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MODERN ELECTRONICS™

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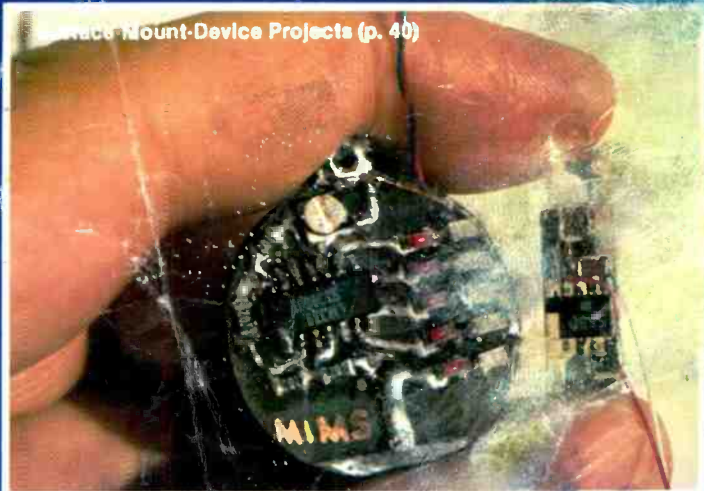
THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

- **A $30 ACCELERATOR KIT BOOSTS PC SPEED 30%**
- **BUILD A MULTI-EPROM PROGRAMMER**



Surface-Mount-Device Projects (p. 40)

Full Construction Plans:

- A Radio-Controlled Remote Doorbell
- Inexpensive Wireless Headphones

Plus:

- Using the LM723 Power-Supply IC
- Surface-Mount-Device Circuits: A Design & Construction Guide

Stand-Alone EPROM Programmer (p. 50)

Screen display generated by Tornado Notes (p. 82)

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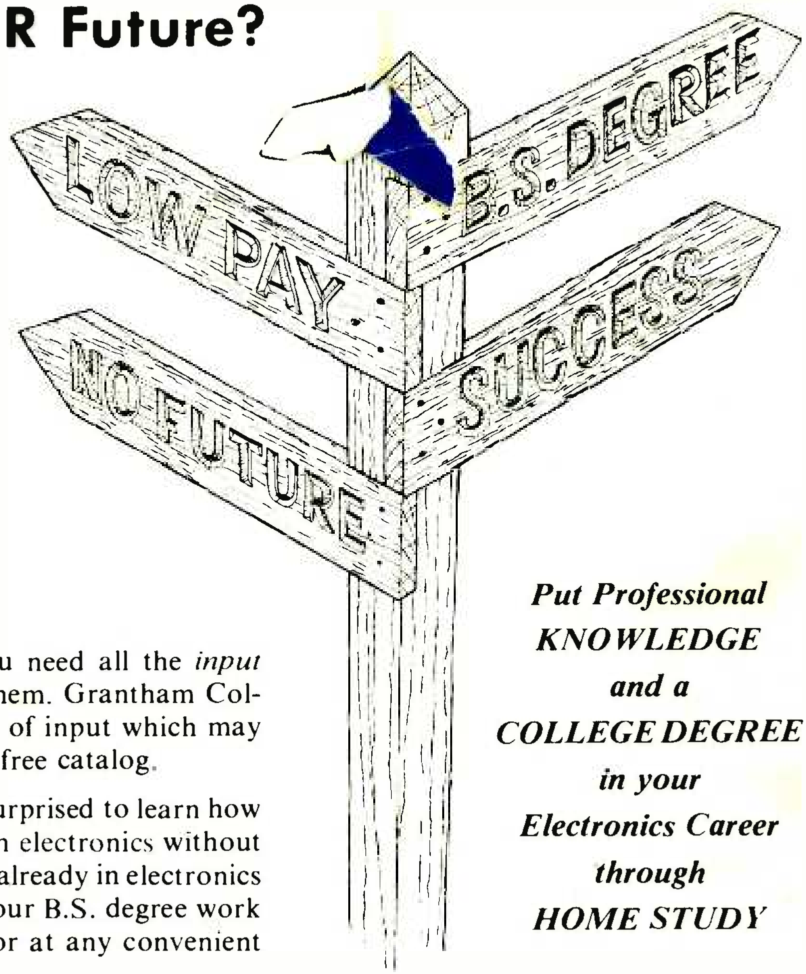
Also: Eric Grevstad's impressions of Tornado Notes and JumpStart • Don Lancaster discusses thermoelectric modules; multiple video monitor setups; laser printer toner cartridge refills • English-Language Shortwave Broadcasts • Electronic and Computer News . . . and more.

Which Way To YOUR Future?



Are you at a crossroads in your career? Have you really thought about it? Are you *planning* for your future, or perhaps refusing to face the subject? Which way will you go — down the same old road? Or are you ready for something else?

In electronics you can't stand still. If you are not moving ahead, then you're falling behind. At the crossroads of your career, various choices are available — and, yes, *decisions* have to be made.

Which road will you take — one that doesn't go where you want to be, or one that leads to hard work *but also* to the better life? Ah, decisions, decisions!

Career decisions are so important that you need all the *input* you can get before locking-in on one of them. Grantham College of Engineering offers you *one* source of input which may help you in making that decision. It's our free catalog.

Ask for our free catalog and you may be surprised to learn how it is easily possible to earn a B.S. degree in electronics without attending traditional classes. Since you are already in electronics (you are, aren't you?), you can complete your B.S. degree work with Grantham while studying at home or at any convenient place.

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But don't expect to earn that degree without hard work. Any degree that's worth your effort can't be had without giving effort to the task. And of course it is what you learn in the process, as much as the degree itself, that makes you stand out above the crowd — that places you in an enviable position, prestige-wise and financially.

Grantham offers this program, complete but without laboratory, to electronics technicians whose objectives are to upgrade their level of technical employment.

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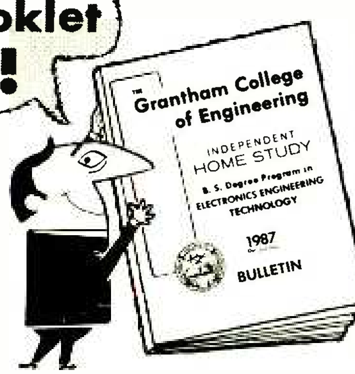

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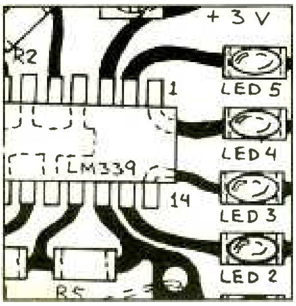
VOLUME 4, NUMBER 2



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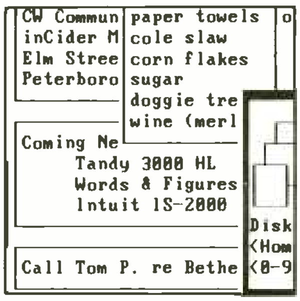

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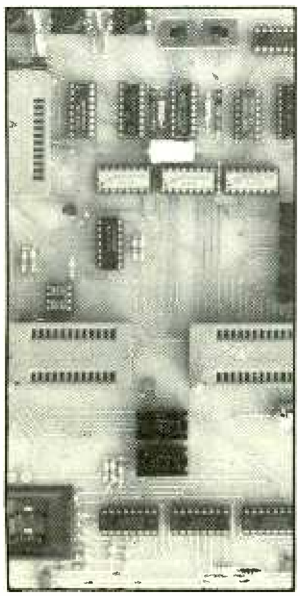
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FEATURES

COLUMNS

DEPARTMENTS

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2.2	35	272-1435	.59
10	16	272-1436	.69
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pF	WVDC	Cat. No.	Pkg. of 2
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47	50	272-121	.39
100	50	272-123	.39
220	50	272-124	.39
470	50	272-125	.39

µF	WVDC	Cat. No.	Pkg. of 2
.001	500	272-126	.49
.0047	500	272-130	.49
.01	500	272-131	.49
.047	50	272-134	.49
.1	50	272-135	.49

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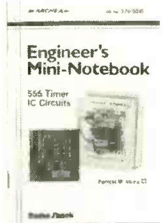
Low As **99¢**



Our Mini-Notebooks By Forrest Mims III help you learn to use ICs and other solid-state devices

Mini-Notebook Subject	Pages	Cat. No.	Only
Timer ICs	32	276-5010	.99
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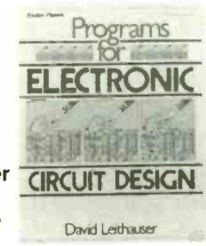
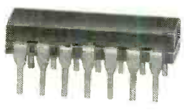


Use Your Computer To Select Proper Component Values

This 132-page book contains listings for BASIC programs that help you design electronic circuits. Topics include R-C, R-C-L and filter circuits, transistor circuits and timer circuits using the popular 555 IC. All programs are written in "universal" BASIC and are designed to run on virtually any home computer. #62-1054

4000-Series CMOS ICs



With Pin-Out, Specs

Description	Type	Cat. No.	Each
Quad 2-Input NOR Gate	4001	276-2401	.79
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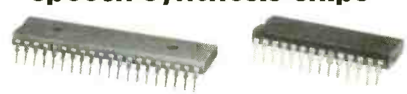
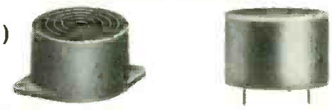
Dual Type-D Flip Flop	4013	276-2413	1.19
Decade Counter/Divider	4017	276-2417	1.49
Inverting Hex Buffer	4049	276-2449	.99
Quad Bilateral Switch	4066	276-2466	1.19

Speech Synthesis Chips



CTS256-AL2 Text-to-Speech IC. 40-pin device translates ASCII from RS-232 into control data for synthesizer below. With data. #276-1786, **16.95**
SPO256-AL2 Speech Synthesis IC. 28-pin MOS LSI device uses a stored program to produce natural speech. With detailed data and circuit examples. #276-1784 .... **12.95**

Sound Values

(1)  (2)

(1) Tri-Sound Siren. You've never heard a buzzer like this! Contains an IC, driver and speaker in a compact case. Wiring options provide three unique, extra-loud sounds. Requires 3 VDC. #273-072 .... **5.95**
(2) PC-Mount Piezo Buzzer. Loud, yet consumes only 12 mA at 12 VDC. #273-065, **2.49**

7400-Series TTL ICs

All Include Pin-Out And Specs

Description	Type	Cat. No.	Each
Quad 2-Input NAND Gate	7400	276-1801	.89
Hex Inverter	7404	276-1802	.99
Quad 2-Input AND Gate	7408	276-1822	1.29
BCD to 7-Seg. Decoder/Driver	7447	276-1805	1.69
Div. by 2 or 5 BCD Counter	7490	276-1808	1.19

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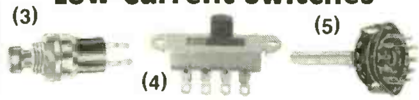
Guard Your Valuable Equipment!

Six-Outlet. Features dual MOVs for common and differential mode protection, push-to-reset breaker, bidirectional noise filter with 500 kHz to 5 MHz range, and status indicator lamp. Handles 13 amps. UL listed AC. #61-2786 .... **24.95**
One-Outlet. With status indicator. Rated 15 amps. UL listed AC. #61-2791 .... **7.95**

Low-Current Switches

(3) (4) (5)



(3) Mini SPST Momentary. 0.5 amp at 125 VAC.
Normally Open. #275-1547 .... **Pkg. of 5/2.49**
Normally Closed. #275-1548 .... **Pkg. of 5/2.69**
(4) Slide Switch Kit. Includes one each: SPDT, DPST, DPDT, plus 3 SPSTs. Rated 0.5 amp at 125 VAC. #275-327 .... **Set of 6/1.79**
(5) Rotary Switches. Rated 0.3 amp at 125 VAC.
2-Pole, 6-Position. Non-shorting. #275-1386 ...... **1.19**
1-Pole, 12-Position. Shorting type. #275-1385 ..... **1.19**

Power Supply Diodes

Micromini 1-Amp. 30-amp surge.

Type	PIV	Cat. No.	Pkg. of 2
1N4001	50	276-1101	.49
1N4003	200	276-1102	.59
1N4004	400	276-1103	.69
1N4005	600	276-1104	.79

3-Amp "Barrel". 200-amp surge.

Type	PIV	Cat. No.	Pkg. of 2
1N5400	50	276-1141	.79
1N5402	200	276-1143	.89
1N5404	400	276-1144	.99

Resistor Kit Bargains!

(6) (7)

(6) 1/8-Watt Carbon Film. Set of 100 with 13 popular values from 10 ohms to one megohm. 5% tolerance. #271-311 .... **Set of 100/1.98**
(7) 1/4-Watt Carbon Film. Jumbo 500-piece set with 54 popular values from 10 ohms to 10 megohms. 5% tolerance.
#271-312 .... **Set of 500/7.95**

Mini Printed Circuit Pots

1/8-Watt

Only 49¢ Each

Sealed against noise-causing contaminants.

Ohms	Cat. No.	Each
1k	271-333	.49
10k	271-335	.49
25k	271-336	.49
100k	271-338	.49

Brushless 3" DC Fan

Quiet, Compact, Powerful

Lightweight yet delivers 27 CFM airflow. Ideal for cooling circuitry that's sensitive to hum or AC fields, or mobile equipment. Ball bearings for long life and low noise. Requires 7 to 13.8 VDC. #273-243 .... 14.95

High-Style Enclosures

Superb Looks And Quality

Dress up your project! These deluxe all-metal enclosures feature eggshell white bottoms and black tops. Complete with hardware and rubber feet.

Size	Cat. No.	Each
$1^{15}/_{16} \times 8^{1}/_{4} \times 6^{1}/_{8}$"	270-272	6.99
$3^{1}/_{16} \times 8^{1}/_{4} \times 6^{1}/_{8}$"	270-274	8.99

The Relay Corner

(8) (9) (10)

(8) SPST Reed Relays. Contacts rated 1 amp at 125 VAC. Pins for circuit board mounting. Each, Only 1.49
5 VDC Coil. #275-232 **12 VDC Coil.** #275-233
(9) Heavy-Duty DPDT Relays. Contacts rated 10 amps at 125 VAC. Plug in or mount on chassis. Each, 5.49
12 VDC Coil. #275-218 **120 VAC Coil.** #275-217
10-Amp Socket for Above. #275-220 .... **1.59**
(10) SPDT Mini-Relay. 6-9 VDC, 500-Ohm Coil. Contacts rated 1 amp at 125 VAC. #275-004 .... **2.99**

Over 1000 items in stock: Binding posts, Books, Breadboards, Buzzers, Capacitors, Chokes, Clips, Coax, Connectors, Fuses, Hardware, ICs, Jacks, Knobs, Lamps, Multitesters, PC Boards, Plugs, Rectifiers, Relays, Resistors, Switches, Tools, Transformers, Transistors, Wire, Zeners and more!

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CIRCLE 91 ON FREE INFORMATION CARD

EDITORIAL

Electronic Surprises

Purchasing electronic or computer equipment can let you in for a lot of surprises. To be sure, it's not like buying a container of milk.

As an example, I ordered a few sets of 256K dynamic RAMs from one of our advertisers (I.C. Express). The 41256 150-ns chips were boldly advertised as $2.69 each ($24.21 per set of 9). These memory ICs go for anywhere from $20.25 to $30 per set, so the price was right, falling in the middle of the range. Besides, I always try to buy from advertising supporters. Calling in my order, using my credit card number, I got a (pleasant) surprise—the RAM was priced at $2.50 each instead of the advertised $2.69! Seems that such parts are commodities whose prices fluctuate in the marketplace much as commodities on the stock market do. Prices can go the other way, too, so don't necessarily believe what you read, I guess.

A friend of mine bought these chips last month from a local retailer that is not conveniently located for me. He paid more than twice as much ($5.89 each vs. $2.50)! He also paid 8¼% sales tax and local transportation costs. He did save a few days, of course, trading personal time for UPS delivery time.

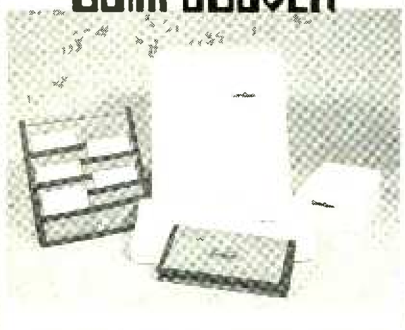
You'll typically pay $5 for shipping costs on a lightweight order, so you must figure this into your cost. But this is canceled out, in truth, by not paying sales tax (unless the mailorder supplier is located in your state). Many mailorder companies also have a minimum purchase amount, which generally ranges from $10 to $25. In the case of the aforementioned supplier, it was $10. There was also a 3% charge for paying by credit card, which added $1.35 to the bill, for a total of $51.35. Still, this was less than half of what my friend paid, so I was rather pleased.

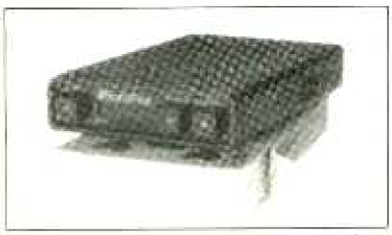
To avoid "surprises," be sure to read the small print in any advertisement, which will note any additional charges. Also, be sure to observe what is *not* printed. For instance, some mailorder companies charge a restocking fee that may range from 10% to 20% of the purchase cost, and you pay one-way shipping charges. This is fair I think if you change your mind about a purchase. It strikes me as being unfair, however, if such a charge is made for exchange of a defective unit. I hear that this has been the case with some computers that were returned because they did not work properly. So check this (for exchange of a defective product) before you plunk down your money for a big-ticket purchase.

Among other things to look for in the omissions field is the absence of a device's speed, where there are choices. Whereas IC Express clearly printed device speeds and accompanying prices, giving the buyer a choice of 100 ns, 120 ns or 150 ns, I've seen ads where speed is omitted. So if you expect, say, an 8 MHz NEC V20 microprocessor that's advertised without mentioning speed, don't be unpleasantly surprised if you get a 5-MHz device. Check it out first, which is easy enough to do (and doesn't even cost you anything because most mailorder operations have a toll-free phone number).

The same caveat goes for any other product that you order through the mail. If you're buying a computer, for example, and the ad does not explicitly state that it comes with a serial port or two drives, or whatever, be sure to ask questions about the system. Don't assume anything; sometimes it's just wishful thinking. For computer software, check out the version number you're getting. They change as often as a woman changes her hairdo, you know. Be aware, too, that some products are advertised with prices that are for quantity purchases, which is noted somewhere in an ad.

In sum, be a wise buyer. Ask intelligent questions beforehand, read an advertisement thoroughly, fine print and all, and you'll reduce the number of electronic surprises you get in your life.



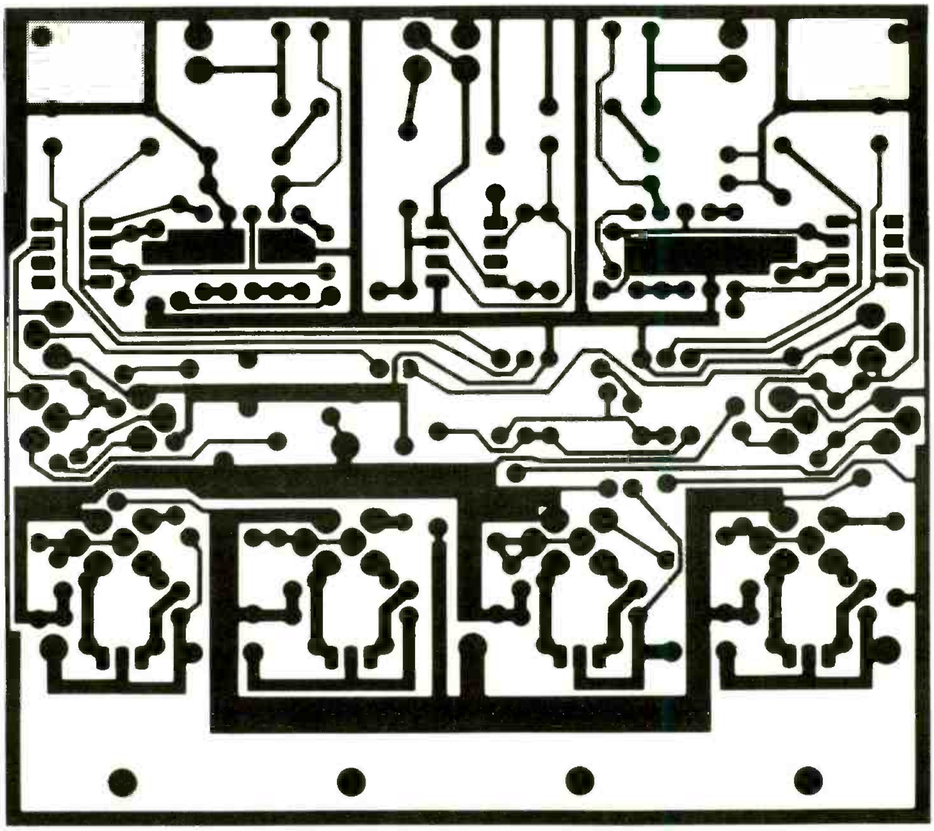


Updates

• In the "100-Watt/Channel, Distortionless Digital Audio Amplifier Booster" in the Dec. 1986 issue, there appear to be a number of short circuits in the etching-and-drilling guide (lower) for the amplifier board. Is there a corrected guide available that I can use for making my own board?

J.E. Fuhrmann
Kew Gardens, NY

You're correct. During printing, a number of short-circuit paths between closely spaced pads and conductors did indeed develop as a result of ink "bleed." Here's the corrected pc guide. Let's hope that the outcome is good this time. . . . Ed.



• My "VCR Hookups With Cable Boxes" article looks very good. However, two of the illustrations need clarification. The A/B switch in Figs. 4 and 5 is actually a flat box with two connection points on the input end and one connection point on the output end. This box is identical to the switch box used with

(Continued on page 92)

MODERN ELECTRONICS NEWS

GRAY-MARKET UPDATE. The gray market labeling bill that requires retailers to notify consumers that they may be buying a gray-market product was signed into law as California AB2735. It went into effect January 1, 1987, and marks California as the only state with a specific statute allowing right of action against retailers who sell gray-market products without disclosure. Good for you, California.

CELLULAR PHONE SNOOPING. As many scanner radio enthusiasts know, conversations on cellular telephones can be overheard on some scanners that include its frequencies. There's a congressional bill, H.R. 3378, to make such cellular eavesdropping illegal. Radio Shack announced that it supports the bill and has never made a scanner that's capable of intercepting cellular frequencies. Its upcoming PRO-S2004 broadband scanner, which includes cellular frequencies, will have these frequencies disabled. Now what about Marine RadioTelephone conversations?

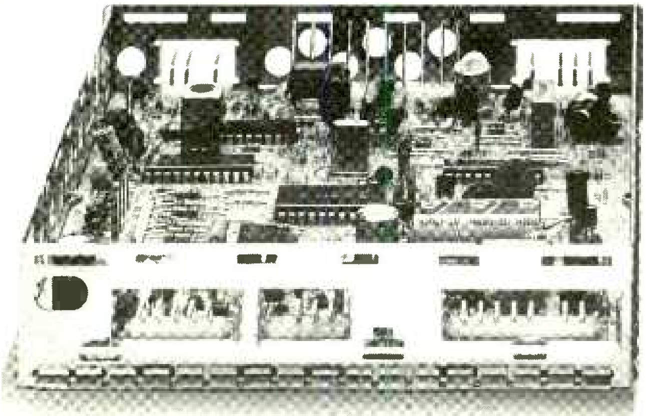
TYPEWRITTEN SHORTHAND. A bevy of new electronic typewriters from Sharp Electronics feature a user-ability to plug their own abbreviations into the machines' memories. Thus, by storing "asap" in a unit's memory, the phrase, "as soon as possible," would be typed when the shorthand abbreviation is entered. Neat, though computers have had this facility for years with macro programs.

DIALING BY NAME. Dialing a telephone number by a name instead of digits promises to grow rapidly. Such a system allows one to dail "MOM" to call your mother, for example, so you don't have to memorize phone numbers. Colonial Data Services (New Milford, CT) has a few models that does this handy electronic trick for you. The company's pocket-size autodialer, Model AD-2 ($79.95), stores up to 200 names and phone numbers for this purpose.

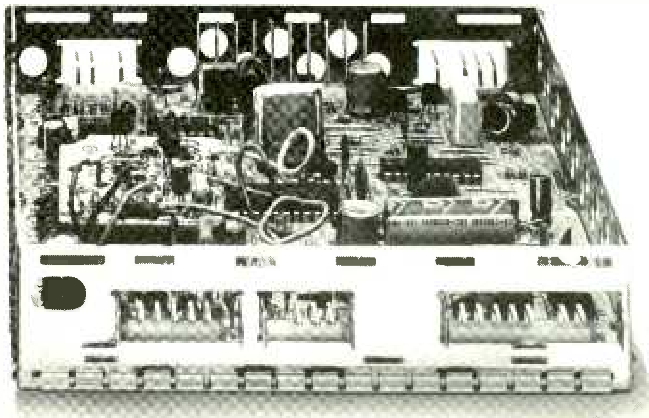
BIOMETRIC COMPUTER SECURITY. The Electronic Signature Lock Corp. (Ardmore, PA) was awarded a U.S. patent for its innovative method of safeguarding computer data. It's based on individuals' neurophysiological patterns when typing on a keyboard or a touchtone keypad. By using mathematical analysis to measure timing between keystrokes and the typing consistency of each subject, the technique is said to monitor individuals accurately. To register, a new user enters an access phrase a number of successive times, which is recorded as an electronic signature. Thereafter, whenever the user enters an electronic signature, it's compared to the registered one. Experiments show that a properly registered person has a one-in-two chance of gaining access on the first try, while an unauthorized person, even one who knows the access phrase, would have a one in one-million chance of gaining access. The Electronic Signature Lock can be implemented in software and/or hardware.

THICK-FILM PRESSURE SENSOR. A thick-film linear potentiometer that's used to measure an object's position and its surface pressure was developed by Interlink Electronics (Santa Barbara, CA). Its very low profile (only 0.015" high) allows it to be integrated within a membrane panel or into any design where space is critical. A Linear Pot Kit for evaluation purposes is available for $30, which includes three linear-pot formats, sample interfacing circuit schematic, and a data sheet. Call 805-965-5155.

Not all RCA modules are re-created equal.



Competitor's rebuilt RCA module



RCA rebuilt RCA module

Only modules rebuilt by RCA guarantee RCA quality.

Recently, one of our competitors slashed prices on their rebuilt RCA modules by up to 40%. Sounds good, until you review their products' performance. Then you'll wonder why they didn't do it sooner.

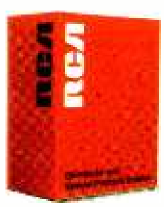
To demonstrate, we selected a random cross-section of their "bargain" boards for inspection. Using the same stringent testing methods RCA applies to its remanufactured boards, more than an incredible 70% of their rebuilt modules were rated unacceptable.

Some simply didn't work. Others lacked design updates, or had a wrong or missing component. The rest suffered from problems in workmanship, such as the use of wire to bridge broken circuit board etchings, which could affect both reliability and performance.

Which all goes to show, RCA modules remanufactured by RCA remain your best bet. Ours are re-created to perform as well as, if not better than, the RCA original. Each contains the latest design updates. And all are thoroughly tested, inspected, and covered by warranty.

Their rebuilt modules may cost less, but the quality just isn't equal.

So do it right the first time. Insist on RCA. Because the quality and performance are built in.



RCA Distributor and Special Products Division

CIRCLE 89 ON FREE INFORMATION CARD

Train for the Fastest Growing Job Skill in America

Only NRI teaches you to service all computers as you build your own fully IBM compatible microcomputer

With computers firmly established in offices—and more and more new applications being developed for every facet of business—the demand for trained computer service technicians surges forward. The Department of Labor estimates that computer service jobs will actually *double* in the next ten years—a faster growth rate than for any other occupation.

Total systems training

No computer stands alone... it's part of a total system. And if you want to learn to service and repair computers, you have to understand computer *systems*. Only NRI includes a powerful computer system as part of your training, centered around the new, fully IBM PC compatible Sanyo 880 Series computer.

As part of your training, you'll build this highly-rated, 16-bit IBM compatible computer system. You'll assemble Sanyo's "intelligent" keyboard, install the power supply and disk drive, and interface the high-resolution monitor. The 880 Computer has two operating speeds: standard IBM speed of 4.77 MHz and a remarkable turbo speed of 8 MHz. It's confidence-building, real-world experience that includes training in programming, circuit design and peripheral maintenance.

No experience necessary— NRI builds it in

Even if you've never had any previous training in electronics, you can succeed with NRI training. You'll start with the basics, then rapidly build on them to master such concepts as digital logic, microprocessor design, and computer memory. You'll build and test advanced electronic circuits using the exclusive NRI Discovery Lab®, professional digital multimeter,

Learn Computer Servicing Skills with NRI's "Hands-On" Training...

Using NRI's unique Action Audio Cassette, you are talked through the operation and practical application of your hand-held digital multimeter—the basic, indispensable tool for the computer specialist.

You'll set up and perform electronics experiments and demonstrations using your NRI Discovery Lab. You'll even interface the lab with your computer to "see" keyboard-generated data.

After you build this digital logic probe, you'll explore the operation of the Sanyo detached "intelligent" keyboard and its dedicated microprocessor.

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.

Digital Multimeter/ Storage Oscilloscope

Leader's new Model LCD-5840 is a combination digital multimeter and 200-kHz storage oscilloscope that uses an LCD screen rather than a CRT tube for display. In the scope mode, the LCD-5840 offers a 10-mV sensitivity and an auto-range function that automatically sets the timebase. Sensitivity, timebase, triggering, slope and sync settings are displayed on-screen. Other scope features include roll mode, pretrigger mode and a memory that stores up to three waveforms with their setting conditions. Memory is battery protected when the instrument is turned off. The LCD window has a 64 × 192-dot resolution, of which 64 × 160 dots are used for waveform display and the remaining 62 × 32 dots are used for on-screen indication of setting conditions.

The DMM mode allows the user to measure ac and dc voltages and currents and resistance. In the voltage function, range is from 320 mV to 1,000 V dc and from 3.2 mV to 750 V on ac. Currents up to 320 mA can be measured in both dc and ac. Resistance can be measured from 320.0 ohms to 32.0 megohms full-scale. Measurement values are displayed in the LCD window with a maximum count of 3199. $950.

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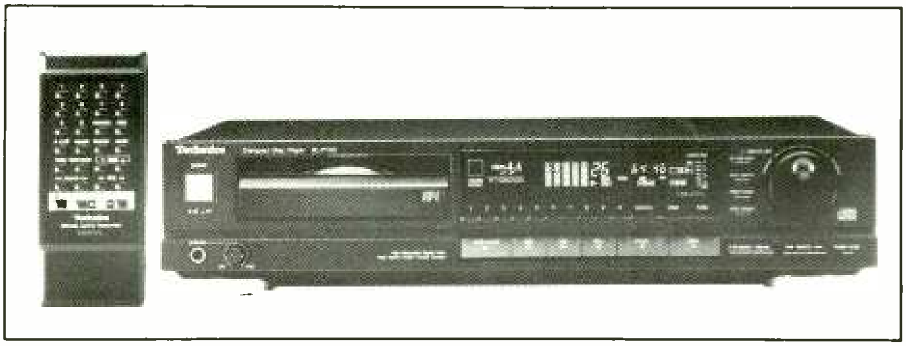

Cueing CD Player

A High Speed Transport (HST) that locates the beginning of any track on a compact disc in less than a second and sets the precise movement of the laser pickup for cueing operations is highlighted in Technics' new Model SL-P720 programmable compact-disc player. Cueing can be performed at either of two speeds. In "fast," one revolution of the cueing dial in either direction advances or regresses the sound by about 30 seconds, while in "slow," one revolution moves the pickup through about 1 second of sound.

The high-resolution laser pickup uses a six-segment photodetector for optimum tracking capability. Class AA technology in the sample/hold circuitry and line output amplifiers help to improve high-frequency resolution and amplifier linearity. The high-resolution digital filter employs double-oversampling at 88.2 kHz and is said to exhibit superb phase (group delay) characteristics. Separate power supplies reduce interference between the digital and analog circuits. Other features include: 20-step random-access programming; auto space; A-B repeat; repeat; search; skip; recall; programmable preview music scan; fluorescent display; and a preset editing function. Almost all functions, including volume, are accessible via the handheld wireless remote controller. $549.

