continue a few more times and then cease.

You can now proceed to final installation. Simply leave the project plugged into the telephone line but locate the automatic telephone flasher where its flashing light will easily be seen from anywhere in the room. **ME**

A Solid-State Electric-Blanket Controller*

Eliminates problems usually encountered with electromechanical controllers and provides greater efficiency and better heating comfort

By Joseph O'Connell

Standard electromechanical controllers vary the average heat output of an electric blanket by repeatedly cycling on and off the embedded heating elements in a more or less "digital" manner in response to changing ambient temperatures. The solid-state replacement controller to be described continuously controls the blanket's temperature in an *analog* manner by varying the amount of power delivered to the heating elements, rather than switching between only full-off and full-on. This eliminates temperature fluctuations and provides more comfortable heating.

Our electronic controller also eliminates the bright dial light and contact clicking common to electromechanical controllers. Instead of a dial light, the electronic controller employs a multi-color light-emitting diode whose color gives an indication of the amount of power being delivered to the blanket's heating elements at any given moment. With this arrangement, you do not even have to read the numbers off a dial. Though bright, the LED is a small point source that will not be annoying—yet it can be "read" in the dark even from across a room. All "switching" is done in complete silence by electronic means.

About the Circuit

The major distinction of our electronic blanket controller is that it controls the power supplied to the heating elements with a triac that interrupts the ac line voltage at different points on its waveform by a process called "phase control." (See the "How Phase Control Works" box for a detailed description of the circuit.)

Outputs from typical electromechanical and electronic controllers are compared in Fig. 1. You can readily see that although both controllers produce the same average temperature, the electronic phase-controlled version exhibits none of the long-term fluctuations exhibited by the electromechanical version.

The amount of power supplied by the solid-state controller depends on the ratio of the on time to the off time. To simplify setting the controller—especially in the dark—light-emitting diode *LED1* in Fig. 2 indicates this ratio. When the output of the controller is zero (no power delivered to the blanket), *LED1* glows green. As the heat control is turned up, *LED1*'s color goes to yellowish-green and then to fully yellow at the half-power setting. Further power increases to the blanket cause *LED1* to go through shades of orange until it becomes fully red at full power. Hence, a single multi-color light-emitting diode gives at-a-glance indication of the heat setting. For convenience, during construction, *LED1* is placed at the index of HEAT control *R2* so that the latter can be easily located in the dark.

Note also in Fig. 2 that this controller also has a special FAST WARM switch, *S2*, that makes it easy to

*Adapted from *Twenty Innovative E Projects for Your Home* by Joseph O to be published July 1988 by Tab Boo Blue Ridge Summit, PA 17214.

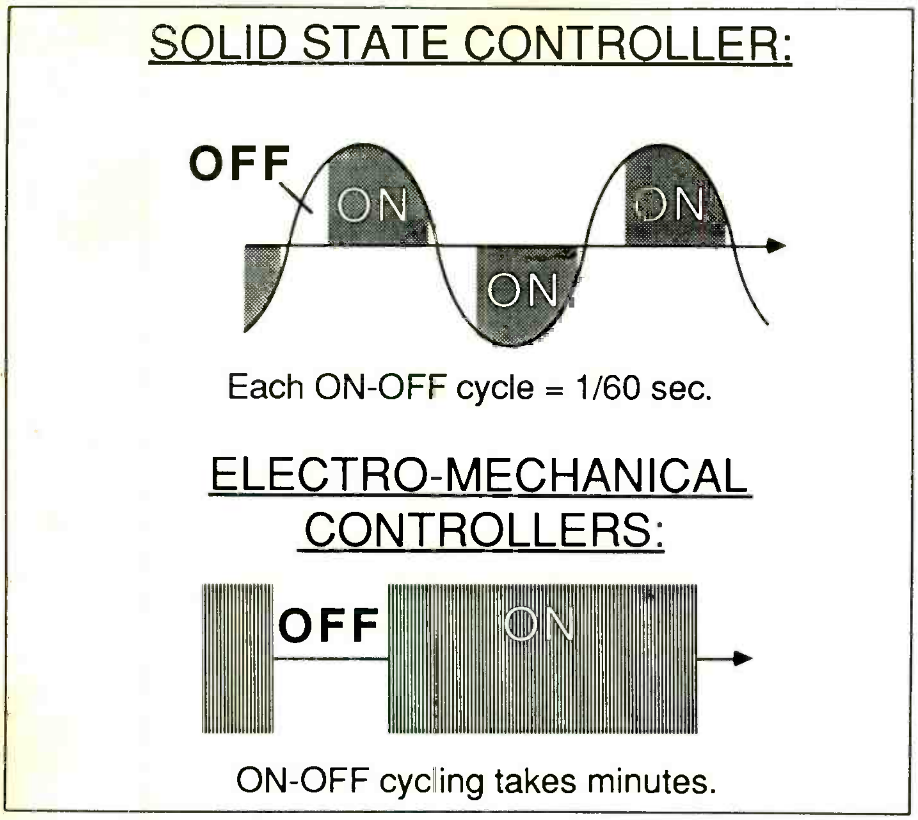


Fig. 1. Solid-state controllers have none of the long-term output variations that characterize electromechanical controllers.

warm up a cold bed quickly. Setting this switch to "on" bypasses the control circuitry and sends the full 117 volts of the ac line to the blanket. Although the HEAT control set to MAXIMUM does the same thing, a separate switch eliminates the need to frequently reset *R2*. Red light-emitting diode *LED2* flashes to let you know when the FAST WARM function has been selected.

Electromechanical controllers that the Fig. 2 circuit replaces have a rudimentary form of temperature compensation. The power they send to the blanket's heating elements varies in response to ambient room temperature and the dial setting. By building in temperature compensation, these controllers allow you to go to bed when the ambient temperature is still comfortable but drops to an uncomfortable level later on. It automatically increases power to the blanket as the room becomes colder.

In most cases, temperature compensation is not needed. Located inside the controller's housing, the temperature sensor cannot monitor the temperature of the sleeper. Thus, it cannot take into account the amount of insulation the bed provides or the amount of heat produced by the body. So even at best, this type of temperature compensation will be inaccurate.

Another reason why temperature compensation is not necessary in most cases is that changes in room temperature throughout a sleep period are usually slight in most homes. But the most important reason is the body itself. During sleep, the body regulates its own temperature throughout a wide range of ambient temperatures. Hence, the human body is remarkably tolerant of temperature variations.

The solid-state controller circuit shown in Fig. 2 is built around triac *Q1*, resistors *R1* and *R3*, potentiometer *R2* and capacitors *C2* and *C3*. Operation of this circuit is similar to that of a conventional lamp dimmer. Setting of the desired heating level is accomplished with HEAT control *R2*.

Three leads are provided on dual light-emitting diode *LED1*, one for the cathodes that are internally tied together and one each for the anodes of the red and green LEDs inside the device's molded plastic case.

At minimum setting of *R2*, *Q1* does not conduct, but current does flow through *S1*, *D1*, *R4* and the electric blanket's heating element to light the green LED element inside *LED1*. At this time, the red LED element remains off due to the triac's high resistance. However, when the setting of *R2* is turned up slightly, *Q1* begins to conduct for a brief period of time at the beginning of each half-cycle. For this short time, the green LED is shorted by *Q1* and power is switched to the red LED. Both LED elements inside *LED1* are never on simultaneously. The eye's image persistence combines a comparatively long interval of green and a short interval of red to resolve a yellowish-green color.

As the setting of the HEAT control is turned up, the red LED element remains on for longer portions of the ac waveform, the green LED element for shorter periods. This yields first a yellow, then an orange and, finally, a red perception of colors.

With *S2* set to FAST WARM, full ac line power bypasses *Q1* and is delivered directly to the blanket's heating element. When *S2* is in this position, *LED1* is switched out of the circuit and only *LED2* is switched in. Built into *LED2* is a CMOS chip that operates from a 3- to 7-volt power-supply potential. The dc supply for *LED2* is provided by *R6*, *D3* and *C7*.

Bypass capacitors *C1*, *C4*, *C5* and *C6* suppress arcing and radio-frequency emission in the circuit. Though the controller circuit will operate without these capacitors, the switches

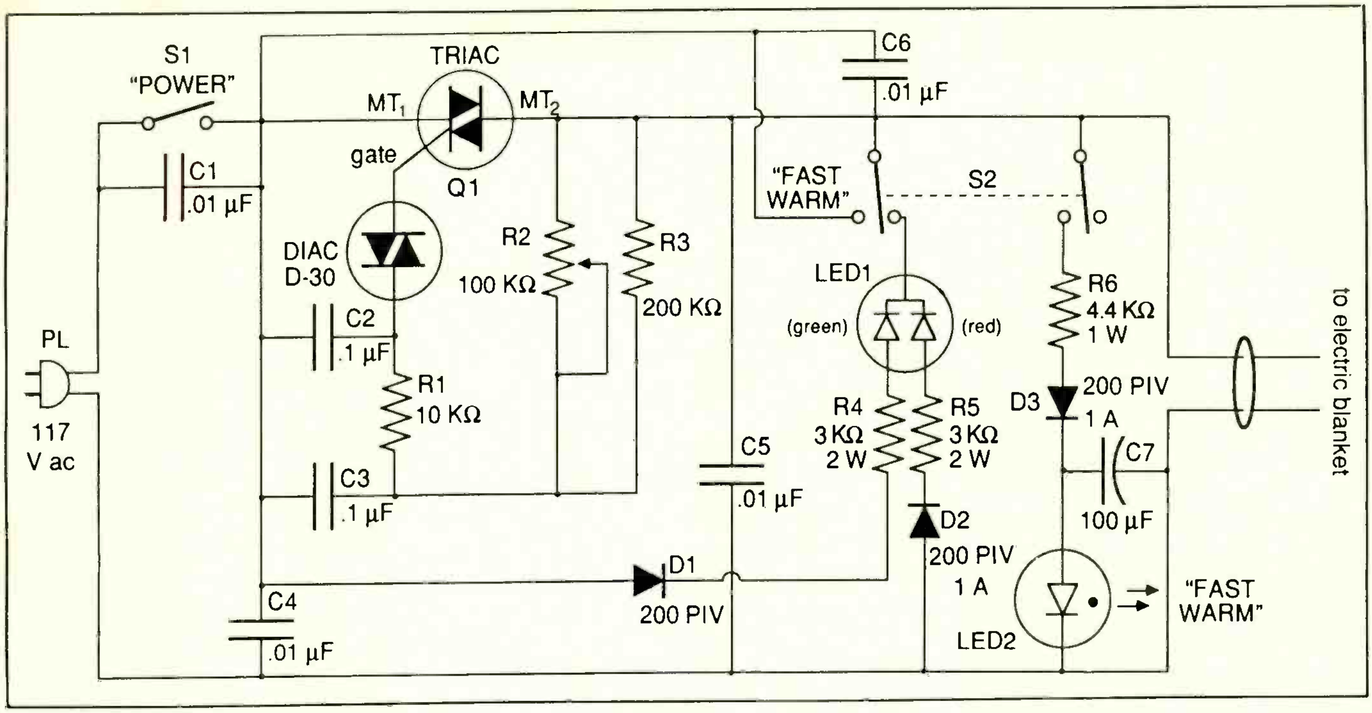


Fig. 2. The complete schematic diagram of all-electronic solid-state electric-blanket controller.

will soon wear out and nearby radios may pick up noise generated by the switching action of the triac.

Construction

A suitable enclosure for this project is one of the plastic project boxes that come with an aluminum faceplate. If you use such a box, mount the control, switches and LEDs in holes drilled through the box's plastic bottom and use the aluminum plate as the base of the box and the heat sink on which you mount the triac. When the project is fully assembled, affix four small anti-skid plastic feet to the metal plate.

Almost half of the components that make up this project mount on the plastic portion of the box and the aluminum faceplate. Those that do not mount directly to the box can be supported by terminal strips to which whatever wiring is needed is made. This being the case, the project is more suited to point-to-point wiring than it is to printed-circuit or perforated board wiring.

Components that mount directly to the plastic portion and aluminum faceplate of the box, include the LEDs, switches, potentiometer and triac. The point-to-point wiring arrangement is illustrated in Fig. 3. Solid black dots identify connections that are made without the aid of terminal-strip lugs. Circles with Xs in them indicate points where terminal-

PARTS LIST

Semiconductors
D1 thru D3—200-PIV, 1-ampere rectifier diode
D4—D-30 or equivalent (available from Active Electronics, P.O. Box 9100, Westborough, MA 01581; tel.: 1-800-343-0847)
LED1—Two-color light-emitting diode with three leads
LED2—Flashing red light-emitting diode (Radio Shack Cat. No. 276-036 or equivalent)
Q1—200-volt, 2-ampere triac

Capacitors
C1,C4,C5,C6—0.01-µF, 200-volt or better disc (value not critical)
C2,C3—0.1-µF, 200-volt or better disc
C7—100-µF, 10-volt electrolytic

Resistors (10% tolerance)
R1—10,000 ohms, ¼ watt
R3—200,000 ohms, ¼ watt (or whatever value gives smoothest control response over entire range of R2 when project is tested with incandescent light)
R4,R5—3,000 ohms, 2 watts (3,300-ohm, 2-watt resistor in parallel with a 33,000-ohm, ¼-watt resistor)
R6—4,400 ohms, 2 watts
R2—100,000-ohm linear-taper potentiometer

Miscellaneous
PL1—Ac line cord with plug
S1—5-ampere spst miniature toggle switch
S2—5-ampere dpdt miniature toggle switch
Suitable enclosure (see text); terminal strip (see text); rubber grommets (2); small-diameter heat-shrinkable or plastic tubing; mica washer and shoulder fiber washer for Q1 (see text); fast-set clear epoxy cement or hot-melt glue; lettering kit; machine hardware; hook-up wire; solder; etc.

strip solder lugs are needed. Any terminal strip used should be mounted on the aluminum faceplate of the box with machine hardware.

As shown in Fig. 3, you need at least three terminal-strip solder lugs to wire the circuit. Keep in mind that not every connection indicated by an X in a circle requires a separate solder-lug tie point. For example, no separate tie point is needed between *R5* and *D2*. You simply connect and solder together one lead of *R4* and the cathode lead of *D2* and then connect the anode lead of *D2* to the solder lug to which *PL1*, *C4*, cathode lead of *LED2* and one output conductor tie together.

When you connect to the lugs on the terminal strip, be sure not to use any that are electrically connected to the strip's mounting tab(s).

As you install each component and solder it into place, it is a good idea to use a red pen to indicate what you did on the Fig. 3 illustration or a photocopy of it. This reduces the possibility of wiring errors and shows you your progress. To make wiring even simpler, you might consider numbering the tie points on both the schematic diagram and the solder lugs.

Machining of the enclosure is quite simple. You need a separate 13/64-inch hole for each LED and suitably sized holes for mounting the switches and potentiometer on the plastic portion of the box. You also need an entry hole for the ac line cord entry and blanket cord exit. Arrange the holes for the potentiometer and switches in a pattern that you will readily recognize in the dark (see lead photo).

Mount the LEDs, potentiometer and switches in their respective holes. Secure the LEDs in place with clear fast-set epoxy cement or hot-melt glue. Then line the hole for the ac line cord and electric blanket cord with a rubber grommet.

Cut the blanket cable from the electromechanical controller that was originally supplied with the electric blanket. Separate the conductors at the cut end a distance of about 1½ inches and trim from each about ¼ inch of insulation. Tightly twist together the fine wires in each conductor and sparingly tin with solder. Prepare the free end of the ac line cord in the same manner.

Pass the free ends of both cords through the rubber grommet into the box and tie a knot in both about 4 to 5 inches from the ends inside the box to serve as a strain relief. Referring to Fig. 3, crimp but do not solder one ac line cord conductor to one lug of *S1* and repeat for the other conductor and the tie point identified with the X in the circle at the bottom of the illustration. Then crimp but do not solder the output cable to one lug of *S2* and the same tie point to which you crimped the second ac line cord conductor.

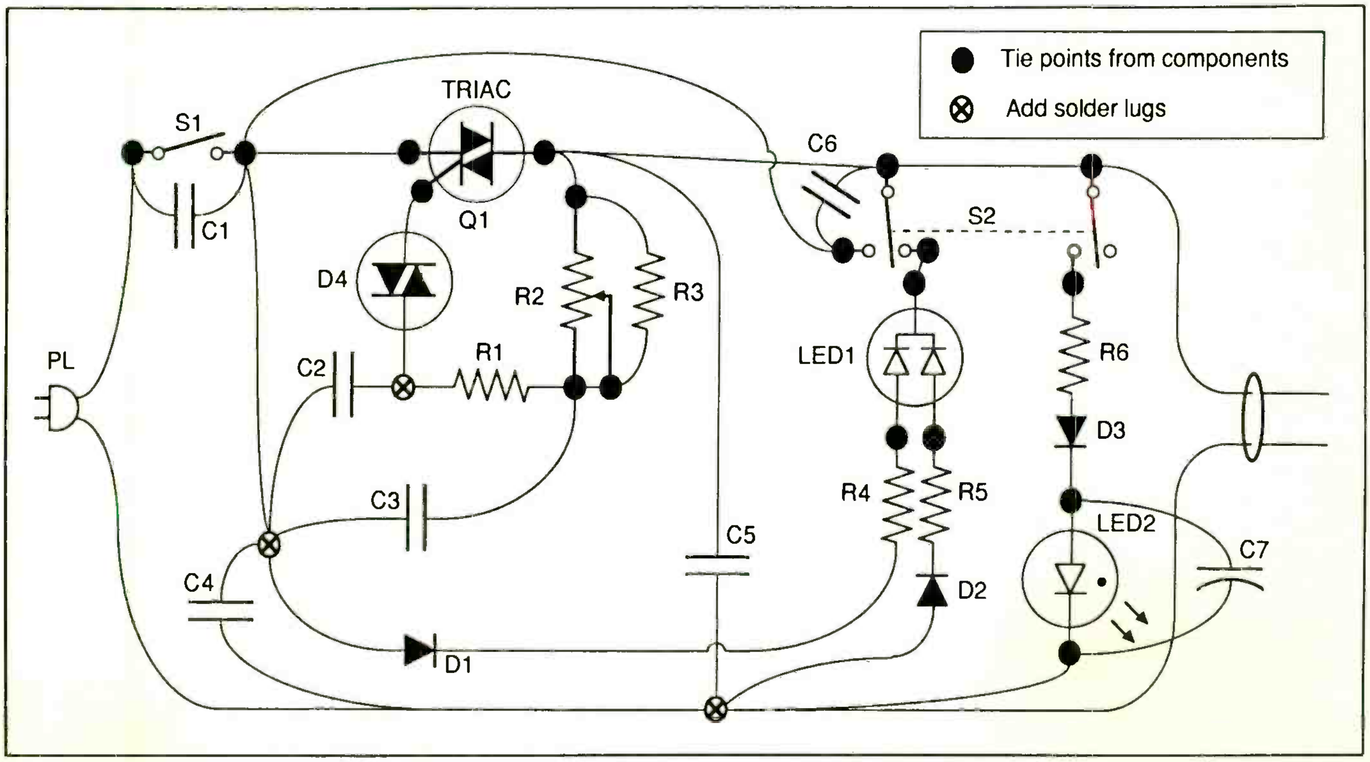


Fig. 3. The wiring guide for controller. Components are wired between each other's lugs/leads and a few added tie points, the latter indicated by Xs in circles.

How Phase Control Works

When controlling a large electrical device, it is more efficient to have it turned all they way on or all the way off, rather than in between. For the load to receive less than full power, the controlling circuit would have to dissipate the excess as heat. That would be inefficient. This is why high-power loads are controlled by rapidly switching them on and off. The average power the load receives can be any fraction of its full power, but at every instant it is either fully on or fully off.

A common and efficient way of controlling large ac loads is by means of phase control. Most phase-control circuits make use of the fact that ac already switches on and off twice in each cycle. To vary power, the circuits interrupt a selected part of each waveform and keep it from reaching the load. A typical output would show the ac waveform chopped into sections that are either fully on or fully off, as shown in Fig. 1 of the main article.

Switching is usually performed electronically, rather than electromechanically, with a triac whose gate pulse is derived in some way from the ac waveform itself. This assures that the control pulses are automatically synchronized with the power that is being switched on and off.

Shown in Fig. A is a phase-control circuit of the type commonly used in lamp dimmers and some motor speed controllers. There are two series RC phase-shift networks in this circuit: one made up of *R1* and *C1* and the other made up of *R2* and *C2*.

When ac is applied to a series-connected resistor and capacitor, as in the two cases in this circuit, an ac voltage appears at the top of the capacitor. This ac voltage lags the applied voltage by a phase difference of from 0 to 90 degrees, depending on the setting of the potentiometer in the first RC network. If you could see both the applied ac voltage and the voltage across *C1* on an oscilloscope, you would see the ac line voltage and, following it, a second delayed voltage.

With a 100,000-ohm potentiometer,

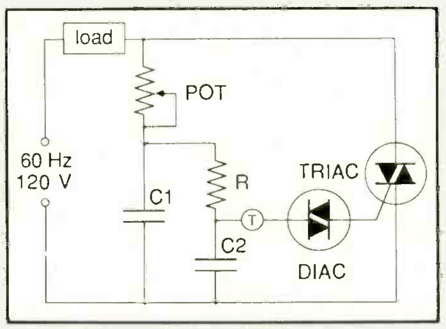


Fig. A. A full-wave phase-control circuit typically used in light dimmers and motor speed controllers.

the phase shift is variable from 0 at minimum setting (where the output is electrically connected to the input) to a maximum of about 75 degrees. The *R2/C2* network extends the total phase shift range from 0 to 180 degrees at point *T* in Fig. B by varying the setting of the potentiometer. The phase-shifted signal at point *T* is used to trigger the triac that controls power to the load.

The diac in Fig. A is a two-way voltage threshold switch that is needed here because the gate sensitivity of a triac is not symmetrical. A diac's triggering voltage is the same in both directions and is well in excess of the triggering voltage of the triac. Use of a diac makes the triac equally sensitive in both polarities of gate signals since the triac must wait for the diac to conduct before it fires. The diac used in the project described in the main article will conduct when 30 volts appears across its terminals in either direction.

In Fig. B, the point at which the voltage at *T* reaches ±30 volts determines the point at which the triac begins to conduct power to the load. However, bear in mind that the voltage present at point *T* is the delayed sine wave. Relative to the main ac waveform, the time at which point *T* reaches 30 volts can be varied by the potentiometer in Fig. A. Consequently, the point where the triac begins to conduct can be varied to take place over a 0-to-180-degree range in the ac waveform. Once the triac triggers into conduction, it remains conducting until the zero-crossing point in each half-cycle is reached. Therefore, what the potentiometer is actually controlling is the *interval* during which the triac remains on. This interval is the amount of on time to off time and is responsible for the amount of power the load receives.

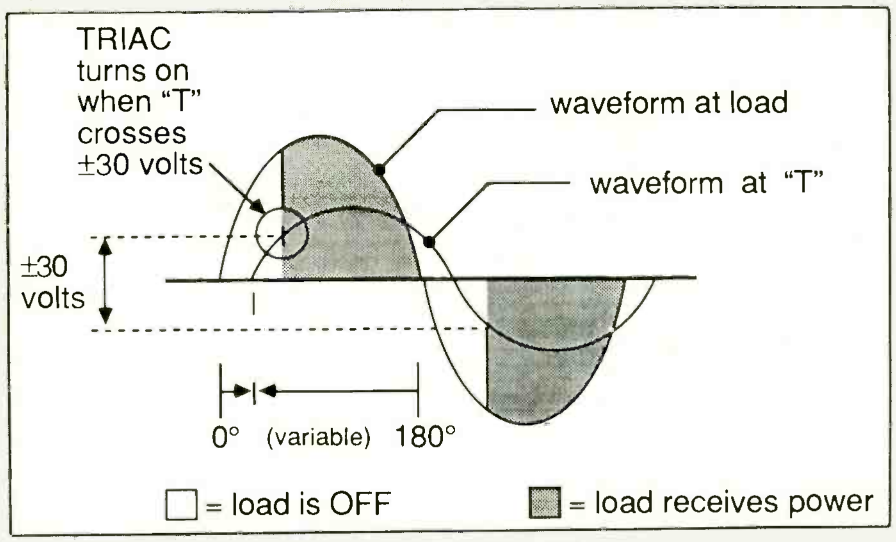


Fig. B. Large-excursion ac waveform is output to load; smaller-excursion waveform that appears at point T in Fig. A can be "moved" left or right by the potentiometer.

In the following procedure, hookup-wire lengths are given for a small enclosure box. If you use a larger box, adjust the lengths as needed. Also, always trim all component lead lengths so that, when mounted, the components cannot sag and possibly cause unwanted short circuits. Wherever possible, use small-diameter heat-shrinkable tubing or plastic tubing to insulate bare wire leads and connections. In any case where a component's lead length is insufficient to bridge two points, you can lengthen the lead with insulated hookup wire. The best way to do this is to cut the component's lead to ½ inch long and crimp and solder it to the hookup wire. Then insulate the connection with tubing.

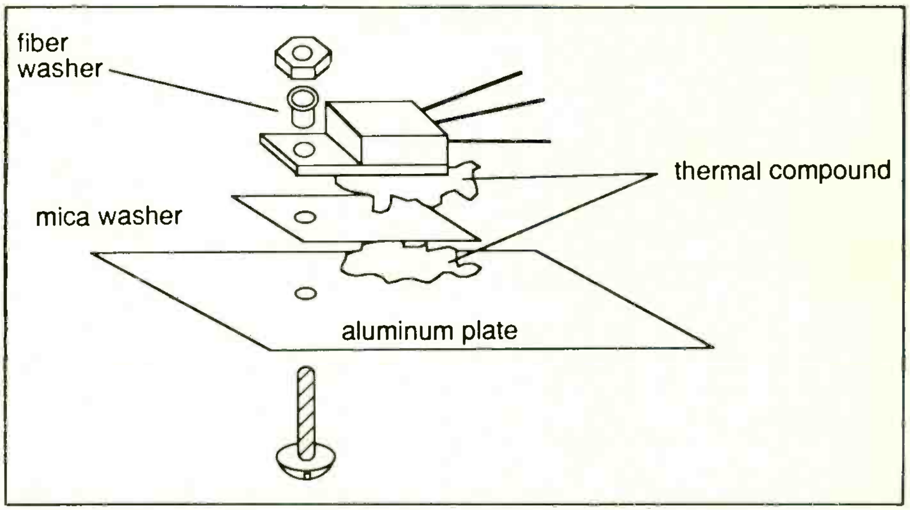


Fig. 4. The proper way to isolate the triac from the project box's metal faceplate heat sink.

Crimp the anode lead of *D2*, one lead of *C4* and *C5* and the cathode lead of *LED2* to the tie point to which you crimped the line cord and output cable conductors. Before soldering, heat sink *D2* and *LED2* and solder all six leads to the terminal strip solder lug.

Crimp the other lead of *C4*, a 3-inch insulated wire from which you have stripped ¼ inch of insulation from both ends, and one lead of *C2* and *C3* and the anode lead of *D1* to a second lug on the terminal strip. Heat sink the diodes and solder the four leads and one wire to the solder lug. Crimp the free end of the wire to the unoccupied lug of *S1*.

To the third and final lug on the terminal strip, crimp but do not solder the other lead of *C2* and one lead of *D4* and *R1*. Once again, heat sink the diac and solder all three leads to the lug.

After trimming them to appropriate length, if needed, crimp but do not solder the leads of *C1* to the lugs of *S1* and *C6* to the appropriate lugs of *S2*. Then interconnect the specified switch lugs by crimping an appropriate length of hookup wire as shown. Trim ¼ of insulation from both ends of a 3-inch hookup wire and crimp one end to the specified lug of *S1* and solder the capacitor lead and all three wires to the lug.

Now crimp but do not solder a hookup wire to the specified outer lug on *R2*. Crimp the leads of *R3* and the free leads of *C3* and *R1* to the other outer lug of *R2*. Pass a bare solid wire from the lug to which *C3*, *R1* and *R3* are crimped to the center lug on the potentiometer. Solder the center-lug connection and trim away any excess wire length that might possibly short to the third lug. Then solder the two outer lug connections of *R2*.

Crimp one end of a 4-inch hookup wire to the toggle lug of *S2* to which *C6* is crimped. Pass a bare solid wire through both toggle lugs of *S2* and solder the connections at both lugs of the switch.

Carefully twist the leads of *C7* around those of *LED2* (observe polarity). Solder both connections. Then solder the cathode lead of *D3* to the junction of *C7* and anode lead of *LED2*. Solder the anode lead of *D3* to one lead of *R6* and crimp and solder the other lead of *R6* to the appropriate lug on *S2*.

Identify the anode lead for the green LED element in *LED1* and connect and solder to it one lead of *R4*. Do the same for the red LED element and *R5*. Connect and solder the free leads of *R4* and *R5* to the cathode leads of *D1* and *D2*, respectively. Then crimp and solder the common cathode lead of *LED1* to the appropriate pole lug of *S2*.

Drill a hole for mounting triac *Q1* on the aluminum faceplate. When mounted, make sure that neither the triac nor its mounting hardware make electrical contact with the aluminum plate. To assure this, use thermal grease or paste and a mica washer between the triac and metal plate and an insulating shoulder fiber washer between the machine hardware and the triac's mounting tab, as illustrated in Fig. 4.

Once the triac is mounted into place, carefully connect and solder the free ends of wire coming from *S1* to *Q1*'s MT1 terminal. Use a 1-inch length of tubing to insulate the connection. Connect the free end of the wire coming from the potentiometer and the free lead of *C5* to the triac's MT2 terminal. Finally, connect and solder the free lead of *D4* to the GATE terminal of the triac, again using tubing to insulate the connection. This completes wiring the circuit. Place a control knob on the potentiometer.

Shown in Fig. 5 is a photo of the fully wired project inside a small plastic project box that has an aluminum faceplate.

Checkout & Use

With the project completely wired and double checked for poor soldering and incorrectly connected or oriented components, particularly with regard to the triac, test it before putting it into service. To do this, you need an incandescent lamp to use as the load instead of the blanket itself. Using a lamp gives an immediate visual indication of circuit operation.

A convenient way to connect the lamp to the output of the project is to temporarily solder a zip cord terminated in an ac receptacle to one toggle lug of *S2* and the terminal strip lug to which one conductor of the ac line cord is connected. Plug the lamp's cord into the ac receptacle. Then turn on the lamp and make sure *S1* and *S2* are set to "off" and *R2* is set for minimum output. Plug the project's line cord into an ac outlet; neither LED should be on.

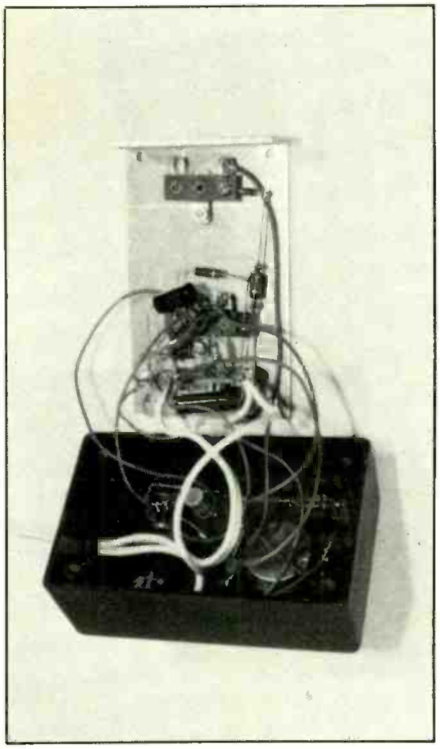


Fig. 5. Interior view of completed project.

Setting POWER switch *S1* to "on" should cause *LED1* to glow green. If this occurs, setting FAST WARM switch *S2* to "on" should cause *LED2* to light and flash and the lamp to turn on at full brilliance. If you do not obtain these results, power down the project and recheck all wiring. Do not proceed until you have corrected the problem.

With *S1* on and *S2* off and *R2* set for minimum output, *LED1* should be glowing green and the incandescent lamp should be off. Slowly adjusting the setting of *R2* toward full output should cause *LED1* to change color to first yellow, then orange and finally, at full power, to all red. Simultaneously, the lamp should begin to glow and become brighter as the control is turned up. At full output power *LED1* should be glowing red and the lamp should be at full brightness.

Once you obtain the above results, the circuit is working properly. Unplug the project from the ac outlet and desolder the test cable from *S2* and the terminal strip lug. Finally, mount the aluminum faceplate on the box and fix to it four small antiskid rubber feet. Label the switches, LEDs and control, as shown in the lead photo.

As mentioned previously, this controller is a direct replacement for the electromechanical controller originally supplied with your electric blanket. Once you have made the substitution, use your blanket as you normally would, controlling it with this project instead of its original unit. Lack of temperature cycling and silent operation will not be noticed, except by their absence, but other features can be appreciated more readily.

The FAST WARM function is useful on those cold days when you want to quickly warm your bed before getting into it. Set both switches to "on" about 5 minutes before you plan to retire to use this function.

Take care not to leave *S2* on too long, especially if your electric blanket is covered or folded. Even though all electric blankets come with built-in thermal cutoffs; and no fire hazard exists, too much heat is not good for the blanket's fabric.

Once your bed is warmed sufficiently in the FAST WARM mode, set *S2* to "off" and adjust the setting of HEAT control *R2* for a comfortable heat setting. Use two-color *LED1* as a guide to temperature setting. With a little experience, you will quickly come to know what setting is best for you simply by observing the color of the LED as you adjust the control setting. **ME**

Surface-Mount-Device Repair

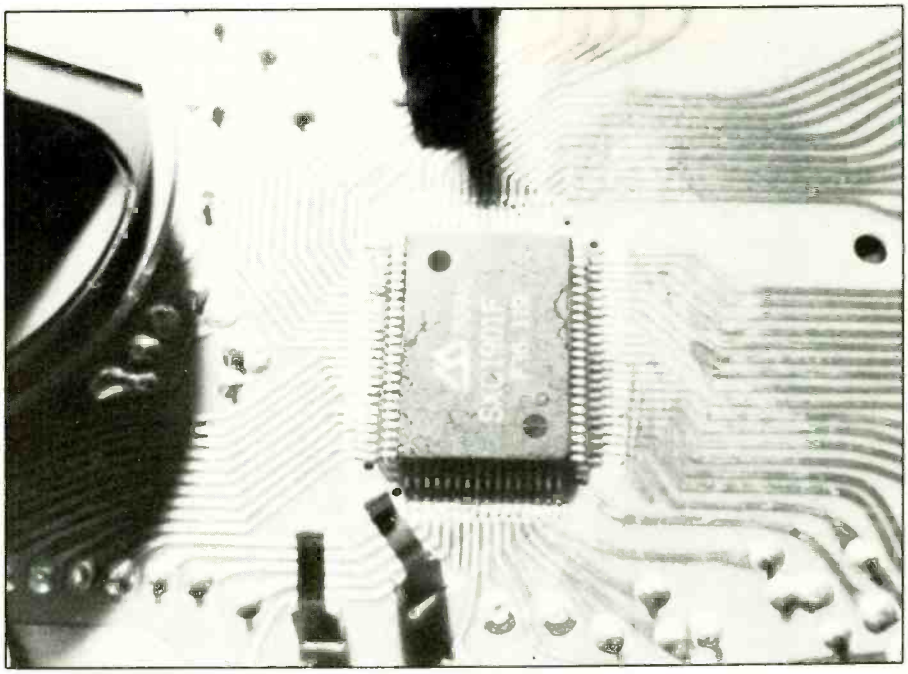
How to remove flat-packaged SMDs using soldering tools

By Victor Meeldijk

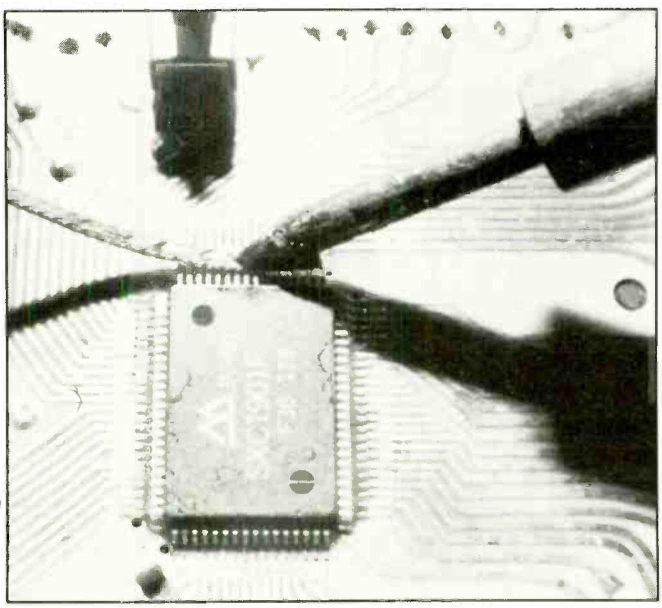
In a manufacturing facility, replacement of surface-mount integrated circuits, such as the 80-pin flat package pictured, would be accomplished with either a conduction soldering iron, which heats all soldered connections at once and lifts the part up with its tong-like tips, or a convection soldering machine. The convection uses low-pressure hot air directed at both the top of the component and the circuit card's underside. When all connections are molten, the device is lifted off the pc board using tweezer tongs.

While these are rapid and efficient methods for production work, such repairs can be accomplished using common soldering tools for occasional SMD removal.

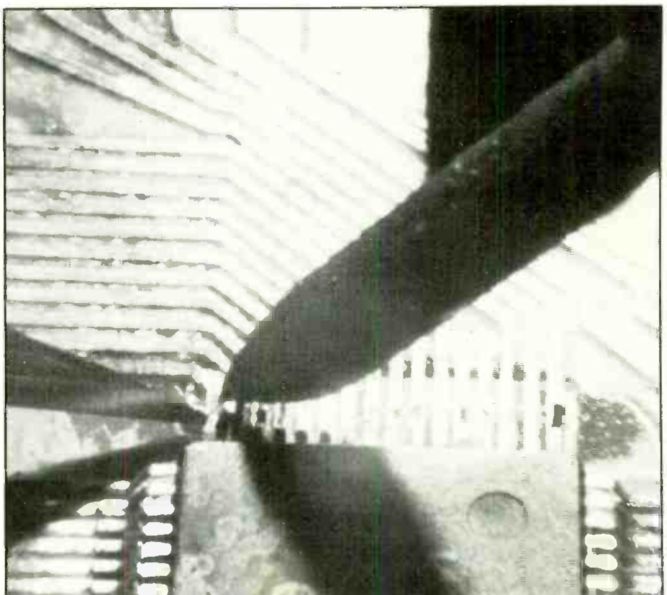
(Continued on page 90)



An 80-pin surface-mount flat package device to be replaced.