CIRCLE 8 ON FREE INFORMATION CARD

Scanning Monitor Receiver

A professional-grade scanning monitor receiver that covers 25 to 550 MHz and 800 to 1,300 MHz continuously has been introduced by Ace Communications (Lake Forest, CA). The Model AR-2002 receiver, with an LCD display, utilizes microprocessor technology to provide 20-channel memory scan, priority scan, band search, multi-mode reception, conventional dial tuning, selectable frequency increments and bargraph signal strength indication. Also featured are a 750-MHz i-f carrier, high-level double balanced mixer, low-noise wideband r-f amplifier and high-stability vco unit. $499.

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Autoranging DMM

Mercer Electronics (Div. of Simpson Electric) introduced a compact handheld autoranging digital multimeter, Model 9370, that allows a user to choose autoranging or manual selection of voltage and resistance ranges. It can measure full-scale to 1,000 volts dc in five ranges,

(Continued on page 49)

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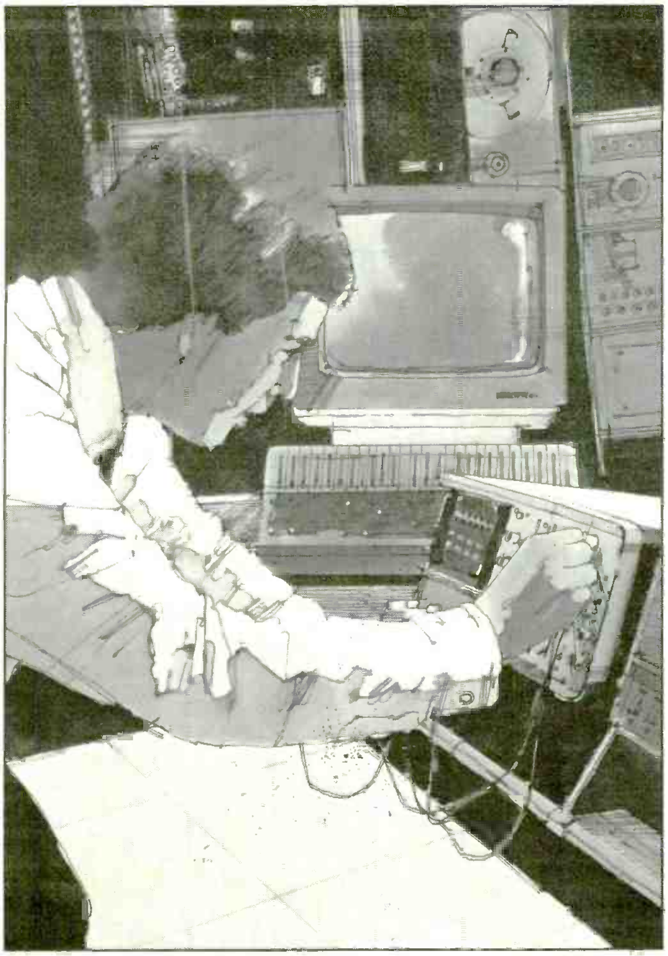

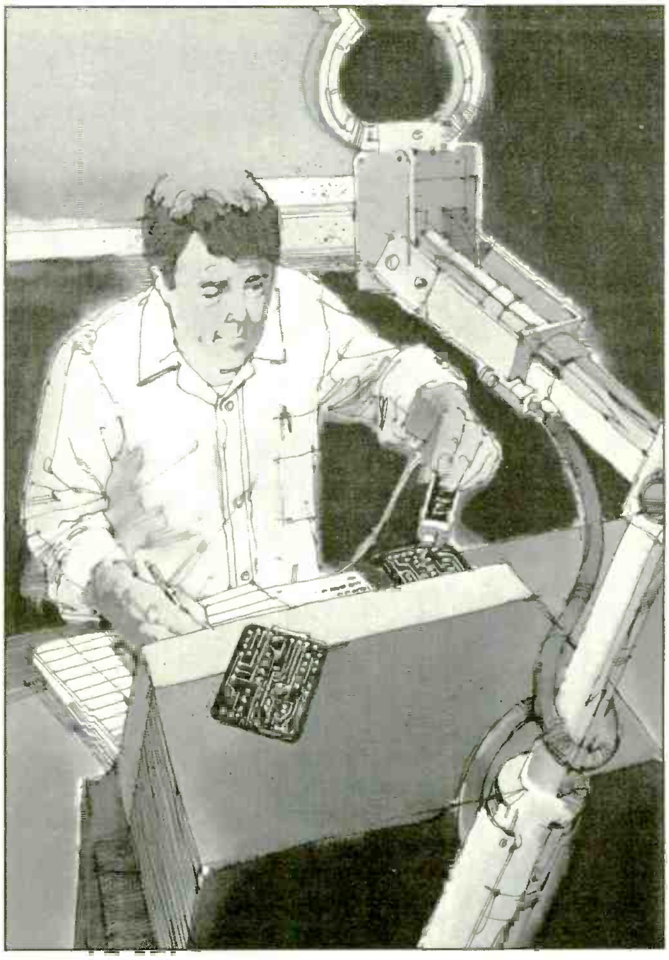

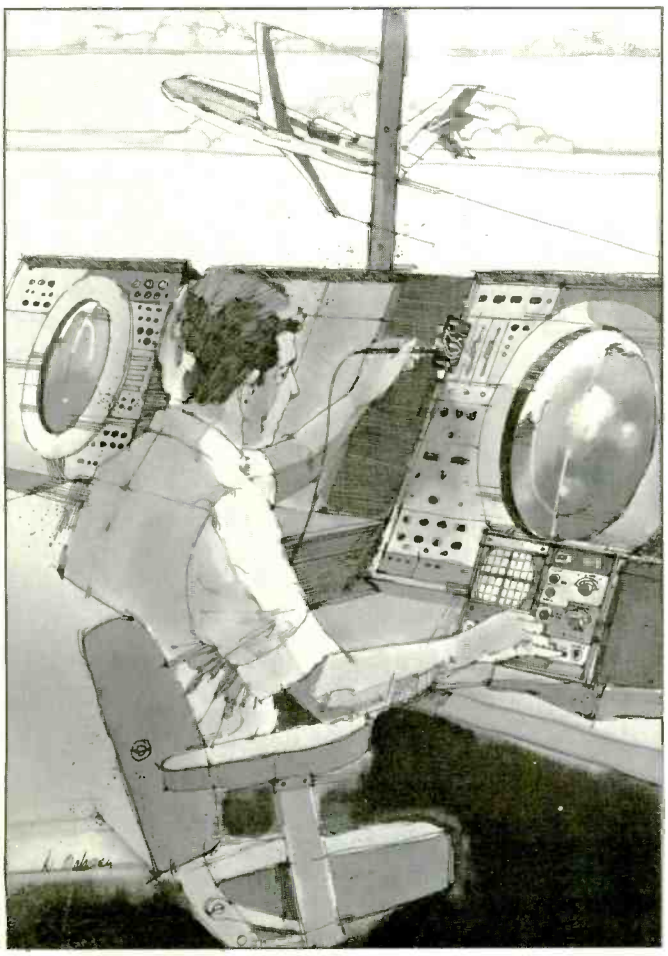

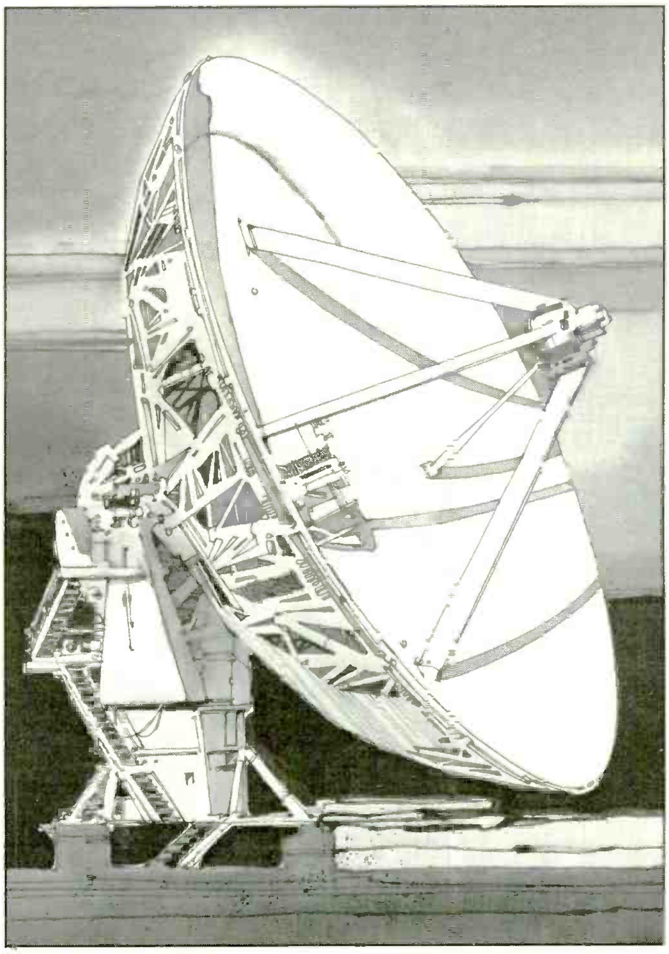

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The Versatile LM723

This may well be the world's greatest power-supply IC—if you can understand what it can do

By J. Daniel Gifford

One of the oldest and most repetitious problems in electronics is that of regulating power supplies. Whether for bench or project use, regulated supplies have become more and more necessary, due to the ever more finicky requirements of ICs and discrete circuits. While small-size, high-conversion-efficiency switch-mode power supplies have become popular for commercial use (especially in computers), the traditional linear power supply will probably remain the choice of hobbyists and experimenters in the forseeable future, basically due to its relative ease of design and construction.

A linear power supply is best designed from scratch, using individual op amps, precision voltage references, and hand-selected transistors. Since this is obviously an overkill approach for all but the most demanding circuits, a better alternative for the experimenter is to use an "all-in-one" IC to do the job.

Of the many all-in-one ICs available, three types are the most common and least expensive. The first actually represent a group of devices in the LM78xx and LM79xx, along with the nearly identical LM340/320 fixed-voltage three-terminal types. These easy-to-use devices are often found in simple ±5- and 12-volt supplies so popular in experimenter projects and commercial products. For variable and adjustable supplies, there is also the popular three-terminal LM317.

The third all-in-one IC is the LM723, a "precision voltage regulator" that is one of the oldest and least expensive ICs around and is also one of the most versatile! It is so versatile, in fact, that it can replace *all* other linear power-supply chips and do a better job for less money. (Many mail-order houses sell prime 723s for about 50¢, even Radio Shack's price is only 99¢.)

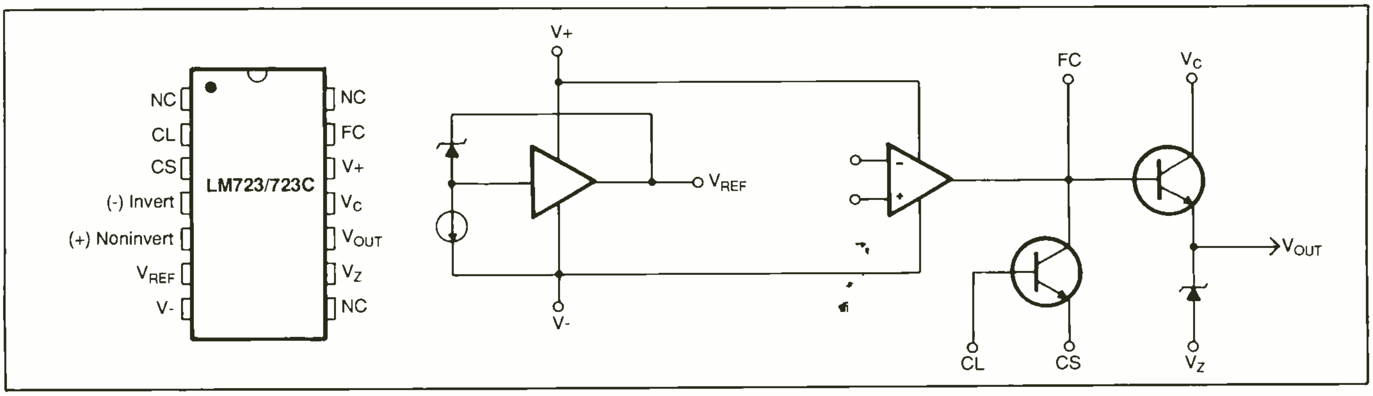
If you're like most hobbyists, you've probably skipped over the 723 in favor of the LM317. The LM317 is very easy to use because it requires only two resistors and an optional capacitor to provide a regulated 1.2-to-37-volt output. The 723 is also easy to use, though not as easy as the 317. It would be a lot easier to use if it didn't suffer from poor documentation by the manufacturers of the device. Current data and application notes are so confusing that many potential users of the 723 shy away from it for lack of information they can understand.

In this article, we will cut through the confusion about the 723 and take a detailed look at this versatile IC chip. Once you understand how flexible and talented this device is, you'll probably never use any of the other ICs for your fixed and variable low-voltage power supplies again.

Regulated Power Supplies

A regulated power supply requires four things: a source of clean, ripple-free dc power, a precision voltage reference, a means of sampling the output voltage, and a means of comparing the reference and output volt-

Fig. 1. Pinout and internal details the LM723/LM723C.



ages and correcting the latter as the load and supply voltage fluctuate. The three-terminal fixed-voltage regulators have all but the first of these built into them, with the output sampling fixed for a particular output voltage (usually 5, 12, 15, 18 or 24 volts). Though the LM317 is similar in design, its output sampling is controlled with two external resistors.

The major drawback of all three-terminal regulators is that current limiting is internally fixed and is, thus, not adjustable. Hence, the only way to lower the level of current limiting in these devices is with external circuitry. The external circuitry can be a simple "brute-force" limiting resistor or, for variable-voltage supplies, a relatively complex circuit using op amps and a negative-voltage supply. Neither type of circuit is particularly satisfactory because a great deal of heat must usually be dissipated by the resistor, while the external operational-amplifier circuit is unnecessarily complicated.

Enter the LM723. Not only does this device have a precision voltage reference, an output comparator (error amplifier) and all of the circuitry needed for adjustable current limiting on-board, this circuitry is only partially interconnected. Most of the circuit connections are made externally, which lets you tailor your power supply to suit particular requirements. Obviously, this results in a more complex circuit layout than is needed for three-terminal regulators. But the enormous flexibility gained by using the LM723 more than makes up for the added complexity.

Inside The LM723

Two versions of the 723 are available, as with nearly all ICs: the military-grade LM723 in a ceramic case and featuring an extended temperature range, and the more common LM723C in a plastic case with a 0-to-70-degree C temperature range. The pinout of the device is shown in Fig. 1, along with a diagram of the internal circuitry. At the left of the diagram is the voltage reference circuit, the heart of which is a nominal 7.15-volt zener diode. (The specified range for the LM723C is 6.80 to 7.50 volts.) The zener is connected to a buffer amplifier and is biased by a constant-current source to keep the reference level stable under varying supply conditions. For the most part, this portion of the circuit can be ignored, because the only external portion of the reference circuit is the V_{ref} output at pin 6, which is a stable 7.15 volts for external reference use.

In the center of the diagram is a regular op amp with both its inverting (−) and noninverting (+) inputs externally available at pins 4 and 5. This "error" amplifier and the reference circuit are powered via the V+ and V− at pins 12 and 7. Maximum supply voltage to the 723 must not exceed 40 volts, but the IC is protected against spikes of up to 50 volts that are no longer than 50 ms in duration. Sustained voltages greater than 40 volts will damage the IC.

Minimum supply level is about 9.5 volts; any lower than this will impair the reference voltage's accuracy and stability. Supply voltage must always be at least 2.5 volts higher than the maximum desired output voltage, due to common-mode voltage range limitations of the error amp.

The output of the error amplifier is connected to the base of an internal npn pass transistor. Both the collector and the emitter of this device are externally available at V_C and V_{out} pins 11 and 10. In most circuits, the V_C pin will be connected to the same supply as the V+ pin; indeed, these pins are side by side to facilitate such a connection. Having separate pins permits use of a separate output supply source, which can be an advantage under some circumstances. The internal pass transistor can pass up to 150 mA over the 723's full output voltage range. (Higher output currents can be obtained by using an external pass transistor.)

Also available at FC pin 13 is the connection between the error amplifier's output and the pass transistor's base. This connection is provided because the error amplifier isn't internally compensated like a 741. An external capacitor between pin 13 and either the inverting input or (more rarely) V− or ground stabilizes the amplifier.

A second internal npn transistor has its collector connected to the base of the pass transistor and has its base and emitter externally available at current limit (CL) and current sense (CS) pins 2 and 3. This transistor is the current-limiting sensor. The CL and CS pins are connected across a series output resistor. When current drawn from the output is sufficient to cause a 0.65-volt difference across the resistor, the sense transistor turns on and either reduces or cuts off the error amplifier's drive to the pass transistor. This limits output current flow to the selected level. Limiting is basically the same whether the internal pass transistor is used or an external pass device is added for up to 10 amperes or more of output current.

The only remaining element of the 723 is the zener diode connected to the pass transistor's emitter, with its anode available at V_Z pin 9. The voltage rating of this diode is nominally the same as the reference voltage and is primarily used to offset the output voltage when the 723 is used as a negative voltage regulator.

Voltage Adjustment

Setting the output voltage of the 723 is simple, though from the application sheets, you would never know it. Of the three basic ways to set the 723's output, two are best suited to fixed-voltage regulation, and the third is the all-around best technique and is best suited to variable or adjustable output supplies.

With respect to voltage, the 723 has three inherent limitations. The first is the maximum 40-volt differ-

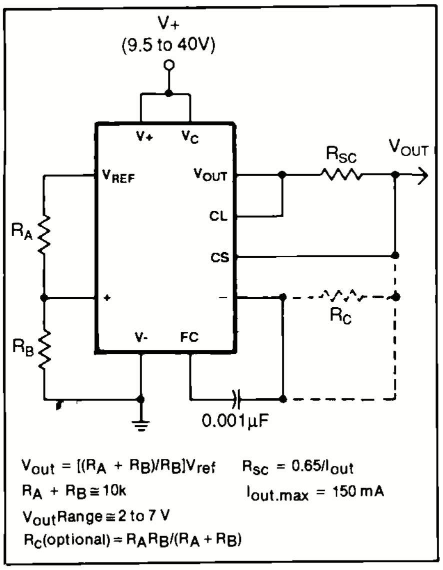


Fig. 2. The basic circuit for low outputs between about 2 and 7 volts.

ential that can be applied between the V+ and V− pins. There's no way to get around this, although the 723 can be used to regulate potentials up to 250 volts or more by offsetting its V− voltage.

Next is the 723's 2.0-volt lowest possible output referenced to the V− pin, which is due to common-mode voltage range limitations of the error amplifier. But an output adjustable to 0 volt is possible by offsetting the IC's V− pin by 3 to 4 volts below ground.

A final voltage limitation is that the maximum is about 2.5 volts below the V+ supply level, which is again due to common-mode limitations. Thus, for an output of 20 volts, V+ must be at least 22.5 volts. With a V+ of 40 volts, maximum output is about 37.5 volts.

Shown in Figs. 2 and 3 are the two most basic circuit configurations that are most suitable for fixed-output and limited-adjustability supplies. In all circuit configurations, V_{ref} is coupled to the error amplifier's + input and the output voltage is coupled to the amp's − input. To adjust the regulated output voltage, the reference voltage is divided before connection to pin 5 (Fig. 2), or the output voltage is divided down before connection to pin 4 (Fig. 3).

In Fig. 2, with the output voltage connected directly to the error amplifier's − input, the output voltage is held equal to the actual reference voltage at the + input. If the reference voltage is connected directly to this input (if R_A = 0 ohm), the output voltage will be equal to the reference, or about 7.1 volts. If R_A and R_B are equal, the reference voltage will be divided in half, and the output will be about 3.5 volts. Thus, it's the *ratio* of R_A to R_B that determines the output voltage, as the first equation in Fig. 2 shows. The total value of R_A and R_B should be about 10,000 ohms, but this isn't critical.

For maximum simplicity, the output voltage can be connected directly to the error amplifier's + input. However, for maximum thermal stability, resitor R_C should be added to the circuit. The value of R_C to have maximum stability is determined by dividing the product of R_A and R_B by the sum of their values in Fig. 2.

Since the output range of this circuit is from 2 (the error amplifier's lower limit) to 7 volts (the reference level), it's best used for low-voltage fixed-output regulation. (Ignore R_{SC} in this and the following figures for the time being.)

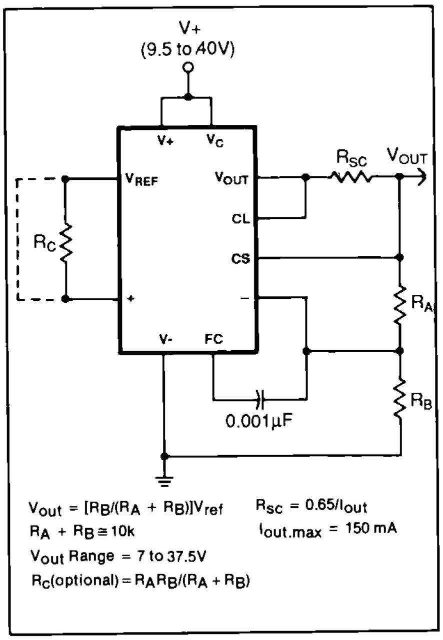
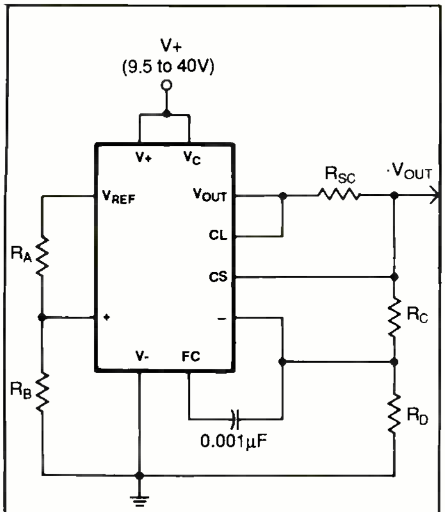


Fig. 3. The basic circuit for high outputs between about 7 and 37 volts.

Figure 3's circuit is the exact opposite of Fig. 2's. Here, V_{REF} is connected directly to the error amplifier, and the output voltage is divided down before reaching the amplifier's − input. With the output voltage connected directly to the error amplifier (R_A = 0 ohms), output voltage will be equal to V_{REF}, or about 7.1 volts. If R_A and R_B are equal, the output voltage will be divided in half before reaching the error amp and the absolute level will thus be double the V_{REF} level, or about 14.1 volts.

Here again, it is the ratio of R_A to R_B that determines the output voltage. The output range of this circuit is from about 7 (the reference level) to about 37.5 volts (assuming a 40-volt supply). As with the Fig. 2 circuit, R_A and R_B should total about 10,000 ohms, and R_C is optional but recommended for stability. This circuit is best used for higher-voltage, fixed-output and limited-adjustability supplies.

A major problem with the 723's data sheets is that they show only these two configurations, with no hint given as to how to bridge the 7-volt barrier. It's quite easy, as you might have guessed. All you have to do is divide down *both* the reference and output voltage inputs! This is illustrated in Fig. 4, where R_A and R_B divide V_{REF} down to any convenient level. The voltage thus delivered to the error amplifier's + input sets both the minimum output voltage and the "multiplier" for the output voltage divider string consisting of R_C and R_D and is used to vary the output voltage. Minimum output (with R_C = 0 ohm) is equal to the voltage at the − input, which cannot be lower than 2 volts. Maximum voltage, assuming a V+ of 40 volts, is 37.5 volts. Thus, this configura-



$V_{out} = V_{ref}[R_B/(R_A + R_B)][(R_C + R_D)/R_D]$
$R_A + R_B \cong R_C + R_D \cong 10k$
$V_{out.min.} = V_{ref}[R_B/(R_A + R_B)] \geq 2V$
$V_{out.max} = V+ - 3V$
$R_{SC} = 0.65/I_{out}$
$I_{out.max.} = 150\ mA$

Fig. 4. A configuration for any output between 2 and 37 volts.

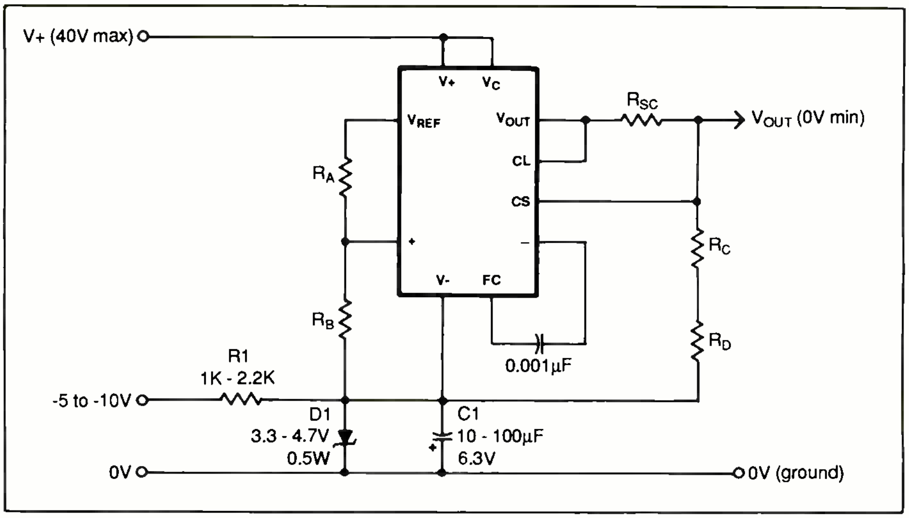


Fig. 6. A negative bias supply permits adjustment of 723's output down to 0 volt. Negative supply can come from an extra tap on power transformer.

tion can be used for a variable supply that can be swept from 2 to 37.5 volts with a single control.

One drawback is that R_A and R_C are difficult to optimize for maximum thermal stability. But this is a minor problem because the 723 has good stability even without optimization.

Note in Figs. 2, 3 and 4 the compensating capacitor connected between the FC and − input pins. Although the recommended all-around value for this capacitor is about 0.001 µF, it can range from 100 pF to 0.01 µF without causing difficulties.

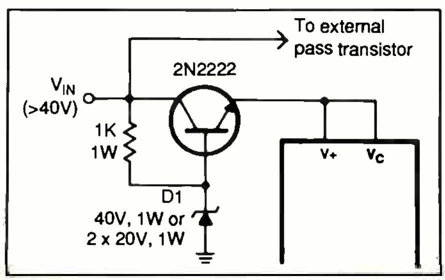


Fig. 5. Preregulator circuit used to protect LM723 against greater than 40 volts at V+ input terminal.

There is often a bit of a problem, particularly with high-voltage, high-current supplies, with keeping the supply to the 723 within the 40-volt limit. Although designing the supply transformer to suit the application is one way to go, a much easier approach for hobbyists is shown in Fig. 5. Here, a preregulator circuit is used to limit the 723's supply. A zener-resistor string biases a medium-power npn transistor to provide a limited and semiregulated supply to the IC.

A 40-volt zener diode would be ideal in the Fig. 5 circuit. Because this is not a common value two 20-volt zeners are used for *D1*. With the 0.7-volt drop across the transistor, the resulting supply to the 723 will be about 39.3 volts, assuming a 40-volt V+ supply. If necessary, exactly 40 volts can be obtained at the IC's inputs by hand-selecting the zener diode(s) or by adding a forward-biased 1N914 diode to the zener-diode string to exactly compensate for the 0.7-volt drop.

A limitation to the preregulator trick is that the preregulator transistor must carry the entire current that passes through the regulator and the internal pass transistor, which can be as high as 160 mA. This should not be a problem as long as a suitable transistor is used in the preregulator. Even so, there's a better way to accomplish your aim.

If an external pass transistor with a V_{CE} higher than the raw dc supply level is used, the preregulator can be used to provide power to only the 723 itself, and the raw dc is passed to the external transistor's collector. This drops the current required from the preregulator to about 5 mA or less.

Another voltage-related problem with the 723 is that its minimum output of 2 volts may be a drawback in some applications, particularly with variable-output bench supplies. Since the ony reason for the 2-volt minimum is the common-mode range limits of the error amplifier, the problem is easy to circumvent. As Fig. 6 shows, all you need do is offset the 723's V− level by a few volts negative with respect to power ground.

Raw dc of about −5 to −10 volts is regulated and stabilized by low-voltage zener diode *D1* and capacitor *C1*. All of the 723's negative connections (V− pin and the bottoms of the reference and output divider strings) are connected to the resulting −3 to −5-volt rail instead of to 0 volt. The common-mode limit of the error amplifier doesn't vanish; it's now offset

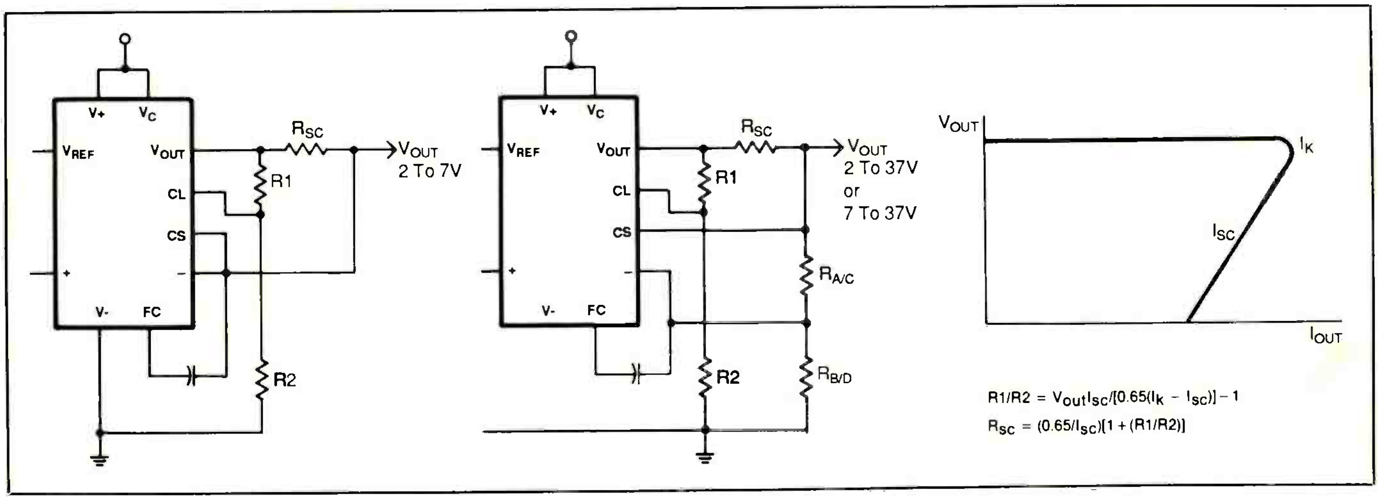


Fig. 7. Foldback current limiting, which gets its name from its voltage/current plot on a graph that appears to "fold back" on itself, requires slightly more complex circuitry than simple short-circuit limiting does. However, the forgiving nature of its limiting characteristic makes it ideal for test supplies.

below 0 volt, and the regulated output voltage can be reduced to 0 volt with respect to power ground.

It's important to note that resistor strings R_A/R_B and R_C/R_D *must* be selected so that it's impossible to adjust the output to below 0 volt. Otherwise, damage to the 723 may result.

Current Limiting

Setting the 723's short-circuit current level is a simple procedure. It's determined solely by the value of R_{SC} shown in most of the figures. Under no circumstances should R_{SC} be omitted. Although the 723 will operate without its over-current protection connected, even a momentary short-circuit in this mode will destroy the regulator IC and external pass transistor.

Setting the desired short-circuit current-limiting level is a simple matter of choosing a value for R_{SC} by dividing the base-emitter or turn-on voltage of the current sensor transistor (nominally 0.65 volt) by the desired current-limiting level in amperes. For example, with maximum output current using the internal pass transistor being 150 mA,, R_{SC} would equal 0.65/0.150 = 4.3 ohms.

You must take into account the power rating of R_{SC} as well. To determine the resistor's wattage rating, simply multiply the short-circuit current (I_{SC}) by the maximum output voltage to determine the maximum output power in watts. If the output is 20 volts and I_{SC} is 150 mA, output power would be 20 × 0.150 = 3 watts. In this example, a 4.3-ohm, 5-watt resistor would probably be the closest standard value you would be able to find.

Use of a simple short-circuit limiting resistor provides for only constant-current or shutdown limiting. If the load exceeds the I_{SC} level or if the output is shorted to ground, maximum current will flow while output voltage drops to nearly zero. While this kind of protection is adequate for most types of circuits, a slightly more forgiving type of limiting called "foldback current limiting" is also possible with the 723.