Use desoldering braid to remove solder from all device connections. Be sure to employ a grounded soldering iron and wear an ESD wrist strap while doing such work to prevent electrostatic damage to the IC.

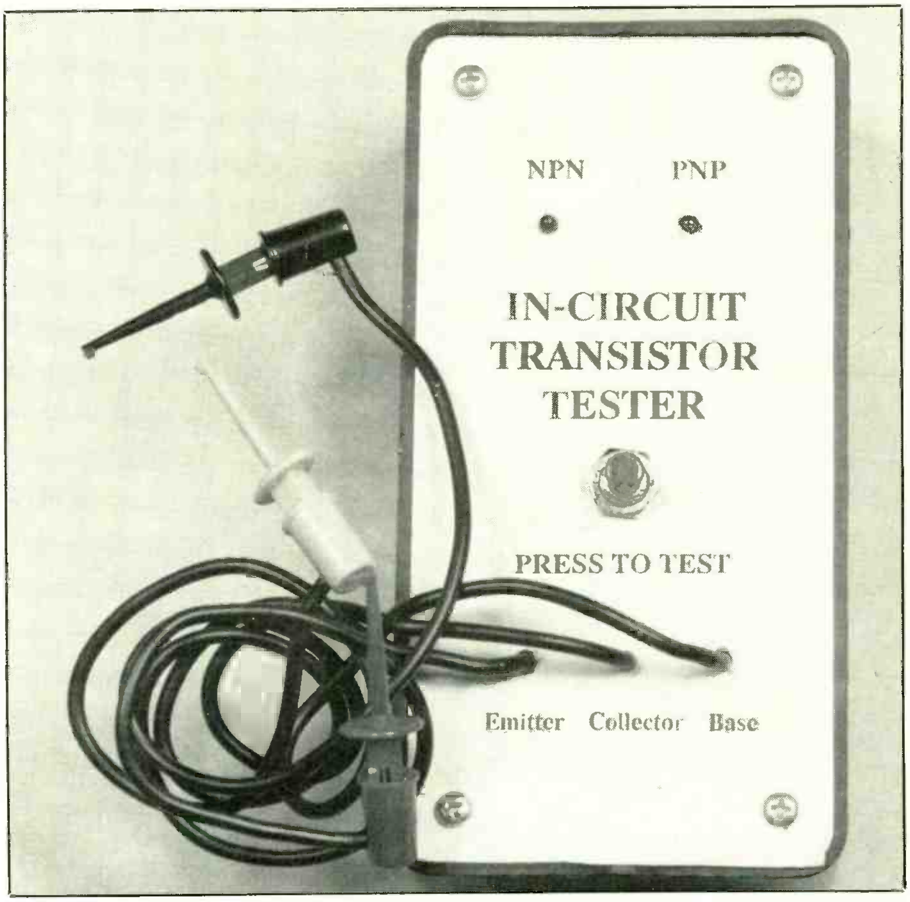


While heating IC connections with a soldering iron (left), free them from the circuit card by using a sharp-pointed hobby knife.

An In-Circuit Transistor Tester

A low-cost bench/portable instrument for testing bipolar transistors in- and out-of-circuit

By Jules H. Gilder



Even if you have good electronic troubleshooting skills and can zero in on a defective circuit section, you are still faced with confirming your suspicion that a transistor is bad. To do this, you will likely have to remove the device from a crowded area and test it with either a transistor tester or an ohmmeter. If your guess proves wrong, you will have to solder the device to the printed-circuit board land, risking excessive-heat damage to the transistor and possibly to the pc foil . . . then repeat the process with another suspect.

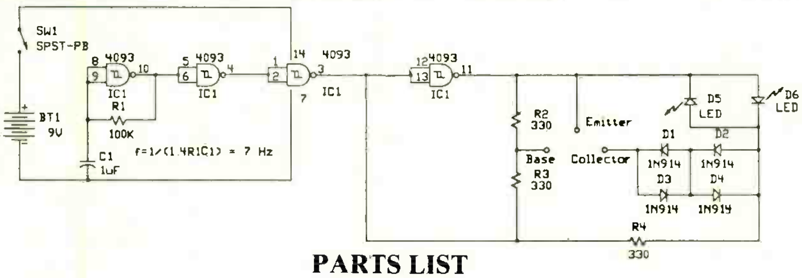
A much better way to troubleshoot transistorized circuits is provided by an *in-circuit* transistor tester, which eliminates the foregoing problems and saves a lot of time and frustration. You can build the one to be described for about $25 or less, including the enclosure. It is worth its weight in gold.

Our In-Circuit Transistor Tester's test clips make it easy to connect it directly to the leads of any bipolar transistor, even if the transistor is on a densely packed pc-board assembly. Using a pair of light-emitting diodes, one each for npn and pnp transistors, the Tester indicates when a suspect transistor is good or bad and simultaneously identifies it by type. If either LED lights, the transistor is good. On the other hand, if the two LEDs alternately flash or do not flash at all during a test, the transistor is bad.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the In-Circuit Transistor Tester. Its simple, straightforward design makes use of a single CMOS NAND-gate Schmitt trigger integrated circuit, identified as *IC1*. This 4093 IC is a bistable device that does not respond directly to an input signal. Rather, its snap action response, known as "hysteresis," creates a dead band that is useful for cleaning up slow and noisy digital signals.

The dead band is the result of the fact that a Schmitt trigger's input



PARTS LIST

BT1—9-volt battery
C1—1-μF, 25-volt electrolytic capacitor
D1 thru D4—1N914 switching diode
D5,D6—Miniature red light-emitting diode
IC1—4093 CMOS quad 2-input NAND Schmitt trigger
R1—100,000-ohm, ⅛-watt, 10% tolerance resistor
R2,R3,R4—330-ohm, ⅛-watt, 10% tolerance resistor
SW1—Momentary-action, normally-open spst pushbutton switch
Misc.—Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware (see text); suitable enclosure (see text); 14-pin DIP socket for IC1 (optional); snap connector for BT1; three ball-type or miniature alligator-clip test connectors (see text); three small rubber grommets; double-sided foam tape; adhesive-backed clear plastic laminate (see text); test cable and hookup wire; solder; etc.

Note: A complete kit of parts (less 9-volt battery, IC socket, plastic laminate and grommets) is available for $19.95 from: Redlig Systems, Inc., 2068 79 St., Brooklyn, NY 11214.

Fig. 1. Complete schematic diagram of In-Circuit Transistor Tester.

voltage must rise above a certain level, known as the high trip point, before the output voltage can change. Similarly, the input voltage must drop below a certain level, which is lower than the high trip point, before the output can change once again. Any change that occurs within the dead band itself has no effect on the output.

Built-in hysteresis makes it possible to design and build an astable oscillator with just a single gate, as shown for the gate at the left, capacitor *C1* and resistor *R1* in Fig. 1. Frequency of oscillation is calculated using the formula $f = 1/(1.4RC)$. With the component values shown in the schematic diagram and specified in the Parts List for *R1* and *C1*, oscillator frequency is approximately 7 Hz.

All remaining gates in *IC1* are used simply for inversion and buffering. The first of these gates following the oscillator isolates the latter from the rest of the circuit to prevent frequency drift as a result of loading. The remaining two gates are used to produce the complementary outputs needed to enable testing of both npn and pnp transistors.

Note that both inputs of each of the four gates that make up *IC1* are tied together. This is done because only the Schmitt trigger inversion—not the normal NAND—function is required in this project. Although a 4584 hex inverter Schmitt trigger could have been used to accomplish the same results, a 4093 (with the circuit modifications shown) is much more readily available from consumer sources.

The complementary outputs produced by the final two gates in *IC1* are connected to light-emitting diodes *D5* and *D6* through current-limiting resistor *R4*. Only one current-limiting resistor is needed in this arrangement because only one of the LEDs will normally be on at any given time.

The LEDs are connected in a reverse condition that is often referred to as anti-parallel. That is, the anode of one is connected to the cathode of the other and the remaining two leads are tied together. With this arrangement, when a logic high voltage appears at pin 11 of *IC1* and the voltage at pin 3 is at a logic low voltage, *D5* is held in reverse bias while *D6* conducts and the LED lights. With no transistor connected to the circuit, the outputs at pins 3 and 11 of *IC1* change at a frequency of about 7 Hz, allowing the LEDs to blink on and off alternately.

In addition to being connected to the LEDs, the complementary outputs at pins 3 and 11 of *IC1* are applied to the resistor network composed of *R2* and *R3*. The junction of these two resistors is brought out as a test point and is connected to the base of the transistor under test. The emitter of the transistor connects directly to pin 11 of *IC1*, while the collector connects to the *D1* through *D4* parallel diode arrangement and *D5* and *D6* anti-parallel LED arrangement.

An important purpose is served by the strange diode arrangement. When a transistor under test has an internal short circuit between its collector-base or base-emitter junctions, the good half of the transistor acts like an ordinary diode and will normally conduct and indicate a "good" transistor. When either *D1* and *D2* or *D3* and *D4* are conducting, a drop of about 1.2 volts appears across the operating pair. This voltage adds to the voltage dropped across the transistor being tested. If the transistor is good, the drop will be about 0.1 volt, and the total drop across the LEDs will be 1.3 volts for the half cycle that the transistor is conducting.

On the other hand, if the transistor being tested has a base-emitter or base-collector short, the 1.2-volt drop across the diodes adds to another 0.6-volt drop across the bad transistor to produce a drop of 1.8 volts. This is enough to turn on the LED. Therefore, internal short circuits will cause both LEDs to alternately flash.

Construction

Because the circuitry for this project is very simple, just about any wiring technique can be used to build the project. For example, you can etch and drill your own printed-circuit board using the actual-size etching-and-drilling guide shown in Fig. 2 (or purchase a complete kit of parts that contains a ready-to-wire board from the source given in the Note at the end of the Parts List). Alternatively, you can assemble the circuit on perforated board with holes on 0.1-inch centers using suitable soldering or Wire Wrap hardware. The following describes pc construction.

With the pc board component side up and oriented as shown in Fig. 3, start populating it by installing and soldering into place a 14-pin DIP IC socket in the IC1 location. Be careful to avoid creating solder bridges between the closely spaced copper pads on the bottom of the board. (Note: A socket is optional but highly recommended should the 4093 IC ever have to be replaced. If you do not use a socket for this IC, do *not* install the 4093 itself at this stage of construction.)

Next, install diodes *D1* through *D4* on the lower left of the board, taking care to properly orient each. Then flip over the board and solder all leads to the copper pads.

Install and solder into place the resistors, once again clipping off excess lead lengths. Making sure to properly polarize the electrolytic capacitor as shown, plug its leads into the specified holes in the board.

Prepare three 18-inch lengths of miniature test-lead wire by stripping from both ends of each ¼ inch of insulation. Tightly twist together the

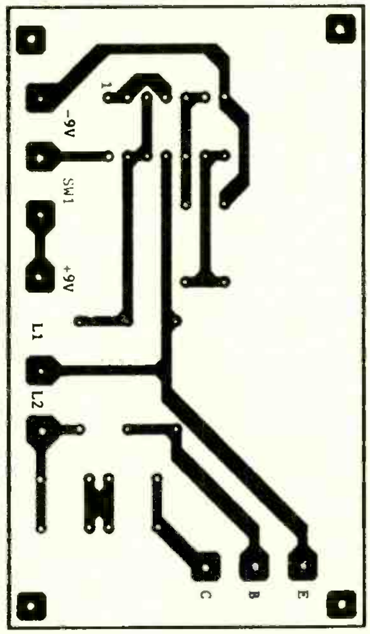


Fig. 2. Actual-size etching-and-drilling guide for fabricating printed-circuit boards.

fine wires at both ends of each wire and sparingly tin with solder. Plug one end of these wires into the holes labeled E, B and C in the upper-left of the board and solder into place.

Prepare four 6-inch lengths of hookup wire as you did for the test-lead wires and plug these into the holes labeled L1, L2 and SW1. Crimp the anode lead of one LED to the cathode lead of the other and then crimp together the remaining two LED leads. Solder the crimped con-

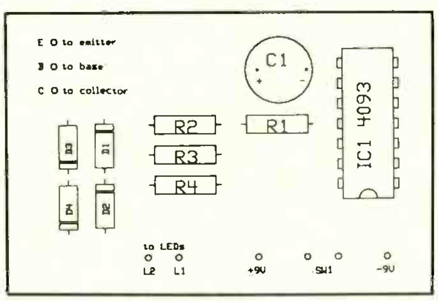


Fig. 3. Wiring guide for pc board. Use this layout as a general guide to component placement if you build circuit on perforated board.

nections, making sure to use soldering heat judiciously, and heat sink the LEDs to prevent heat damage.

Connect and solder the LED connections to the free ends of the L1 and L2 wires. Then connect and solder the free ends of the SW1 wires to the lugs of the normally-open spst pushbutton switch.

Tightly twist together the fine wires of both conductors of the 9-volt battery snap connector and sparingly tin with solder. Plug the red-insulated wire into the hole labeled +9V and the black-insulated wire into the hole labeled −9V.

You can use any suitably sized project box as an enclosure for the project. An ideal enclosure to use is a project box that has an aluminum front panel and measures 5 inches long by 2.5 inches wide by 1.5 inches deep. Only the front panel requires machining to prepare it for housing the project.

If possible, make a same-size photocopy of the actual-size artwork shown in Fig. 4 to use as a machining template for the project's front panel. Trim the photocopy to the outline border and tape it to the front panel. Using a center punch or sharp nail, gently detent the metal panel in the locations indicated by the six dots to prepare it for drilling the holes for the LEDs, switch and exits for the test leads.

Remove the template and use a 17/64-inch bit to drill the hole for the switch and test leads. Then use a 7/64-inch bit to drill the holes for the LEDs. Deburr all holes to remove sharp edges.

You can use either the actual artwork shown in Fig. 4 or a photocopy of it as a finished front panel for the project. The latter is recommended, since you will avoid any possibility of print on the opposite surface of the paper from "bleeding" through when the artwork is mounted to the panel.

Trim the artwork to about ¼ inch wider and longer than shown. Then

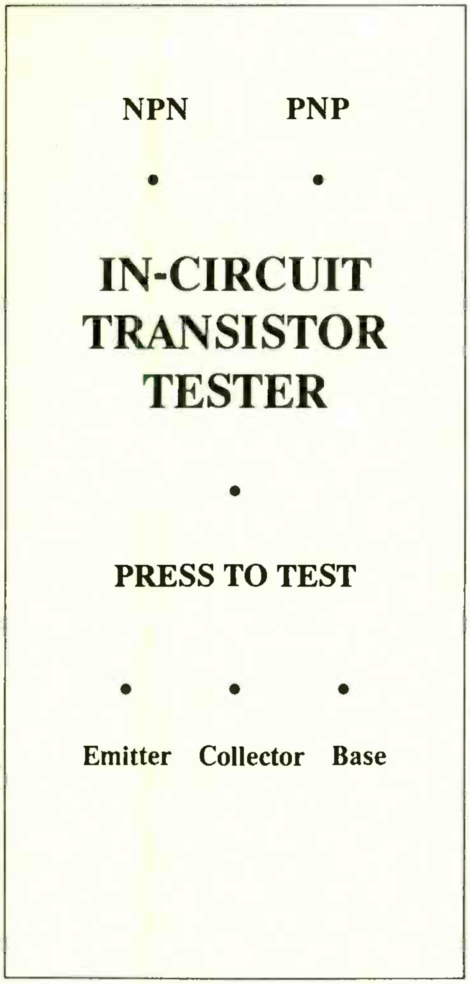


Fig. 4. Actual-size front-panel artwork. Use this or a same-size photocopy also as a machining template for front panel of project box.

face it with clear adhesive-backed plastic laminate (available from photographic, art-supply and most stationery stores) to protect it from damage as you use the project. Work carefully to avoid wrinkling the artwork as you lay on it the plastic laminate. After the laminate is completely down on the artwork, place the assembly laminate side up and solidly burnish it to the paper. Then trim the artwork to the exact dimensions of the metal front panel plate.

Coat the rear surface of the artwork and outer surface of the front panel with rubber cement and allow both to dry until they are tacky to the touch. Then very carefully place the artwork on the panel, starting from one corner. Once again, burnish the artwork to the panel.

Working *very* carefully with a sharp hobby knife, cut the artwork away from all holes. Work on the *artwork* side of the panel as you do this and be as neat as you possibly can. Gently work small rubber grommets into the EMITTER, COLLECTOR and BASE holes in the front panel from the artwork side to avoid lifting the artwork. Then mount the pushbutton switch in its hole in the center of the panel.

Tie a strain-relieving knot in each of the test-lead wires about 5 inches from the circuit-board end. Pass the free ends of these wires through the appropriate grommet-lined holes in the panel. Refer to both Fig. 3 and Fig. 4 to identify the test leads and the holes they are to exit the box.

You have a choice of either ball-type connectors like those shown in the lead photo or ordinary miniature alligator clips with insulated boots for terminating the test leads. The ball-type connectors are preferable because they provide more positive electrical contact and a more solid mechanical grip and present very little bare metal to short against points in a circuit that should not enter into a test.

Checkout & Use

Snap a fresh 9-volt battery onto the connector. Touch the common lead of a dc voltmeter, set to indicate at least 10 volts, to the pin 7 connector and the "hot" lead to the pin 14 connector of *IC1*'s socket. Press the switch's pushbutton and note the reading on the meter. If you do not obtain a reading of approximately 9 volts, release the switch and carefully check all components for proper orientations (diodes, LEDs and electrolytic capacitor) and all soldering for bridges and poor connections. Correct the problem before proceeding.

Once you obtain the proper 9-volt dc reading between pins 14 and 7 of the IC socket, release the switch's pushbutton and install the 4093 in the IC socket. Make sure you orient the IC as shown and take care to avoid having any pins overhang the socket or fold under between socket and IC body as you push the 4093 home. Exercise the usual precautions for MOS devices when handling the IC. If you are soldering the IC directly on the board, us a soldering iron with a grounded tip.

With the IC installed, press and hold down the switch's pushbutton and observe the activity of the LEDs. If everything is working properly, the two LEDs will alternately flash on and off. If both LEDs flash in step with each other, the two are not properly connected in anti-parallel with each other. In this event, power down the circuit and transpose the leads of one LED. If neither LED flashes, you have an error in construction and must recheck your wiring to correct the problem.

Having obtained proper flashing, release the switch's pushbutton and connect to the test leads a good transistor (you can use either a pnp or an npn transistor). Once again, press and hold the switch's pushbutton and note which LED lights. Mount this LED in the appropriate hole in the front panel of the enclosure. That is, if you are using an npn transistor for this test, the LED that lights goes into the NPN hole in the panel. The other LED then goes in the remaining LED hole. If the LEDs tend to fall out of their holes, secure them in place with either clear nail enamel or fast-set epoxy cement.

Cut a piece of double-sided foam tape to the approximate length and width of the the circuit-board assembly and another to the approximate length and depth of the 9-volt battery. Peel the protective backing from one side of the larger piece of foam tape and affix the tape to the

(Continued on page 90)

How to Build Your Own IBM PC-Compatible Computer by Gordon McComb. (Comprehensive Guides, 7507 Oakdale Ave., Canoga Park, CA 91306. Soft cover. 106 pages. $12.95.)

Written to guide the person who wants to assemble an IBM PC compatible computer, this book provides general details needed to do the job. Coverage begins with an introduction to PC technology and the hardware that makes up a true PC clone. The author then discusses where to buy clone parts and subsystems, and three levels of PC clones (a starter system, a basic business system and an enhanced business system). Assembly of the components that make up each is detailed step by step so that even someone with no knowledge of electronics or computers will understand how to put together the system of his choice. Following assembly comes testing of the system and installation of add-ons.

There are no photos in the book. Instead, an array of drawings guide the reader through assembly, setup and testing. Frankly, the drawings are easier to follow and less prone to lead the reader to interpretation errors than is the case with photos.

Despite a handful of typographical errors (none of a nature to cause problems), this is a worthwhile book to have if you are seriously considering putting together a PC-compatible computer. Its appendices provide such important technical details as specifications, connector pinouts, installation of a hard disk, troubleshooting charts, using the turbo motherboard and, always important, schematic diagrams.

The Benchtop Electronics Reference Manual by Victor F.C. Veley. (Tab Books. 620 pages. $34.95 hard cover, $24.95 soft cover.)

Handbooks like this one are always popular among electronics technicians and hobbyists alike because they provide a one-stop source of valuable information on a wide variety of topics. Though this book is encyclopedic in nature, it is by no means arranged is dictionary-like fashion. Rather, it is written more along the lines of a traditional textbook, with explanatory text, lucid illustrations, schematic diagrams and a host of mathematical formulas. The contents are of a fairly technical nature instead of being a simple overview, as is the case with many such books.

Divided into five parts, the book contains 160 topic chapters on direct current, alternating current solid-state devices and circuits, vacuum tubes and circuits and radio communications. Succeeding chapters build upon the material presented in previous chapters. Each chapter contains a brief but fairly complete description of the material to be covered. Wherever applicable, mathematical derivations are provided. At the end of each chapter there are one or more examples that show how the material covered is put to practical use, using real component values. This makes possible using the manual for laboratory experiments. Following each example is a detailed solution that reinforces the point or points being made.

Though basic solid-state devices and circuits are covered, vacuum-tube circuits, still a part of the radio communications scene, are discussed in more detail than usual. In fact, taking all the communications topics together, this book covers most of the requirements for the FCC Commercial General Radiotelephone Operator's License. The book concludes with eight appendices, all of which supplement the material presented in the communications section. In all, this thick book (it measures almost 2 inches between its covers) deserves a prominent place on your bookshelf.

NEW LITERATURE

Instruments/Accessories Catalog. An all new 164-page catalog that lists and describes some 2,000 items of interest to electronics enthusiasts and professionals is available from Fordham Radio. Among the items listed are: test instruments and accessories; CATV, CCTV and MATV equipment and accessories; tools and assembly aids; CB radios, car stereos and auto accessories; replacement components; security devices; video equipment and accessories; radar detectors; and an assortment of consumer electronic and entertainment products. All items listed are illustrated and fully described with specifications and applications data and show discount pricing. For a free copy, write to: Fordham Radio, 260 Motor Parkway, Dept. ME, Hauppauge, NY 11788.

Test Equipment Catalog. A new catalog that lists and describes new and custom-reconditioned electronic test instruments available at savings of up to 70 percent has been announced by Accutest Instruments. Listed are a wide range of models of ac and dc power supplies, recorders, plotters, X-Y recorders, oscillators, pulse and function generators, oscilloscopes, component testers, calibration instruments, r-f and microwave sources and accessories, counters, timers, line conditioners, logic and spectrum analyzers, DVMs, analog meters and environmental chambers. Products from most major manufacturers are represented. For a free copy, write to: Accutest Instruments, Inc., P.O. Box 130, Rte. 526, Clarksburg, NJ 08510.

Cellular Telephones Antenna Catalog. ORA Electronics' new catalog contains listings for more than 20 different models of cellular telephone antennas. Included in the catalog are listings for through-glass, disguise, motorized, 3-dB gain and 5-dB gain antennas for a variety of applications. Special-purpose antennas for marine and briefcase applications are also listed, as are control head mounting kits, antenna mounts, a signaling horn, tools, connectors and cable. Provided are complete performance specifications, applications information, descriptive text and a photo for each antenna listed. For a copy, write to: ORA Electronics, 20120 Plummer St., P.O. Box 4029, Chatsworth, CA 91313.

Ceramic Filter Catalog. A new selection guide to ceramic filters that takes the mystery out of emi filter specification is available from Sprague. Descriptions of circuit configurations and functions, with a filter selection flow chart, installation guidelines, definitions of terms, and a look at military test procedures make it possible for a reader to make an informed choice for almost any application. The catalog is divided into dc rated and ac/dc rated sections. Subcategories are defined by circuit configuration (function). Within each general circuit category, devices are shown in order of current rating and then voltage rating. For a copy of Ceramic Emi/Rfi Filters Catalog No. FD-129, write to: Sprague Electric Co., Technical Literature Service, P.O. Box 9102, Mansfield, MA 02048-9102.

LETTERS...

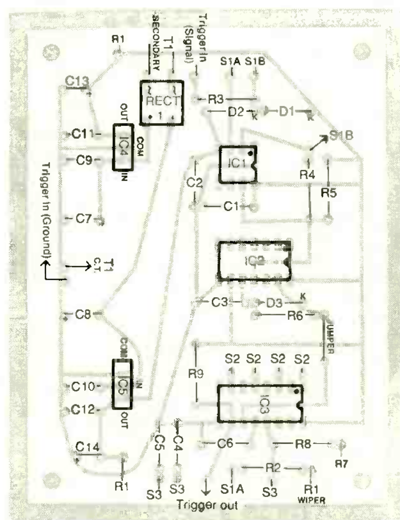
(from page 7)

Which is correct? Shouldn't the resistor symbol shown for C2 in the schematic be a capacitor symbol? Also, where does C7 go in the schematic?

Jerry A. Phelps
Louisville, KY

The correct value for C1 and C2 is 0.1 μF. You're right about the capacitor symbol for C2. Omit C7 from the Parts List; it was a typographical error.—Ed.

• Please make the following corrections to "A Delayed-Trigger Accessory for Oscilloscopes" (January 1988). On page 22, the first paragraph under "Checkout & Use" should read: "Then touch the 'hot' meter lead to pin 8 of the IC1 socket, pin 14 of the IC2 socket and pin 16 of the IC3 socket . . . . Touching the hot lead to pin 4 of the IC1 socket should yield a reading



of −15 volts." Turn the page upside-down for correct orientation of the photos in Fig. 1. The trace in (A), now lower-right, is triggered on the rising edge of the square pulse. The manufacturer of the ICM7250 chip is Intersil. Finally, use the corrected wiring diagram shown here instead of the one shown in Fig. 6.

Jan Axelson

• In Fig. 1 of "A miniature LED Beacon" (January 1988), the internal connections going to pins 8 and 2 of the LM3909 should be reversed.

Dan Becker

• To avoid any confusion, please transpose the illustrations (not the captions) for Figs. 3 and 4 in "Choosing Op Amps for Specific Applications" (November 1987).

Charles R. Fischer

Experimenting With a Superconductor

By Forrest M. Mims III

The Nobel prize for physics is generally awarded years after an important discovery is announced. However, in 1987, the prestigious prize was awarded only a year after its two recipients announced the development of a remarkable new kind of superconductor. Equally remarkable is that low-cost samples of this new kind of superconductor have been available from several sources since the fall of 1987. This means that anyone can now experiment with what many people are calling one of the most significant discoveries of this century.

I have recently experimented with a disc of superconducting material. I will describe some of my observations later. Let's first explore the background of the momentous discoveries that led to the 1987 Nobel prize in physics.

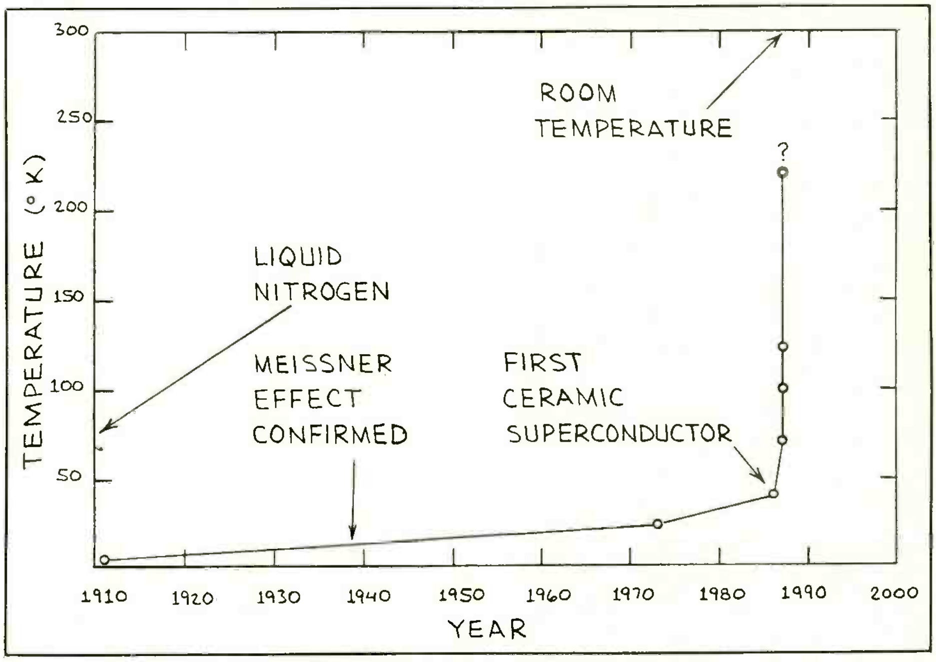


Fig. 1. Major advances in superconductivity.

Traditional Superconductors

A superconductor is a substance that possesses absolutely no resistance to the flow of electrons. A current induced in a coil of superconducting wire will continue to flow even after the power source has been removed. This property makes possible several important applications. For instance, electromagnets made from superconducting wire are substantially more powerful than conventional electromagnets. A junction of two superconductive materials, called a Josephson junction, is among the fastest of all switches.

Other applications for superconductors include levitated trains, highly efficient motors and zero-resistance long-distance power transmission lines and telecommunications links. Unfortunately, however, present superconductors are not suitable for these and a host of other fascinating applications since they do not exhibit superconductivity unless they are first cooled to very low temperatures.

This brings us back to the 1987 Nobel prize for physics. Prior to 1986, the best superconductors had to be cooled down to around 30 degrees above absolute zero (30 degrees Kelvin) in order for them to exhibit superconductivity. This was not a significant improvement over the state of the art in 1911 when Dutch physicist Kamerlingh Onnes first discovered superconductivity in mercury. When Onnes cooled a sample of mercury to the temperature of liquid helium (about 4 degrees Kelvin), he was amazed to find that the resistance of the mercury suddenly fell to zero. He later coined the word "superconductivity" to explain this previously unknown phenomenon.

Superconductivity was later discovered in lead, zinc, aluminum, tin and other metals and a variety of metal alloys. Applications for superconductors, however, remained limited due to the requirement that they be cooled with liquid helium by specialized cryogenic refrigerators. Besides being difficult to produce and rather expensive, liquid helium is tricky to store and use. Cryogenic refrigerators are expensive and have limited cooling capacity.

Ceramic Superconductors

Because of their enormous potential, a few scientists have stubbornly attempted to devise materials that would exhibit superconductivity at warmer temperatures, especially at the temperature of liquid nitrogen (77 degrees Kelvin) and above. Most scientists were skeptical that superconductivity would ever be achieved at warmer temperatures. But in 1986, K. Alex Muller, a physicist at an IBM research facility in Zurich, Switzerland, startled even the skeptics when he and J. Georg Bednorz announced the discovery of superconductivity in a ceramic compounded of various metallic oxides. It was necessary to cool the new material to 35 degrees Kelvin before it would exhibit superconductivity. But even that frigid temperature was 12 degrees Kelvin warmer than the highest temperature achieved with previous metallic materials.

In April 1986, Muller and Bednorz submitted a paper that summarized their results to a physics journal. When the paper was published in September 1986, it was generally viewed with skepticism. But Ching Wu "Paul" Chu at the University of Houston and a team of Japanese scientists soon duplicated Muller's and Bednorz's feat. When the Japanese team reported its results at a meeting of the Materials Research Society in Boston, those in attendance quickly realized that Muller and Bednorz had indeed made a momentous discovery.

What followed over the next few months can only be described as near-pandemonium. Normally conservative, staid physicists rushed back to their laboratories to begin concocting metallic-oxide ceramics.

Duplicating Muller's and Bednorz's results was surprisingly easy to do. The ingredients were simply ground together using a mortar and pestle and then were fired in a furnace. Thanks to the simplicity of this procedure, over the next six months more progress was made in superconductor technology than in the previous 75 years.

At first, most researchers user Muller's and Bednorz's ingredients. Then, after achieving superconductivity, they modified their recipes and increased the temperature at which superconductivity could be achieved. By the end of January 1987, Chu's group at the University of Houston achieved superconductivity at more than 90 degrees Kelvin, which is well above the temperature of liquid nitrogen (77 degrees Kelvin).

The frantic pace of new superconductor developments caused organizers of the American Physical Society to add a special session on the subject at their annual meeting. On March 18, some 1,800 people jammed the 1,200-seat ballroom at New York City's Hilton Hotel. A few thousand more watched the proceedings via closed-circuit television.

Normally, scientific papers are received with a few yawns at worst and polite applause at best. Those in attendance at the APS special session, however, cheered, laughed and applauded as they listened to the papers being presented. The session, which ended at 3:00 a.m., lasted some eight hours. It was so unusual that *Science* called it a "happening." A cover story in *Time* quoted Bell Labs physicist Michael Schluter as describing the meeting as the "Woodstock of physics."

Figure 1 graphically illustrates the pace of developments in superconductivity. Even if the present trend slows down, eventual development of room-temperature superconductors appears to be a distinct possibility.

Applications for New Superconductors

Liquid nitrogen is much easier to use and costs only a 50th of the price of liquid helium. Therefore, until room-temperature superconductors become available, materials that exhibit superconductivity at the temperature of liquid nitrogen can be used in many practical applications. The ultimate goal, of course, is superconductors that operate at room temperature and even above. Already, several scientists and research laboratories have reported tantalizing evidence of superconductivity at and even above room temperature. In the meantime, here are some of the applications that will greatly benefit from availability of materials that become superconductors at or above the temperature of liquid nitrogen:

• *Communications.* In theory, a superconducting wire can carry a modulated signal with zero loss. While preparing this column, it occurred to me that a steady current through a superconducting wire can be digitally and possibly analog modulated by applying an external magnetic field anywhere along the length of the wire. This is because a superconductor begins to exhibit resistance in the presence of a sufficiently strong magnetic field. While this capability makes possible new modulation methods, it also means that the signal carried over a superconducting wire can be jammed by applying a sufficiently great magnetic field anywhere along its length.

• *Power Transmission.* Conventional high-voltage transmission lines typically lose 20 percent of their power to electrical resistance and leakage to ground. A superconductive transmission line could, in theory, reduce this loss to near zero. Besides reducing the cost of electricity, power plants could be located farther away from metropolitan areas.

• *Electronics.* Superconducting Josephson junctions can switch an electrical signal in 1 picosecond. This is some 10 times faster than the best conventional electronic switches. Hypress, Inc., an IBM spinoff, uses Josephson-junction arrays to make the PSP-1000, the world's fastest oscilloscope and signal processor. The PSP-1000 can display a signal that has a risetime of only 5 picoseconds, making it useful in radar and lightwave communications.

• *Transportation.* The levitated train has long been the dream of transportation engineers. Japanese National Railways has tested a prototype train that floats on the magnetic field generated by magnets wound with conventional superconducting wire cooled with expensive liquid helium. Availability of wire that becomes superconductive at or above the temperature of liquid nitrogen might finally make the levitated train a practical reality. Motors wound with superconductive wire would greatly increase the efficiency of electrically powered cars and ships.

• *Research.* The United States government is presently planning to build the world's largest particle accelerator, the Superconducting Super Collider (SSC). The SSC will incorporate some 10,000 superconducting magnets around the length of a circular tunnel that has a circumference of 53 miles. Projected cost of the project is from $6 billion to $8 billion. If the new generation of high-temperature superconductors can be fabricated into practical magnets, operating cost of the SSC could be significantly reduced. Availability of powerful liquid-nitrogen-cooled superconductive magnets would be useful in many other kinds of research as well.

Recent Developments

Superconductive ceramics are so easy to make that several high school students have managed to make their own samples. A typical recipe requires that the ingredients be mixed, ground and heated to around 1,000 degrees Celsius. The mixture is then reground and reheated. Finally, the material is pressed into pellets and is reheated for several hours. Variations in the temperature and length of the

ELECTRONICS NOTEBOOK...

heating cycles can greatly affect the superconducting properties of the finished pellet.

Pellets by themselves have few applications beyond research use and classroom demonstrations. For practical applications, the materials must be formed into wires and other shapes. Already, scientists at IBM, Bell Labs and other institutions have made superconducting wires and tapes from the new materials. They have also developed various ways to apply thin films of superconductive ceramics to conventional wires and other materials.

Much more progress must be made before the new superconductors can be used in practical applications. Since ceramics are inherently brittle, superconducting wires may have to be bonded to the surface of conventional wires or formed inside hollow wires.

The current-carrying capacity of the new materials must also be greatly increased. Conventional niobium superconductors cooled with liquid helium can carry up to 500,000 amperes per square centimeter. As this is being written, the best new ceramic superconductors can carry around 1,100 amperes per square centimeter. Above this level, the superconducitivity of the material is quenched.

Experimenting With a Superconductor

Superconductivity manifests itself by zero electrical resistance and the repulsion of a magnetic field (the Meissner effect). In ceramic superconductors, the latter is much easier to demonstrate than the former. Besides a superconducting pellet, all that is required is a strong magnet, a foam-plastic cup and some liquid nitrogen.

Superconductive ceramic pellets are already available from several sources. According to a front-page item in *The Wall Street Journal* (October 19, 1987), Arthur Ellis, a chemist at the University of Wisconsin, has developed a $25 superconductor kit for the Institute for Chemical Education. This kit includes a ceramic superconductor, magnet and instructions for making superconductors. The article also reported that recipes for do-it-yourself superconductors have been published in *Johns Hopkins Magazine* and *New Scientist*.

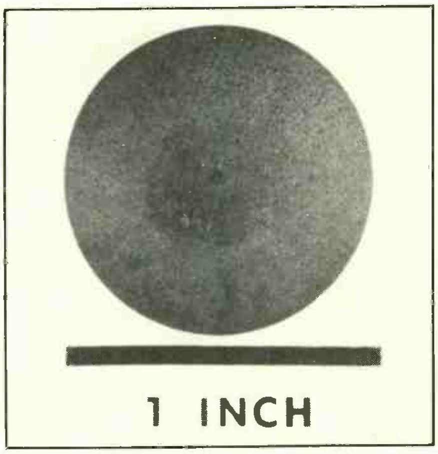


Fig. 2. A ceramic superconducting pellet.