Foldback limiting is best suited to fixed-voltage supplies and limited-adjustability supplies, such as a nominal 12-volt supply that can be adjusted for output between 10 and 14 volts. This is because the current-limiting point changes with the output voltage with foldback limiting.

To design a 723 circuit with foldback current limiting, you must select three values. Choose output voltage V_{out} or the center point of the adjustment range. Then select short-circuit current level I_{SC}. Finally, select the maximum current that you want to flow before the output begins to "fold back" towards the short-circuit level. This peak level, called the "knee current," or I_k, is always higher than the short-circuit current. How much higher it is is up to you. Now that you have these figures, you can use the circuit and

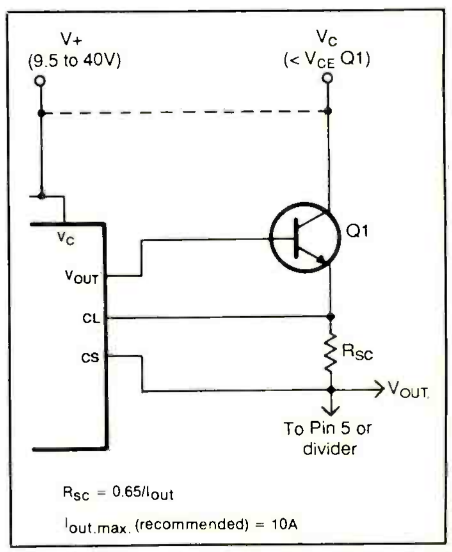


Fig. 8. Using a single external pass transistor with the LM723.

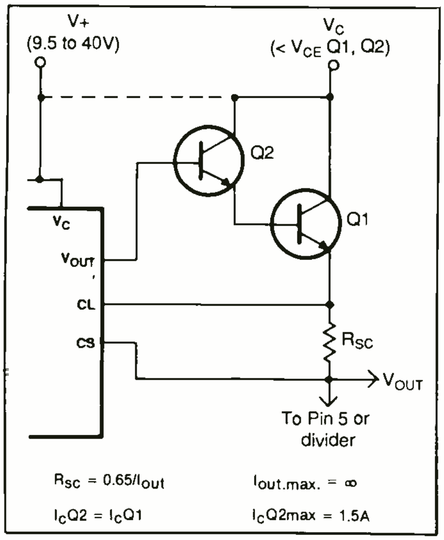


Fig. 9. Dual pass transistor arrangement is better than single transistor type and is recommended for all supplies with outputs greater than 5 A.

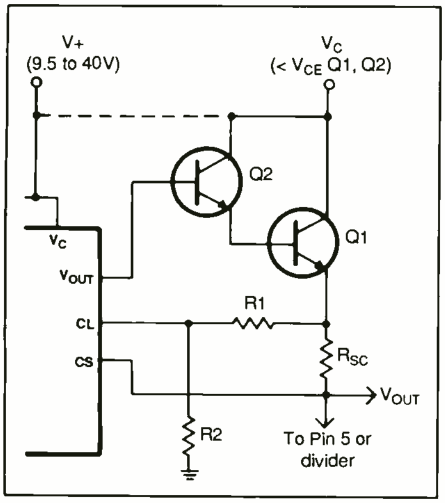


Fig. 10. Using foldback limiting with a pass transistor output.

equations in Fig. 7 to design a foldback limiting circuit.

Note that I_k must be less than 150 mA if the internal pass transistor is being used, or less than the I_C rating of an external pass transistor. It should also be evident from Fig. 7 that current-limiting circuitry R_{SC}, *R1* and *R2* remains the same whether the error amplifier's input is directly connected to the output or a divider string is used.

The first equation in Fig. 7 lets you

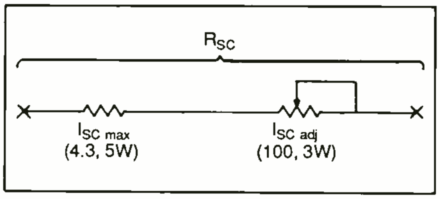


Fig. 11. A simple means of obtaining adjustable current limiting; use only without an external pass transistor.

determine the *ratio* of *R2*'s value to that of *R1*. (*R1* is temporarily assigned a value of 1). When you have the ratio, the next step is to find the nearest standard resistence values for *R1* and *R2* that add up to approximately 10,000 ohms while maintaining the ratio. For example, if the calculated ratio is 24.26:1, first add the two figures (25.26), divide the result into 1 (1/25.26 = 0.0396) and multiply this result by 10,000 to obtain *R1*'s value, which is 396 ohms. The value of *R2* would then be 10,000 − 396 = 9,604 ohms. The closest standard values to those calculated would be 392 (or 390) ohms and 9,530 (or 9,100) ohms.

The second equation in Fig. 7 is used to determine the value of R_{SC}. Note that I_{SC} remains the same for all output voltages, but the knee current increases as voltage increases. If you're designing a supply with an adjustable range of more than 2 to 3 volts, use the *highest* output voltage for design purposes—not the center voltage—to prevent an inadvertent overload. The power rating of R_{SC} is determined in this circuit by multiplying the *knee* current by maximum output voltage. Resistors *R1* and *R2* can be rated at ½ watt.

Pass Transistors

Since many power supplies must provide more current than the 723's internal capacity of 150 mA, an external pass transistor is needed. This is very easy to add, since only the transistor itself is required. Additionally, all phases of design remain exactly the same when using a pass transistor. The only change is that the rated collector current of the pass transistor now becomes the upper limit.

Figure 8 shows the 723 in a single external pass-transistor arrangement and illustrates just how simple this addition is to make. The transistor's collector can be connected either to the same supply as the 723, or (particularly when using a preregulator circuit) to the raw dc supply. The overall voltage rating (V_{ce}) of the transistor must be higher than the peak dc supply voltage, and the transistor's current rating (I_C) must be higher than the maximum current that will be required from the supply. A heatsink is required for almost all pass transistors.

Though a single pass transistor is adequate for any output current up to 10 amperes, a better design for all pass-transistor circuits, especially those to provide more than 5 amperes, is the dual-transistor circuit shown in Fig. 9. This circuit has a small buffer transistor between the 723 and the pass transsitor, and can be used for any practical current, even 50 amperes or more if a suitable pass transistor (or several paralleled transistors) is used. Buffer transistor *Q2* must have a V_{ce} and an I_C that are at least equal to the pass transistor's up to a maximum of about 1.5 amperes. Transistor *Q2* should not require a heatsink, except in very high-current supplies.

Figure 10 shows that foldback current limiting can be used with either a single or dual pass transistor, as well as with simple short-circuit limiting. The knee current of a foldback limiting circuit must be below the pass transistor's I_C rating, of course.

Selection of R_{SC} for high-current pass-transistor supplies is the same as for lower-current types, but a combination of very low values and high power ratings will be required. For example, a 5-ampere, 20-volt supply will require a 0.13-ohm, 100-watt resistor for R_{SC}. Wirewound resistors with the necessary combination of ratings are relatively cheap, and smaller resistors can be paralleled to obtain the required resistance and power ratings. Wattage ratings in parallel-connected resistors add to each other. For example, connecting in parallel a 25- and a 50-watt resistor yields a combined power rating of 75 watts.)

Many variable-voltage supplies cannot produce the full designed output current at maximum voltage. For example, the supply shown in Fig. 13 will produce the full 3.5 amperes up to an output of about 20 volts, but current will fall off (at a rate depending on the supply's transformer, among other things) to about 0.75 ampere at the full 35-volt output. The point is that R_{SC} in this circuit doesn't have to be large enough to handle the theoretical maximum power (3.5 × 35 = 122.5 watts)—only the peak *actual* power of 3.5 × 20 = 70 watts. Using an oversized power resistor is never a bad idea, but the difference in size (and cost) between a resistor selected to meet an unobtainable theoretical maximum and one chosen to suit the actual maximum output power can be considerable.

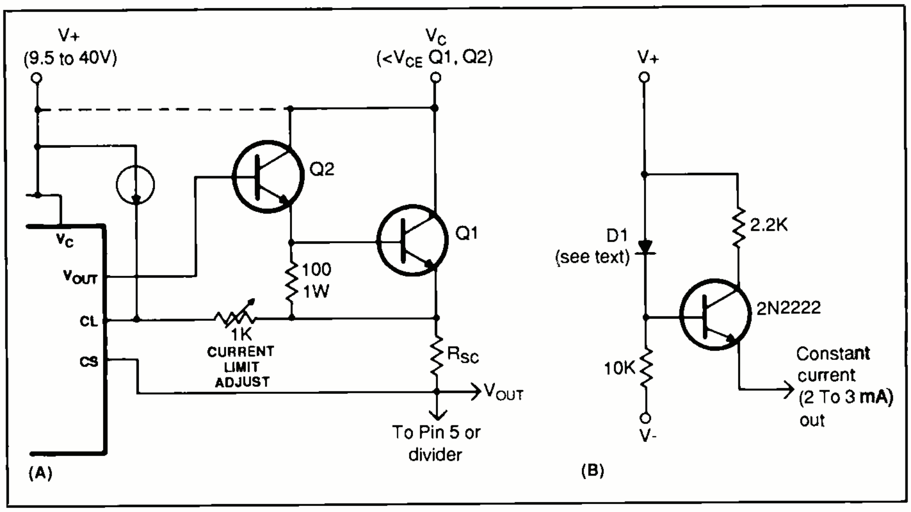


Fig. 12. An adjustable current-limiting scheme (A) that can be used to adjust limiting from near zero to maximum limit, even if upper limit is 10 amperes or more. Suitable constant-current source (B) for use with circuit (A) allows replacement of 2.2k resistor with trimmer to obtain fine adjustment of minimum current level.

Variable-Current Limiting

Most fixed-voltage power supplies will be adequately protected with fixed current limiting of either the constant-current or foldback type. However, most bench and test supplies will require adjustable current limiting to accommodate and protect a variety of experimental circuits and gear under test. Fortunately, smooth, effective variable limiting is easy to achieve with the 723.

The first variable current-limiting technique that may occur to you is something like that shown in Fig. 11, where a potentiometer replaces a fixed-value R_{SC}. Though this arrangement will work, it is limited in operating range by the 2-to-3-watt rating of most panel potentiometers. Higher power pots and rheostats are available, but they're bulky, expensive and inefficient.

The simple technique shown in Fig. 11 is suitable for use in circuits without pass transistors designed to deliver no more than 150 mA, since even ordinary panel pots can handle the maximum 3 watts of power produced. A fixed resistor should always be used in series with the pot, to protect it against overcurrent. If a 4.3-ohm, 5-watt resistor is used in series with a 100-ohm pot, minimum output current will be 0.65/104.3 = 6.2 mA, and maximum current will be 0.65/4.3 = 150 mA.

A far more satisfactory technique for variable current limiting is shown in Fig. 12(A). Here once again, R_{SC} is selected to set maximum output current. A 1,000-ohm panel pot is inserted between the emitter of the pass transistor and the CL pin of the 723, along with a 2-to-3-mA constant-current source connected to the CL pin. When the panel pot is set to minimum resistance, the constant-current source will be swamped by the current flowing from the pass transistor, requiring a full 0.65-volt difference across R_{SC} (full output current draw) to initiate current limiting. However, the farther advanced the pot, the stronger the influence of the current source on the CL pin and the smaller the differtial across R_{SC} (the smaller the current draw) will have to be to cause an *apparent* 0.65-volt difference to have current limiting to take effect. In fact, with the potentiometer set for maximum resistance, only a few milliamperes of output current are required to trigger current limiting.

Any sort of constant-current source can be used in this circuit—constant-current diode, op-amp circuit, etc.—as long as it can withstand the maximum supply voltage used in the circuit. A very suitable source is shown in Fig. 12(B). Here, the npn transistor is biased by a constant collector-base voltage (the drop across *D1*), regardless of the output voltage at its emitter. The diode should have a drop of between about 1.2 and 2.5 volts. Suitable diodes for this purpose include two 1N914s in series (1.4 volts), a red LED (1.5 volts), a yellow or orange LED (1.8 volts) and a green LED (2.0 volts). To fine-adjust the current, the 2,200-ohm re-

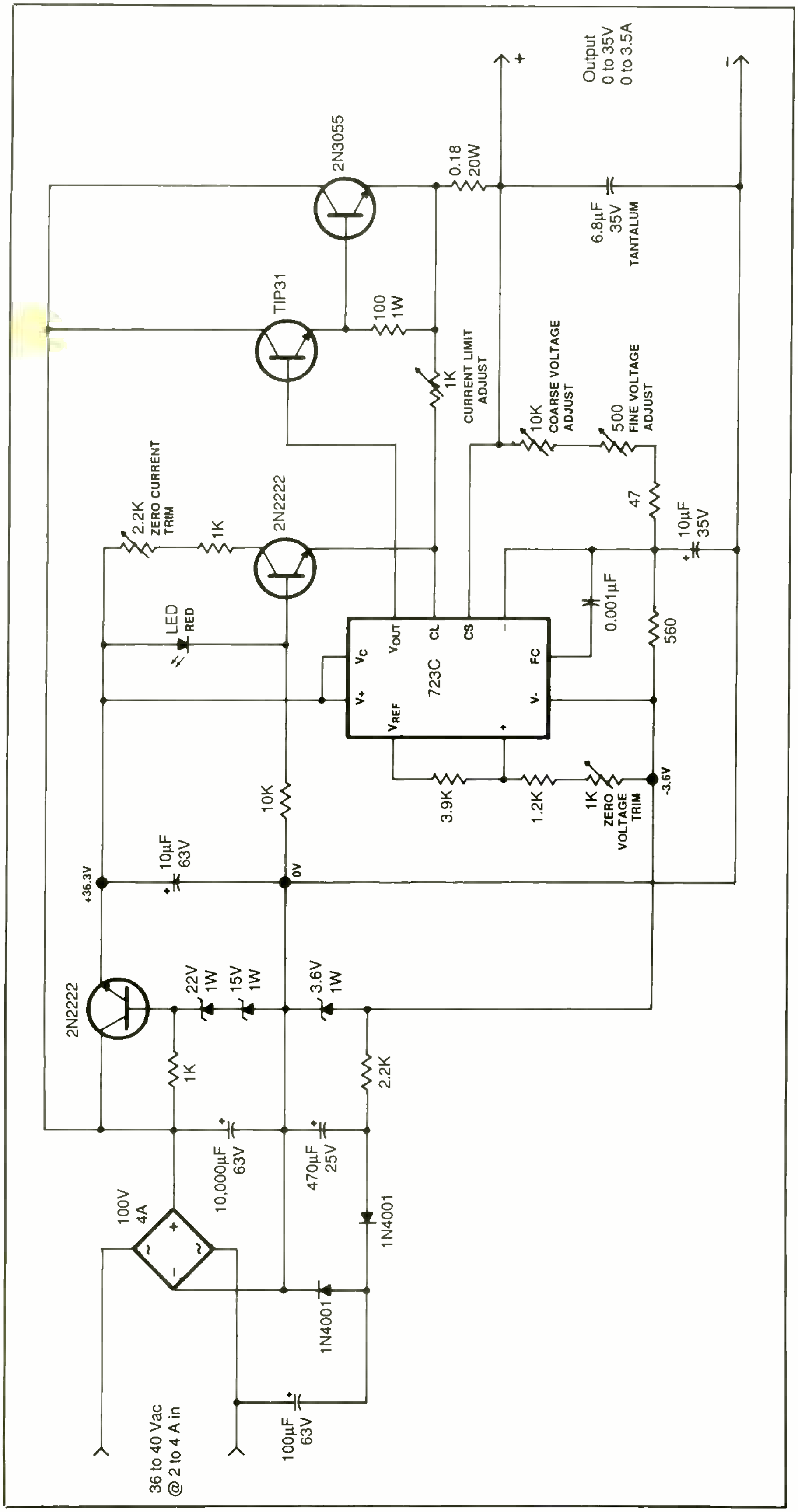


Fig. 13. An all-in-one bench power supply with 0-to-35-volt output at 0-to-3.5-ampere adjustable limiting. Trim points are provided to optimize circuit operation.

sistor can be replaced with a 1,000-ohm resistor in series with a 2,000-ohm trimmer potentiometer.

Figure 12(A)'s circuit can be trimmed to provide a smooth adjustment from zero to the maximum current set by R_{SC}, even if the upper limit is 10 amperes or more.

Practical Circuit

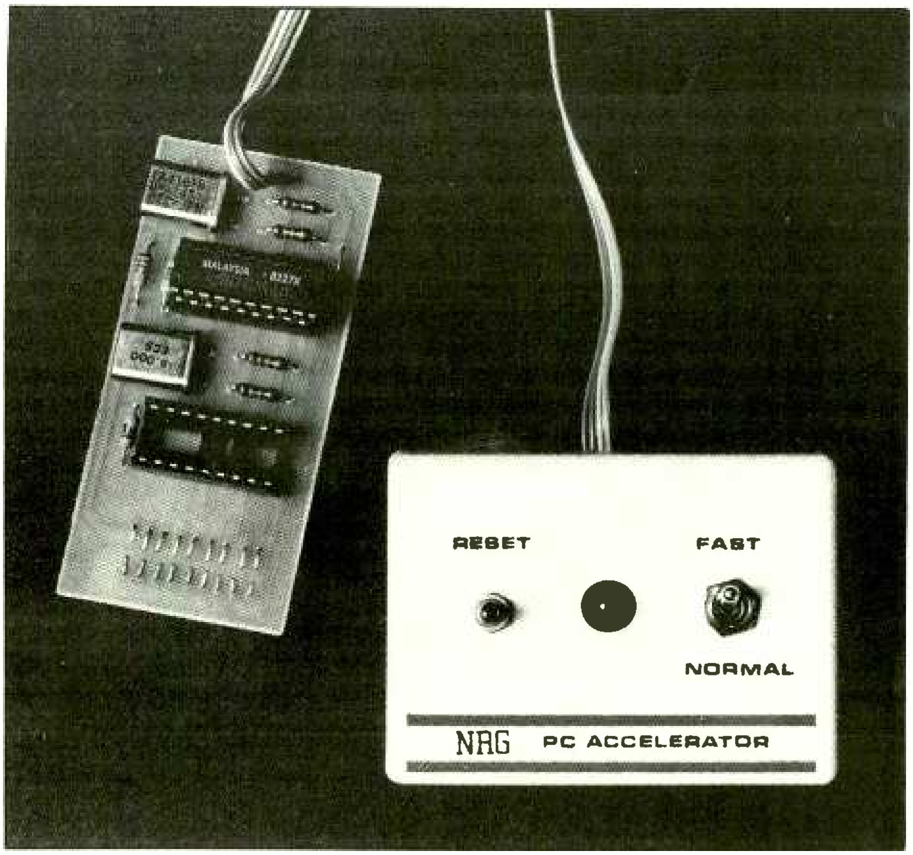
Shown in Fig. 13 is the schematic diagram of a complete variable bench-power supply that utilizes almost every element of design we've discussed above and features a variable output from 0 to 35 volts and adjustable current limiting from 0 to 3.5 amperes. The circuit is pretty straightforward, but two areas are worthy of discussion, beginning with the negative bias supply. Note that an ordinary single secondary power transformer is used, and no extra tap is needed to provide the negative voltage supply. Instead, a 100-µF capacitor and a pair of rectifier diodes are used to produce a raw dc of approximately 5 to 10 volts below ground reference. A 470-µF capacitor smooths the supply, and a resistor/zener-diode circuit produces a stabilized −3.6 volts. This trick works only with circuits like this one in which a minimal amount of current (5 mA) is all that's needed.

Since the 723 is now referenced to −3.6 volts at its V− pin, V+ must be reduced accordingly, which is done by lowering preregulation diodes from 40 to about 36 volts. Connecting a pair of 22- and 15-volt zeners in series as shown provides a supply of about 36.3 volts (22 + 15 − 0.7) to the 723's V+ and V_C pins. This gives the 723 a total maximum supply of about 39.9 volts. If you hand pick the zeners, you can bring this up to the full 40 volts. **ME**

A $30 6-MHz PC Speed-Up Board

Gives 30% more typical operating speed to 4.77-MHz IBM PCs and compatibles without changing any parts

By Barry W. Grider



Though I was happy with my 4.77-MHz IBM PC-compatible computer's features, I did yearn for the much faster operating speed that later models provide. I considered upgrading old faithful with a commercial speed-up board, but these run $100 to $500, with the lower-cost ones giving only a marginal increase in speed. What I wanted was something a lot less expensive that boosted speed significantly—like the $30 PC Accelerator (PCA) described here.

By just installing the PC Accelerator in my 4.77-MHz computer, I can now run my software and hardware at a much faster 6-MHz and still retain the original speed for software that won't run in this faster environment. Typically, you'll enjoy a 30% speed increase with the PCA installed in an IBM PC or compatible with an 8088 CPU; this rises to 40% if you substitute a NEC V20-8 (8-MHz version) for the 8088. It wasn't necessary to change logic or RAM chips, or install special software to be able to do this, either.

In designing the PC Accelerator, my aim was to make as few changes in the computer's circuitry as possible so that it was fully compatible with my existing hardware and software. To accomplish this, I had to make sure that I didn't make my computer run *too* fast. Happily, the PCA satisfies all requirements. Only one chip in the computer had to be removed—and that plugs into the PCA board, which is then plugged into the vacated socket in the computer. The project is very easy to install and requires no special hardware and/or software to use the faster speed. Speed selection is accomplished at the DOS prompt simply by flipping a switch on the external control box to the desired position.

This speed-up board will work in any IBM PC or compatible computer built around the 5-MHz Intel 8086 family of logic elements. It requires no permanent changes to the computer and retains all the functions of the original, in addition to providing a substantial increase in speed when desired.

Preliminary Information

Speeding up a PC involves a complex relationship between four separate conditions. The first is how fast the

Routine:	IBM PC 8088	IBM PC V-20	IBM PC AT 6 Mhz	IBM PC AT 8 Mhz	Yours	Yours	Yours	Yours
Integer Count	24 (1.0)	23 (1.0)	9 (2.7)	6 (4.0)	24 (1.0)	26 (0.9)	20 (1.2)	20 (1.2)
Real Count	29 (1.0)	26 (1.1)	11 (2.7)	8 (3.6)	28 (1.0)	27 (1.1)	22 (1.3)	22 (1.3)
Table Lookup	28 (1.0)	26 (1.1)	9 (3.1)	7 (4.0)	27 (1.0)	28 (1.0)	22 (1.3)	21 (1.3)
String Manipulation	29 (1.0)	17 (1.7)	10 (2.9)	7 (4.1)	30 (1.0)	18 (1.6)	24 (1.2)	15 (1.9)
Empty Loop	29 (1.0)	25 (1.2)	9 (3.2)	7 (4.1)	28 (1.0)	27 (1.1)	21 (1.4)	21 (1.4)
Total Timing	139 (1.0)	117 (1.2)	48 (2.9)	35 (4.0)	138 (1.0)	126 (1.1)	109 (1.3)	99 (1.4)

Press any key to continue

System Speed Evaluator Ver #2, by T. Gray

Fig. 1. Composite of four screen displays obtained by author when SSE-V20 program was run in his Zenith Z-151 PC-compatible computer. When compared against IBM PC references, the "Yours" columns from left to right show that the author's computer performs marginally better than IBM PC and became increasingly faster when he installed the V20-8 microprocessor only, the PCA only, and the PCA plus V20 installed.

8088 CPU (microprocessor) in IBM PC and compatible computers runs and what's the system clock (4.77 MHz, 8 MHz, etc.). The second is the speed of the RAMs and ROMs used in the system and the number of wait states during access of data in memory. The third is speed of peripherals in the system, especially floppy- and hard-disk drives. (A slow disk drive can make even the fastest computer unbearably slow.) Finally, is the design of the overall system. This takes into account the motherboard's bandwidth, bus loading, etc. To be able to speed up any computer, each of these conditions must be addressed.

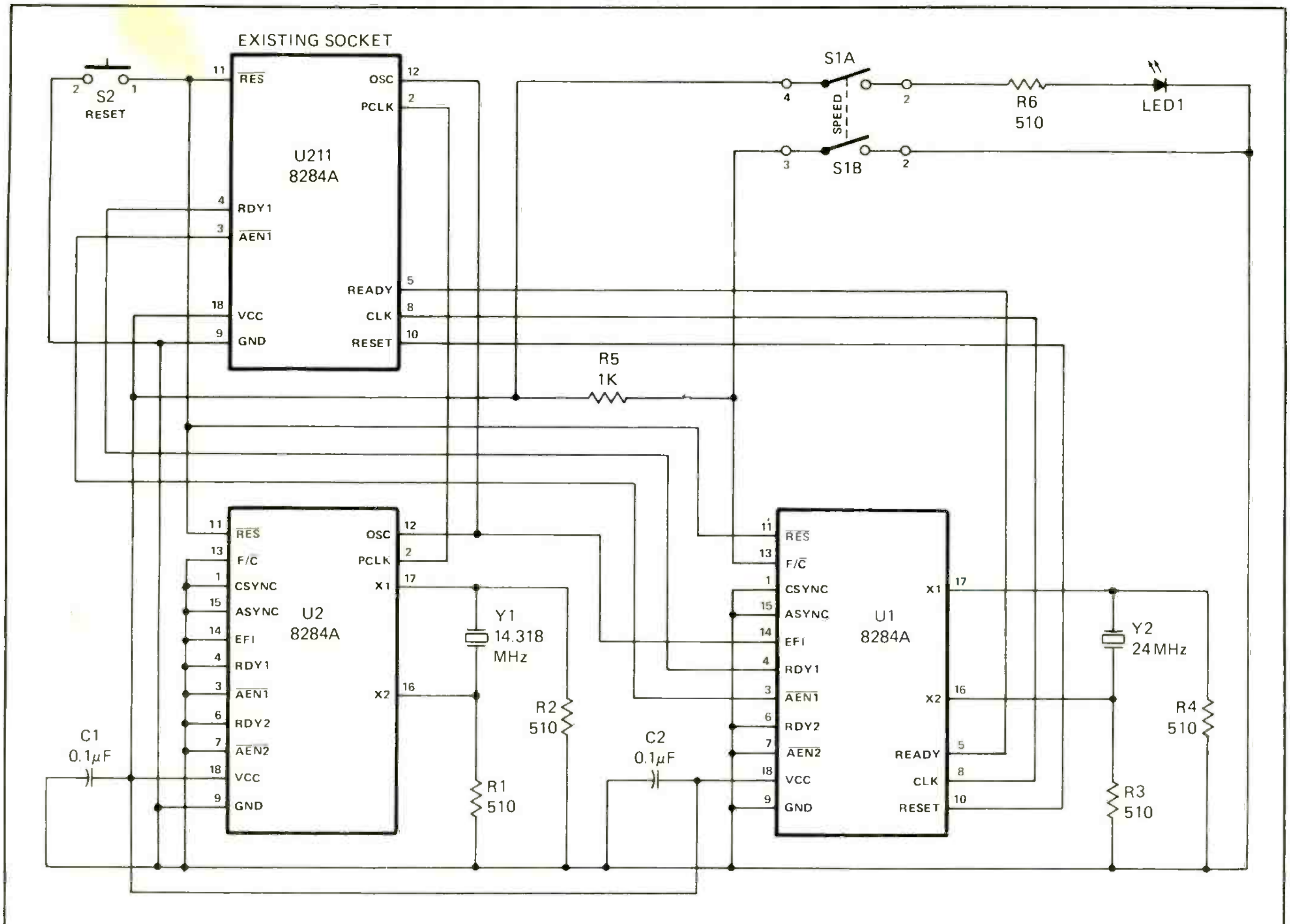
On the surface, the CPU's speed appears to be easiest to adjust. You might think that all you have to do is install a faster version 8088 microprocessor or a NEC V20 processor in place of the original 8088 and change the crystal to obtain a faster clock that will speed up everything and put you in business. Unfortunately, the problem is that all PCs and compatibles are built around the Intel 8086 family of components. If you install a faster CPU, you must also upgrade the speed of the bus controller, clock driver, peripheral interrupt controller (PIC), peripheral interval timer (PIT), etc. In fact, the whole computer is only as fast as the slowest component in the system. Additionally, the manner in which the components are tied together by the system logic significantly affects total operating speed of the system.

Fortunately, Intel does not manufacture "5-MHz" components. All elements in the 8086 family are intended to operate at 8 MHz or faster. The 5-MHz operating-speed Intel specifies simply means that the company tests these components at 5 MHz and guarantees their performance at this speed and below. You can probably increase the system clock speed and not have any problems. The exact speed is best determined by experimentation.

A relatively simple way to increase system operating speed is to replace the Intel 8088 with NEC's V20-8 microprocessor, which is selling for as low as $14 from mail-order suppliers. NEC enhanced the microcode of the V20 to make some arithmetic and string operations faster than in the 8088. Just replacing the 8088 with the V20 gives you 10% to 20% faster speed if nothing else in the computer is changed. (How much of an increase you get within this range depends on the computer's design.) Another benefit of the switch to the V20 is that a public-domain CP/M system that uses the V20's Z80 mode is available. This gives you access to and lets you use any CP/M programs you might have.

PCs and compatibles originally designed for 4.77-MHz operation could use slow RAMs that require wait states to be able to interface to a faster CPU. A wait state is used during CPU access to RAM or PROM to make the CPU wait one or more extra clock cycles while data is read from or written to memory. Many PCs already have one or more wait states included in their designs, allowing manufacturers to take advantage of less expensive slower RAMs to keep prices down.

Use of wait states means that an 8-MHz CPU designed for three wait states will actually run *slower* than a 4.77-MHz machine with only one wait state. This occurs when running



PARTS LIST

C1,C2—0.1-μF, 50-volt monolithic capacitor
LED1—Red panel-mount light-emitting diode
R1 thru R4,R6—510-ohm, ¼-watt, 5% resistor
R5—10,000-ohm, ¼-watt, 5% resistor
S1—Dpdt miniature toggle switch
S2—Normally-open spst pushbutton switch
U1—8284A clock generator
U2—8284 clock generator from existing PC (see text)
Y1—14.318-MHz crystal
Y2—18.00-MHz crystal (see text)
Misc.—Printed-circuit board; switch/LED box (see text); sockets for ICs; 3- to 4-ft. 4-conductor ribbon cable; etc.

Note: The following are available from NRG Electronics, P.O. Box 24138, Ft. Lauderdale, FL 33307: Complete kit of parts plus public-domain software mentioned in text for $29.95 plus $2.50 P&H; software alone for $2.50 to cover P&H. For free download of software, call Plantation bulletin board 24 hours a day; 305-791-7302 (2400 baud, 8 data bits, no party and 1 stop bit).

Fig. 2. Overall shcematic diagram of the PC Accelerator.

RAM-access-intensive programs or when a lot of ROM BIOS calls must be made. Like CPUs and other logic elements, RAM and ROM/PROM chips are only tested at the specified rating and may actually run much faster. Also, since most PCs and compatibles are designed with one or more wait states and have RAMs with an access time of 150 ns, they are able to support an 8-MHz clock without any changes.

Floppy and hard disks in any computer can be improved by using a software caching program or by installing faster units. By adding a cache program (these are commonly available in the public domain) to your computer, you can obtain increased disk performance, especially with floppy disks, when running memory-intensive programs like dBase III. The other side of the coin is that a cache program can also *de-*

crease the performance of some types of programs. The best way to evaluate a cache program is to try it in your computer.

The last problem area is the computer's overall design. The maximum speed any system can achieve depends on how many corners were cut during initial design of the hardware. The greatest problem is usually in the address decoding logic. So much time can be used up in the chip-select process that even fast memory chips require wait states to operate properly. In the case of the Zenith Data Systems PC design, for example, the RAM is a separate board on the bus, which means that the number and types of expansion cards on the bus could affect the speed of the overall system.

About the Circuit

The PC Accelerator uses a very simple method to boost the speed of a PC or compatible computer, providing a fast 6-MHz CPU clock and a switch that allows you to set the clock to the compatible 4.77-MHz speed. Identical time tests run on a Zenith Z-158 with an 8-MHz clock and an earlier Z-151 in which the PCA was installed and operating at 6 MHz, revealed that both computers tested out at exactly the same speed. (The wait states used in Zenith's new computers don't make it possible to achieve the full 8-MHz benefit.)

All time tests were run with the public-domain SSE-V20 program, which is designed to accurately measure the performance of PCs and compatibles, including a V20 microprocessor if it has been installed in place of the original 8088 CPU.

Shown in Fig. 1. is a composite of four screen displays I obtained when I ran the SSE-V20 program in my Zenith Z-151 computer. In the "IBM PC" columns, all numbers in parentheses are at the 1.0 reference. In the "Yours" columns, the parenthetical number that is greater than 1.0 indicates an increase in speed. From left to right, the "Yours" columns show performance figures for the Z-151 with no modifications, with a NEC V20-8 microprocessor substituted for the Intel 8088, with the PC Accelerator only, and with both the V20 and PC Accelerator installed.

Using the Total Timing entries at the bottoms of the columns, you can see that the basic Z-151 performs a smidgen better than the IBM PC (first "Yours" column). Installing only the V20 gave a 10% increase in performance (second "Yours" column). Note that the "integer count" speed actually was *slower* with the V20 installed, though overall speed was up as a result of better performance in all other areas, especially string manipulation. With just the PC Accelerator installed and no other changes to the computer, a 30% increase in operating speed was realized (third "Yours" column). Best overall performance, representing an increase in speed of 40%, was achieved with both a V20 and the PCA installed (final "Yours" column). For comparison, performance figures for the IBM PC AT at 6 and 8 MHz are also shown.

Clock speed can be checked with the public-domain V20TIMER program, which gives the user a measure of how well his computer is designed. If an 8-MHz PC tests out at 7 MHz, some corners were cut in the design.

Any speed problems in the Z-151 with the PCA installed have been dealt with by limiting the board's operating speed to 6 MHz. However, if you wish to use the PCA in a true IBM PC, you can safely boost the speed up to 7 MHz by changing *Y2* in the PCA to a 21-MHz crystal.

Three clocks ar supplied by the PCA board. These are the CPU clock, the peripheral clock and the oscillator. For an 8088, the CPU clock is derived by dividing a crystal oscillator's frequency by 3 to produce a 2:1 duty-cycle square wave. The peripheral clock is the same oscillator frequency divided by 2 to produced a 1:1 duty-cycle square wave. The oscillator's square wave is at the same frequency as the crystal.

These clocks are provided by an Intel 8284 clock generator. In the IBM PC, the crystal's frequency is 14.318 MHz, originally chosen by IBM to make the RS-232 baud and video controller clocks easy to derive. According to the IBM Technical Reference, all peripherals should use the peripheral clock when external timing is required. Because the time-of-day clock is driven by the peripheral clock, it must always maintain 7.15 MHz to keep correct time.

The 8284 clock driver chip permits a crystal or an external square wave to control the rate of the three clocks provided. The PCA uses one 8284A (*U2* in Fig. 2) to supply clocks at exactly the standard rates for a 4.77-MHz IBM PC. A 14.318-MHz crystal (*Y1*) is on the PCA board to assure that the 4.77-MHz mode actually operates at 4.77 MHz. If jumpering were to be done to the existing crystal on the CPU board, the extra capacitance and lead length would have produced a clock that operated slower than the intended rate.

A second 8284A, *U1* in Fig. 2, is driven by 18-MHz crystal *Y2* to yield a 6-MHz CPU clock. Changing the crystal frequency will increase or decrease the high-speed operation rate. The oscillator and peripheral clock are always supplied from *U2*. The CPU clock is supplied from *U1*, with a switch that selects the 18-MHz crystal or the oscillator from *U2* to drive the CPU clock.

Light-emitting diode *LED1* is wired to the external speed switch to indicate which PCA mode has been selected. If the *U2* oscillator drives the input of *U1*, the CPU clock is 4.77 MHz and *LED1* will be off. If the crystal drives the input of *U1*, CPU clock speed will be 6 MHz and *LED1* will be on.

Synchronization of the wait-state logic to the CPU ready control is

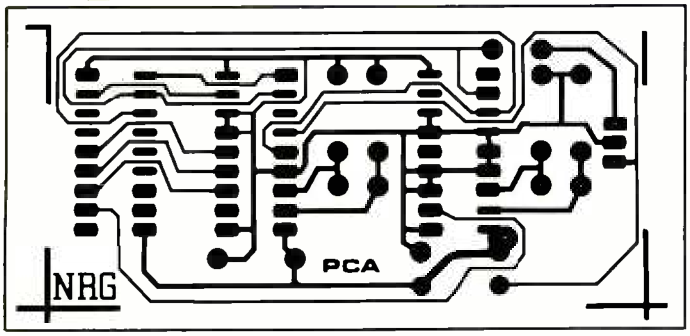


Fig. 3. Actual-size etching-and-drilling guide for the PCA board.

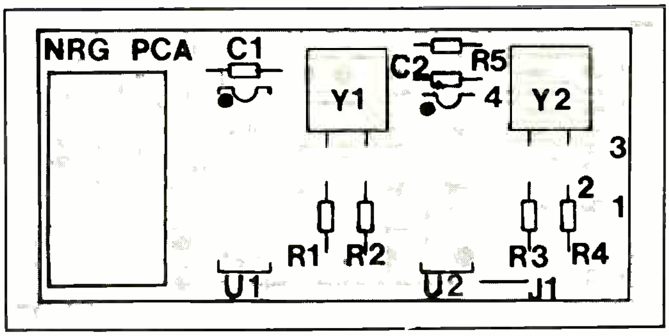


Fig. 4. Pc board wiring diagram.

handled by the RDY1 and AEN1 signals. Momentary pushbutton switch *SW1* wired between the reset input and circuit ground provides an alternative to the Ctrl-Alt-Del sequence required to boot the computer. This is especially helpful when interrupts are disabled and you can't boot from the keyboard.

This PC Accelerator is designed to be installed in place of the existing 8284 on the CPU board of a Zenith Z-151/161 computer or on the motherboard of an IBM PC or PC XT computer. It can also be employed with other PC-compatible computers that use the 8284 in the same manner as these two computers do. The switches are located in a small box that attaches to the PCA board by several feet of cable to permit convenient location outside the computer.

Construction

Printed-circuit-board wiring is recommended for construction of the PCA to maintain compact size and facilitate easy installation inside your computer. You can etch and drill your own pc board using the actual-size etching-and-drilling guide shown in Fig. 3. Alternatively, you can purchase a ready-to-wire pc board from the source given in the Note at the end of the Parts List.

Wiring the circuit is fairly simple, as shown in Fig. 4. Begin wiring the board by installing and soldering into place the solid bare jumper wire labeled *J1*. Next, install and solder into place 18-pin DIP sockets at the *U1* and *U2* locations. (Do *not* install the ICs in the sockets until last.) Install the capacitors and resistors in their respective locations on the board, followed by crystals *Y1* and *Y2*. Use heat judiciously when soldering the crystal pins to the copper pads on the bottom of the board.

In the blank unlabeled box on the left side of the board is where you must install the machined socket pins that allow the board to be plugged into the computer. These pins must be carefully broken out of an 18-pin DIP socket. When you have all 18 pins ready, install them in the holes one at a time and solder them to the copper pads on the bottom of the board. Be sure you orient these pins properly so that they sit exactly as they would if they were still in the moulded socket body. Otherwise, they will not properly plug into the socket in the computer.

Because the machined pins broken out of the IC socket must be soldered to the foil side of the PCA's board, you must reinforce them with wires that solder inside each pin. When this is done, fold each wire over on the component side of the board and make sure that none touches any other. Then epoxy the wire ends to the top of the board.

Machine a small plastic box to accommodate *LED1* and both switches on one panel. Then use a sharp knife to slice a channel to allow a 4-conductor ribbon cable to pass through one wall where the two box halves join (see lead photo). Mount the switches and LED, and connect but do not solder *R6* into place until after the cable that connects to the board is wired into place.

Prepare a 3- to 4-ft. length of 4-conductor ribbon cable, preferably color coded for easy reference, by removing ¼" of insulation from all conductors at both ends and separating the conductors by about 1½". Tightly twist together the fine wires in each conductor and sparingly tin with solder. Then plug the conductors at one end of this cable into the holes labeled 1, 2, 3 and 4 and solder them to the pads on the bottom of the board.

Pass the free end of the 4-conductor ribbon cable into the small plastic box in which the switches and LED are mounted. Use the cable's color coding or an ohmmeter or continuity tester to identify each conductor as you connect and solder it as follows. The conductor from board hole 1 goes to one lug of *S2*. The conductor from hole 2 goes to *S2*'s other lug and both center lugs of *S1*. The conductor from hole 3 goes to the *S1* lug away from *LED1* that will be *on* with the switch set to FAST. Connect *LED1*'s cathode lead (the shorter lead or the one near the flat on the case) to the *S1* lug closest to the LED that will be *on* with the switch set to

(Continued on page 104)

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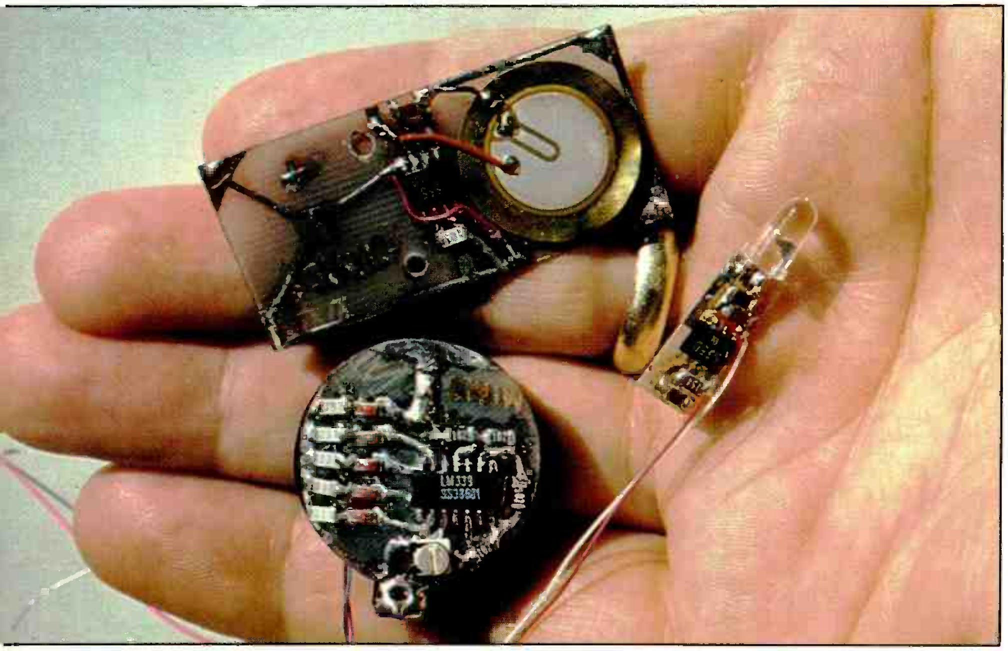
Surface-Mount-Device Circuits: A Design & Construction Guide

The author describes how to work with surface-mount technology to produce three personal subminiature devices



By Forrest M. Mims III

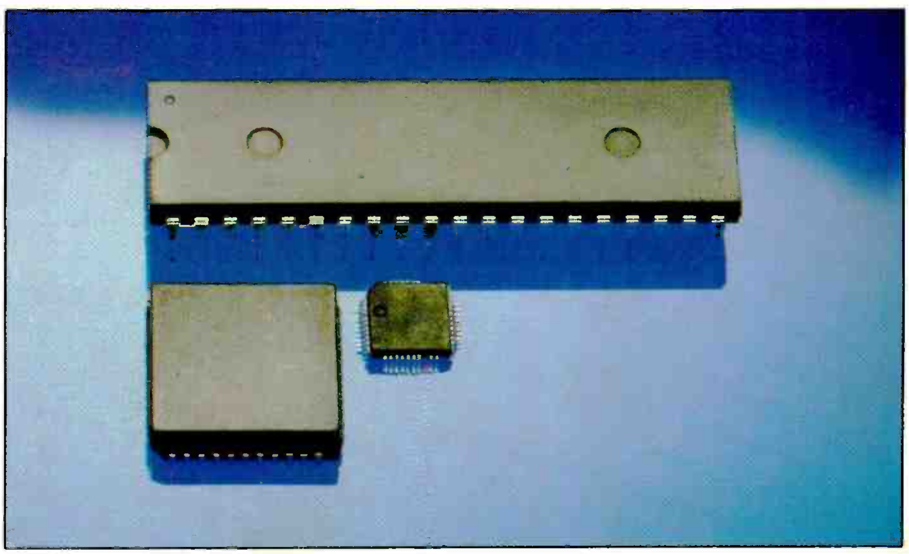
Last month, I set the stage for this article by discussing the current state of surface-mount technology and reviewing a kit that can get you started in SMT assembly techniques. Now I will describe how to assemble three subminiature circuits: an LED transmitter, an LED bargraph "meter" and a light probe. By using tiny surface-mountable components (SMCs), the overall size of these circuits is substantially smaller than if conventional components were used. The emphasis is on hand-assembly procedures that you can use both in your home workshop and on the job.

I am confident that once you master the easy techniques needed to work with SMCs, you will share my enthusiasm for this personal assembly method that is revolutionizing how electronic circuits are built.

Circuit Boards for SMCs

Surface-mountable components are are leadless or have very short pins. Therefore, wiring must be on a substrate having preformed conductive traces. Ordinary etched circuit boards work well in this role, with double-sided boards permitting SMCs to be installed on both sides.

Although any copper-clad board



Standard 40-pin DIP and P-Tape Pak ICs dwarf surface-mount 44-pin plastic leaded chip carrier (PLCC) IC at lower right. (Photo courtesy: National Semiconductor) can be used for SMCs, to preserve their very-small-size advantage, I prefer to use very thin (20-mil or less) single- and double-sided board. Unfortunately, this thin a board is not readily available to small-quantity purchasers. Hopefully, as demands develop for supplies suitable for hand-assembled boards using SMCs, thin copper-clad board will be stocked by electronics suppliers.

If you are unable to locate a source for 20-mil boards, you can use standard boards, of course. Alternatively, you can use ultra-thin (5-mil), double-sided material from Edmund Scientific (Cat. No. G35,738; $2.50). Supplied in 12″ × 18″ sheets, this material is very flexible before etching and can be used as is or be cemented to a rigid substrate. Keep in mind that after this board has been etched, excessive bending will fracture the very thin substrate.

Of the many ways to create etched circuit patterns on copper-clad boards suitable for SMCs, the four most common are:

(1) Use of a standard resist pen to draw the desired SMC "footprints" and traces directly on a shiny copper-clad board. In view of the very small size of SMCs, this method may seem impractical. However, I have found it works surprisingly well, and is the method I used to assemble the miniature circuits described here.

(2) Use of dry-transfer component patterns and traces to form actual-size (1:1 or 1×) footprints and traces directly on the copper-clad side of a board. This one-shot method provides circuit traces as neat as those formed by photographic techniques. Datak sells a complete line of suitable dry transfers. Their flat-pack dry transfers have 0.05″ centers and can, therefore, be used for SO (small outline) integrated circuits.

(3) Use of dry-transfer or self-adhesive component patterns and traces to form a 1× circuit pattern on a clear substrate and then using this pattern to expose a copper-clad board coated with positive photoresist. Suitable patterns are available from Bishop Graphics and Datak.

(4) Use of dry-transfer or self-adhesive component patterns and traces to compose a 2× or 4× circuit pattern. Photographing the pattern to obtain a 1× negative yields a "mask" that can be used to photographically expose circuit boards coated with negative photoresist. This method permits boards to be made in batches.

How to Install SMCs

The principal manufacturing methods for installing surface-mountable components were covered last month. I will focus here on hand-assembly procedures, the method likely to be used for putting together prototype models by engineers and technicians, and for building microminiature products by electronics enthusiasts.

The circuits to be described were assembled with a hand-held 15-watt soldering iron. Most SMCs are so tiny that soldering them to a circuit board with a hand-held iron might at first seem impossible, as I initially felt. I soon learned that, with a little care and patience, the procedure is fast and simple. Here are the basic requirements:

(1) It is *essential* to use a low-power soldering iron with a sharp conical tip. Irons designed specifically for soldering and desoldering SMCs are an added expense, but I have had excellent results with an inexpensive 15-watt pencil iron.

(2) *Always* pretin the copper component footprints on the circuit board. You can do this chemically by immersing the etched board in TINNIT™ to plate the copper pattern with a thin film of tin. Datak sells TINNIT for $4.60 for a 1-pint bottle. The alternative is to heat the copper traces with a soldering iron and flow a thin layer of solder onto them, which is what I did to assemble the circuits to be described.

(3) The SMC must be secured in place before it can be soldered. Otherwise, the surface tension of the molten solder will attract it toward the tip of your soldering iron. Though you can cement SMCs in place before soldering, this requires extreme care to avoid getting cement on the component footprints. A much simpler and faster method is to simply secure one end or side of the SMC in place with a small piece of masking tape. Pick up one end or side of the SMC with the tape, position the SMC in place over its footprint, and press into place on the board.

To solder the connection, first touch the point of the iron to the junction of the footprint and SMC lead and then touch the end of a thin (0.03″ or less) diameter solder wire to the tip of the iron. When a tiny bit of solder flows between the footprint and the SMC terminal, quickly remove both the iron and the solder. Each connection should take only a second or two. After soldering one or more terminals to the copper pads, remove the tape and solder the terminal(s) previously covered and any remaining terminals.

(4) It is *very* important to inspect every solder connection through a magnifying lens immediately after the connection is made and before making the next connection so that SMC movement, solder bridges, etc. are immediately found and corrected.

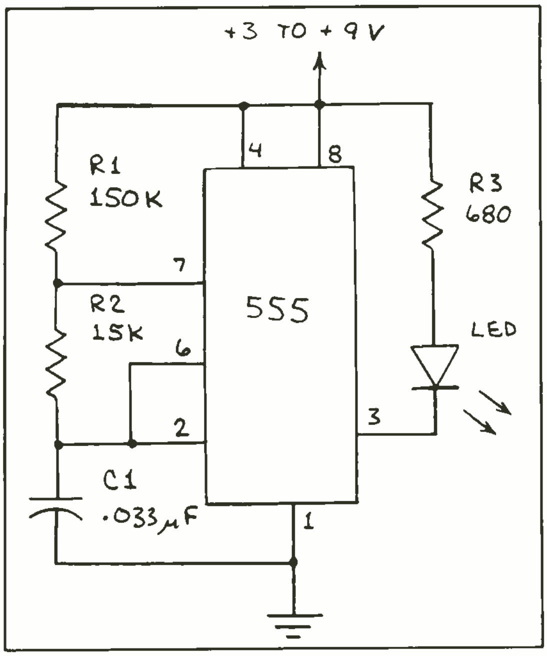
(5) If the SMC is a small outline (SO) integrated circuit, transistor, or diode, make sure all leads are lined up before *and* after the first lead is soldered into place. If necessary, slightly realign the device after making the first connection.

(6) If you tin the copper footprints with solder, be sure to slurp up any excess solder with copper desoldering braid.

(7) For best results, any pretinned solder layer placed over the footprints intended for SMCs should be as thin as possible. If solder tends to pool under an SMC's terminal while soldering, especially a chip resistor or capacitor, carefully press the SMC against the board while the solder is still molten. If the SMC is a leadless device, such as a chip resistor, this technique works for only the first terminal soldered. Otherwise, the chip SMC might be fractured. Therefore, the tinning over the second footprint should be as thin as possible.

Subminiature LED Transmitter

The first circuit I assembled with surface-mountable components was the LED tone transmitter shown at the left in Fig. 1. This is a 555 timer configured as an astable multivibrator that drives a high-brightness GaAlAs



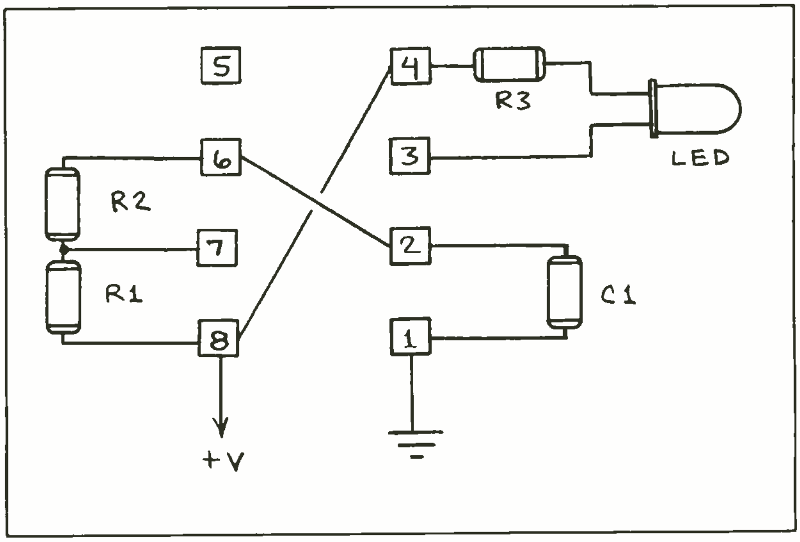


Fig. 1. A 555-timer-based miniature LED tone transmitter circuit (left) and preliminary circuit-board layout (right).

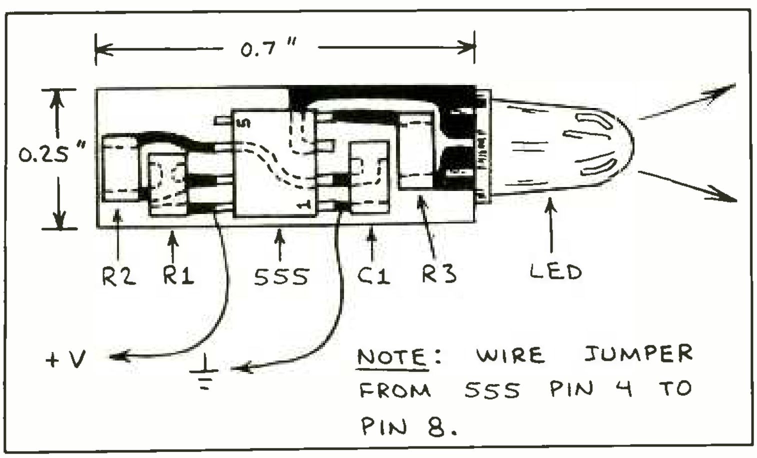
red LED at around 100 Hz. This circuit can be used as an optical transmitter for miniature remote-control systems, intrusion alarms, and object-detection systems. For higher output power or for applications in which an invisible beam is desired, the LED can be replaced with an infrared-emitting diode.

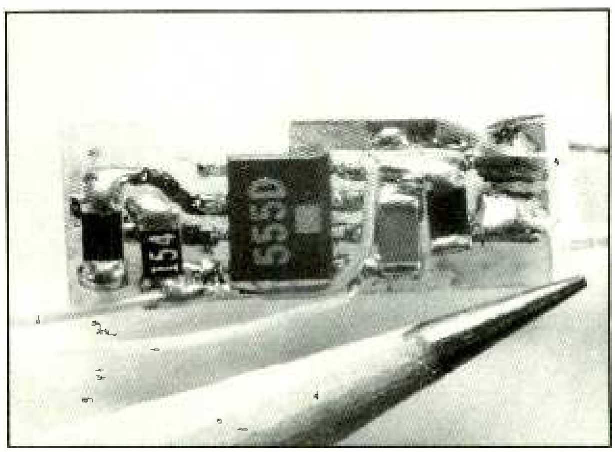
Before building this circuit you may wish to assemble a breadboard version to determine whether or not you want to modify component values. For example, increasing the value of *R1* or *C1* will slow the circuit's pulse repetition rate.

A sketch I made to determine where to place the components in the circuit is shown at the right in Fig. 1. Since I wanted the finished circuit to be as small as possible, I modified the location of the parts by placing them in a row. The result was the final layout shown at the left in Fig. 2, which is a drawing of the completed circuit. To duplicate this circuit layout, first draw the traces on the pc blank with a pencil, placing the SMCs on the board one at a time (use tweezers) and drawing the footprints. Then connect the footprints in accordance with the circuit diagram. Hand-trace the faint pencil traces with a sharp-pointed resist pen (Radio Shack Cat. No. 276-1530 or similar).

Next, etch the board in ferric chloride to remove the unwanted copper and strip the resist with resist solvent. (*Caution*: Always follow the precautions given with these chemicals.) The board shown measures on-

Fig. 2. Assembly details for the miniature LED transmitter circuit (left) and the assembled circuit (right).





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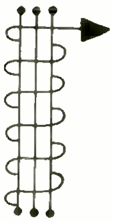

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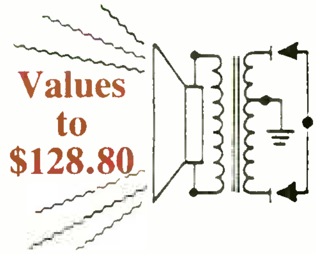

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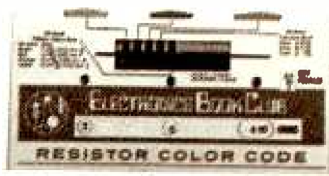

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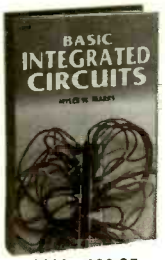

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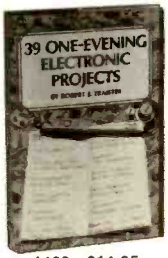

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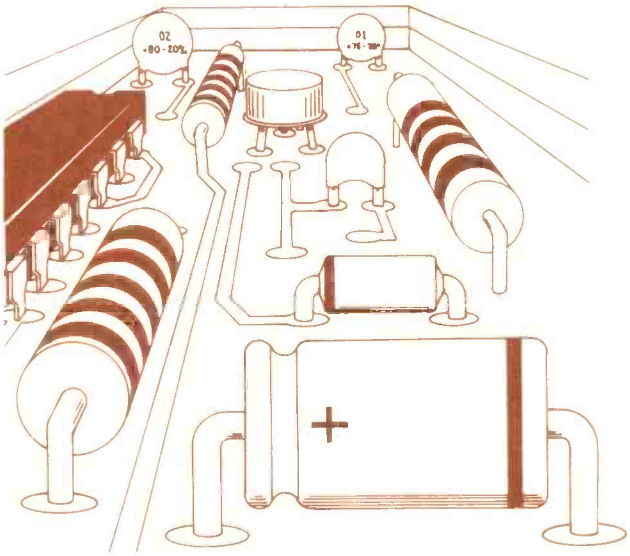

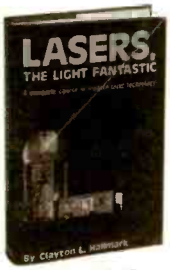

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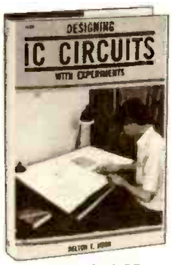

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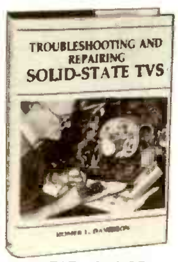

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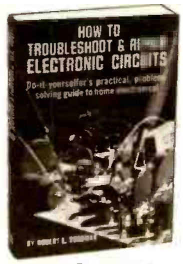

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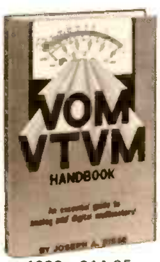

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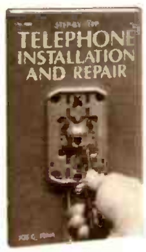

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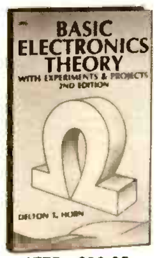

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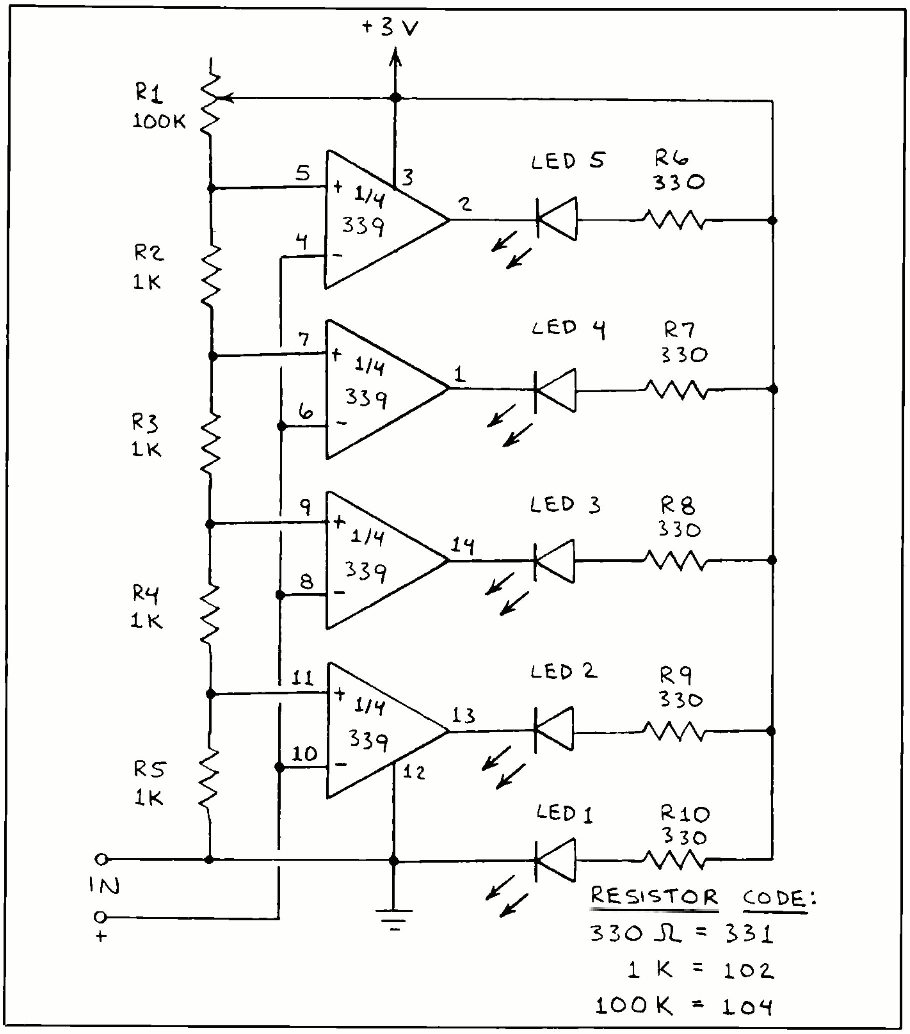


Fig. 3. A simple four-element LED bargraph or "metering" circuit.

ly 0.25″ × 0.7″. You may want to start with a somewhat larger board. After the SMCs are soldered into place, use scissors to trim the board to its final size.

Begin "wiring" the board by first soldering the SO 555 into place using the masking-tape technique described above. Tape one end of the board itself to your workbench to keep it from moving. It is important to work slowly and carefully, and remember that it is absolutely essential to check each connection with a magnifier before soldering the next one.

Although a tiny surface-mountable LED can be used, I used a standard LED because of its higher output power. All that's necessary to convert the LED into an SMC is to clip off all but 0.1″ of its leads. To finish the wiring, solder power supply leads to the board as shown. Wrapping wire works well here. The photo in Fig. 2 shows the completed circuit.

Before applying power to the circuit, carefully inspect the "wired" board with a magnifier. Use a sharp instrument to remove all solder balls. Carefully remove solder bridges with a soldering iron and desoldering braid. Use caution to avoid overheating or moving nearby SMCs.

Apply power (a 3-volt lithium coin cell works well) and point the LED at a nearby optical receiver to test the circuit. A suitable receiver can be made by connecting a solar cell or phototransistor to the input of a battery-powered audio amplifier. [For more specialized receivers, see *The Forrest Mims Circuit Scrapbook* (McGraw-Hill, 1983) and *Forrest Mims Circuit Scrapbook II* (Sams, 1987). Also see *Engineer's Mini-Notebook: Optoelectronic Projects* (Radio Shack, 1986).—Editor] If you use the parts values shown in Fig. 1, you can determine if the circuit is oscillating by simply swinging it sideways. The LED will then be seen to emit a series of fast flashes as it moves.