I obtained a superconductor pellet from the manufacturer that supplies pellets to Edmund Scientific Co. (101 E. Gloucester Pike, Barrington, NJ 08007). The pellets are available from Edmund for $20 (Cat. No. A37,446). They become superconductive at 83 degrees Kelvin. The pellet I received, shown photographically in Fig. 2, is 15/16 inch in diameter and 1/8 inch thick.

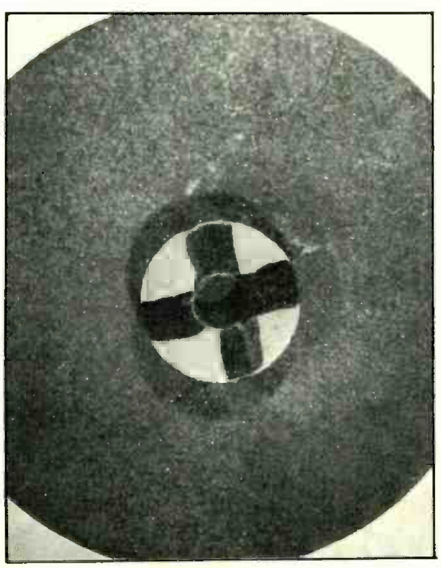


Fig. 3. A samarium-cobalt magnet resting on a superconductor pellet.

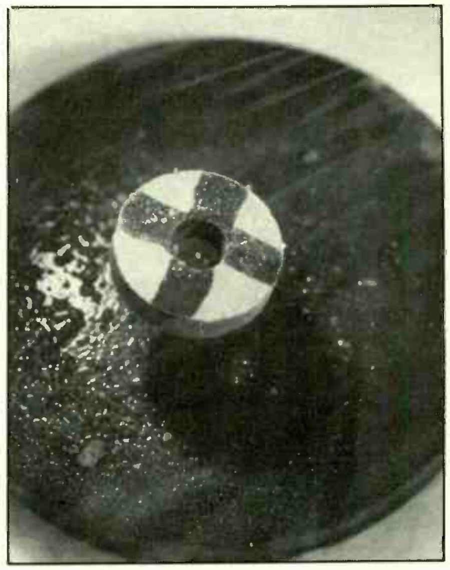


Fig. 4. A samarium-cobalt magnet floating above a superconductor pellet cooled with liquid nitrogen.

Ordinary magnets are not strong enough to demonstrate the Meissner effect. For best results, you must use a samarium-cobalt magnet, which is expensive when purchased individually. Edmund Scientific Co., for example, sells a high-quality samarium-cobalt magnet for $35 (Cat. No. A37,447). Fortunately, you can obtain a pair of small samarium-cobalt magnets by disassembling a suitable pair of earphones. Be aware, though, that not all earphones are equipped with samarium-cobalt magnets; so be sure to check the specifications printed on the phones' package. I purchased a pair of phones that came with samarium-cobalt-magnet elements for about $6.

Prepare the demonstration by slicing the bottom 1/2 inch or so from the bottom of a foam-plastic cup. If one is handy, you can use half of a foam-plastic fast-food container. Place the ceramic superconductor pellet in the center of the container and then place the magnet on top of the pellet. Next, slowly pour enough liquid nitrogen into the container to just cover the pellet and magnet. The nitrogen will immediately and violently boil when it strikes the comparatively warm objects in the container. After 10 or 20 seconds, the boiling will slow to a simmer and the liquid nitrogen will begin to seep over the edges of the pellet. After a few more seconds, the nitrogen will encircle the magnet. Just as it touches the magnet, the magnet will rise above the pellet.

Figures 3 and 4 show the results I obtained when I performed this experiment. In Fig. 3, the magnet is resting atop a superconductor pellet at room temperature. In Fig. 4, the magnet is floating above the pellet. (I placed a cross mark on the magnet to better visualize its rotation.)

As the liquid nitrogen evaporates, the ceramic eventually warms to the point where it no longer superconducts. The magnet then gently descends to the surface of the pellet. The fact that the magnet doesn't touch down until there is a fine layer of frost on the pellet proves that the pellet superconducts at least a few degrees Kelvin *above* the temperature of liquid nitrogen.

Depending on the power of the magnet and quality of the superconductor, the magnet will float about $\frac{1}{16}$ to $\frac{3}{16}$ inch above the surface of the pellet. Unlike two magnets that repel each other, the floating magnet will not violently fly away or flip over. Instead, it will float in place in virtually any position you place it. Moreover, it will spin. Indeed, the turbulence caused by the nitrogen vapor rising from the container may cause the magnet to start spinning. Or you can spin it with a gentle nudge from a pencil or your fingertip.

Figure 5 shows a magnet hovering above a superconductive pellet. Notice the layer of frost formed from water vapor in the air. In Fig. 6, I have spun the magnet with a gentle nudge from a fingertip. Figures 7 and 8 show the same effects when the magnet has been gently tilted to one side.

The behavior of a magnet floating in free space above a superconducting pellet is unlike anything I have observed. On witnessing the Meissner effect for the first time, an engineer at one company is said to have labeled the phenomenon as "counter-intuitive." Once set in motion, the spinning magnet will continue to revolve for many minutes. Apparently, only the resistance of the surrounding air slows down and eventually halts the magnet's rotation.

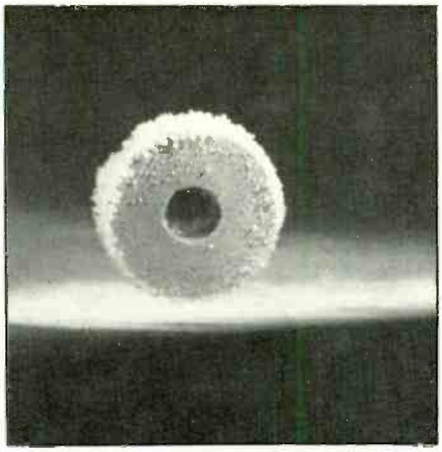


Fig. 5. A perfectly stationary magnet floating above a superconductor pellet.

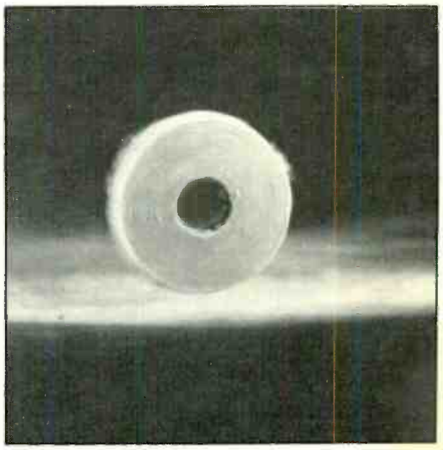


Fig. 6. The magnet rapidly spinning after given a gentle nudge.

The position of the floating magnet, whether spinning or not, remains highly stable. To the unaided eye, the magnet appears to be perfectly motionless. I attempted to detect perturbations in the position of the magnet by reflecting the beam of a helium-neon laser from the shiny edges of a spinning magnet toward a white card several inches away. The position of the reflected spot remained very stable. I also observed the shadow of a spinning magnet illuminated by a laser beam. Again, the magnet appeared to remain precisely in position.

Recall that an electromotive force (emf) is generated in a coil adjacent to a magnet when either the coil or the magnet is moved. I connected a telephone induction coil to the input of an audio amplifier and then placed the coil near the spinning magnet. If an emf was being produced, it would be indicated by a rushing sound from the earphone. No sound was heard.

When a small fragment of a broken samarium-cobalt magnet was attached to the spinning magnet, a very soft sound was detected each time the magnet completed a revolution. The mass of the offset magnet, however, quickly slowed rotation of the main magnet.

Some recent publications that describe the Meissner effect either state or imply that a superconductor is a perfect reflector of a magnetic field. This is misleading since some of an impinging mag-

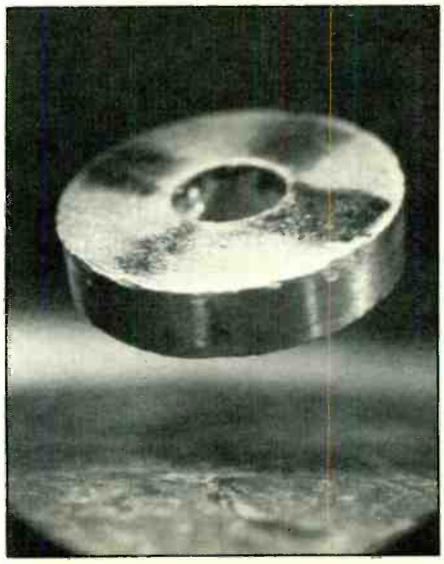


Fig. 7. The floating magnet has been pushed to one side and its rotation has stopped.

ELECTRONICS NOTEBOOK...

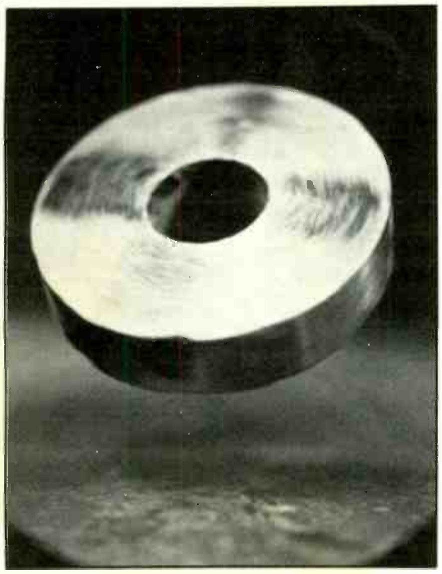


Fig. 8. The tilted floating magnet has again been nudged to spin.

netic field will indeed penetrate a superconductor.

You can easily demonstrate this by placing a very weak magnet *under* a foam-plastic container that holds a ceramic superconductor and a levitating magnet. The floating magnet will drop to the surface of the ceramic, where it can be moved around simply by moving around the lower magnet. A magnet isn't even necessary; the container can be placed on a steel plate and the floating magnet will move closer to the surface of the ceramic.

Incidentally, you can easily use a small magnet to manipulate the position of the floating magnet. Just be sure not to bring the second magnet too close to the floating magnet or the latter will cease floating and fly over to join itself to the first magnet.

Unfortunately, demonstrating zero resistance in a ceramic superconductor is much more difficult than demonstrating the Meissner effect. My efforts to measure the resistance of the Edmund Scientific disk were unsuccessful.

First I used a strong clamp to force two copper electrodes against opposite sides of the disk. When this arrangement, shown in Fig. 9, was immersed in liquid nitrogen, the resistance of the disk typically *increased* an ohm or two. The increase was probably due to a slight relaxation of the clamp's pressure under the cooling influence of the liquid nitrogen.

Next, I attached a pair of ordinary alligator clips to opposite sides of the disk. This time, the results were unpredictable. Sometimes the resistance increased a few ohms, but twice the resistance appeared to fall completely to zero.

Finally, I used a silver-based conductive adhesive to attach wire leads directly to the disk, as shown in Fig. 10. After the adhesive cured overnight, I measured a resistance of 0.2 ohm. When I poured liquid nitrogen over the disk, its resistance *increased* to 1 ohm. After the disk warmed to room temperature, I repeated the measurements and obtained similar results. Eventually, the room-temperature resistance increased to around 4 ohms. When the disk was immersed in liquid nitrogen, its resistance always *increased* about 1 ohm above its resistance at room temperature.

After many unsuccessful efforts to observe zero resistance, I contacted an engineer at the firm that manufactures the ceramic disks for Edmund Scientific. He acknowledged that establishing good electrical contact with the ceramic disk is difficult. He recommended that gold electrodes be fired onto the disk. Perhaps such electrodes could be offered for an additional fee.

Just before this column was to be mailed, I learned about the availability of superconducting ceramic disks equipped with electrodes. The disks are made by Fluoramics, Inc. (103 Pleasant Ave., Upper Saddle River, NJ 07458; tel. 1-800-922-0075). The electrical resistance of these disks falls from about 0.2 ohm at room temperature to zero or near zero resistance at just below 90 degrees Kelvin. A disk equipped with 19K gold wires and painted gold electrodes costs $100. A disk equipped with copper wires and

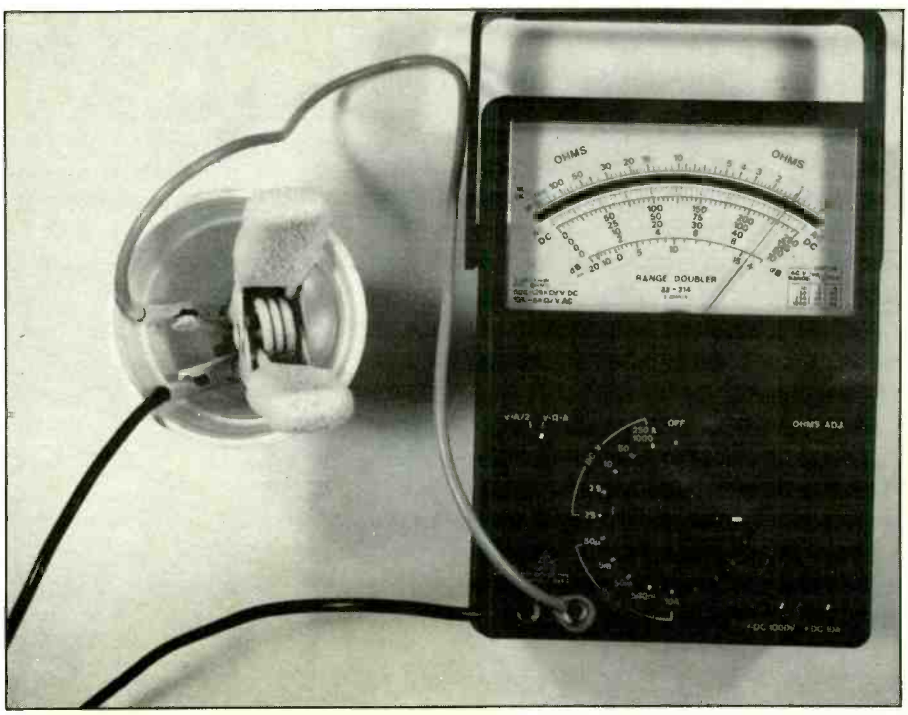


Fig. 9. An unsuccessful attempt to measure the resistance of a ceramic superconductor immersed in liquid nitrogen.

painted nickel electrodes costs $85. Two disks without electrodes cost $100. Quantity discounts are available.

How to Obtain Liquid Nitrogen

It was much more difficult for me to obtain liquid nitrogen than is was to obtain a pellet of superconducting ceramic. That's because I live in a rural area. Fortunately, I was able to purchase liquid nitrogen and to rent a large dewar from a man whose business is artificial insemination of cattle. I paid $30 for 30 liters of liquid nitrogen and $20 to rent the dewar for three days.

A dewar is a cryogenic flask that has an evacuated double-wall construction. Often, the flask is lined with an insulating blanket of foam plastic. An ordinary thermos bottle is a dewar. The dewar I rented is called a liquid-nitrogen refrigerator. It will store a full load for as long as 150 days. Some dewars will store liquid nitrogen for as long as six months.

You need only a liter or two of liquid nitrogen to cool a superconducting pellet. You might be able to buy small quantities of liquid nitrogen from a welding shop for about $1 or $2 per liter. You might also be able to obtain liquid nitrogen from some doctors (particularly podiatrists), hospitals and research laboratories. If one of these sources is willing to sell you some liquid nitrogen, ask for the name of their supplier. Better yet, contact the physics department of a nearby university. Chances are they will be as excited as you are for the opportunity to experiment with a ceramic superconductor.

Unless you are able to borrow or rent a dewar or liquid-nitrogen refrigerator, you will be unable to transport the liquid nitrogen. One possibility is to have the supplier fill a 1-quart thermos bottle with the liquid and perform your experiments nearby. Perhaps the supplier will be interested in observing your experiments. (*Caution:* Under no circumstances should you place a stopper in the mouth of a thermos bottle containing liquid nitrogen! The pressure of evaporating nitrogen gas will become exceedingly high, causing the bottle to *explode*! You can place cotton in the mouth of the bottle and/or place a foam-plastic cup over the mouth of the bottle to reduce evaporation of the liquid.)

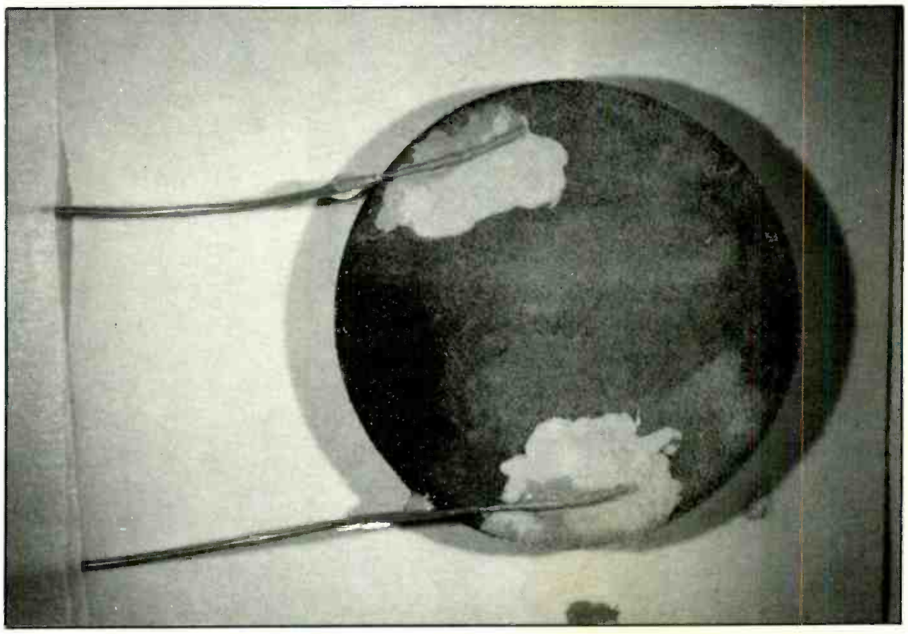


Fig. 10. Wire electrodes bonded to a ceramic superconductor with silver-impregnated conductive adhesive.

An ordinary 1-quart or 1-liter evacuated glass thermos bottle that costs $5 to $10 will easily store liquid nitrogen for a day or so.

Safety Precautions

Some 80 percent of the air we breathe is composed of nitrogen. However, while free nitrogen is safe, liquid nitrogen can be *very* dangerous. It can cause almost instant frostbite on exposed skin. Also, its vapor can quickly develop extremely high pressure inside a closed container. Therefore, you must exercise reasonable care when using liquid nitrogen:

(1.) *Never* place liquid nitrogen in a tightly sealed container. If you do, the container *will* explode!

(2.) Do not transport an open container of liquid nitrogen in a vehicle.

(3.) Wear eye protection when pouring liquid nitrogen.

(4.) Because liquid nitrogen boils violently when it is poured into a container that is at room temperature, make sure to stand clear to avoid being splashed.

(5.) If liquid nitrogen splashes onto your clothing, quickly grasp a *dry* section of fabric and pull the wet area away from your skin. The liquid will soon evaporate from your clothing.

(6.) Once again, *never* attempt to store liquid nitrogen in a tightly closed container!

Going Further

If you've read this far, you might be wondering why I haven't commented on how the new ceramic superconductors lose their electrical resistance. Frankly, I haven't the slightest idea. Several theories have been suggested by researchers in the field, but it's safe to conclude, at least for now, that there is not yet general agreement on the details of how superconducting ceramics work.