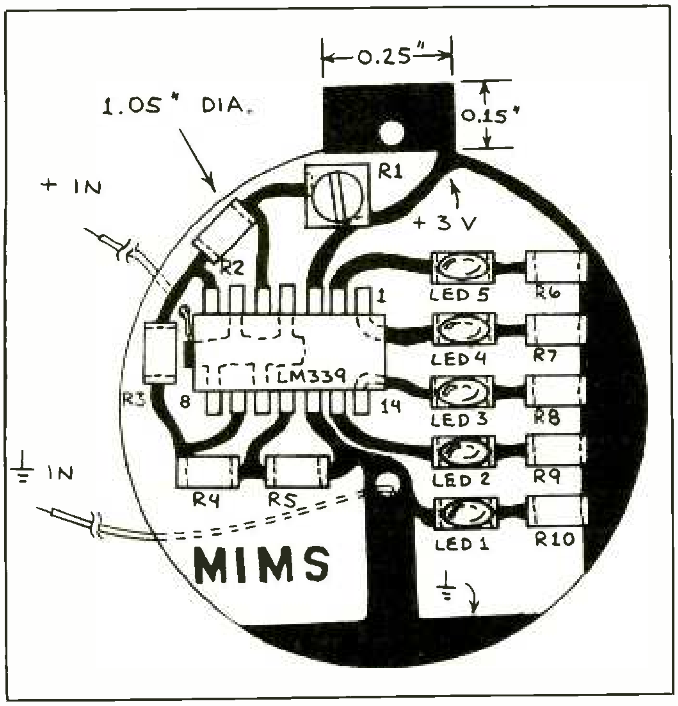
LED Bargraph

The circuit in Fig. 3 is a parallel or flash analog-to-digital (A/D) converter. Though this basic circuit shows only four LEDs (not counting *LED1*, which indicates when power is applied), the comparator/LED string can be extended indefinitely.

When the inputs are open, all LEDs glow. Connecting a variable resistance across the inputs causes the LEDs to extinguish successively as the resistance is decreased. A variable voltage source connected across the inputs causes *LED2* through *LED5* to extinguish. The LEDs begin to glow in sequence when the voltage is reduced. In both cases, *R1* determines the trigger points for the LEDs.

Since this basic circuit responds to both resistance and voltage, it has many applications as an LED "meter." For example, it can function as a miniature light meter if a photoresistor or solar cell is connected across the inputs; it can be adjusted to indicate the voltage of small batteries and power cells; and can even indicate the resistance of the human body.

At the left in Fig. 4 is a drawing of how the circuit in Fig. 3 can be assembled on a board measuring only 1.05″ in diameter. (Incidentally, if you are skeptical about your ability to assemble these miniature circuits, keep in mind that more time was required for me to make the Fig. 3



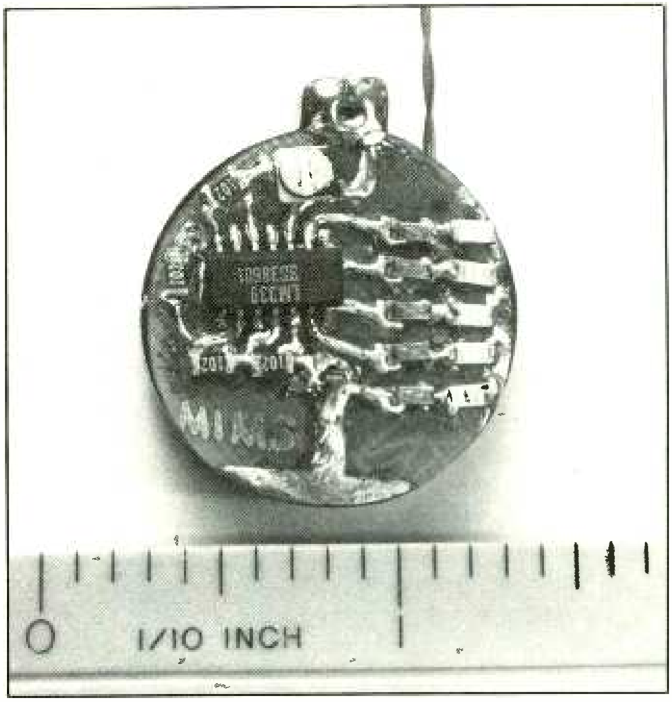


Fig. 4. Assembly details for the four-element bargraph circuit (left) and the assembled circuit (right).

drawing than to design and assemble the entire circuit!) The board is designed to be soldered to the two terminals that protrude from the back of a 3-volt lithium coin cell holder (Mouser Electronics Cat. No. 534-106 or 534-105 or similar). The entire circuit, including the coin cell holder, is ⅜" thick.

Lay out the board with a pencil, coat the traces with a resist pen, and etch it in ferric chloride. Then remove the resist with solvent and drill two holes to receive the coin cell's terminals. Solder the SMCs in place as detailed above. Start with the SO IC and work outward from the center of the board. I used Stettner ceramic chip CR 10 red LEDs for *LED1* through *LED5*. Slightly larger chip LEDs are also available from Mouser Electronics and other sources. Though the LEDs may seem more fragile than the chip resistors, they can be soldered using the masking tape method described above.

Trimmer potentiometer *R1* will be difficult to hand solder if the center terminal is under the device. Therefore, use a 4-mm trimmer having exposed terminals. For best results, select a trimmer having the two stator terminals on one side and the rotor terminal on the opposite side. I used a Bourns single-turn cermet trimmer (Part No. 3304X-1-104). This remarkably tiny device can be adjusted with a small screwdriver.

After the SMCs are soldered in place, slide the board over the terminals of the coin cell holder and carefully solder them into place. You may wish to trim the terminals before soldering to avoid damaging any of the SMCs or the relatively fragile circuit board.

Finally, solder the input leads to the circuit as shown. The ground lead can be threaded through a small hole near the IC. The ground lead can be threaded through the negative battery terminal hole. Use a short piece of heat-shrinkable tubing for a switch. Force the tubing over the exposed battery terminal to switch off the power.

Figure 4 also shows the completed LED bargraph circuit. (After thoroughly testing this circuit, I misplaced it somewhere in my office shortly after taking the photo. The lesson here is that special attention should be given to storing SMCs and subminiature circuits made from them.)

Subminiature Light Probe

Figure 5 shows a simple light-sensitive oscillator designed around a 555

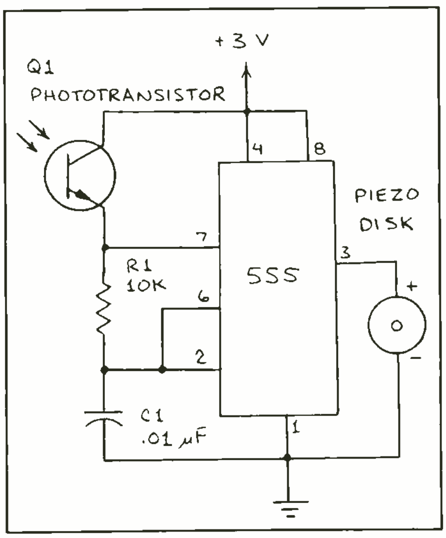


Fig. 5. A light-probe circuit.

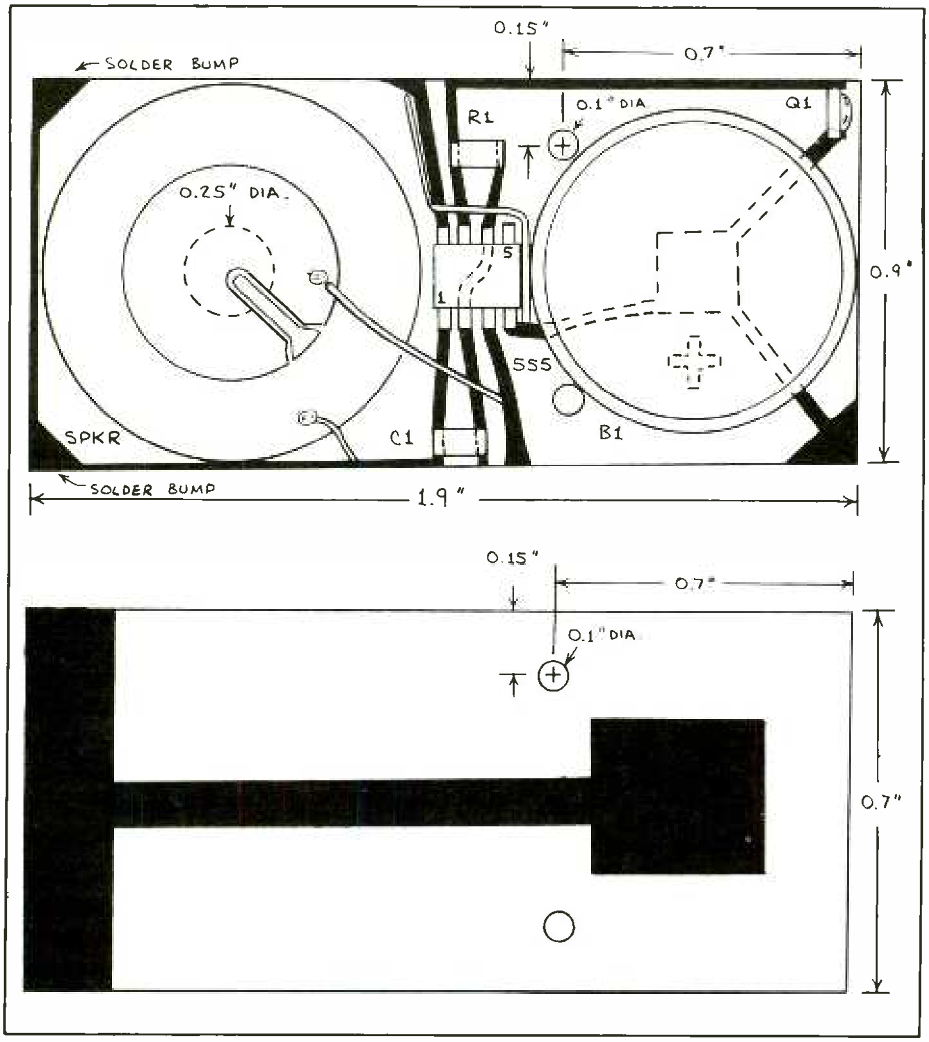


Fig.6. Assembly details for the light-probe circuit (upper) and a switch board for the light-probe circuit (lower).

timer. In operation, light falling on the active surface of phototransistor *Q1* causes the frequency of oscillation to increase. Pulses from the oscillator are made audible by a small piezoelectric alerter element. Among the uses for this circuit is a light probe for the blind.

Figure 6 illustrates how the light probe can be installed on a circuit board measuring 0.9″ × 1.9″. The speaker is a MuRata ¾″ piezoelectric alerter disk. If you cannot find this item, remove the disk from the plastic housing of a Radio Shack Cat. No. 273-064 piezo buzzer element, and clip the blue lead flush with the element.

Fabricate the circuit board as described above, being sure to leave space for the alerter disk and a CR2016 3-volt lithium coin cell. After the board is etched, solder the SMCs into place. The phototransistor is a CR10TE-1 ceramic chip unit available from Stettner Electronics. Though *Q1* can be mounted flat on the board, I soldered it on its side so that its lens faces in the same direction as the plane of the board. Since one terminal of the phototransistor was not fully metalized, it was necessary to use a bit of wire to bridge the space between it and the footprint pad.

Form two solder bumps on the corners of the board as indicated. These bumps should extend very slightly above the back of the piezo disk. If necessary, use short bits or wire to extend the bumps.

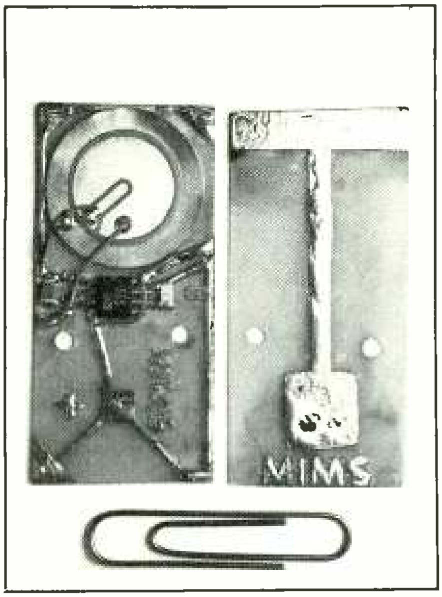
After the components are installed carefully drill a ¼″ hole in the board centered under the space for the piezo disk and a pair of 0.1″ holes in the board adjacent to the space for the battery.

Next, form a thin ring of flexible silicone sealant on the face of the disk, invert the disk, and place it face down over the ¼″ hole. Don't press the disk against the board; instead, allow it to ride just above the board on the sealant bead so that it can resonate.

Incidentally, it's important to apply the sealant bead to the annular node around the center of the disk. Otherwise, the disk will not vibrate freely. If you use a Radio Shack disk, apply the sealant bead to the remnants of the original sealant ring that attached the disk to its plastic case. If you use a new disk, place it flat on a table, connect it to a signal source and place powdered sugar on its surface. The sugar will form a ring directly over the nodal region. Use a pencil to outline the node. (For more details, see *Modern Electronics*, September 1986 "Electronics Notebook.") After the sealant cures, trim the leads to the disk and solder them as shown in Fig. 10.

The lower drawing in Fig. 6 demonstrates how to make a squeeze switch for the light probe from a second circuit board identical in size to the first. Apply resist to the board as shown and etch the board. Remove the resist and plate the copper with TINNIT or solder. Then drill two 0.1″ holes as shown, lined up with the 0.1″ holes in the main board. The left photo Fig. 7 shows the assembled circuit and the switch boards.

The circuit can be installed in the lid of a 1″ × 1″ × 2″ plastic box available from gift and craft shops. Using the switch board as a pattern,



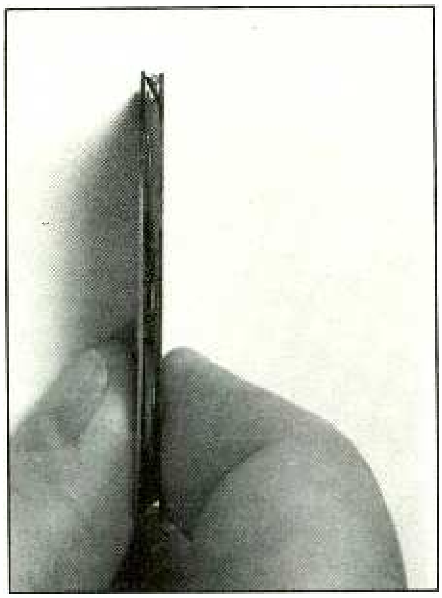


Fig. 7. The completed circuit boards for the light probe circuit (left) and the 0.1"-thin "sandwich" the two make (right).

drill ¼" and 0.1" holes in the plastic lid. Place the assembled circuit board, component side up, in the lid. Then place a small piece of foam plastic on the center of the piezo disk and a CR2016 lithium coil cell, positive side down, over the battery space on the board. Finally, place the switch board, copper side down, over the circuit and secure it with 2-56 screws and nuts.

Gently squeeze the piezo disk end of the switch board to switch on the probe. This will bridge the gap between the negative battery terminal and the two solder bumps.

You may have to experiment with the light probe to obtain best results. If the circuit fails to switch on when squeezed, the foam plastic may be too thick, the solder bumps may not extend high enough above the board, or the light level may be too high. The phototransistor is so sensitive it may be necessary to restrict the light striking it with tape or a daub of paint. Sound volume can be increased by stacking two CR2016 coin cells, but this will increase the thickness of the circuit.

Though the encased circuit is 0.25" thick, the photo at the right in Fig. 7 shows that the two circuit boards sandwiched together form an assembly only 0.1" thin.

Going Further

The circuits presented here provide convincing proof that experimenters, technicians, and engineers can readily assemble subminiature circuits that rival in size considerably more expensive hybrid microcircuits. Consequently, building tiny circuits is now in the grasp of individuals. Though SMCs are more difficult to acquire than conventional components, they will become much more readily available in coming years.

In conclusion, I invite you to join the surface-mount era now by using SMCs to assemble one or more working circuits. In the meantime, stay tuned to my future "Electronics Notebook" columns for more surface-mount ideas and projects.

This article was substituted for the author's "Electronics Notebook" column, which will return next month.—Ed. ME

SMT Materials Suppliers

Bishop Graphics, Inc.
5388 Sterling Center Dr.
Westlake Village, CA 91359

Bourns, Inc.
1200 Columbia Ave.
Riverside, CA 92507

Datak Corp.
3117 Patterson Plank Rd.
North Bergen, NJ 07047

Edmund Scientific Co.
101 E. Gloucester Pike
Barrington, NJ 08007

International Instrumentation
Box 3751
Thousand Oaks, CA 91361

Mouser Electronics
2401 Hwy. 287 North
Mansfield, TX 76065

MuRata Erie North America, Inc.
645 W. 11 St.
Erie, PA 16512

Newark Electronics
4801 N. Ravenswood St.
Chicago, IL 60640
(Plus major cities)

Radio Shack
One Tandy Center
Ft. Worth, TX 76102
(Plus local retail stores)

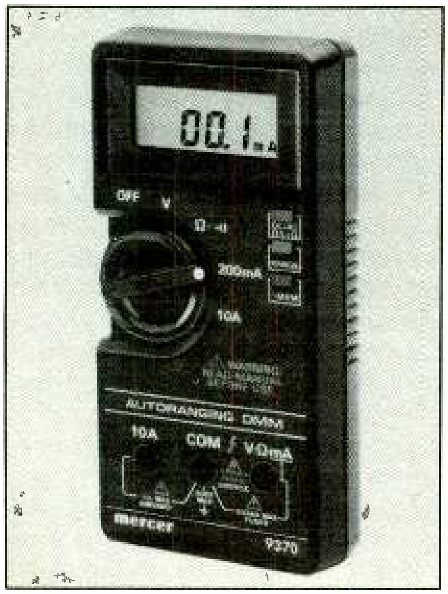
SMD Technology Development Center
5855 N. Glen Park Rd.
Milwaukee, WI 53209

Stettner Electronics, Inc.
P.O. Box 21947
Chattanooga, TN 37421

Vector Electronic Co.
12460 Gladstone Ave.
Sylmar, CA 91342

Note: Since we published our report on the Vector Electronic Model SMT2000 Surface-Mount Technology Training Kit last month, the company has announced an almost 20-percent decrease in price for the kit, from the originally reported $348 to $279.95.

NEW PRODUCTS... *(from page 12)*



750 volts ac in four ranges, 10 amperes ac and dc in two ranges and 2 megohms in five high-power and four low-power ranges. Basic dc voltage accuracy is 0.5%.

A memory mode provides up to 99 counts of zero offset. Among the DMM's features are a large 3½-digit liquid-crystal display (LCD) with function, under- and overrange and low-battery indicators; a rotary function selector switch; pushbutton mode switches; 9-volt battery operation; and low- and high-energy fusing. The instrument measures 5.9"H × 2.95"W × 1.34"D and weighs 12 ozs. It comes with color-coded test-leads with screw-on alligator clips and an operator's manual. $59.

CIRCLE 10 ON FREE INFORMATION CARD

Graphics System for Apple IIs

Demco Electronics (Inglewood, CA) has a versatile, easy-to-use graphics hardware system for Apple II+, IIe and IIGS and compatible computers. It displays the complete width and half the height of an 8½" × 11" drawing. Since it stores the complete drawing in memory and automatically scrolls to the second half, a full page of graphics can be dumped to a dot-matrix printer. Any one of eight 640 × 384 hi-res graphics screens can be displayed. The board has a 100-percent Apple-compatible mouse port built into it.

Included is graphics-design software, similar to MacPaint on the Macintosh, that provides: automatic windowing; variable grid lock; draw options accessible from menu; text insert in four directions; text cursor that matches font height and position; proportionally spaced fonts; block functions (fat bits, move, rotate, flip, duplicate, invert, cut/paste); inverse data displayed to monitor; work on two 8½" × 11" pages simultaneously. The system is

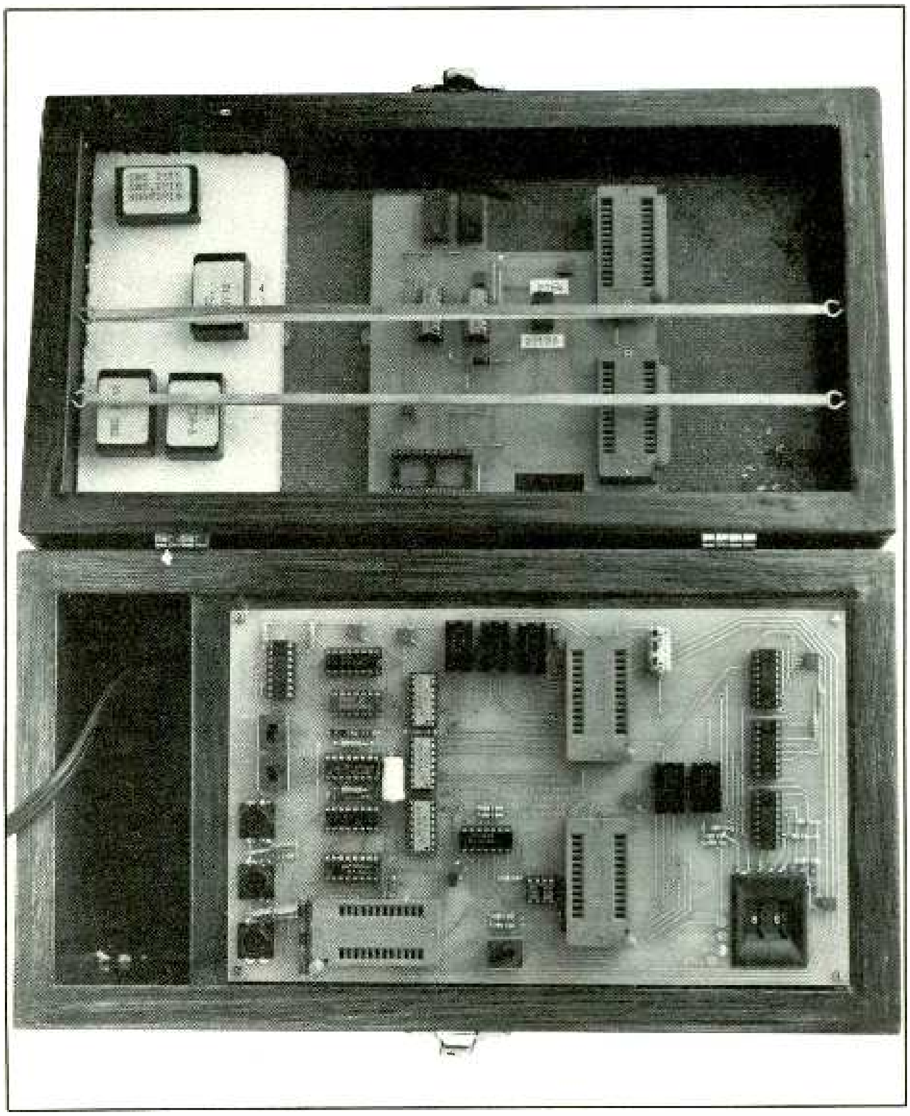
(continued on page 93)

A Stand-Alone EPROM Programmer
Part 1

Read a program or copy programs from one EPROM to another with this versatile Programmer that can be easily upgraded as needed to accommodate new EPROMs as they become available

By W. Schopp

Most inexpensive EPROM programmer/readers are designed to accommodate a single type of EPROM, generally using a personal computer as the controller. If you want a more versatile programmer/reader that can handle a variety of EPROMs of different storage capacities, it's very costly. The Stand-Alone EPROM Programmer to be described offers an alternative to both types of programmers at only a moderate cost. With it, you can program and read most popular EPROMs with capacities up to 32K in the basic unit presented here. Additionally, our Programmer will handle EPROMs with capacities ranging up to 128K with a retrofit add-on adapter that we'll discuss next month.



General Information

An address is the only information needed to access or program data into an EPROM at a specific location. Putting a code consisting of 1s and 0s on the EPROM's address lines finds the location of the desired data, which then appears on the EPROM's data lines and is similarly presented in the form of 1s and 0s.

To be able to address the large

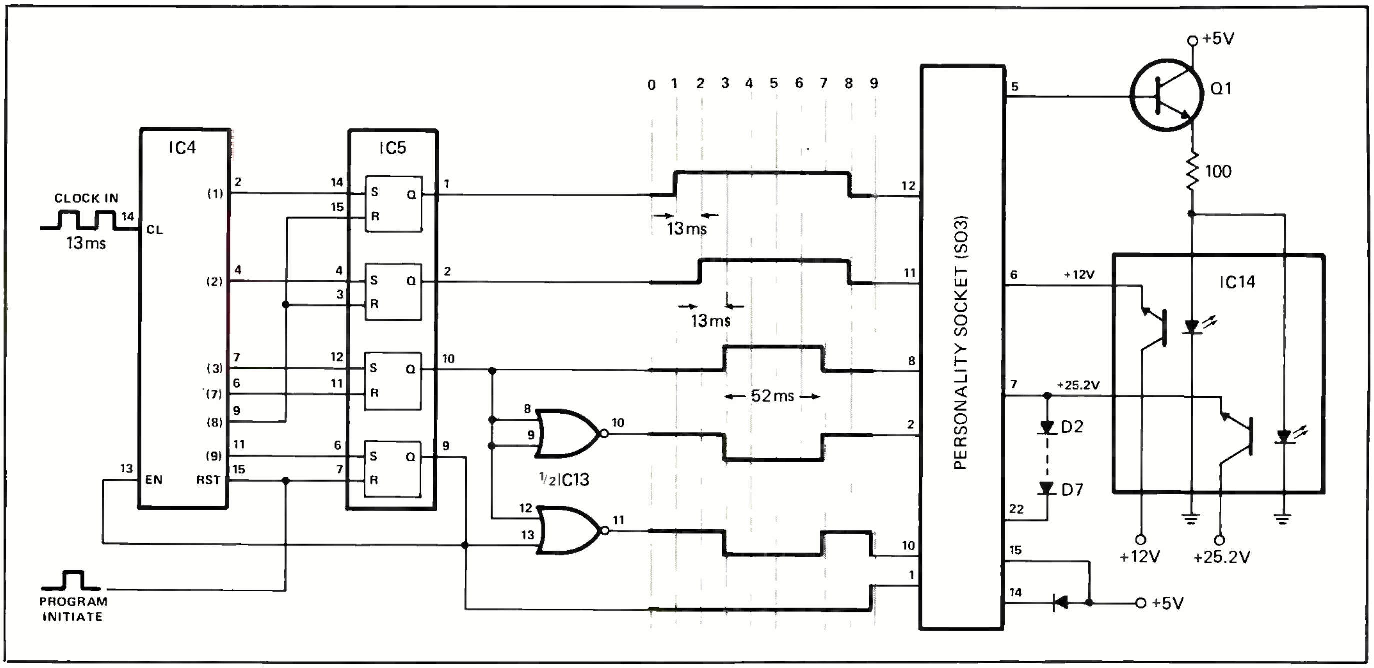


Fig. 1. A sequence generator is the heart of the EPROM Programmer.

number of memory cells in some logical and repeatable order, a three-stage counter is used. Outputs from the counters are connected to the EPROM's address lines. Counting from all 0s to all 1s on the 12 lines of this basic project gives you 4096 different combinations of 0s and 1s. This binary information is read on LED hexidecimal displays. The binary information is decoded by the special displays and is presented in hex format for readings ranging from 000 to FFF.

Two more LED hex displays read the data output after programming has taken place. This method of display verifies that the program being placed in an EPROM has been accepted. Three pushbutton switches provide for counter reset, single-step counter advance and program initiation. Slide switches on the Programmer's main board allow you to select count direction, manual or automatic mode of operation and to select the program source data.

About the Circuit

All waveforms and voltages for programming a variety of EPROMs are available at the project's PERSONALITY socket. Personality plugs for the various EPROMs connect the waveforms and programming pulses to the correct pins of the type of EPROM being programmed. These personality plugs are wired by you on 24-pin headers with covers and are individually labeled according to the type of EPROM with which they are to be used.

The heart of the Programmer is the sequence waveform generator shown in Fig. 1. This circuit provides all the waveforms and programming voltages needed to program 16K 2716, 32K 2732, 64K 2764 and 128K 27128 EPROMs. The generator is made up of half the buffers in hex inverter *IC1*, decade counter *IC4* and latch *IC5*.

Clock pulses of 13 ms duration are generated by *IC1* and applied to the clock input of *IC4*, which feeds pulses in the correct sequence to the set-reset latches in *IC5*. The Q outputs of these latches produce the timed waveform shown. Initiating the program cycle, the counter runs through one complete cycle of waveforms and stops until the program is reinitiated.

A good understanding of this sequence generator will allow you to make up personality modules for new EPROMs, using the waveforms and technical information available from the manufacturers for each type of EPROM. Hence, the Programmer will not become obsolete as new EPROMs become available.

The waveforms produced by the sequencing generator are used to turn on the EPROM's chip-enable (CE) and output-enable (OE) functions. Optoisolator *IC14* (see Part 3 of Fig. 2) keys the higher programming voltages needed to program the EPROM. The appropriate waveform is connected to pin 5 through the personality plug to turn on *IC14* and make the higher programming voltages available at pins 6, 7 and 22 of *SO3* (see Part 2 of Fig. 2).

Pin 14 of *SO3* provides +5 volts and allows the higher programming voltages to be superimposed on it at the EPROM's pin without feeding back into the 5-volt supply. The 22-volt supply required by some EPROMs is derived from the 25-volt

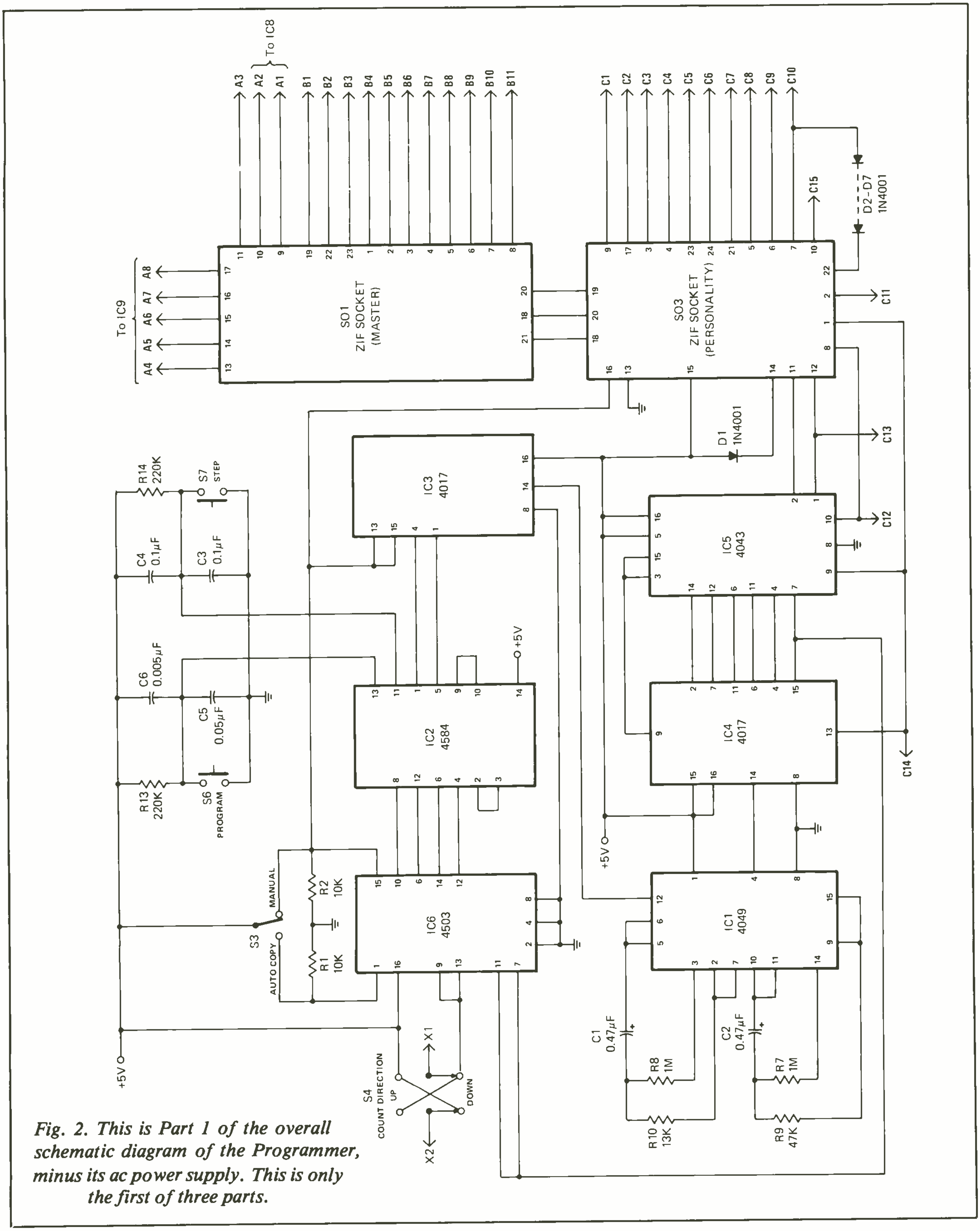


Fig. 2. This is Part 1 of the overall schematic diagram of the Programmer, minus its ac power supply. This is only the first of three parts.