Numerous articles about superconductors have appeared in both the popular press and scientific journals. For additional information, visit a good library and check the periodicals section for publications dealing with this subject, beginning around March 1987. ME

SOLID-STATE DEVICES

A new switching regulator, an improved BCD-to-7-segment decoder, another buzz word and what's new

By Harry L. Helms

Few types of integrated circuits have become as useful as the so-called "three-terminal" linear voltage regulator devices. These devices, such as the classic 723 and 78XX series, quickly became popular among hobbyists and design engineers as a result of their low cost and ease of use. Besides, designing a good linear voltage-regulation circuit was no easy task. Versatile as they are, however, these regulator ICs are generally not suitable in applications where high output voltage and current are needed because these demands require high power dissipation capabilities that are beyond the rated maximum of most three-terminal devices. Exceed the dissipation limits and you soon have a fried (and dead) voltage regulator on your hands.

One popular solution to high-output-demand situations has been the *switching* voltage regulator. In this circuit, an outboard "pass" transistor is used in conjunction with an integrated-circuit or discrete-component voltage regulator. The pass transistor supplies whatever current the regulator itself can't. To maximize the power dissipation capabilities of the pass transistor, it is rapidly switched between saturation and an open circuit. Switching is done quickly (in excess of 50 kHz in many cases) to produce an easily smoothed and filtered output. The result is a high-efficiency regulator with excellent high-current-handling ability.

Designing a switching voltage regulator has generally not been an easy task. Most regulator ICs have required several external components to implement a switching design, and the resulting circuits have not been easy to "tame" for desired operation. However, Linear Technology Corp. recently introduced a new switching regulator IC that has the potential to make switching regulators as commonplace as conventional linear regulators. The LT1070 is a rugged device capable of supplying up to 5 amperes of output current while accepting inputs ranging from 3 to 60 volts. It can deliver load power up to 100 watts without requiring external devices.

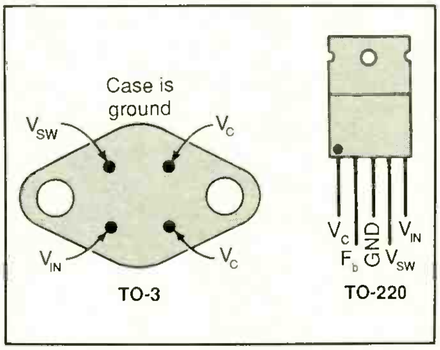


Fig. 1. Package configurations and pin identifications for LT1070 switching regulator IC.

The LT1070 is available in TO-3 and TO-220 packages (see Fig. 1). An internal 5-ampere, 75-volt pnp switching transistor serves as the pass transistor for the regulator. Output voltage control is obtained by using the output of a voltage-sensing error amplifier to set the current trip limit.

The LT1070 might be referred to as a "five-terminal" regulator. In addition to the usual input-voltage (V_{in}) and ground (GND) pins, it has compensating-voltage (V_c), feedback (F_b) and output- or switching-voltage (V_{sw}) pins. The extra pins make the LT1070 more complex to use than ordinary three-terminal regulators, but they also provide the means for using these devices for some interesting applications that are difficult or impossible to implement using conventional regulator ICs.

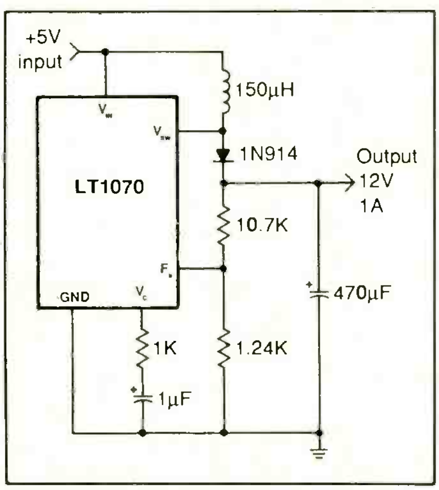


Fig. 2. A 5- to 12-volt boost converter.

Figure 2 shows the LT1070 being used in a circuit that is capable of taking a +5-volt input and producing a +12-volt, 1-ampere output. This is known as "boost-mode" operation. The configuration shown produces about 22 watts of output power. Output power levels up to 100 watts in this mode are possible, depending on the input voltage and values of components selected. The diode should be a general-purpose switching type that is capable of safely handling over 5 amperes and switching at a 60-Hz or better rate.

Linear Technology explicitly warns against using common diodes with lower ratings in their literature with the following statement: "The LT1070 will *eat* 1N914 and 1N4001 diodes and not even burp." How's *that* for making a point clear! However, diodes such as the 1N4001 can be used in LT1070 circuits if current through them is limited by resistors or other means.

The LT1070 is capable of boosting and inverting input voltages, as shown in Fig. 3. This circuit is an example of the "buck-boost mode," which is similar to the boost-mode regulator except that the load is referred to the inductor side of the input instead of the switching side. In the Fig. 3 circuit, the ground pin of the LT1070 is switched back and forth between the positive input and the negative output.

Substantial output voltages can be obtained from the LT1070 at lower currents. For example, Fig. 4 shows a circuit that can deliver 100 volts at 300 mA from a 15-volt input. The crucial component in this circuit is inductor *L*, which has a total inductance of 4 mH. It consists of five bifilar, or interleaved, turns of No. 14 wire on a core or form that is capable of handling at least 5 amperes. The winding is tapped as shown at the third turn. The form should be a "permalloy" type, al-

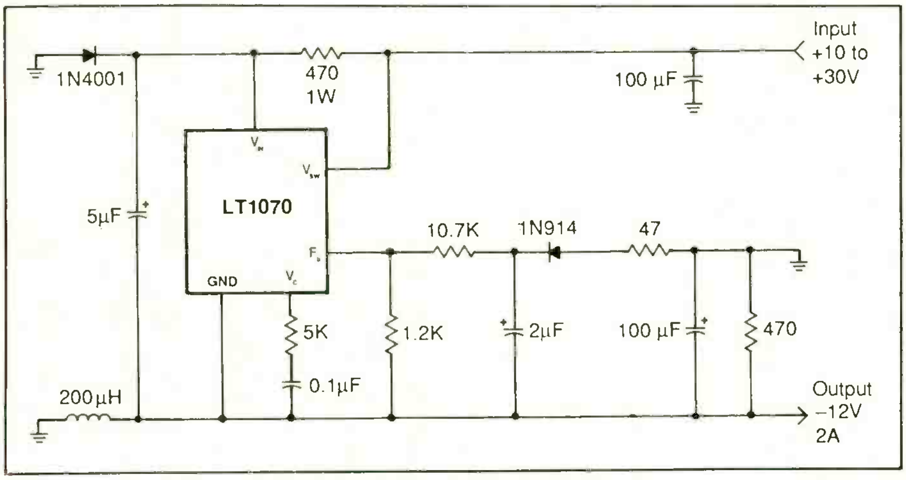


Fig. 3. A Positive-to-negative boost converter circuit.

though powdered iron can be used if lower efficiency is acceptable.

Building circuits with the LT1070 requires some precautions that must be closely observed. Obviously, the voltages and currents that appear at the outputs of these circuits are substantial and have the potential to cause serious damage or injury. (*Caution:* Don't attempt to build or use these circuits unless you are experienced in working with high-voltage and high-current circuits!)

High switching speeds can also produce some of the problems normally found in high-speed digital circuits. For example, long component leads or/and wires connected to the LT1070 will act as inductors at high switching rates, usually causing unpredictable operation. When selecting components such as diodes and inductor cores, be conservative and use those parts with ratings well above the levels you expect to encounter.

I have only scratched the surface of possible LT1070 applications here. Linear Technology has put together a 72-page *LT1070 Design Manual* that is packed with applications circuits and design tips. This Manual, Application Note No. 19, is available upon request on pro-

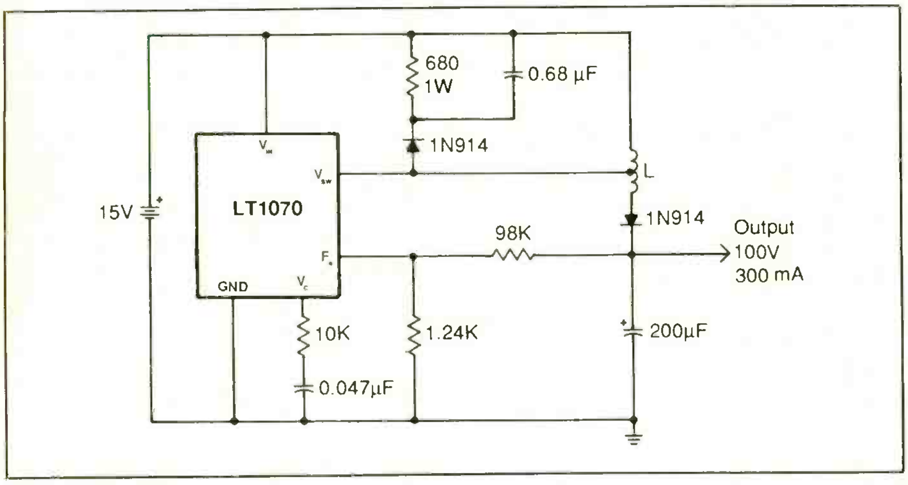


Fig. 4. A high-voltage output converter circuit.

fessional or business letterhead by writing to the company at 1630 McCarthy Blvd., Milpitas, CA 95035-7487.

An Improved BCD-to-7-Segment Decoder

Devices that decode a BCD address and drive seven-segment LED displays are popular among designers and hobbyists alike. However, most require current-limiting resistors to be used on the outputs to prevent damage to display segments. The new GE/RCA CA3161 from GE Solid State provides a constant 24 mA of current at the outputs, eliminating the need for resistors on the outputs. In addition, the CA3161's +5-volt inputs are compatible with TTL and CMOS logic levels. The device is also pin compatible with other industry-standard decoders.

A complete data sheet for the CA3161 can be obtained from GE Solid State, Rte. 202, Somerville, NJ 08876. When writing, ask for File No. 1079.

LT1070 Specifications
Maximum supply/input: 60 volts
Maximum switch output: 75 volts
Maximum output power: 100 watts
Maximum switching current: 5 amperes
Maximum quiescent mode current: 6 mA
Prime vendor: Linear Technology Corp.

POACHers???

Add another acronym to those already in vogue in electronics: "POACH," which stands for "*PC* on *a Ch*ip." This refers to a technique whereby custom application-specific ICs (ASICs) are used in 80286 PC AT-compatible systems in place of the standard "merchant" ICs used in the original PC AT computer from IBM. The result of POACH technology is a dramatic savings in component count and space.

How big are these savings? VLSI Technology recently introduced a five-chip CMOS set that cuts the number of non-memory chips on a PC AT motherboard from 110 to just 16! The resulting motherboard occupies less than half the physical space of a conventional PC AT version. Other manufacturers offering chip sets for AT systems include: Chips and Technologies, Faraday, G2, Logicstar and ZyMOS.

Short Takes

Speaking of ASICs, National Semiconductor has added analog function cells to its library of standard digital design cells. These functions include comparators, op amps, a voltage reference, an analog switch and resistors. This is part of a trend in ASICs to allow designers to combine linear and digital functions on the same chip . . . Siemens is offering *SMD Technology: An Introduction to Surface Mounting*, a guide to surface-mount devices and their applications. It is profusely illustrated in full color. Request Publication No. B3-B3289-Q-1-7600 from Siemens computers, Special Products Div., 186 Wood Ave. S., Iselin, NJ 08830. **ME**

A Sampling of Winter 1988 English-Language International Shortwave Broadcasts

By Gerry L. Dexter

Time	Station/Country	Frequencies
0000	Radio Exterior de Espana, Spain	9630
	Radio Luxembourg	6090
	Radio Discovery, Dom. Rep.	15045
	All India Radio	9910, 11715, 11745, 15110
	Radio Portugal (30)	9680
	Radio Havana Cuba	6080, 6140, 9740
	BBC	5975, 6175, 6195, 7325, 9515, 9590
	WRNO	7365
	Radio Moscow	5915, 5940, 6000, 7115, 7215, 7310, 12050
	Voice of Israel	9435, 9885, 11610
	Radio Baghdad	11705
	HCJB, Ecuador (30)	9870, 11755, 15115
	Voice of America	5995, 6130, 9455, 9775
	Vatican Radio (50)	6150, 9605, 11780
	Radio Berlin Int'l.	6080, 9730
	AFRTS, USA	6030, 9700, 11790, 15355
	Radio New Zealand	11780, 15150
0100	Radio Canada Int'l.	5960, 9535, 9755, 11940
	RAI, Italy	9575, 11800
	RAE, Argentina	9690, 11710
	Radio Prague, Czechoslovakia	5930, 6015, 6155, 7345, 9740, 11990
	Voice of Germany	6040, 6085, 6145, 9505, 9545, 9565
	KVOH, California	9495
	Radio Moscow	5915, 5940, 6000, 7115, 7215, 7310, 7440, 12050
	Voice of Israel	9435, 9855, 11610
	Voice of Greece (30)	7430, 9395, 9420
	Radio Austria Int'l. (30)	9550
	All India Radio	7215, 9535, 9910, 11715
	Radio Budapest, Hungary	6025, 6110, 9520, 9585, 9835
	Radio Baghdad, Iraq	9705
	Radio Exterior Espana, Spain	9630
	WCSN Boston	7365
	Radio New Zealand (45)	15150

Times are in UTC. Numbers in parentheses are starting times that many minutes past the hour.

Time	Station/Country	Frequencies
0200	Radiobras, Brazil	11745
	Swiss Radio Int'l.	6135, 9725, 9885, 12035
	Radio Exterior Espana, Spain	9630
	Radio Bucharest, Romania	5990, 6155, 9510, 9570, 11810, 11940
	Radio RSA, South Africa	6010, 9615, 11730
	Radio Havana Cuba	6080, 6140, 9525, 9740
	Voice of Germany	5955, 6035, 7285, 9615, 9690
	Radio Warsaw, Poland	6095, 7145, 7270, 9575, 11815
	Radio Moscow	5915, 5940, 6000, 7115, 9635, 12050
	Radio Sweden Int'l. (30)	9695
	Voice of Free China	7445, 9680, 9765, 11740, 11745, 11860, 15345
	HCJB, Ecuador	6205, 9870, 11775
	Radio Cairo, Egypt	9475, 9675
	Radio Tiarana, Albania	9765
	Radio France Int'l. (15)	5950, 9715
	Radio Budapest, Hungary	9520, 9585, 9835
	Radio Kiev, Ukraine	7260, 9800, 11790, 11875, 13645
	Radio Netherlands (30)	6020, 6165, 9590, 11730
	Radio New Zealand	11780, 15150
0300	Radio Portugal	9705
	Radio Prague, Czechoslovakia	5930, 6015, 6055, 7345, 9540, 9630, 9740, 11990
	Voice of Germany	5965, 6010, 6045, 9545, 9565
	Radio Moscow	5915, 5940, 6000, 7115, 9635, 12050
	Voice of Greece (40)	7430, 9395, 9420
	HRVC, Honduras	4820
	Voice of Free China	5955, 7445, 9680, 9765, 11745, 15345
	Radio France Int'l. (30)	6055, 9800
	Voice of Turkey	9560
	Radio Belize	3285
	Radio Budapest, Hungary	6025, 6110, 9520, 9585, 9835, 11990
	Radio Havana Cuba	6100, 6140, 9740, 11725
	Radio Beijing, China	9645, 11660, 11970, 11980, 15445
	TIFC, Costa Rica	5055
	Radio Warsaw, Poland	6095, 6135, 7145, 7270, 9525, 11815
	TWR Netherlands Antilles	9535
	Radio Austria Int'l. (30)	6150

Time	Station/Country	Frequencies
0400	Radio Cameroons (30)	4850
	Radio Bucharest, Romania	5990, 6155, 9510, 11810, 11940
	RAE, Argentina	9690, 11710
	Radio Havana Cuba	5965, 6035, 6080, 6140, 9575, 9740
	UAE Radio, UAE	9640, 11940, 15345
	TWR Netherlands Antilles	9535
	Radio Beijing, China	9645, 11980
	BBC	5975, 6175, 9510
	TGNA, Guatemala	5955
	Voice of Israel	9435, 9815, 11585, 11960
	Radio Finland Int'l. (30)	11715, 11755
	Radio Austria Int'l. (30)	9550
	Radio France Int'l. (15)	6055, 9800
	Swiss Radio Int'l.	6135, 9725, 9885, 12035
	Voice of America	5995, 6130, 9455, 9775
	Radio Berlin Int'l.	9560, 9620
0500	Radio Korea, S. Korea	6060, 9570
	Voice of Nigeria	7255
	Voice of Germany	5960, 6120, 6130, 9645, 9700
	WRNO New Orleans	6185
	Radio Moscow	6020, 7125, 7260, 9580
	Radio Dublin Int., Ireland	6930 (or 6950)
	Radio Netherlands (30)	6165, 9715
	Vatican Radio	6185, 9645
	Radio Havana Cuba	6090, 6100, 6140, 9740, 11725
0600	Voice of Nicaragua	6015, 6100
	Radio Havana Cuba	9525
	WYFR, Florida	7355, 9852
	ELWA, Liberia	4760
	Radio Cook Islands	11760
	ABC Perth, Australia	9610
	SIBS, Solomon Islands	5020, 9545
0700	HCJB, Ecuador	6205, 9870
	Radio Netherlands (30)	9630
	Radio New Zealand	9600, 11780
	Radio Havana Cuba	9525
	Radio Japan	11705
	Voice of Free China	5985
0800	TWR Monaco	7165
	KNLS Alaska	6095
	Radio Australia	9580
	BRT Belgium	9880
	WCSN Boston	9465
	Radio Austria Int'l. (30)	6000
	FEBC Philippines (30)	11850

Time	Station/Country	Frequencies
0900	Radio Canada Int'l. (30)	5960, 9755
	Radio Afghanistan	4450, 15255, 17655
	HCJB, Ecuador	6130
	Radio Australia	6060, 9580, 11720
	KTWR, Guam	11715
	AFRTS, USA	6030, 9530, 9590, 15265
	Radio Singapore	5052, 11940
1000	KNLS, Alaska	6085
	Voice of Vietnam	9840, 12035
	NBC Papua New Guinea	4890
	Radio Australia	6060, 9580, 11720
	Radio Netherlands (30)	6020, 9650
	TWR Monaco	9495
	Radio Oman	9735, 11890
	SLBS Solomon Islands	5020, 9545
1100	VOIRI, Iran (15)	11790
	Radio Pyongyang, N. Korea	6576, 11735
	TWR Netherlands Antilles (10)	11815
	Radio France Int'l. (10)	6175, 9805, 11670, 11845, 15195, 15300, 15315, 15365, 17620
	Radio Bangladesh (30)	12030, 15525
	Voice of Vietnam	9755, 12035
	Radio New Zealand	6100, 9600
	Radio Singapore	5052, 11940
	Radio Japan	5990, 12035
	Radio Pakistan	15605
	Radio Tirana, Albania (30)	9480, 11855, 15185
	Radio Australia	5995, 9580
	Radio Thailand	9655, 11905
	Radio Beijing	9535, 15280
	BBC	9510, 11775
1200	Radio Canada Int'l.	9625, 11855, 17820
	Radio Pyongyang, N. Korea	9600, 9715, 9977
	Radio Ulan Bator, Mongolia	9615, 12015
	Radio Bangladesh (30)	15525
	Radio Beijing	9535, 11650, 13650
	HCJB, Ecuador	11740, 15115, 17890
	VOPK Kampuchea	9695, 11938
	Radio Finland	11945, 15400
	Radio Tashkent, Uzbekistan	7325, 9600, 9715, 11785, 15460
	Radio Australia	6060, 9580, 9770
	Radio Austria Int'l.	15320
1300	All India Radio (30)	9545, 11810, 15335
	Radio Korea, S. Korea	9750, 15575
	WRNO New Orleans	9715
	Radio Canada Int'l.	11955, 15440
	HCJB, Ecuador	11740, 15115, 17890

COMMUNICATIONS

Time	Station/Country	Frequencies
	Radio Norway Int'l. (Sun)	9590, 15310, 17775
	BRT Belgium	15590
	Radio Finland Int'l.	11945, 15400
	TWR Netherlands Antilles	11815
	Radio Pyongyang, N. Korea	9325, 9345
1400	FEBC Philippines	11850
	Radio Norway (Sun)	15310
	Radio Sweden	11785, 15345
	Radio Netherlands (30)	15560
	TWR Netherlands Antilles	11815
	Radio Finland	15400
	Radio Japan	5950
	AFRTS USA	6125, 9700, 11890, 15330, 15430
	Radio Canada Int'l.	11955, 15440
1500	Radio Pyongyang, N. Korea	7290, 9325, 9940, 9977
	Radio Veritas, Philippines	9770, 15215
	KVOH California	17775
	WRNO New Orleans	11965

"The extra $36 is for the call to Micronesia to get the part."