CIRCLE NO. 180 ON FREE INFORMATION CARD

supply by dropping 0.6 volt for each of the *D2* through *D7* diodes between pins 7 and 22 of *SO3*. Future expansion connections are also brought to PERSONALITY socket *SO3*. These connections include reset, carry up and carry down lines.

The balance of the Programmer is straightforward, as shown in the three Parts that make up Fig. 2. (Note: Because this Programmer's circuit is fairly complicated, though relatively inexpensive, to be able to present it in its entirety, the very large schematic diagram had to be divided into the three Parts that make up Fig. 2.—Editor.)

Pushbutton switches *S6* and *S7* are debounced by Schmitt trigger buffer *IC2*. The half of *IC1* not used in the sequence generator produces 48-ms pulses for the automatic program mode. These pulses go to decade counter *IC3*, which alternately produces step and program pulses. Tristate buffer *IC6* selects manual inputs from *S6* and *S7* or automatic step and program pulses from *IC3*. Switch *S3* controls *IC6*'s tristate operation.

Counters *IC10, IC11* and *IC12* have outputs that are tied directly to the address inputs of MASTER and PROGRAM sockets *SO1* and *SO2*. The outputs of each counter are read with hex displays *DIS1, DIS2* and *DIS3*. The data lines of the EPROM being programmed are read on *DIS4* and *DIS5*. The LED numeric displays are isolated from the input program data by *IC7, IC8* and *IC9*. These ICs read data only after it has been programmed into the EPROM. The tristate buffers momentarily make the connection between the data to be programmed and the EPROM being programmed. All buffers are normally in the tristate (float) mode and are opened briefly during the programming cycle by the waveform from pin 12 of *SO3*.

Switch *S5* selects *IC7* and half of *IC8* to select the input data from manual programming switches *S1*

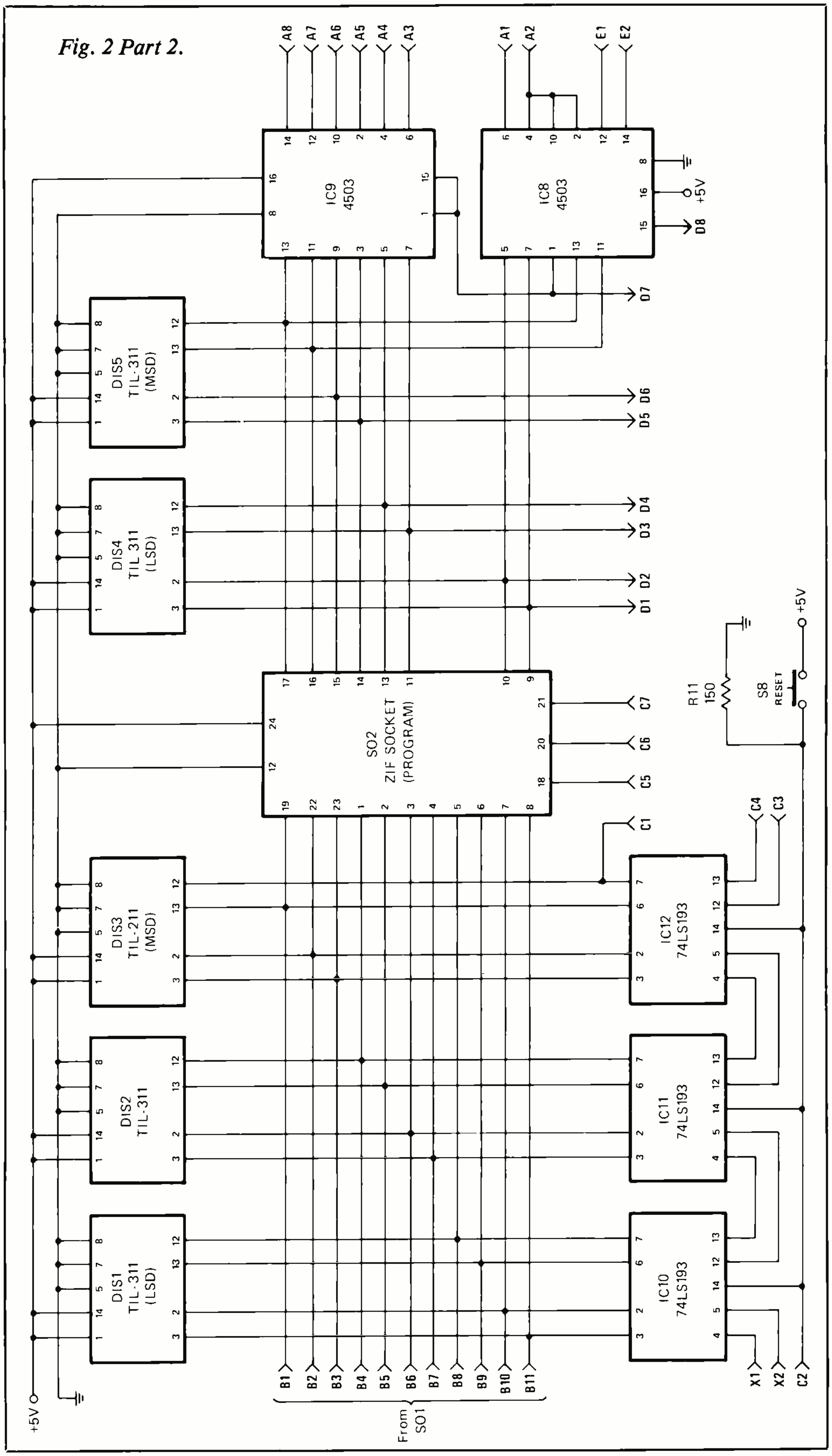


Fig. 2 Part 2.

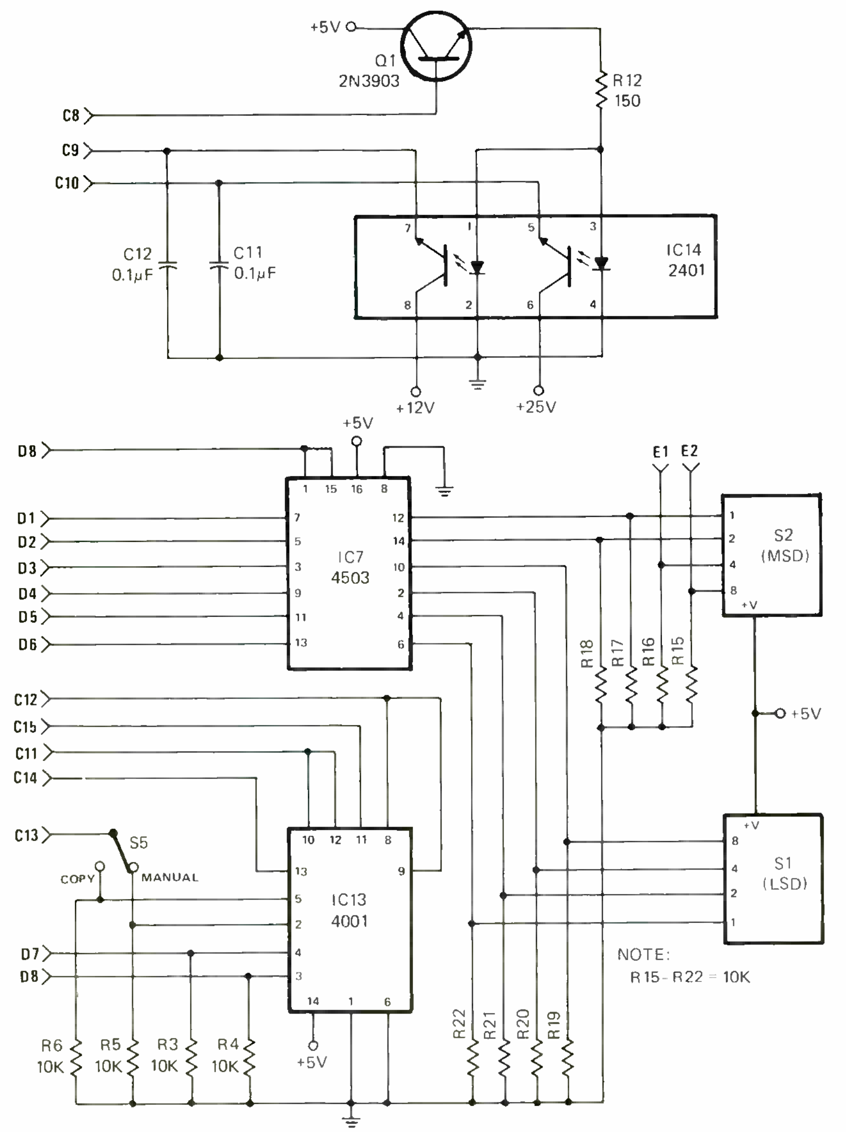


Fig. 2 Part 3.

PARTS LIST

Semiconductors

D1 thru D13—1N4001 rectifier diode

DIS1 thru DIS5—TIL-311 LED hexidecimal display (Texas Instruments; available from Jameco)

IC1—CD4049 hex inverting buffer

IC2—CD4585 hex Schmitt trigger

IC3,IC4—CD4017 decade counter

IC5—CD4043 quad R/S flip-flop

IC6 thru IC9—CD4503 tristate hex buffer

IC10,IC11,IC12—74LS193 4-bit up/down counter

IC13—CD4001 quad 2-input NOR gate

IC14—NEC 2401 dual optical isolator (available from Digi-Key)

IC15—7824 +24-volt regulator

IC16—7812 +12-volt regulator

IC17—7805 +5-volt regulator

Q1—2N3903 or equivalent transistor

Capacitors (25-volt)

C1,C2—0.47-μF tantalum

C3 thru C6—0.05-μF disc

C7,C8—100-μF electrolytic

C9 thru C17—0.1-μF disc

C18 thru C23—1,000-μF, 50-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1 thru R6,R15 thru R22—10,000 ohms

R7,R8—1 megohm

R9—47,000 ohms

R10—13,000 ohms

R11,R12—150 ohms

R13,R14—220,000 ohms

Switches

S1,S2—Hex thumbwheel type (Unimax No. SF-52 plus end plates; available from Jameco)

S3,S4,S5—Miniature pc-type dpdt slide type (No. 1201 M2QE; available from M&Q Components)

S6,S7,S8—Normally-open spst push-button type (Panasonic No. EVQ-PAR11K; available from Digi-Key)

Miscellaneous

T1—24-volt, 180-mA center-tapped transformer (EWC No. EL-24-180A18; available from Digi-Key as Part No. T104-ND)

T2—12-volt, 350-mA center-tapped transformer (EWC No. El-12-350A6; available from Digi-Key as Part No. T101-ND)

Double-sided main printed-circuit board with plated-through holes and two single-sided power-supply pc boards (see text); 24-pin ZIF sockets (3); sockets for all other ICs (except IC15, IC16 and IC17) and displays; materials for personality modules (see text); suitable enclosure; machine hardware; hookup wire; solder, etc.

Note: A ready-to-wire main board with plated-through holes is available for $22.00, including P&H, from Electronic Enterprises, 3305 Pestana Way, Livermore, CA 94550.

Addresses of Suppliers

C&K Components
15 Riverdale Ave.
Newton, MA 02158-1082

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

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

and *S2* or selects *IC9* and the other half of *IC8* to accept program data from the EPROM plugged into MASTER socket *SO1*. Only "read" voltages are present on *SO1* so that no alterations can be accidentally made to the EPROM being copied.

Not shown in Fig. 2 are *C7* and *C8*, which provide extra on-board dc filtering, and *C9, C10* and *C13* through *C17*, which provide electrical noise bypassing from the + dc lines to ground in various parts of the circuit.

Figure 3 is the schematic diagram of the Programmer's three-voltage ac-operated power supply. Each of the output lines from this power supply is fully regulated and filtered. Note that 24-volt regulator *IC15* is raised 1.2 volts above ground by the voltage dropped across diodes *D10* and *D11*. This gives an actual output from this supply of 25.2 volts.

Wiring details for personality modules for a variety of popular EPROMs are shown in Fig. 4.

Construction

Because this project makes extensive use of integrated circuits, sockets and other miniature components, printed-circuit wiring is the recommended method of construction. Though it is possible to wire the Programmer using Wire Wrap hardware and wire, the many wire runs that must be made can easily result in wiring errors. The basic project is wired on three boards—one large one for the programming circuits and two smaller ones for the power supplies.

To keep the project as compact as possible, a double-sided pc board with plated-through holes is actually needed for the main board. The actual-size etching-and-drilling guides for both sides of this board are shown in Fig. 5. The actual-size guides for the two power supply boards are shown in Fig. 6.

If you cannot have the double-sided board with plated-through holes made locally, you can purchase it

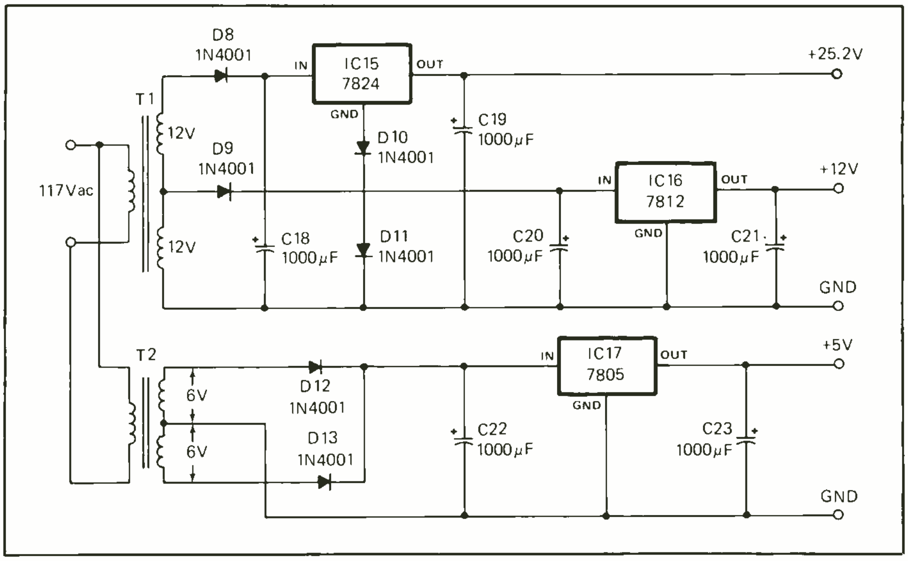


Fig. 3. Three dc voltages are required by the Programmer for powering the circuitry and programming EPROMs.

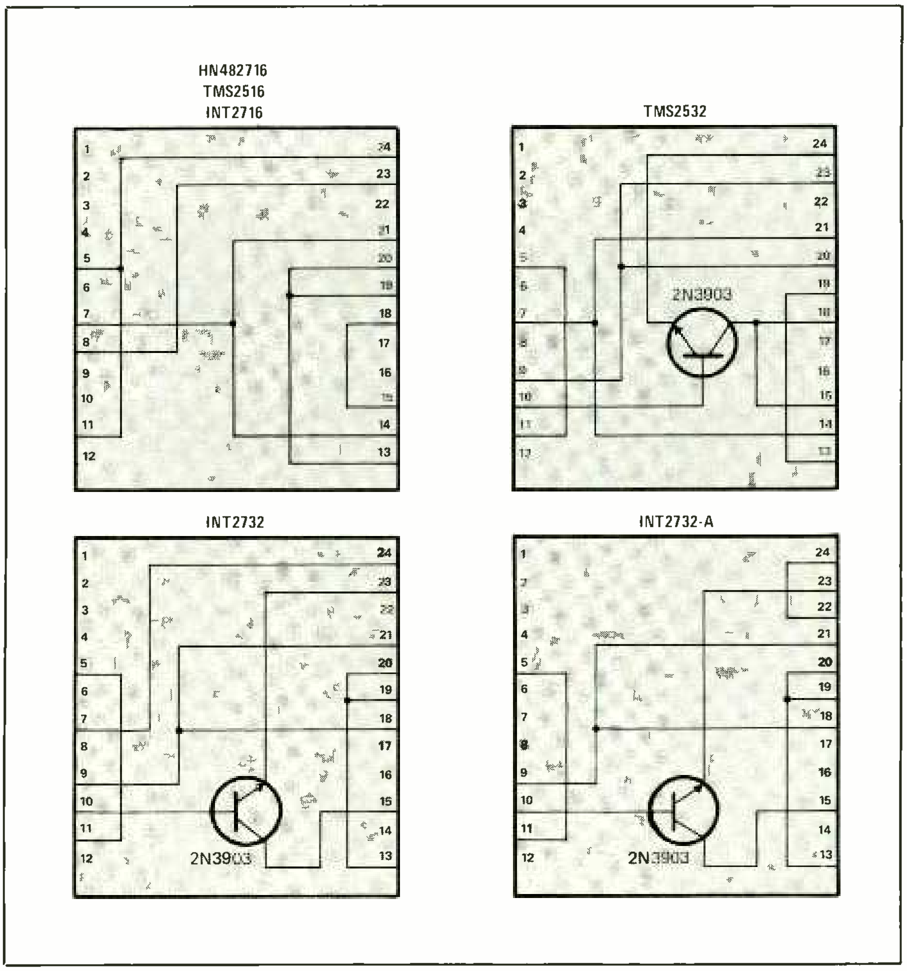
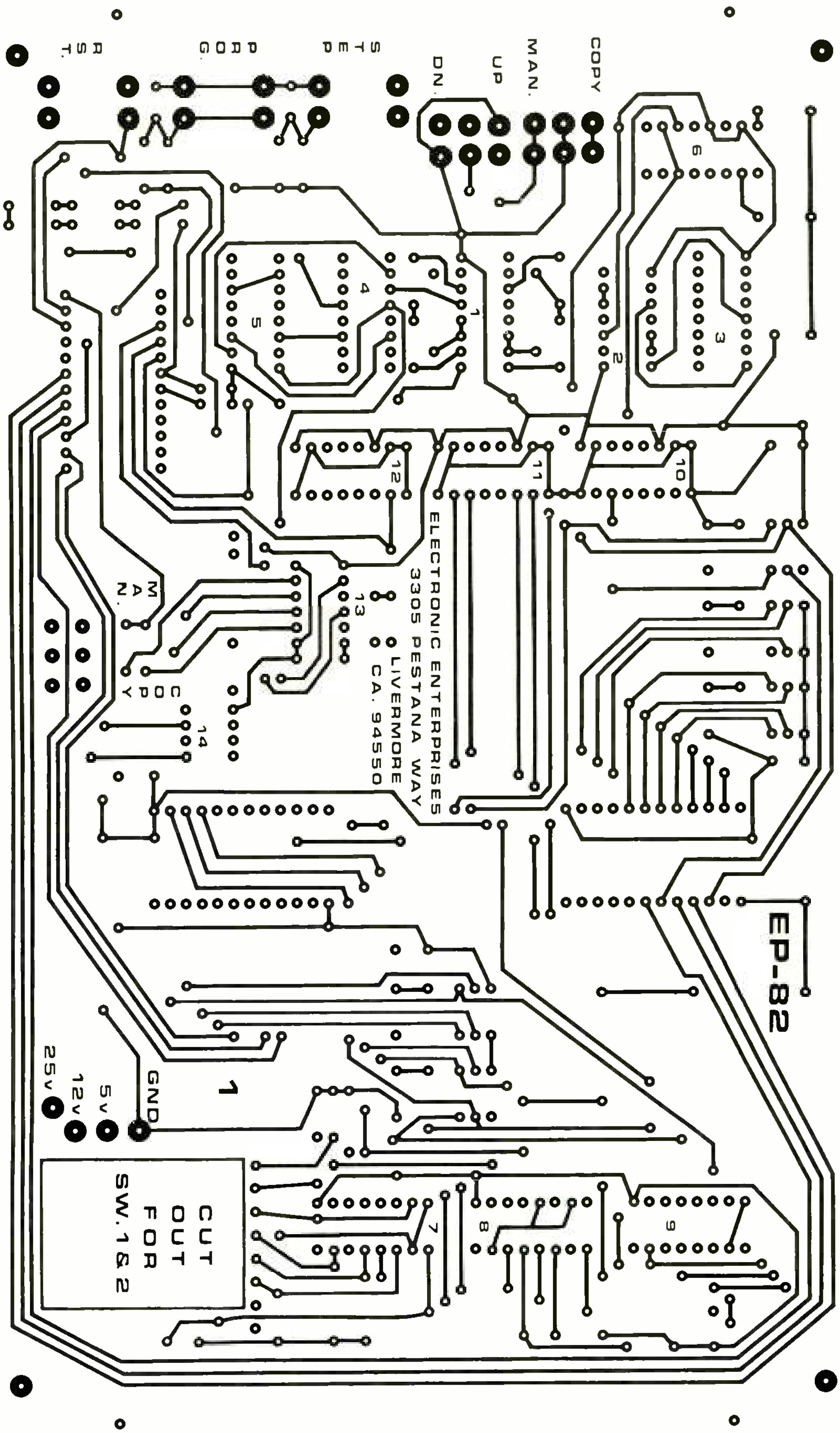


Fig. 4. Different personality modules are required for different types of EPROMs. Wiring for four such modules inside plug-in headers is shown here for popular 16K and 32K EPROMs.

Fig. 5. Actual-size etching-and-drilling guides for both sides of project's main printed-circuit board.

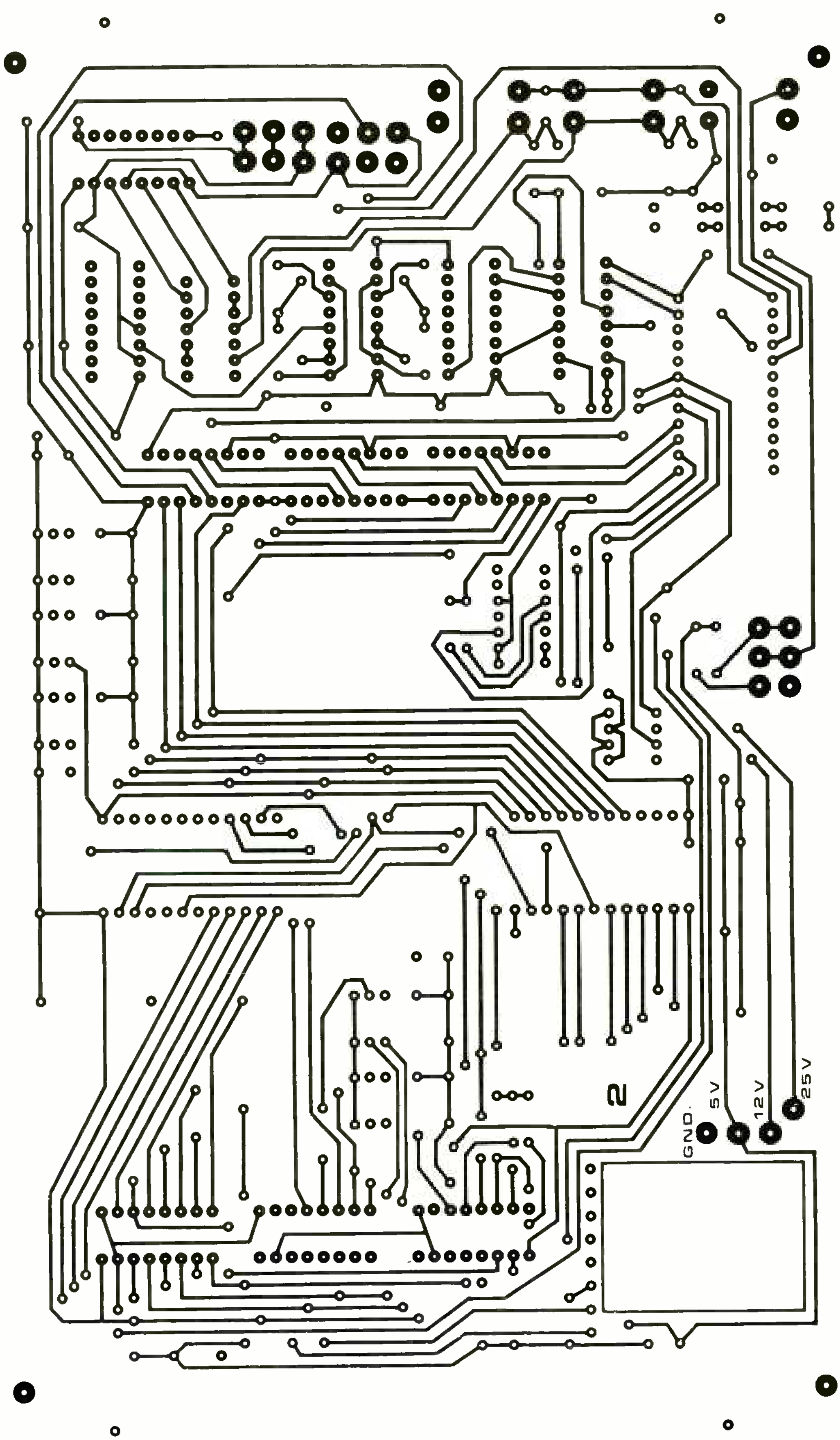


ready to wire from the source given in the Note at the end of the Parts List. This is the easiest—and recommended—approach because all you have to do is install the components and solder them into place, rather than running the risk of having the top and bottom foil patterns being misregistered and having to go through a complicated and tedious procedure to make do. (The power-supply boards are not commercially available from the same source as the main board. Therefore, you must either fabricate them yourself or have them made locally.)

You can, of course, fabricate all three boards yourself—even the double-sided main board—using single-sided techniques. A couple of tricks when working with the double-sided main board will yield a properly operating project. Before you do anything after fabricating your boards, carefully read and do the following.

For the main board, the easiest way around the plated-through dilemma is to install the ICs directly and solder their pins to the pads on both sides of the board. If you wish to socket the ICs, use Molex Soldercons or Wire Wrap sockets to provide soldering access to the pin/pad junctions on the top as well as on the bottom of the board.

Soldercons are easier to work with because you install them and solder their pins to the board's pads just as you do for the pins of the ICs themselves. If you use Wire Wrap sockets, you must space them about ¼" above the top surface of the board to have soldering access and work very carefully with a fine conical or needle point soldering tip and fine-wire solder to avoid creating solder bridges between the closely spaced soldering pads. No matter



what method you use to install the ICs, Wire Wrap zero-insertion-force (ZIF) sockets should be used for *SO1*, *SO2* and *SO3*.

The LED hex displays present a problem because their pins are molded into cases with no pin/pad soldering access when they are directly installed on the board. For these devices, you must use Soldercons or Wire Wrap sockets. Also, note that several pins that are not needed have been left off the hex displays by the manufacturer and that for these no holes are provided on the board. So when using Soldercons omit those for which no holes are provided and when using sockets clip the associated pins flush with the bottoms of the sockets.

Pc-mount slide, toggle and pushbutton switches generally have shouldered lugs whose pins plug into the board holes and provide limited access for soldering on the top side of the board. So you should have few problems in this area, except if you use keyboard-type switches for *S6*, *S7* and *S8*. If you do find yourself in difficulty here, you have the option of locating the switches off the board—on a separate panel—and running hookup wires between their lugs and the appropriate holes on the board. Thumbwheel switches *S1* and *S2* can mount on the board regardless of whether or not your board has plated-through holes.

Small components—like resistors, capacitors, diodes and the transistor—offer no obstacle in terms of whether or not your main board has plated-through holes. Because these components have no hidden leads or pins, it is a simple matter to solder all leads to all visible pads on both sides of the board.

If you are using a main board that does not have plated-through holes, refer to Fig. 7 and do the following first. With a soft black pencil, mark the locations of every point indicated by a large solid black dot. Each of these locations indicates a point

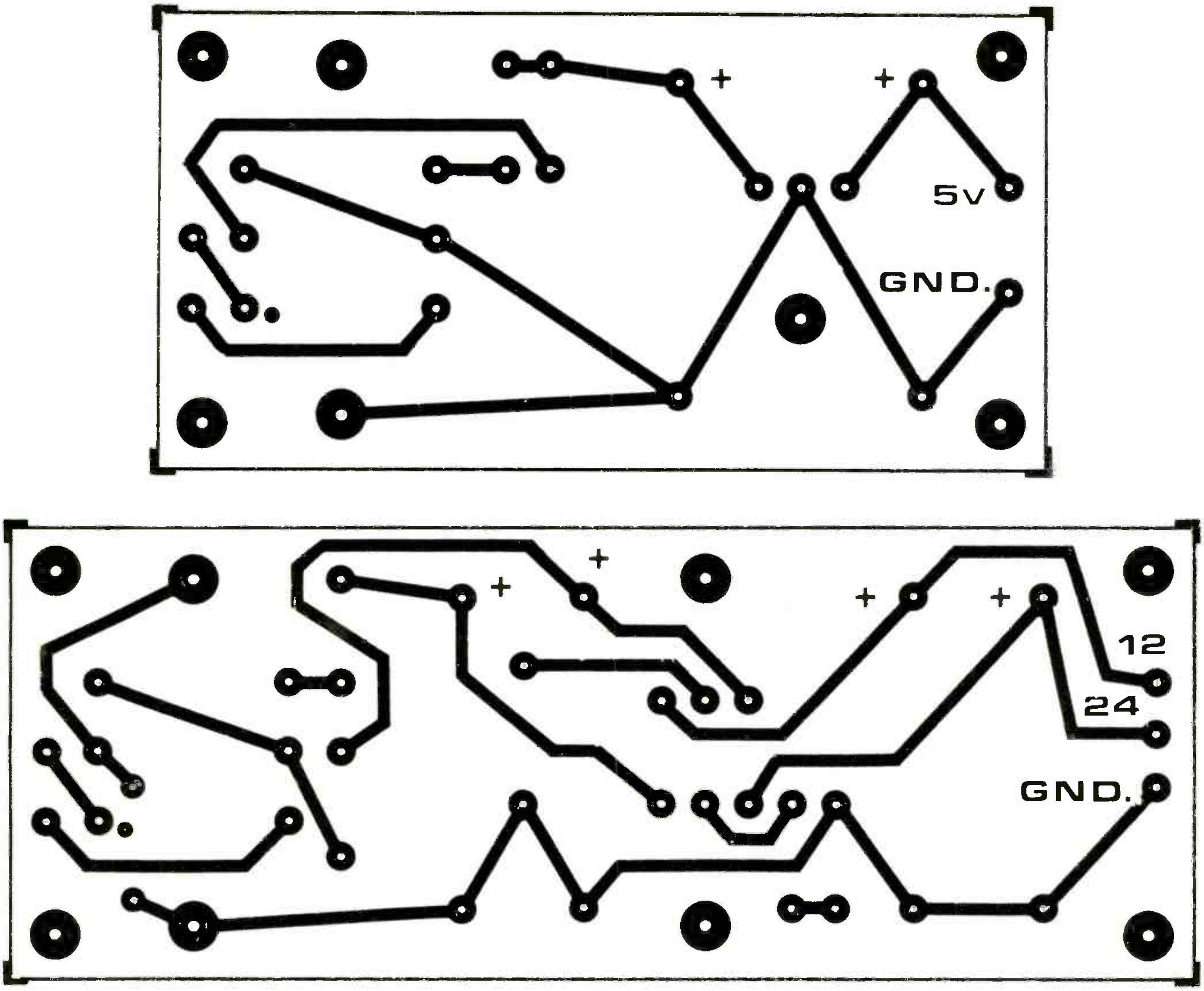


Fig. 6. Actual-size etching-and-drilling guides for power supply boards.

where the conductor pattern on one side continues on the other side of the board and, hence, requires a wire jumper to bridge the pads for the hole so that the conductor pattern is indeed continuous and the project operates properly.

Use solid bare 22-gauge wire to make the jumpers. Pass the end of the wire through one hole until it protrudes through the hole on the other side of the board by about ⅛" and solder the short end to the pad on that side of the board. Flip over the board and solder the wire to the pad on the other side. Allow the connection to cool, and then clip the wire close to the board. Repeat this for all the holes you marked. There are quite a number of these bridging conductors; so work carefully to make sure you get every one of them. If you miss just one and discover it after installing the component, you may have to destroy the component or an expensive socket to be able to rectify your oversight.

Once the bridging conductors are installed, you can proceed to populate the main board. Start with installation of the sockets—*not* the ICs themselves—so that you have unobstructed soldering access to their

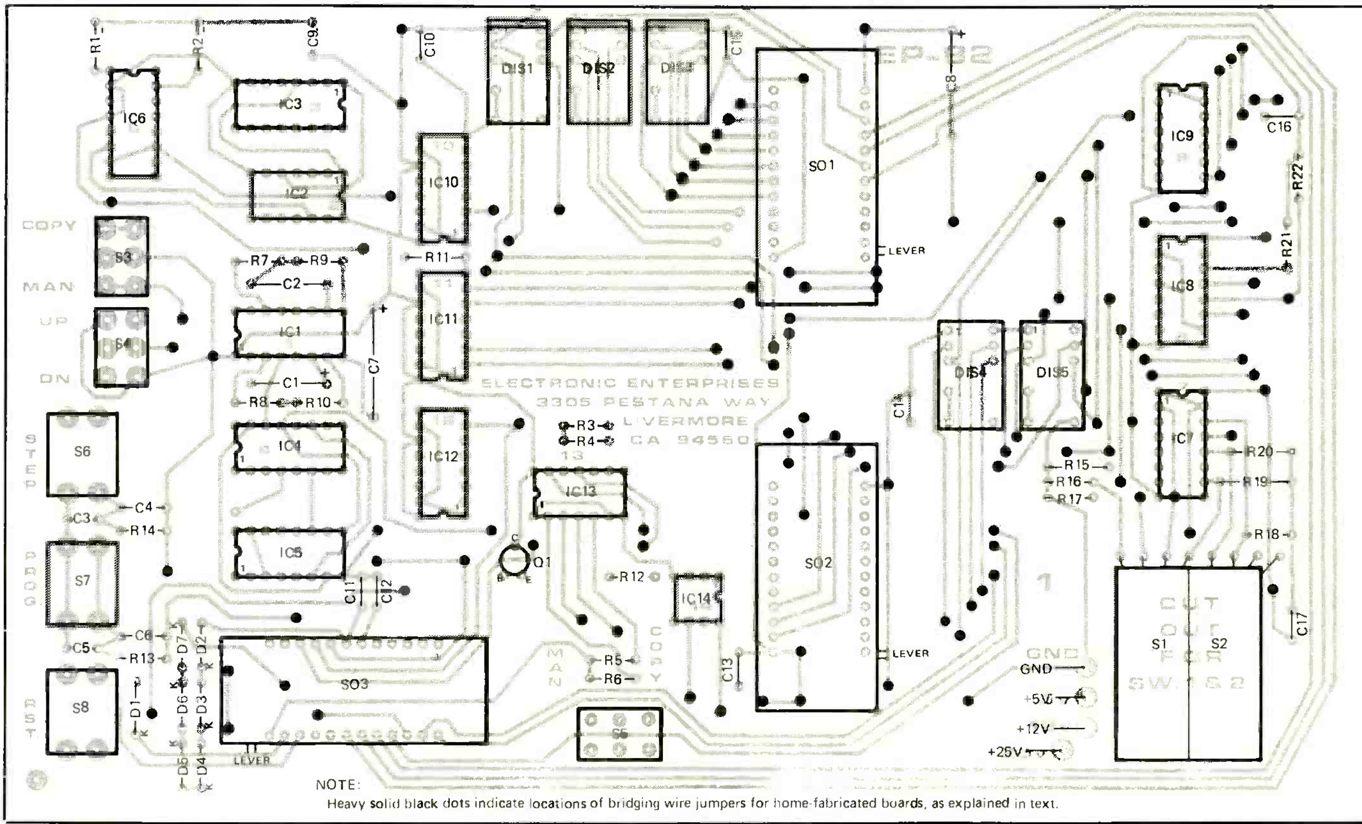


Fig. 7. Wiring diagram for main board.

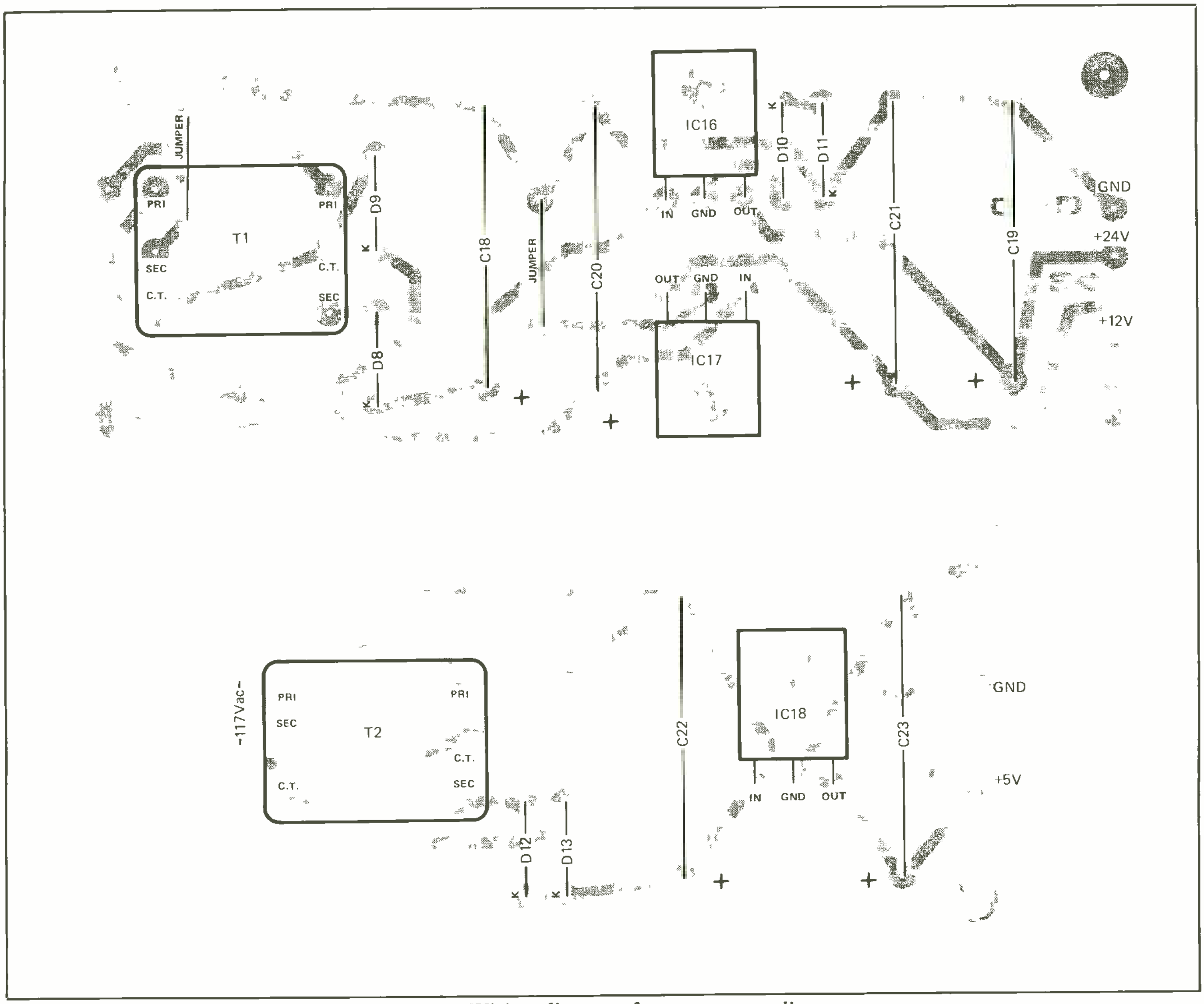


Fig. 8. Wiring diagram for power supplies.

pin/pad connections on the top of the board. Use only enough solder to assure a good electrical joint on the component side of the board at each connection point.

After installing the sockets, mount the transistor and diodes in their respective locations, taking care to properly orient them according to Fig. 7. Use soldering heat judiciously to avoid damaging these components. Then install and solder into place the capacitors (observe polarity where required). After soldering the leads of all components to the pads on the bottom, flip over the board and do the same for all leads on the top of the board.

Thumbwheel switches *S1* and *S2* drop into the cutout area in the lower-right of the board. Connections from their lugs to the appropriate holes in the board are made with insulated hookup wire with ¼" of insulation removed from both ends.

When all components, except the ICs and displays, have been installed, carefully inspect the board for poor soldering and for solder bridges, especially between the closely spaced IC and socket pads with respect to the latter. Reflow the solder at any suspect connection and remove excess solder to clear away any solder bridges you discover.

If you have purchased the commercial plated-through-hole board, all you have to do is stuff it with the components and sockets according to the wiring details in Fig. 7. Soldering of each connection need be done on the bottom side of the board only because the plating completes the circuit and draws solder to the top-of-the-board connections by capillary action. Use solder judiciously to avoid creating solder bridges between the closely spaced conductors of the foil pattern. Do not install the displays and ICs in their sockets yet.

Now wire the power-supply boards, referring to Fig. 8 for details. These single-sided boards require soldering on only one side. Make sure you properly orient the rectifier diodes and electrolytic capacitors and double check that the correct transformer is installed on each board before soldering any leads or pins to the copper pads.

You can house your Programmer in any enclosure of your choice that is large enough to accommodate the two power-supply and main boards and provides a panel on which to mount any switches you decide to locate off the board. The prototype of the Programmer project was housed inside a home-made wooden enclosure with a hinged top, as shown in the lead photo. The flip-up top was made deep enough so that it does not interfere with the circuitry—including the retrofit expansion add-on board that will be described next month. It also has room for handy storage of the personality modules.

Only after the Programmer is installed in its enclosure (do not forget to wire the power supplies to the main board), should you install the LED hex displays and integrated circuits. Make sure as you install these devices in their sockets that you orient them as shown in Fig. 7 and that no pins fold under or overhang the sockets. Also, practice safe handling when working with the ICs, since these devices can be damaged by static electricity.

Using the Programmer

Plug the EPROM Programmer's line cord into an ac outlet and set AUTO/MANUAL switch *S3* to MANUAL. In this position, nothing happens until a pushbutton switch is pressed. Set COUNT DIRECTION switch *S4* to UP and MANUAL/COPY switch *S5* to MANUAL to accept programming data from thumbwheel switches *S1* and *S2*. Press and release RESET switch *S8* to set the counter to 000. Momentarily set *S3* to AUTO and note that the counter starts incrementing sequentially. Return *S3* to MANUAL and press and release *S8* to reset the counter to 000.

Select the proper personality module for the EPROM to be programmed and plug it into PERSONALITY socket *SO3*. Plug the EPROM to be programmed into PROGRAM socket *SO2*. The Programmer is now ready to run a manual-entry program.

Enter the program data for the first address by setting *S1* and *S2*.

The LED hex displays should read FF if there is no program data at that address. Push the PROGRAM button and, as you release it, notice that the program data entered is displayed on *DIS4* and *DIS5*. This completes your first entry.

Press and release STEP button *S7* to advance the counter by one step and program in your next data entry. Then keep programming in data at each successive address according to the program you wish to burn into the EPROM.

You can reverse count direction at any time to check entered program data at any previous address by setting COUNT DIRECTION switch *S4* to DOWN. It is a good idea to record on paper each step of your program as it is entered so that if you stop in the middle of a programming job you can return to where you left off when you resume programming.

Some EPROMs will instantly read programmed data, while others will have a short lag between the time the data is programmed and when the data appears in the display. This delay is in the display circuitry and only when in the manual mode and you wish to see a piece of data.

To read data from an EPROM that has already been programmed, plug into the PERSONALITY socket the appropriate personality module and plug the EPROM into the PROGRAM socket. Set *S1* and *S2* to read location FF to insure that the existing program does not become altered should the PROGRAM button accidentally be pressed during the read operation. Step through the EPROM's addresses with the manual STEP button. The data for each address will appear in *DIS4* and *DIS5*.

To copy an EPROM, set *S3* to MANUAL to stop the action. Set *S4* to UP and *S5* to COPY to accept data from the programmed EPROM. Plug the EPROM to be copied into the MASTER socket and the EPROM to be programmed into the PROGRAM socket. Set *S3* to AUTO to start the Programmer copying at a rate of 2.5 to 3 addresses per second. This is a slow enough speed for you to see the data being displayed to verify that programming is taking place.

Coming Next Month

This completes the information on constructing and using our basic 32K EPROM Programmer. Next month, we will show you how to upgrade the basic Programmer so that you can program and read 64K 2764 and 128K 27128 EPROMs with a plug-in add-on board that retrofits on the main programmer board.

Inexpensive Wireless Headphones

A simple induction system lets you listen to audio sound in privacy without disturbing others in the same room

By Philip Kane

Have you ever wished you could hear the sound from your TV receiver, radio or hi-fi system without bothering anyone else in the same room — but dislike using headphones with a long cable tether? Perhaps you thought of buying a commercially available infrared wireless headphone system but didn't want to pay its hefty price. If you'd really like the convenience of wireless headphone listening without breaking your budget, our low-cost mono induction headphone system provides an inexpensive solution.

You can build this wireless headphone system for about $25, including the low-cost phones (if you don't already have them). The project is built around readily available components, many of which you may already have on hand. Though our wireless headphones do not provide for stereo listening, they do produce good audio quality for mono listening.

How it Works

Three basic elements make up the wireless headphone system: a transmitter, an antenna and a receiver. The transmitter you already have in the form of your TV receiver, radio, hi-fi system or shortwave receiver. All you need to transform these into a transmitter of audio signals are a resistor and a long loop of wire to serve as a load/antenna system. The receiver can be any battery-powered audio amplifier that is small enough for you to conveniently carry around. All you need to convert the amplifier into a "receiver" is an inductive pickup coil that you can purchase from your local electronic parts store.

A loop of wire you string completely around the perimeter of the room in which you have the equipment to which you wish to listen serves as the transmitting antenna. As shown in Fig. 1, the loop connects across the "transmitter's" output terminals. Since this wire is rarely long enough to have a safe enough resistance to prevent damage to the equipment's amplifier, load resistor *R9* must be installed in series with the antenna as shown.

The value and power rating of *R9* must be chosen to match the characteristics of the speaker output of the transmitting amplifier. For example, if your amplifier is rated at 25 watts into 8 ohms, you would use a 25-watt power resistor whose value, when added to the resistance of the wire used for the antenna, is 8 ohms.

The system works in much the same manner as an ordinary transformer does. That is, the transmitter's antenna and the receiver's telephone pickup coil serve as the primary and secondary windings, respectively, of the "transformer." The ac signal (the audio signal) is coupled through the "primary," which creates an electromagnetic signal that travels through the air. This signal is intercepted by the "secondary," which converts it into a current that is then coupled into an amplifi-

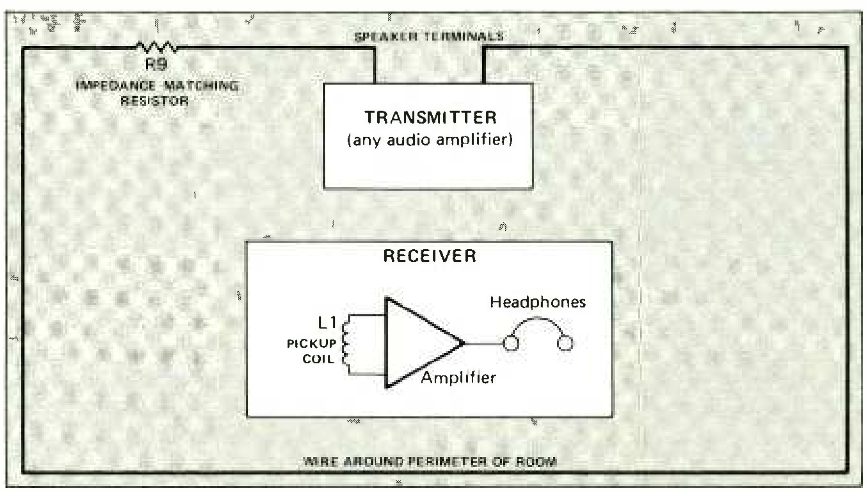


Fig. 1. Overall functional diagram of inductive wireless headphone system.

er. The "receiver" then amplifies the weak signal to a level sufficient to drive headphones.

Though you can purchase a compact battery-powered audio amplifier that can serve as the receiver for your wireless headphone system, it is more fun—and usually less expensive—to build your own. A typical example of a circuit for such an audio amplifier is shown in Fig. 2.

Operation of the Fig. 2 audio amplifier is quite simple. An ordinary telephone pickup coil plugged into INPUT jack *J1* serves as the receiver's antenna that picks up the audio signal from the transmitter. This signal is passed through *R1* into the base of preamplifier *Q1*, which boosts the low-level signal to drive the *IC1* operational amplifier via its noninverting (+) input. Additional gain is provided by *IC1*, sufficient to drive mono headphones plugged into OUTPUT jack *J2*. Potentiometer *R1* serves as the volume control for the receiver.

Resistors *R6* and *R7* and capacitors *C2* and *C3* isolate the *Q1* preamplifier and *IC1* amplifier stages from each other. This is done to prevent feedback that could otherwise result in unwanted circuit oscillation.

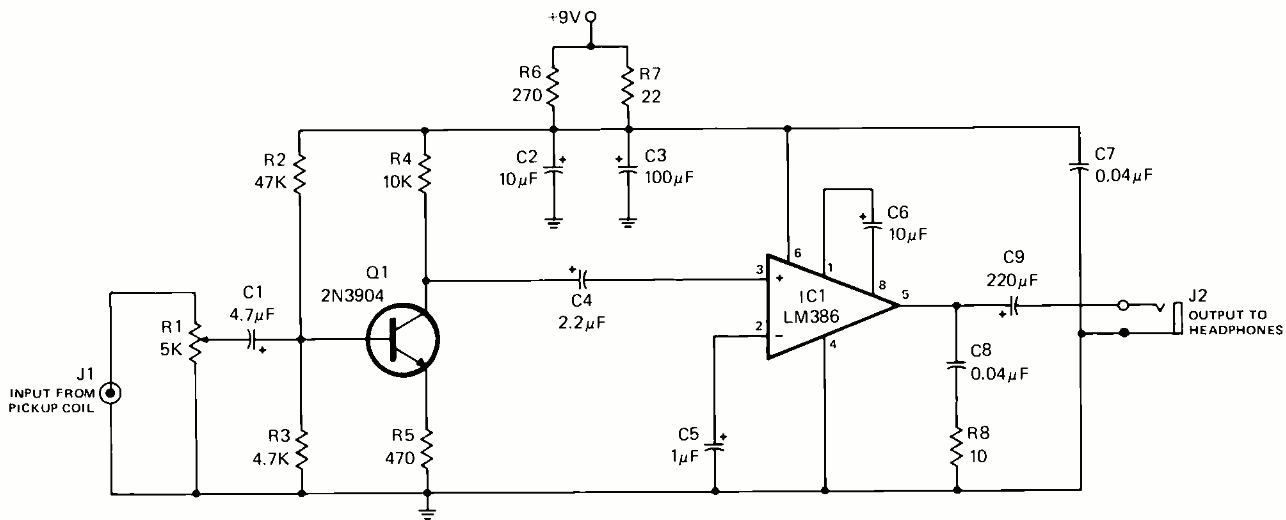
Power for the amplifier is provided by an ordinary 9-volt transistor battery connected between the +9 V terminal and circuit ground. You might wish to install an spst switch between the positive terminal of the battery and amplifier circuit.

Note in Fig. 2 that a phono jack is shown at the receiving amplifier's INPUT. This jack is optional. If you plan on using the amplifier as a dedicated mono headphone receiver, you can permanently wire the telephone pickup coil directly across *R1* and eliminate *J1* altogether.

Construction

The very simple receiver circuit can be assembled with any of the traditional wiring techniques. You can fabricate and use a printed-circuit board of your own design or assemble the circuit on perforated board using a socket for *IC1* and other soldering hardware. In fact, the circuit is so simple, it can be assembled on a small solderless socket.

When assembling the receiver circuit, make sure you observe the proper polarity of the electrolytic ca-



PARTS LIST

Semiconductors
IC1—LM386 operational amplifier
Q1—2N3904 or similar npn transistor

Capacitors (15 volts)
C1—4.7-μF electrolytic
C2,C6—10-μF electrolytic
C3—100-μF electrolytic
C4—2.2-μF electrolytic
C5—1-μF electrolytic
C7,C8—0.04-μF elecrolytic
C9—220-μF electrolytic

Resistors (¼-watt, 10% tolerance)
R2—47,000 ohms
R3—4,700 ohms
R4—10,000 ohms
R5—470 ohms
R6—270 ohms
R7—22 ohms
R8—10 ohms
R1—5,000-ohm audio-taper potentiometer

Miscellaneous
J1—Phono jack (optional; see text)
J2—Miniature phone jack
Printed-circuit board or perforated board and suitable soldering hardware (see text); socket for IC1; plastic enclosure for receiver; telephone pickup coil (available from Radio Shack telephone section and other electronic/telephone part stores); 9-volt transistor battery and snap connector; load resistor for transmitter antenna (see text for value/power rating); mono headphones with miniature plug; heat-shrinkable tubing; machine hardware; hookup wire; solder; etc.

Fig. 2. Schematic diagram of "receiver" amplifier.

pacitors, properly orient the transistor and operational amplifier, and keep all lead lengths as short as possible. It is just as important that you wire the battery's snap connector to the proper points in the circuit.

When you have your receiving amplifier assembled, select a suitably sized enclosure in which to house it. The enclosure should be plastic and should be large enough to accommodate the circuit assembly, 9-volt battery, jacks, power switch and volume control *R1*. If you plan on making the telephone pickup coil an integral part of the receiver, the enclosure selected should be large enough to accommodate it, too.

To make the transmitter, run a length of insulated hookup wire completely around the room in which you plan to listen. Strip about ⅜″ of insulation from both ends of the wire and connect one end to either speaker output terminal on the transmitting amplifier. Using an ohmmeter, measure the resistance of the antenna wire. Then select a value for *R9* that, when added to the resistance of the wire, is the same as the output rating of the amplifier. For example, if the wire's resistance measures 1 ohm and your transmitting amplifier's output is rated at 8 ohms, *R9*'s value should be 8 ohms − 1 ohm, or 7 ohms. If you can't find a resistor of the calculated value, use the next higher standard value. In our example, you would use an 8-ohm resistor.

Remember, too, to choose a resistor for *R9* whose power rating is the same as or greater than the maximum output power rating of your transmitting amplifier. If you're using an amplifier rated to deliver 50 watts (use the per-channel rating if it's a stereo amplifier), *R9* should be rated at at least 50 watts. If in doubt, always use a higher-power resistor.

Clip both leads of *R9* to 1″ in length and form a small hook in both. Prepare a 6″ to 10″ length of insulated hookup wire by removing ⅜″ of insulation from both ends. Slip 2″ lengths of small-diameter heat-shrinkable tubing over the free end of the antenna wire and the just prepared hookup wire. Crimp the free end of the antenna wire to one lead and one end of the hookup wire to the other lead of *R9*. Securely solder both connections. Then push the heat-shrinkable tubing over the connections and against the body of the resistor and shrink tight.

Connect the other end of the hookup wire to the other speaker terminal. If you are using a stereo amplifier as your "transmitter," make sure you use the speaker terminals for a single channel. Don't bridge from a speaker terminal in one channel to a speaker terminal in the other.

System Operation

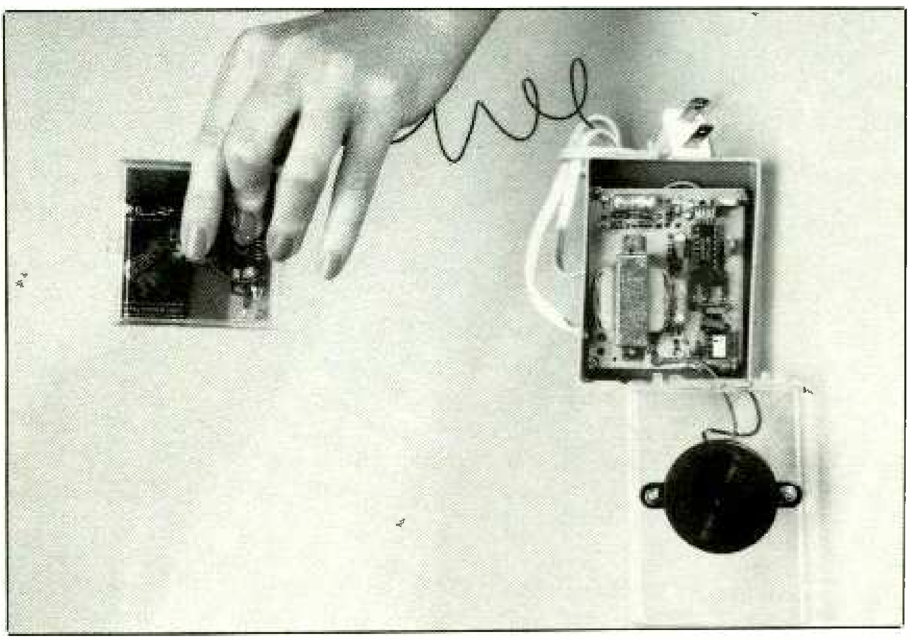
To test your wireless headphone system, connect the telephone pickup coil and headphone to the receiving amplifier and turn on the "transmitter." Set the latter's volume control to a low to moderate level. Turn on the system's receiver and slowly turn up the volume via *R1* until you hear the audio signal. If you notice that power-line noise is interfering with reception, reorient the pickup coil to reduce it to a minimum. (Using a smaller value for *C1* will also help, though bass response of the system will suffer a bit.)

Once you know that your wireless headphone system works as designed, you're ready to listen in private. If you are using it with a "transmitter" that you wish to also use in the normal manner, you might wish to install a switch that will let you disable its speaker(s) and switch in the antenna as needed. **ME**

A Radio-Controlled Doorbell

This wireless system makes it easy to add remotely located doorbells so that you can hear someone ringing you at an outside entrance while you are in the basement, attic or other distant area

By Anthony J. Caristi



Is the doorbell wiring in your home or apartment defective? Or would you like to know when a visitor or delivery person rings your entrance doorbell when you are in your basement, workshop or attic, on your patio, or even when you are at poolside? The Radio-Controlled Doorbell presented here offers an easy solution to all these situations. It uses radio waves to bypass the problems posed by running wires throughout your home. Its only condition is that the remotely located receiving element that contains an attention-getting piezoelectric buzzer (instead of a bell or chime) must be positioned close to an ac outlet to provide power. The small transmitter, on the other hand, is battery powered.

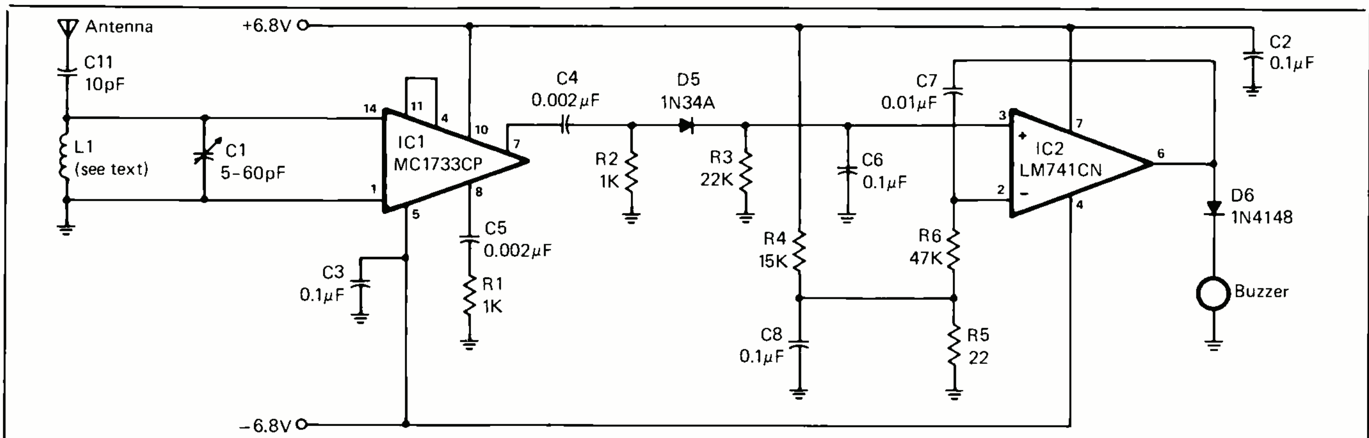
This project takes advantage of Part 15.205 of the FCC Rules and Regulations that permits unlicensed transmitters to be operated as remote-control devices, providing that the r-f energy of the fundamental carrier frequency does not exceed 1,250 microvolts per meter at a distance of 3 meters. Operating at very low power, the Doorbell's transmitter is legally limited in length, but there is no length restriction on the receiver's antenna. It is even possible to take advantage of the enormous signal-gathering power of your home's ac power wiring.

Construction of the Doorbell system has been designed to be simple. The only requirement is that you must use printed-circuit wiring as detailed here. Since the system operates at high frequencies, point-to-point wiring on perforated board is not an acceptable alternative.

About the Circuit

Two basic elements make up the Doorbell system. These are the receiving module and its power supply, and the miniature transmitting module. The schematic diagram of the basic receiver, minus its power supply, is shown is Fig. 1. This tuned radio-frequency (TRF) receiver is built around just two integrated circuits and their support components, plus a piezoelectric buzzer.

Differential r-f amplifier *IC1* has a voltage gain of approximately 400 (52 dB). One input of this IC is grounded; the other is driven by an r-f signal intercepted by the antenna. The r-f signal appears across the



PARTS LIST

Semiconductors
D1 thru D4—1N4001 silicon rectifier diode
D5—1N34A germanium detector diode (Radio Shack Cat. No. 276-1123 or similar)
D6—1N4148 silicon switching diode (Radio Shack Cat. No. 276-1122 or similar)
D7,D8—6.8-volt zener diode (1N5235 or similar)
IC1—MC1733CP differential amplifier (Motorola)
IC2—LM741CN operational amplifier (Radio Shack Cat. No. 276-007 or equivalent)
Q1—2N5179 npn high-frequency transistor
RECT1—50-volt, 1-ampere bridge rectifier
Capacitors (15 or more working volts)
C1,C13—5-to-60-pF trimmer (Radio Shack Cat. No. 272-1340 or similar)
C2,C3,C6,C8,C15—0.1-µF ceramic disc
C4,C5—0.002-µF ceramic disc
C7—0.01-µF ceramic disc
C9,C10—470-µF electrolytic
C11—10-pF, 100-volt ceramic disc
C12—0.001-µF ceramic disc
C14—10-pF ceramic disc
Resistors (¼-watt, 5% tolerance)
R1,R2—1,000 ohms
R3—22,000 ohms
R4—15,000 ohms
R5—22 ohms
R6—47,000 ohms
R7,R8—56 ohms
R9—33,000 ohms
R10—150 ohms
Miscellaneous
B1—9-volt transistor battery
L1,L2—R-f coil (see text)
S1—Spst momentary-action, normally-open pushbutton switch
T1—12.6-volt, 300-mA power transformer (Radio Shack Cat. No. 273-1385A or similar)
Piezoelectric buzzer (Radio Shack Cat. No. 273-069 or similar); printed-circuit boards (see text); wire for L1 and L2; suitable enclosures for receiver and transmitter; ac line cord with plug; zip cord (see text); battery holder and snap for B1; stranded hookup wire for antennas; machine hardware; hookup wire; solder; etc.

Note: The following are available from: A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Etched and drilled transmitter pc board for $3.00; etched and drilled receiver pc board for $6.00; MC1733CP integrated circuit for $3.75; 2N5179 transistor for $3.50. Add $1.00 S&H; New Jersey residents, please add state sales tax.

Fig. 1. Schematic diagram of receiver minus its power supply.

tuned circuit composed of *L1* and *C1*. The incoming signal is coupled through *C11* into the tuned circuit, which must be tuned to the carrier frequency of the system's transmitter. This signal is then passed into *IC1* through input pin 14.

Variable capacitor *C1* in the tuned circuit provides a means for tuning the receiver to the system's transmitter carrier. This is necessary to assure that only the system's transmitter—not a standard broadcast FM transmitter operating near the same frequency—triggers the "bell."

Only one of *IC1*'s differential outputs, at pin 7, is used in this application. The amplified r-f carrier voltage that appears at pin 7 is detected by *D5* to produce a dc voltage that is then fed to the noninverting (+) input of operational amplifier *IC2* at pin 3. Capacitor *C6* attenuates any unwanted noise pulses that might be detected by the receiver, which could otherwise result in spurious operation of the buzzer. Op amp *IC2* is configured as a voltage comparator in this setup. This arrangement takes advantage of the operational amplifier's very high gain without requiring negative feedback.

The inverting (−) input at pin 2 of *IC1* is biased with a positive potential of about 10 millivolts to ensure that the output at pin 6 is driven to about −5 volts when no signal is detected by the receiver. This cuts off *D6* to ensure that the buzzer remains silent.