Time	Station/Country	Frequencies
	Voice of Greece (40)	11645, 15630, 17565
	Voice of Indonesia	11790, 15150
	HCJB, Ecuador	11740, 15115, 17890
	Radio Australia	9580
	FEBA, Seychelles	15325
1600	UAE Radio	9640, 11955, 15320, 17865
	Radio France Int'l.	11705, 17620, 17795
	Radio Budapest, Hungary	9835
	Radio Pakistan	15605
	WYFR Florida	9535, 11875
	Voice of America	15410, 15445, 15580, 17785, 17800, 17870
	BSKSA, Saudi Arabia	9705, 9720
	Voice of Vietnam	10040, 12020, 15010
	Voice of Nigeria	15120
	BRT Belgium (30)	17595
1700	WRNO New Orleans	15420
	Radio Norway Int'l. (Sun)	11850, 15310
	Radio Yugoslavia	5980, 6100, 7240, 11735
	Voice of Israel	9460, 11585, 13750
	WHRI Indiana	15105
	BBC	9410, 12095, 15070, 15420
1800	Radiobras, Brazil	15265
	Radio Canada Int'l.	15260, 17820
	All India Radio	11620, 11935
	Radio Netherlands (30)	17605
	WINB, Pennsylvania	15400
	Radio Kuwait	11675
	Voice of Nigeria	11770
1900	VOIRI, Iran (30)	9022, 11930
	TWR Monaco	11635
	Radio Norway (Sun)	9590, 11850, 15310
	HCJB, Ecuador	11740, 15270, 17790
	Radio Afghanistan	9530, 9635
	Radio Canada Int'l.	15260, 17820
	Radio Japan	11705
	Radio Algiers	9640, 15160, 17745
	Radio Kuwait	11675
	Voice of Nigeria	11770
	Voice of Greece (20)	9395, 9425
2000	Radio Discovery, Dom. Rep.	15045
	KVOH California	17775

Time	Station/Country	Frequencies
2000	Radio Baghdad	9875
	Radio Sofia, Bulgaria (30)	6070, 9700, 11750
	Radio Budapest, Hungary	9835
	Radio Netherlands (30)	9715, 11740
	Swiss Radio Int'l.	12035
	Radio Damascus, Syria (05)	9950, 12085, 15020
	Radio Havana Cuba (10)	17845, (50) 15300, 17750
2100	Radio Canada Int'l.	11835, 151550, 17820
	RAE, Argentina	11710
	WRNO New Orleans	11705
	Voice of Israel (30)	9435, 11610, 13725
	Radio Sofia, Bulgaria	9700, 11720
	BRT Belgium	5910, 9675
	Radio Australia	15395
	All India Radio	5965, 6125
	Radio Yugoslavia (15)	6100, 7240, 9620
2200	Radio Canada Int'l.	5960, 9755
	Radio Korea, S. Korea (30)	15575
	Radio Vilnius, Latvian SSR	7260, 9640, 11790, 11875, 13645
	Voice of Free China	5985, 9955, 15370, 15440, 17845
	Voice of Turkey	9560
	Vatican Radio	9615, 11830
	Radio Berlin Int'l.	6125, 6165, 11750
	Radio Jamahiriya, Libya	7245
	WHRI Indiana	9770
	Radio Sofia, Bulgaria (30)	6070, 11720
	BBC	6120, 6175, 9590, 9915
	Radio Moscow	7190, 9530, 9720, 9760, 9860, 9880, 11750, 11770, 11850, 12030, 12050, 12060, 13600, 15420
2300	Radio Canada Int'l. (30)	5960, 9755
	Radio Moscow	7115, 7310, 12050, 13665, 15425
	Voice of Israel	9435, 9855, 11610
	Radio Sweden	9695, 11705
	Radio Sofia, Bulgaria	9700, 11720
	Voice of Greece (35)	9395, 11645
	BRT Belgium (30)	9790
	Radio Japan	11800
	Radio Mediterranean, Malta	6110
	Radio Berlin Int'l.	6080, 9730
	Radio Korea, S. Korea	15575
	Radio Kiev, Ukranian SSR (30)	7260, 9640, 9800, 11790, 11875, 13645, 13775

ME

Computer spreadsheets for technical calculations and Car compact disc player considerations

By Curt Phillips

No doubt you have heard about how well computer spreadsheet programs also calculate budgets, balance checkbooks and perform a variety of mathematical tasks. What you may not have considered is how useful computer spreadsheets can be for performing technical and engineering calculations. Because spreadsheets are generally marketed as "financial management programs," their capability for doing technical calculations has been given little exposure.

Actually, most spreadsheet programs work better for technical calculations than some programmable calculators that are often used. Being able to see all the data and constants on the screen at once helps the user to better understand the calculations. Furthermore, the full-size paper you can print the calculations on is easier to work with than a small paper tape.

Although many electronics calculations require only the four basic functions of addition, subtraction, multiplication and division, most spreadsheets support a full range of complex mathematical functions such as sine, cosine, arc-tangent and the other trigonometric functions, as well as logarithms, natural logs, absolute value, exponents and square roots. Remember that even when square roots are not intrinsically supported, raising a number exponentially to the ½ power is the same as taking the square root.

It doesn't take a complex formula to show you the advantages of using a spreadsheet to make calculations. Let's say you are working on an electronics project and need a resistance of a certain value. A search through your parts box yields no resistor with the needed value, and no combination that will add to the needed value by connecting them in series.

The formula for resistors in parallel:

$$R_T = \frac{1}{1/R1 + 1/R2 + 1/R3 \ldots}$$

requires no complex math, only division and addition. But it is tedious enough that you might not want to punch the calculator buttons repeatedly to compute the different possibilities through trial and error. When the formula is entered into a spreadsheet, however, it becomes easy to calculate many combinations of resistors in parallel (also capacitors in series).

```
E2: (F2) @IF(C18>0,1/C18,0)                                              READY

     A      B          C        D          E          F        G        H
1    R  Value      1/value
2    1      1000     0.001  Total >>     322.58
3    2      1000     0.001
4    3      1000     0.001
5    4     10000    0.0001
6    5         0         0
7    6         0         0
8    7         0         0
9    8         0         0
10   9         0         0
11   10        0         0
12   11        0         0
13   12        0         0
14   13        0         0
15   14        0         0
16   15        0         0
17
18                  0.0031
19
20
10-Dec-87   04:14 PM                                        NUM
```

Fig. 1. An example of using a spreadsheet to calculate values for resistors in parallel. This one is limited to 15 resistors but can be readily expanded to any number needed.

I set up this spreadsheet to handle up to 15 resistors in parallel, but I could easily expand it to handle any number needed. In column A of Fig. 1, I placed a label for the resistor number to keep track of what value goes where. Column B is where the individual resistances are entered. Column C merely computes the inverse of the number in Column B.

At this point, cells in Column B with a value of zero can cause a problem. Some spreadsheets allow you to set division by zero to equal zero instead of giving you an error message or some indication of infinity. Other spreadsheets allow for an IF..THEN..ELSE function. With this you can enter the formula so that if the value of X in column B is greater than zero, it will calculate 1/X. Otherwise, it will display zero (@IF(B3> 0,1/B3,0) in the Lotus 1-2-3 formula format).

At cell C18, the sum of all the inverses is calculated and at cell E2, the inverse of this total (C18) is taken (with the same precautions against division by zero). Cell D2 serves as a label for E2.

With this you can easily calculate the equivalent resistance of many combinations of resistors in parallel. Once the formula is entered correctly in the spreadsheet, all subsequent calculations will automatically be correct. Although you could calculate this simple formula repeatedly with a calculator, all the key punching required increases the possibility of mistakes. The probability that you would get tired of doing the calculations and quit is even higher.

Another example is shown using the formula:

$$f = \frac{10^6}{2\pi\sqrt{LC}}$$

Although this formula, where f = frequency in kHz, L = inductance in microhenrys, C = capacitance in picofarads, and π = 3.14, is more complex, it still does not require use of advanced math functions. This formula calculates the resonant frequency of a series circuit.

Here (Fig. 2) inductance L in microhenrys (μH) is entered in cell B4 and capacitance C in picofarads (pF) is entered

```
B1: (,0) @IF(B4*B5>0,(10^6)/(2*3.14159*((B4*B5)^0.5)),0)                    READY

        A              B            C            D            E            F
1   Frequency >>     12,031
2
3
4   L in uH              35
5   C in pF               5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
10-Dec-87   04:22 PM                                             NUM
```

Fig. 2. In this example, the spreadsheet is set up to calculate resonant frequency "f" for given values of capacitance "C" and inductance "L."

in cell B5. The cells in column A immediately to the left are used for labeling. The calculation is done in cell B1, where the formula is entered as (10)/92*3.14*-((B4*B5)0.5)). The Lotus 1-2-3 IF statement is used to test B4*B5 for greater than zero to prevent division by zero. Again, the square root can be expressed by the 0.5 exponent, which is what I used in this example.

This spreadsheet is not only useful for practical calculations of circuit resonance, but as a teaching tool to easily illustrate the effect of changes in capacitance and inductance on resonant circuits.

Spreadsheet programs are available for almost all brands of computers, and even the less-expensive spreadsheet programs are useful for these types of calculations (graphics are not needed). So the next time you have some electronic calculations to do, give a spreadsheet a try.

Cars and Compact Disc Players

Compact disc players have made substantial inroads in home audio systems and are now being pushed for the automobile. Both as original equipment and in the after market, CD players are now readily available in car-stereo configurations. Before you rush out and spend the extra money for a car CD player, however, you should consider several reasons why compact disc players might not be the best choice for use in automobiles.

First, consider the advantages of the compact disc and how they interact with the automotive environment. Compact discs offer a greater dynamic range than other forms of recordings and the noiselessness of the quiet passages is especially striking. However, the noiseless quiet passages are difficult to appreciate in a car where wind noise, engine noise and other sounds are mixed in.

The car's level of background noise also affects the usefulness of the wide dynamic range. Recording with a wide dynamic range may compel the listener to constantly adjust the volume; if it is turned loud enough for the soft passages to be audible over the background noise, the loud passages will shatter the windows (or the eardrums, whichever comes first). Similarly, if the loud passages are set at a tolerable volume level, the soft passages will be lost in road noise. This situation is worse with sports cars and not as annoying with luxury cars, but all cars exhibit these characteristics to some extent. For many years, I have purposely compressed the dynamic range on tapes I record for use in my (sports) car, to overcome just these problems.

The cost of compact discs must also be considered. The cassette tapes I use at present are copies of albums that are kept safely at home. At $10 to $20 per CD, I won't buy two copies of each album, and I dislike the idea that my only copy of an album will be subjected to the extreme temperatures and other rigors of use in an automobile. Although CDs are certainly more rugged than LPs, I concur with the growing belief that they are not as indestructible as was first advertised. Compact disc players have error-correction and interpolation circuitry, but there's a limit to what the miracles of electronics can do when discs are severely damaged.

The possibility of theft must also be considered . . . and not just theft of the CD player. The considerable investment in the CDs themselves is at risk. Several years ago, my car was broken into and the thieves took my ham-radio transceiver (evidently thinking it was a CB rig) and 25 tapes in a case. My in-dash radio/tape deck was evidently more trouble than they had time for. My insurance covered loss of the radio but didn't pay a penny for the stolen tapes.

Because I had recorded almost all of the tapes, the pure monetary loss was limited and I had the means to replicate the collection (though the labor was enormous). Even if the cost of replacing stolen CDs is unimportant to you, sooner or later, certain CDs will be irreplaceable. Over time, production of some CDs will be discontinued, and you may have to choose between having your only copy at risk in the car or not listening to it in your car.

These are several reasons why I don't consider a car CD player to be a good choice for me; perhaps some of them will apply to you as well.

Your comments and ideas for this column are welcomed. You can contact me at P.O. Box 678, Garner, NC or by computer on Delphi (CURTPHIL) or The Source (BDK887). **ME**

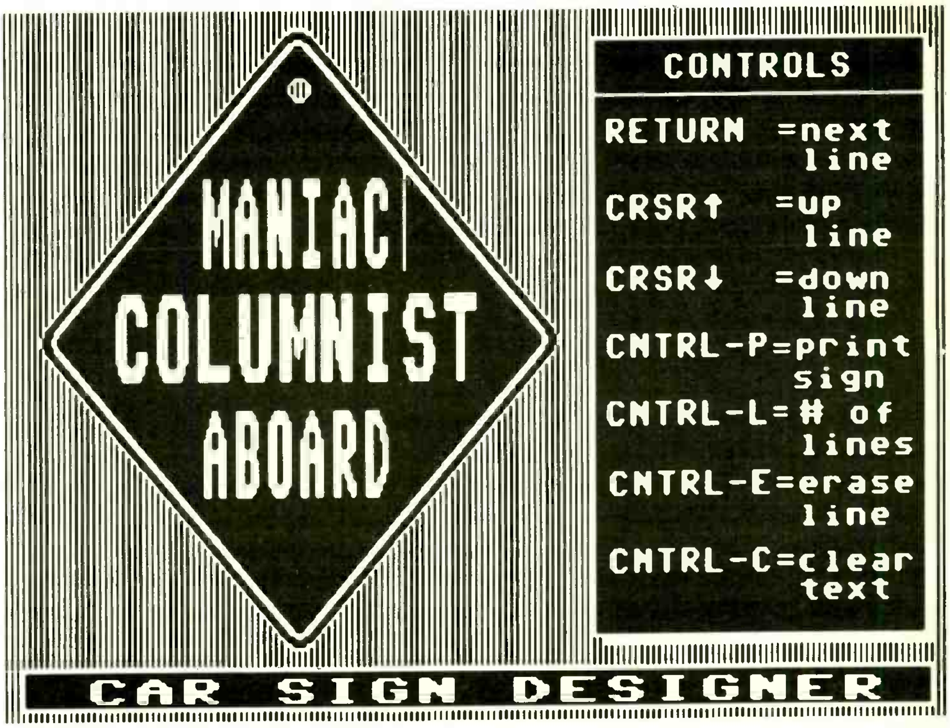
Clone compatibility; making car signs; computer "mice"

By Ted Needleman

A question that I'm frequently asked is whether a PC compatible, or clone, is as good as a "true blue" IBM. If you already know the answer, and the reasons for it, just skip ahead a bit. But for those of you who don't, the answer today is often "Yes," but always with at least one reservation. This reservation is that as close to 100 percent compatibility as some clones are, *nothing* except another IBM is completely compatible. And even IBMs are not necessarily 100 percent compatible when comparing different IBM models.

Comparing compatibles to an IBM model is a complex subject that can be broken down into many categories. It would require a book to do justice to it. In this brief space, however, comparisons can be briefly considered in two areas: 1) software and hardware compatibility; 2) parts quality.

The major concern in the first group is with the model's BIOS (basic input/output system). This is coded information contained in Read Only Memory (ROM) on the system's motherboard. Its data tells the computer how to read the rest of the operating system from a disk when the computer is powered on, as well as performing self-test diagnostics. It also has much of the control codes on dealing with how disk drives, printers, video screen and keyboard are handled. Since IBM copyrighted this code and holds it close to its vest, supported by a battery of lawyers who are on the lookout for copyright infringement, a different BIOS must be used by compatible makers that gets around the copyright while being as compatible as possible. If the substitute BIOS isn't *very* compatible, you'll have problems running certain MS-DOS applications programs that go directly to BIOS routines rather than through the operating system to attain greater speed. Graphics-oriented programs are notorious for this. Happily, there are ways around the copyright that were found right from the start. Compaq, for example, was fully compatible with IBM's PC at the outset. Other "majors" have done the same.



Example of a sign printout using Zebra Systems' "Car Sign Designer."

The more serious BIOS challenge for today's buyer is with computer brands that do not carry a major company's name. They're generally sold by mail and feature remarkably low prices.

Today, two companies, Phoenix Technologies and Award Software, provide the BIOS for the majority of compatibles on the market. The BIOS from either company is good (though Phoenix's seems to be held in slightly higher regard by some). Since they're the major makers of BIOS's proven to be compatible with MS-DOS software, I have greater confidence when buying a "no-name" compatible or assembling one from mail-order sources if it comes with a BIOS from one of them. This assures me that the system will run most, if not all, software written for the IBM. Other BIOS brands may do the same...or may not. Check it all out with the supplier before you buy. Sometimes you can get one of the cited BIOS ROMs substituted.

In addition to software compatibility concerns, hardware compatibility is another consideration. For example, some Tandy computer models use shorter-length full-size expansion boards than the standard IBM size. As a consequence, most of the clone boards sold at low prices won't fit into these machines, forcing you to pay much more when you expand your system (as everyone eventually does).

Other factors are not critical, but can affect compatibility. Disk format (5.25 or 3.5 inch) is a matter of choice. Most major software suppliers include both sizes in their packages now, but software from many smaller companies is only available in the 5.25-inch format. The pc bus format is evolving, too. While IBM's new Micro Channel bus will become a standard, it won't happen for another year or two. Its new VGA graphics will become a standard a lot sooner. Therefore, when upgrading, you might try and buy a graphics display board that is either compatible or can be upgraded for use with higher-resolution VGA monitors.

Comparing an IBM computer's quality with that of a compatible is a wide-ranging proposition. One has to determine which brand of drives are used and which ones are better, for example. What size (power output) power supply is employed, are the ones used in "no-name" computers UL improved, ad infinitum. IBM in the past has used various brand drives, so it's difficult even here to make a judgment. The same holds true for unsocketed ICs. IBM has done it both ways. For me, I'd always want sockets so that it's easy to change parts.

One can go on and on here. The upshot now for prospective buyers of standard PC/XT/AT compatible computers is that IBM no longer makes them in their original form. So unless you're interested in a PS/2-series model, comparing them directly might be considered moot. Nevertheless, these models are still very much alive and kicking as compatibles. And it's an enormous market.

Should you buy a compatible? I believe so. There are a large number of systems, from companies big and small, which offer a better price/performance than Big Blue ever did. And while there is a saying that "Nobody ever got fired for buying IBM," I know several people who boosted their careers by purchasing three compatible computers for the price of two "true-blues."

To Less Serious Matters

While the greatest amount (in dollars) of software sold these days is for "serious" applications, such as word processing, spreadsheets, and the like, there is still a large market for entertainment software. After all, "All work and no play...." One such piece of software is Car Sign Designer from Zebra Systems. This program, available for the IBM, Apple II and IIGS, and C-64 and C-128, lets you make your own yellow diamond-shaped car signs. You know the ones. They bear such messages as "BABY ON BOARD," "WIFE IN TRUNK," and other such witticisms.

If you've always wanted to express your own sentiments, such as "TAKE A LONG DRIVE OFF A SHORT PIER," now is your chance. For under $30, you get two yellow sign holders, a package of yellow fan-fold pin-feed paper and the program disk with which to do it.

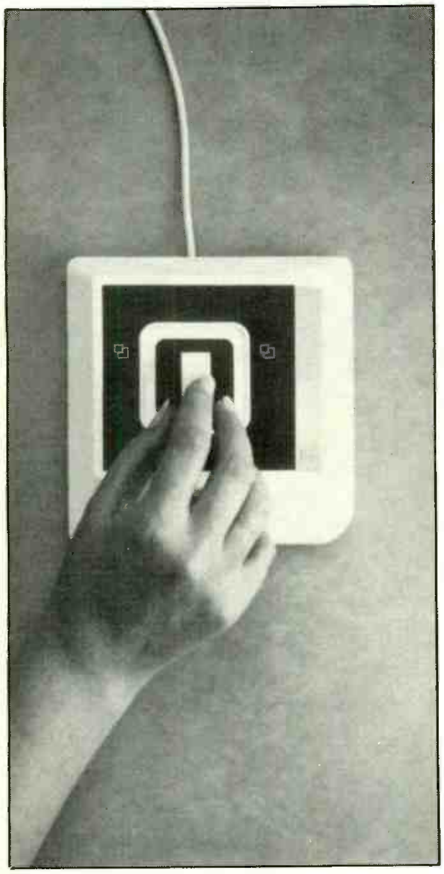
I received the IBM version. After copying it to my hard disk, and running an INSTALL program to specify my display adapter and printer, I proceeded to start making signs. The program comes with its own simple editor, and both the sign in progress and the editing keys are shown on the display (see screen dump). The CTRL-L command determines the number of lines on your sign (from one to four) and more or less centers everything. When the sign is printed (with CTRL-P) you fold the paper along the edges and slide it into the yellow plastic holder.

Extra sign holders, in packages of six, are available from Zebra. The signs come out with the letters a bit jagged, and not all printers are supported, so check with Zebra to make sure your configuration will work with the software. It's not the most serious piece of software I've reviewed in the last couple of months, but it is fun and very easy to use.

A Mouse-Eating Cat?

Until I started using an Apple Macintosh, I couldn't figure out what all the "mouse-mania" was about. After all, much of what I do is word processing, and while I'm not the world's greatest typist, anything that requires taking my hands off the keyboard is only going to slow me down even further. Then I started using PageMaker and MacWrite on the Macintosh. I discovered that pull-down menus, changing fonts, and selecting portions of text with the mouse quickly becomes addictive, and now all three of my PCs also sport little rodents.

Two of these are mechanical (Microsoft and Torrington), and the third is optical (Mouse Systems). Each has its pluses and minuses, but all require some



Felix for Mac Plus.

Felix for the IBM PC.

amount of clear desk space for "moving and shlepping." Substituting a joy-stick or trackball for these non-game applications never met with success. Last week, however, what may ultimately be the mouse's replacement showed up. It's called Felix.

I received both the IBM and Macintosh versions from Lightgate, but have only had the chance to experiment with the Mac Felix so far. Felix is a small box about the size of a floppy disk and approximately ¾ inch high. It has a small handle that slides about in a square area of about 1.25 inches on a side. On top of this handle is a button. The Mac version has two small membrane switches on the base to either side of the "slide area" (more about this in a while). It works with the original 128K Mac, the 512K Mac and the Mac Plus. Versions for the SE and Mac II will be out soon. Felix plugs into the mouse port on the Mac, and into a Comm port on the IBM. The Mac version takes its power from the mouse port, while the IBM version includes a small "wall-plug" power supply which plugs into the serial computer's DB-25 connector.

Setting up the Mac version took about 45 seconds. First I unplugged the mouse, plugged Felix in, booted the Mac and selected the Control Panel from the Finder. After clicking on the tablet pointing mode, I "taught" Felix the screen size by running the pointer around the video screen's perimeter. That's all there is to setting up the system!

Felix is an interesting device. The handle is held with your fingers like a pencil. A very small displacement of the handle translates into a much larger one on the screen. For those of us who are used to sweeping movements with a mouse, this takes a little getting used to. Once mastered (about 10-15 minutes), though, the fingers exercise a great deal of control.

The device operates electromechanically. Inside the case is an array of LEDs and detectors. The sliding handle operates a gate through which the beams shine as the handle is moved. There is little to go wrong with this design. Additionally, both versions of Felix have a precision mode, where full travel of the handle is limited to movement of the cursor over only a portion of the screen. The switch to precision mode is accomplished by pressing the membrane switch on the Mac version, and a scheme called "Hot-Spots" on the IBM version. Here, moving the handle to the lower right corner of travel and clicking the handle button serves to put Felix into precision mode. By using combinations of the CTRL, ALT and SHIFT keys, various macros can be assigned to three of the corner "Hot-Spots."

Felix is a cleverly designed device that overcomes many of the limitations of conventional mice. Whether the "cat" can catch up with the mouse, much less devour it, remains to be seen. At a list price of $199 for the PC version and $149 for the Mac version, it is considerably more expensive than a mouse. Its precision mode, however, will be very attractive to those of you who work with CAD or paint programs, while the "Hot-Spots" can make working with spreadsheets and word processors much simpler and efficient. **ME**

Names and Addresses

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Woodhaven, NY 11421
(718) 296-2385

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6300 Telegraph Ave.
Oakland, CA 946098
(415) 653-8500

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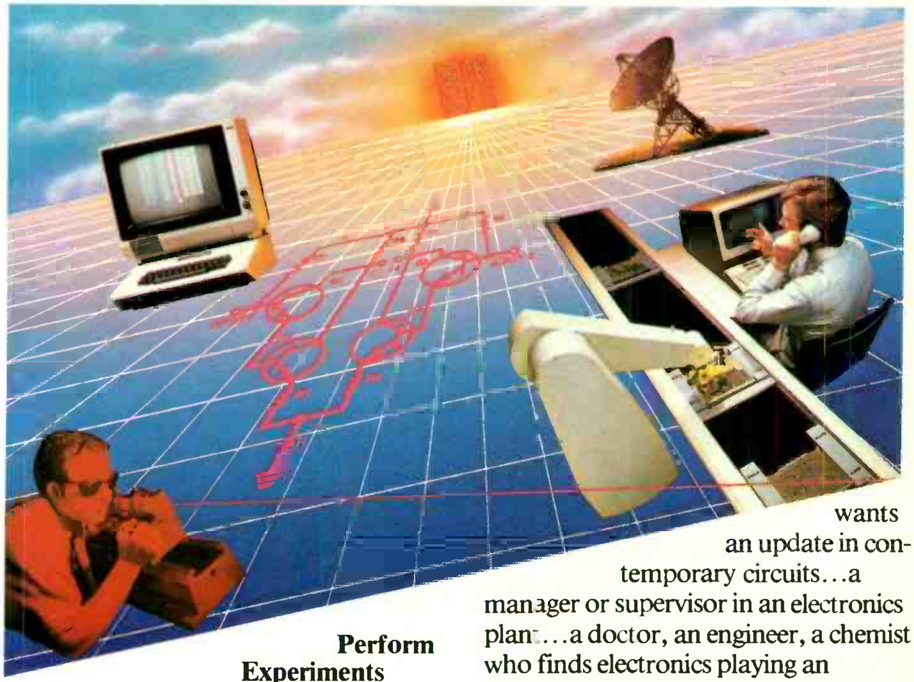

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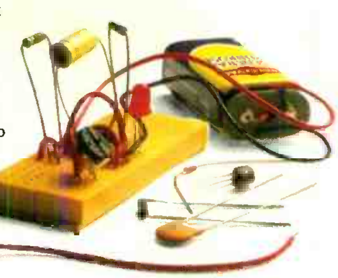

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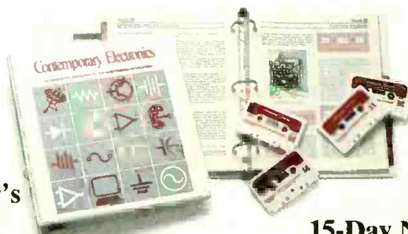

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GOfer—A High-Speed Text Searcher

By Art Salsberg

Microlytics, Inc. (E. Rochester, NY) established itself as a winning software company in the auxiliary word-processing field with its Word Finder thesaurus program, followed by a hardware spelling checker developed in conjunction with Xerox, PC Type Right. Now it has introduced a text searcher that can be added on to popular word processors and other programs—GOfer.

Fast text-retrieval software is the latest type of utility that appeals to computer users. The $79.95 GOfer pop-up program is one of this new breed. It's designed for use with IBM PC/compatible computers and PS/2 machines, working with PC/MS-DOS 2.0 and higher. It comes on a 5¼-inch disk and is also available on a 3½-inch disk.

GOfer takes up 79K of RAM when it's memory resident (it can be loaded from DOS without being RAM resident, too), and is not copy-protected. A clearly written and satisfactorily illustrated 78-page manual accompanies the program.

Using GOfer

GOfer installs easy enough with the aid of menus for the user to choose a variety of options. One of the setup options requires you to select programs you want GOfer to work with; about 30 programs are listed, including ASCII (editor), Lotus 1-2-3, PFS-Write, Sidekick, WordPerfect, Xywrite, WordStar, and dBase III, among them. At least one has to be selected, while the maximum number that can be chosen is ten. Buffer size and files choices can be changed from its preset sizes to adjust RAM memory size to be used if available memory is limited.

Read-from (source) and Write-to (target) programs are selected, with the most popularly used one chosen as the default. This might be your word-processor, for example.

Activating GOfer while within an applications program is accomplished by pressing the traditional hot keys, in this case Alt-G. (Another command key can be chosen if there's any conflict with a different program.) Pressing these keys places two windows on the screen while you're in the application program: the Main Menu, which is a horizontal line-up of major choices such as DriveDirectory?, and a Text Entry Window (see illustration). Pressing ESC at any time activates the Main Menu.

```
                              GOfer Main Menu
  Text?  Drive\Directory?   Files?   View?  GOfer It    Quit   Options

                    ENTER TEXT TO GO FOR
                               or
      or                       or
                               AND
                               or
      or                       or
        Exactness: Upper and/or lower case

  Alt-L : AND/OR/NOT/NEARBY                 Enter: Accept Entry
  Alt-E : Change Exactness                  Alt-F: Accept All
  Arrows: Move Cursor                       Esc  : Main Menu
```

GOfer's Export Menu.

One normally starts by typing out text-search needs in "Enter Text To Go For." Pressing the Return key moves the cursor along its way. Up to 20 characters can be typed in each field. The eight fields presented are divided in half by a logical relationship, starting with AND. Pressing Alt-L changes the relationship between the upper and lower groups to OR, NOT or NEARBY. Choosing the latter brings up a small window to let you choose just how close they can be. An EXACTNESS selection fine tunes the search even more by allowing greater deviances, such as upper and/or lower case and misspelled words.

This done, you choose the drive and directory by either entering what's highlighted or typing in what you want. You can choose a directory tree, too, in the event you're not sure what the name is. All files in the chosen directory can be listed and the user simply navigates with the cursor-movement keys to the one(s)

```
ASCII (editor)                  View Find              Hit :    4  Top:      68
Volume: MIKE'S DISK            File:MCI921.MDR         Line:   76  Bottom:   84
Path: C:\PROCOM\
                                                                           PgUp
First, a word about GOfer... It's FAST (searches multiple files at over 1
megabyte a minute a standard AT!). You can look for something from inside your
document in your word processor, or while on-line on MCI Mail, Compuserve, or
your office LAN, or ]/q can be in Lotus, dBase, or in any other program. When

Press RETURN for more; type NO to stop:
Press RETURN for more; type NO to stop:
                                  EXPORT
you want to find something, j               look for, and a clue, if
you have it, as to where to l  Export to:    what you want, shows it to
you, and lets you copy and pa               u're in, or send the find
to the printer, or to a file.  Current Program  this gives you a good
flavor for the product. There
                               Disk File
Attached is an flat sheet cre               full page ad, running now
in the latest PC Magazine, Pe  Printer       and elsewhere. Look for
many super reviews in the wee               are implementing an
                               Esc  : Cancel                               PgDn
Arrows: Scroll Screen          Enter: Accept               Enter: Next Find
Home  : Top of File                                        F    : Next File
End   : Bottom of File        E: Mark for Export           Esc  : Stop/Summary
```

The program's Text Entry Window.

he wants, selecting it by pressing the space bar, which highlights it. Pressing Return confirms this and brings up an Output window.

Here you have a choice of viewing each find on the screen, writing to a disk file, printing or just plain browsing through the retrieved text. By pressing the key, E, while viewing or browsing, a small window pops up in the middle of the screen that's titled EXPORT. This gives you an opportunity to select the beginning and end of the retrieved text for transfer of the information to a destination you choose, such as the application program you're working in.

Selecting "Options" from the Main Menu provides the user with operating flexibility such as creating a second file that's compressed up to 50 percent, decompress, copy, delete, rename, changing the configuration, varying colors, etc.

Comments

GOfer worked admirably. It operates speedily in practice, while being spec'd at search rates through multiple files at up to 16K bytes per second on a PC-AT computer. There's no time wasted in compiling an index, as some other text-retrieval programs require, so the search starts immediately.

An indexed program, however, can have the ability to do the actual search faster once the index is compiled, though. This would be better if one had enormous files that don't change much. For most purposes, however, GOfer fits the bill very well.

Twenty characters and eight fields might seem limiting to some, but I found that I didn't need that much descriptive space at all. I like GOfer's compatibility with so many programs, which also includes communications programs. WordStar 3.x or 4.0 users will particularly welcome GOfer since they do not incorporate windows. Now, at least, there's some type of shot at quickly checking out text in another file while working within the word processor.

In all, GOfer is a useful utility to add, along with other handy ones. **ME**

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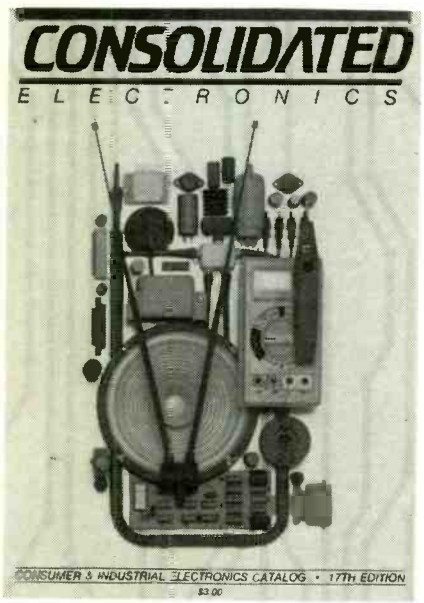

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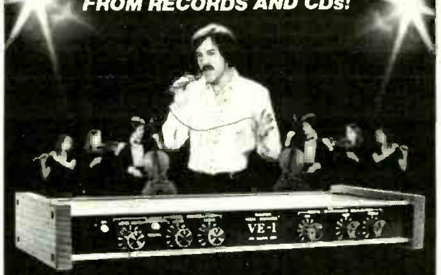

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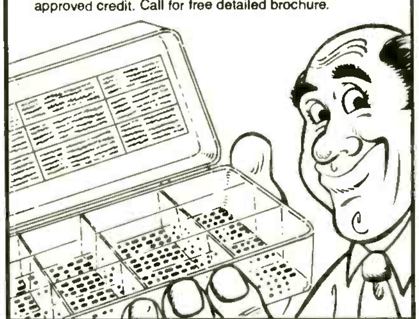

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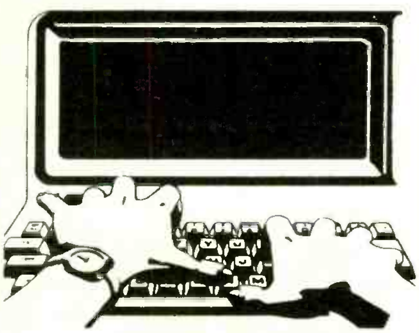

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Surface Mount *(from page 53)*

Step 1 in the repair process is to remove most of the solder on the IC connections. (*Caution:* Prior to doing repair work, make sure that your soldering iron is properly grounded and that your electrostatic-discharge control wrist strap is properly connected.) Using a soldering iron and desoldering braid, slowly remove the solder from connections on all sides of the IC, as illustrated.

Next, using a fine-pointed hobby knife and a cone-tip soldering iron, gently free each IC connection from the circuit card. Once all connections have been freed, the IC can be removed.

When replacing the surface-mount IC, first align the IC's leads with the printed-circuit card traces. Holding the IC in place with your finger, solder a lead at each corner of the device to the board's pads. This will hold the IC in place until all connections are soldered. **ME**

Transistor Tester *(from page 57)*

bottom of the board. Peel the protective paper from the other side of the tape and mount the board assembly in the enclosure flush with one end of the box. Then mount the battery to the other end of the box with the other piece of foam tape.

Place the front panel on the box and secure it in place with the four screws that were provided.

Using the In-Circuit Transistor Tester is almost self-explanatory. You simply determine the base, emitter and collector leads of the transistor to be tested, clip the test-lead connectors to them accordingly and press the PRESS TO TEST pushbutton while observing the LEDs. If the transistor is good, either the NPN or the PNP LED will light, simultaneously identifying the type of transistor under test and verifying that it is good. If both LEDs or neither LED lights, the transistor is almost certainly bad, regardless of type, and should be replaced. **ME**

Mixing Frequencies *(from page 33)*

to intermediate frequencies and even individually checked there with a frequency counter.

The examination revealed one of the unsung marvels of the superhet: the intermediate frequencies maintain proper relative amplitude and phase relationships and thereby mimic the shape of the signal at the antenna very nicely. This test yielded the photo shown in Fig. 9, confirming the result shown in Fig. 8. A considerable improvement was realized when the amplitude of the sideband was reduced to half that of the carrier, shown in Fig. 10.

Further reducing the sideband for a 1:3 amplitude ratio gave additional improvement, but the modulation envelope never actually became sinusoidal, and the percentage of modulation decreased even more. Perhaps at near 0-percent modulation a sinusoidal variation in the envelope may almost be there.

This single sideband information may be of use to someone who is attempting to modify a conventional receiver. However, the secret to whatever success SSB operation enjoys is in an additional heterodyning step that is not found in, for example, the AM broadcast-band receiver. There is simply no way to recreate a good modulation envelope by *linearly* mixing carrier and one sideband. Acceptable audio more likely comes from generating a proper carrier and heterodyning it with the output from the final intermediate-frequency range. By filtering out all audio frequencies, only the difference frequency remains, and that is the audio. **ME**

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