When an r-f signal from the system's transmitter appears at output pin 7 of *IC1*, the positive voltage that results due to detection by *D5* is sufficient to drive the pin 3 input of *IC2* to a level that is greater than 10 milli-

"Due to high r-f frequencies, printed-circuit wiring is mandatory"

volts at output pin 6. Since this is greater than the bias level delivered to inverting input pin 2, the output of the op amp is driven to about +5 volts, which is sufficient for *D6* to conduct and turn on the buzzer.

Power for the receiver is supplied from the 117-volt ac line with the power supply shown schematically in Fig. 2. Note that this is a bipolar power supply that delivers both the +6.8 and −6.8 volts with respect to ground required by the receiver circuit. The +12 and −12 volts out of the *D1* through *D5* bridge rectifier circuit are regulated down to the desired +6.8 and −6.8 volts by zener diodes *D7* and *D8* to ensure that the voltages fed to *IC1* do not exceed the IC's maximum ratings under any power-line variation conditions.

Power consumption of the receiver is less than 5 watts. So it is economical to leave it on continuously (average power consumption cost should not exceed 25¢ to 30¢ per month). For this reason, no power cord or switch is included in the circuit. If practical, the receiver's power supply can be wired directly into your house wiring so that it is always ready to signal when a caller "rings." Alternatively, you can use a standard ac line cord and plug this into a convenient ac outlet.

Shown in Fig. 3 is the system's simple transmitter. It consists of a single-transistor oscillator powered by a common 9-volt transistor battery and operates at a carrier frequency of approximately 88 MHz. Operating frequency is basically determined by the tuned circuit made up of *L2* and *C13*. Capacitor *C13* is variable to allow the oscillator's frequency to be set to a point at the low end of the FM radio dial where there are no broadcast transmitters operating to ensure against interference.

Transistor *Q1* is specifically designed for use in very-high-frequency (vhf) oscillator and amplifier applications. Its base is held at r-f ground potential by *C12*. The

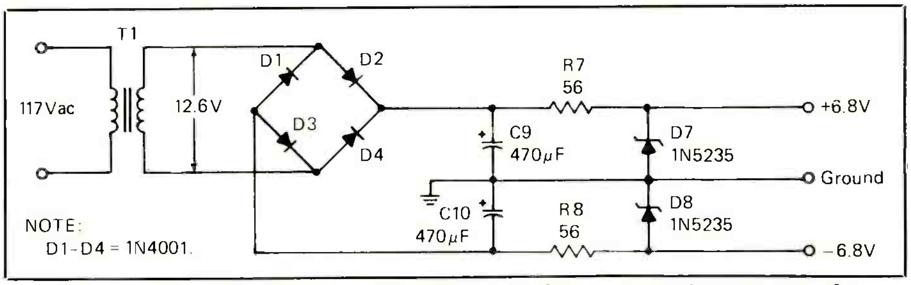


Fig. 2. Schematic diagram of receiver's ac-line-operated power supply.

L2/C13 tuned circuit is in the collector circuit. The feedback path that initiates and maintains oscillation is through *C14*.

An unmodulated carrier that can be detected by the system's receiver is generated by the transmitter whose schematic diagram is shown in Fig. 3. The transmitter is unpowered except when "doorbell" pushbutton switch *S1* is pressed. It remains powered only as long as this switch is held closed. Since in this doorbell application the battery is used infrequently and only very briefly when *S1* is pressed to signal a caller, *B1*'s useful life should approach what its normal shelf life would be. Generally, this would be a year or more.

Construction

Due to the very-high r-f frequencies involved in this system, printed-circuit wiring is mandatory, both to ensure proper operation and to conform with FCC regulations. Each of the two circuit boards in this project, one for the receiver and the other for the transmitter, must be double-sided. This is necessary because one side of each board must serve as a ground plane for the circuit.

If you plan to fabricate your own pc boards, use the actual-size etching-and-drilling guides shown in Fig. 4. Start with pc blanks that are copper clad on both sides. Mask off the side that will be the tops of the boards to make sure that when etching the copper on this side remains intact. If you prefer not to make your own pc boards, you can purchase them ready to wire from the source given in the Note at the end of the Parts List.

Although the top (component-mounting) sides of the pc boards are solid copper, certain holes on each must be cleared of the conductive copper cladding so that component leads and pins do not short out. It is not necessary (or even advisable) to etch the copper from these areas, as you do for the conductor traces and pads on the bottom (solder) side of the board.

After etching and bottoms per the

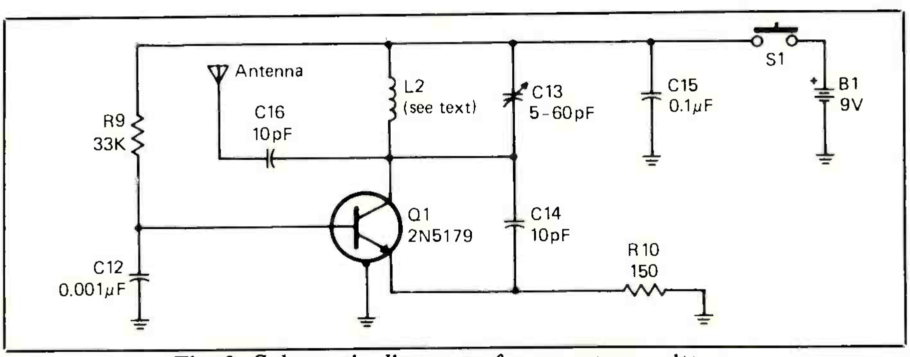


Fig. 3. Schematic diagram of system transmitter.

etching-and-drilling guides, you drill all lead and pin holes. Then refer to Fig. 5 and carefully mark on the copper cladding only those holes indicated. Then use a sharp 3/16" drill bit to remove only enough copper around each marked hole to assure that the component leads or pins that are to go into them will not short out to the ground plane. Work carefully to avoid drilling clear through the board. As you complete removal of the copper for each component's leads or pins, test install the component and check to make sure enough copper has been removed.

Coils *L1* in the receiver and *L2* in the transmitter must be hand-wound. This is a simple operation that requires only a 1/4" coilform (a standard wooden lead pencil will do) and a length of No. 20 enameled magnet wire. Simply wind five turns of the wire for each coil, leaving about 1/2" of lead length at each end of each coil. After winding each coil, slip it off the coilform and use a sharp knife to scrape away 3/8" of the insulating enamel from the lead ends. Then carefully spread the coils so that their leads plug into the proper holes of the receiver and transmitter boards (left and right, respectively, in Fig. 6). Space the turns of the coils evenly. Remove the coils, identify which is which, and set them aside until called for during circuit board wiring.

Referring to the left guide in Fig. 6, wire the receiver board exactly as shown. When you install trimmer capacitor *C1*, mount it so that the adjustment slot is connected to the "cold" side of the circuit. Failure to do this can result in a difficult-to-tune circuit. You can use sockets for the integrated circuits to facilitate easy replacement should either or both become defective during the circuit's lifetime. Even though pin 1 of *IC1* is to go to ground, this will be adequately accomplished by soldering its socket pin on the bottom of the board.

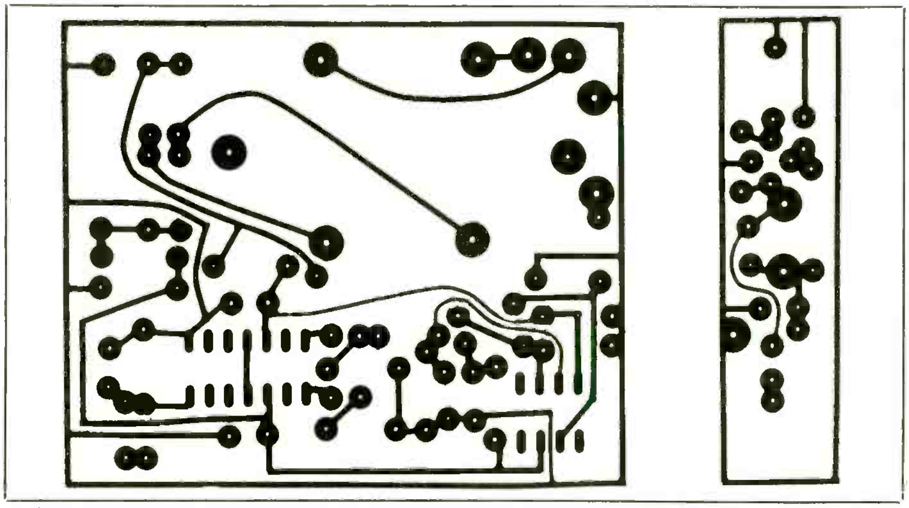


Fig. 4. Actual-size etching-and-drilling guides for receiver and transmitter.

As you install the components on the receiver board, ground-plane side up, make sure you properly orient the diodes, electrolytic capacitors and power transformer, and make sure that you do not forget *L1*. Solder all leads and pins to the pads surrounding the holes through which they pass on the bottom of the board. Then flip over the board and note which component leads are to be soldered to the ground plane, as evidenced by those that pass through holes that are *not* cleared of copper. In each case where a component lead is to connect to the ground plane make a good soldered electrical connection. This is very important because if you fail to make these extremely short ground connections, the circuit will not operate as desired at the very-high 88-MHz frequency for which it is designed.

Install the ICs (or sockets) in their respective locations, making certain that they are properly oriented. Solder the pins only to the pads on the bottom of the board. All pins of both ICs should pass through holes that have been cleared of ground-plane copper. Hence, no IC pin should be soldered to the ground plane. When you are finished wiring the board carefully inspect it for solder bridges

(Continued on page 98)

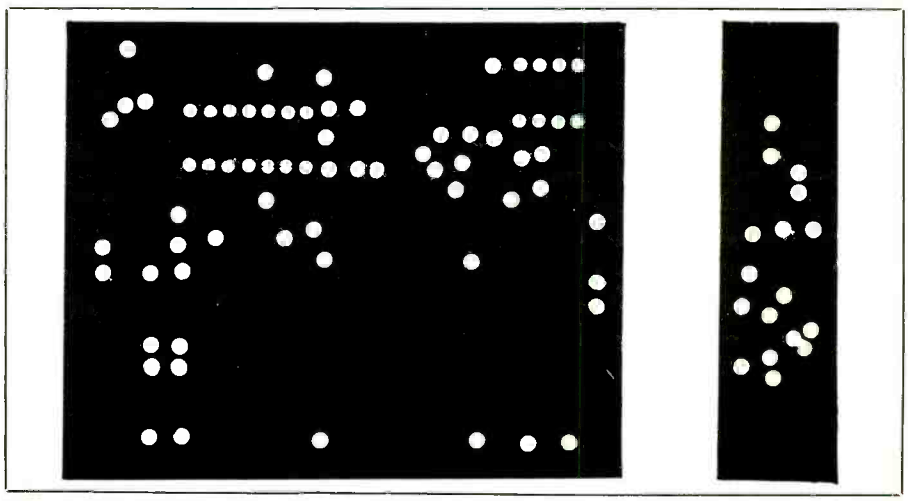


Fig. 5. Top views of top (ground-plane) sides of receiver (left) and transmitter (right) pc boards showing holes that must be cleared of copper cladding.

Thermoelectric modules, multiple video monitor setups, $5 toner cartridge refills for laser printers, unique hacker sources

By Don Lancaster

There have been a lot of help-line calls lately, with a lot of you working on some really exotic things, like home recorded CD disks using photo techniques, neon sign sequencers, cattle weighing stations, vehicle position sensing, gas-leak alarms, laser-printed sheet music, voice synthesizers, perspective drawing software, capacitance meters and bunches more.

I guess it was Pogo that first introduced the concept of the *insurmountable opportunity*. We seem to be buried in them today. One thing fer sure, there never was a time like the present to be into hardware hacking. There's so much out there that can be done in so many newer, better, cheaper, and more powerfully different ways.

But, my oh my, where do we even start? Maybe by asking . . . .

How do thermoelectric modules work?

They don't! At least not well.

Since there has been mucho interest on this, let's have at it anyway. A thermoelectric module is a solid-state cooling device. All you do is input a current, and heat moves through the device, cooling one side and heating the other.

Figure 1 shows a typical package. This one is the *Cambion* No. 801-2007. Similar units are also available from *Melcor*. This dude measures some two inches square and can move up to 22 watts of heat when powered by a 12-volt car battery at 7 amps. Cost is in the $20 to $30 range.

Solid-state cooling modules use the Peltier effect. Figure 2 shows details. You start with bismuth telluride or some other semiconductor. Then cut it into blocks while heavily p-doping some of them and n-doping others.

When a current is applied in the proper direction, the electron carriers in the n material and the hole carriers in the p material "tow" thermal energy along with their motion. In both cases, the heat gets moved downward, creating a hot side and a cold side.

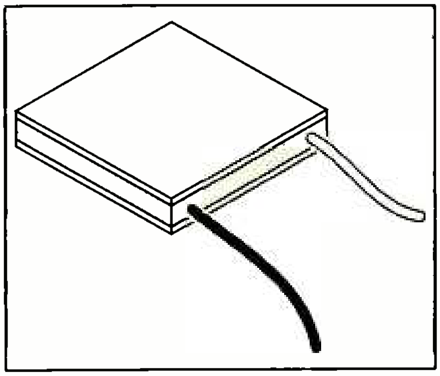


Fig. 1. Typical thermoelectric module.

The amount of heat you move depends highly upon the temperature differential you have to maintain. As Fig. 3 shows, this particular device can hold a 60-degree C difference between the hot and cold side *provided you pump no heat through it*. On the other hand, if you maintain both sides at the same temperature, you can pump up to 22 watts of heat through the device.

In most uses, of course, you will both want to cool something and move heat, so you must use the middle of the curve. For instance, you can pump 8 watts of heat at a 40-degree centigrade drop. To put this into perspective, this module can, under ideal conditions, make a small ice cube in around one hour.

The trouble is that conditions are never ideal for TE modules. There are a number of nasty gotchas that will gang up on you when you try to use them.

Thermoelectric modules are rather expensive, mostly because they have not been improved one iota in the last two decades. Worse yet, these modules are horribly inefficient. In a typical use, you have to input 5 watts of power to provide just 1 watt of cooling. Mechanical air conditioners are almost 50 times more efficient than this!

The heat sink you connect the hot side of the module to must be absolutely flat, machined to within 0.001 inch over its entire area and carefully covered with a thin layer of thermal grease. Obviously, those portions of a module not thoroughly contacting the heat sink cannot deliver any useful cooling.

The real killer to most TM module applications lies in the thermal drop between the heat sink and the ambient temperature. For higher-power uses, a fan or water cooling is almost essential.

For instance, a large plain old heat sink will have at best a 1-degree C-per-watt temperature rise above ambient. Say you want to pump the 8 watts at a 40-degree drop. The heat sink will have to sink these 8 watts, plus an additional 32 watts or so of input power for a total of 40 watts. At 1 degree C per watt heat sink

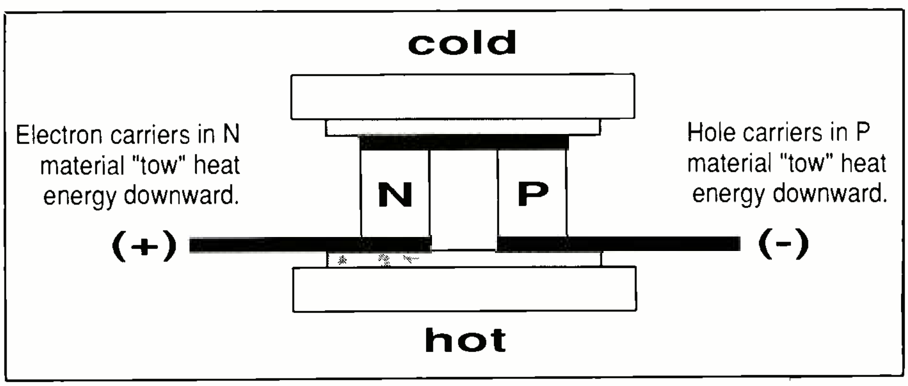


Fig. 2. How a thermoelectric module works.

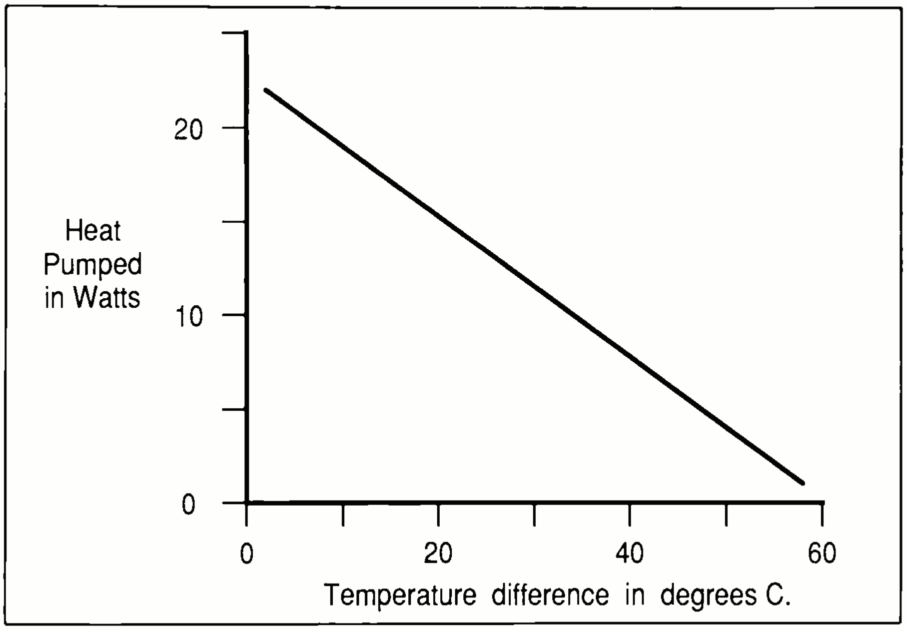


Fig.3. In thermoelectric modules, heat pumped depends on temperature difference as shown here.

rise, the heat sink will warm to 40 degrees C *above* ambient temperature.

So, a low thermal drop from heat sink to ambient is absolutely essential. Also essential is an incredible amount of insulation around whatever you are cooling, for any net heat into the area being cooled will only make matters much worse than they already are.

The modules are reversible by reversing the current. Because of the inefficiency, the heating mode is five times more effective than the cooling mode.

One side effect of this inefficiency is that you must run the modules off nearly pure direct current. The least bit of power supply ripple will dramatically cut the cooling ability, since the ripple troughs will heat five times better than the ripple peaks will cool.

A car battery is often the best choice to drive a TE module. You can temporarily demonstrate a module by holding it between your thumb and finger and then connecting the module to a single alkaline D cell. Do not use the D cell for more than a few seconds at a time.

What good are TE modules? You definitely can't buy a 4 × 8 foot panel of these and use them to air-condition your house. But they are lots of fun to play with. These are a sure-fire topic for a winning science fair project or student paper. Besides that, though, thermoelectrics are limited to specialized and low-load uses where nothing else can do the job, such as coolers for infrared detectors, dew-point humidity sensors, chillers for microscope stages, and for thermal management in satellites.

Both Cambion and Melcor have lots of interesting tech literature on thermoelectrics, so you may want to contact them both for more info.

Can more than one monitor be used with a personal computer?

Yes, if you are careful enough about it. If you are lucky, you might even be able to put some of the monitors as much as several hundred feet away from the computer with which it is used.

There are some gotchas involved, though. First, it is far and away best to run one continuous cable from monitor to monitor, rather than using a bunch of separate cables from computer to each monitor.

Secondly, just about all monitors have provisions to terminate or not terminate their inputs. Termination is done by putting a 75-ohm resistor directly across the video input. Sometimes this is done with a switch at the back of the monitor. Other times, you have to use a solder jumper or a custom plug of some sort.

Regardless of the method used, *only the final monitor in the daisy chain should be terminated!* All of the intermediate monitors should be switched to their unterminated, or high-input-impedance, mode.

Naturally, you should keep cables as short as possible, and never use a long cable without terminating its far end. For longer runs, you will get the best results with "real" coaxial cable and BNC connectors, instead of plain old audio cable and the usual phono plugs.

For extremely long lengths of cable, you might need a video buffer of some sort. *RCA* has a 3450 video op amp that could be useful here. There's also a new product called the Rabbit, that's in the *Heath* catalog, among many other places. This device gives you a way to extend VCR signals all over your house by cable. I'm not sure if this product also handles baseband video.

Tell me about toner cartridge reloading

Toner cartridges used in both the Laserwriter and the Laserjet laser printers cost nearly $100 each and are only good for 2,500 copies, giving you an operating toner cost of around 4¢ per page. Yet, you can easily reload these cartridges up to six or more times, using a 3-minute process that costs $5 and needs no special tools.

If you are an owner of a laser printer,

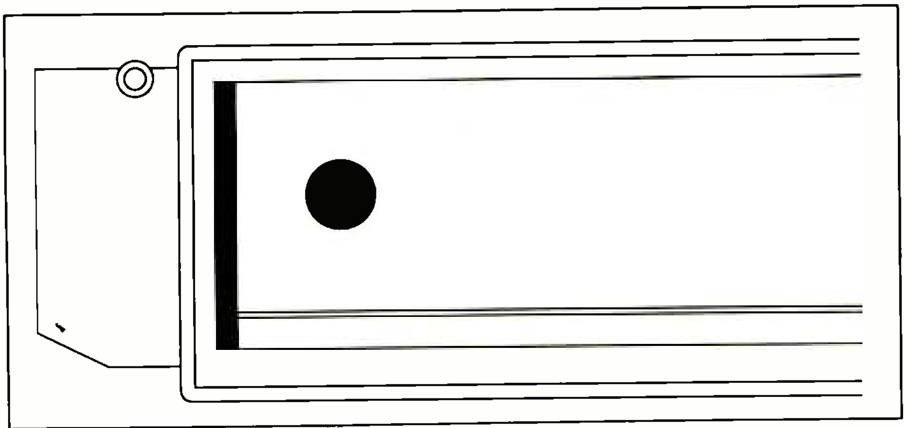


Fig. 4. Large black dot indicates where to add filling hole to top of fresh toner tank.

you'll get dramatically lower toner costs while at the same time producing much blacker images. The blacker images result because the cartridge itself does not get up to full blackness until *after* the second or third reload, and because the refill toner is usually blacker than the original. If you do not own a laser printer, this could be an interesting and profitable sideline business for you, since toner cartridge refills can easily be resold for as much as $19.

First, you will need a reliable source of refill toner. Three sources that I have found useful are EP-350 refills from any *Minolta* copier dealer, kits and pads from *Laser Printer Products*, and wholesale CX toner from *Repeat-O-Type*. Their CX toner sells in bulk for as little as $5 per refill. Around 170 to 225 grams of toner (0.4 pound) is needed per refill.

One gotcha here. It is extremely important to use monocomponent *negative-acting* toner intended specifically for organic drum laser printers. Ordinary copier toner refills definitely will *not* work.

Two simple modifications must be made to the cartridge for refilling. Note that you do *not* have to disassemble the cartridge. What you have to do is add a filling hole to the toner tank and an emptying hole to the spent toner holding tank.

First, pop off the large cardboard label by lifting an end with a pocket knife. The toner tank will be under this label. As Fig. 4 shows, you melt a ½-inch diameter C-shaped hole in the end of the tank with a soldering iron. Then, while the plastic is still hot, snap this hole off and trim the bead with a pocket knife.

Be very careful to get no plastic chips into the hole and do not under any circumstances sand the hole or use steel wool on it. Acutal refilling is done with a plastic funnel and dumping one bottle of toner into this hole, while tilting and shaking slightly.

After refilling, tape the hole shut and replace the label. Put a new label on top of the existing one and write the cartridge history on it. Include the date, brand of refill, number of the refill, and any drum defects noted.

To provide an emptying hole in the holding tank, turn the cartridge upside down and find the area shown in Fig. 5. Then melt a ¼-inch hole in the area shown. This hole can be sanded smooth without major problems. Go outside and shake the used toner out of this hole. Since there are some baffles in the holding tank, you will have to rock the cartridge back and forth a few times to get rid of all the spent toner. When finished, tape the hole shut.

For successive refills, just untape the holding tank, empty and retape. Then untape the toner tank, fill and retape. You should also use the special tool to clean the corona wire at this time.

Instead of replacing the fusion wiper pad, just remove the wiper portion of it and lay a new wiper in place. I've found that you can use both the top and bottom surfaces of the new wiper this way. Wipers cost around 50¢ each.

Keep the toner cartridge right-side up as much as possible while you do your refilling. It is definitely *not* feasible to ship cartridges refilled this way except by hand carrying.

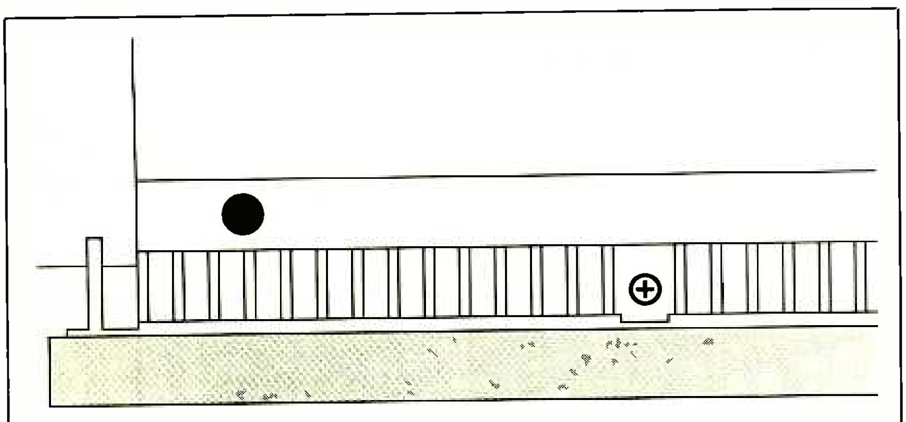


Fig. 5. Large black dot indicates where to add emptying hole to bottom of spent toner tank.

NAMES AND NUMBERS

Adistor Technology, Inc.
PO Box 51160
Seattle, WA 98115
(206) 523-6468

Beta Phase Inc.
1060 Marsh Rd
Menlo Park, CA 94025
(415) 494-8410

Cambion
One Alewife Pl.
Cambridge, MA 02140
(617) 491-5400

Circuit Specialists
PO Box 3047
Scottsdale, AZ 85257
(800) 528-1417

EVCO
3451 Lorna Rd.
Birmingham, AL 35236
(205) 822-5381

Jensen Tools Inc.
7815 South 46th St.
Phoenix, AZ 85044
(602) 968-6231

Laser Printer Products
11 Freeman St.
Sloughton, MA 02072
(617) 341-3005

L-COM, Inc.
1755 Osgood St.
North Andover, MA 01845
(617) 682-6936

Melcor
990 Spruce St.
Trenton, NJ 08648
(609) 393-4178

Meredith Instruments
6403 North 59th Ave.
Glendale, AZ 85301
(602) 934-9387

Motorola Semiconductor
Box 20912
Phoenix, AZ 85036
(602) 244-6900

Precision Movements
2024 Chestnut St.
PO Box 689
Emmaus, PA 18049
(215) 967-3156

RCA Solid State
Route 202
Somerville, NJ 08876
(201) 685-6000

Repeat-O-Type
665 State Hwy. 23
PO Box 486
Wayne, NJ 07470
(201) 696-3330

RMC
East Park Ave.
Attica, IN 47918
(317) 762-2491

SignCraft
1938 Hill Ave.
PO Box 06031
Fort Myers, FL 33906
(813) 939-4644

There is absolutely no need to take the cartridge apart. But if you really want to open one, the special screwdriver needed is a #10 tamper-proof torx insert bit from *EVCO*'s No. 945B700 set, that is also available from *Jensen Tools*.

How about a grab bag?

Sure thing. Here we go . . . .

Meredith Instruments has a $75 special on helium-neon lasers that include power supplies. Low-cost ceramic resonators that are useful as filters and crystal replacements are available from *Radio Materials*. An RS-232C adaptor kit for null modems and custom interfaces is bargain priced at $10 from *L-COM Inc.* Shape memory (nitional) and super-elastic alloys are newly available through *Beta Phase Inc.*

A new catalog from *Circuit Specialists* lists all sorts of unique hacker integrated circuits available in small quantities. *Signcraft* is a neat magazine on sign painting. For the location of your nearest *Apple Computer* club, call (800) 538-9696, extension 500. One low-cost source of clock parts, electronic and otherwise, is *Precision Movements*.

A new component from *Adistor Technology* can be used for low-cost fuel-vapor detection and other "sniffer" applications. *Motorola*'s new MC14534 LCD driver should very much simplify low-power microprocessor display interfaces. For "old-line," high-quality tools that are hard to get elsewhere, check into the catalog from *C.S. Osborne*.

For some new products of my own, check into my *Postscript Show & Tell* that shows off laser printers on the Apple, Mac, or PC (plus others), or the newly bound reprint volumes from my *Ask the Guru* column.

As our usual reminder, this is your column and you can get technical help per the box below. If you haven't done so already, be sure to write or call for your copy of the brand new free stuff list. **ME**

NEED HELP?

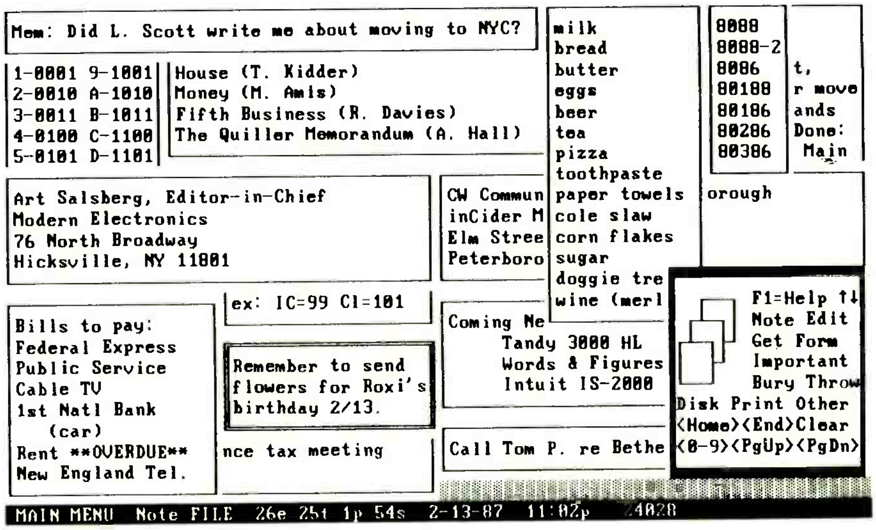
Phone or write your **Hardware Hacker** questions directly to:
Don Lancaster
Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

Nice and Simple: Tornado Notes and JumpStart

By Eric Grevstad

Let me try a theory on you: If earlier days in personal computing were dominated by the idea of or desire for an individual application, the computer as a means to run a spreadsheet such as VisiCalc or word processor such as WordStar, the archetypal image today is Borland's SideKick. With the latter, the computer is used as a grab bag of smaller solutions, replacing a group of separate tools or desk accessories. We're not willing to use a computer for one thing at a time anymore. What's the impatient frenzy for a multi-tasking 80286 or 80386 DOS but an admission that we're hooked on the SideKick concept, wanting WordPerfect for a notepad and Lotus 1-2-3 for a pop-up calculator?

Memory-resident, multi-purpose utilities are so popular nowadays that they're inspiring new types of programs as well as straightforward SideKick imitations like HomeBase or Spotlight. Of the two programs tested this month, one takes a component of many pop-up packages—the notepad—and transforms it into a new category of software in its own right. The other, aimed at computing beginners, presents a decent set of background utilities—calculator, phone dialer, and so on—as a foreground program, an integrated package that's like using SideKick without a "real" application in front of it.



Free-form information: a powerful pile of Tornado Notes.

Jotting Up a Storm

I've never personally relied on pop-up utilities—I already have a calculator, appointment calendar, and phone list in my watch, though I'm not crazy about the tiny keyboard. But Tornado Notes ($49.95) is a memory-resident program that's worth keeping on your computer all day, or even using without other software. If you want an address book or card file, Tornado Notes is a free-form, fast-fetching database. If you'd like a clipboard to cut and paste between your programs, Tornado Notes gives you two dozen. If you want to jot thoughts in a notepad, Tornado's has a hundred pages to SideKick's one.

Tornado's trick is that, once it's in memory (taking 53K plus a 5K to 50K buffer), typing Alt-J or another specified sequence jumps from your application to a desktop cluttered with overlapping, unrelated notes. You can have as many notes as your buffer can hold, adding new ones as fast as you can press <N> and type them into blank rectangles (with word wrap and WordStar editing commands), using the program's shrink-to-fit borders or setting shape and size yourself. Your 20 or 200 notes are free of titles or filenames, loaded into RAM from a single disk file.

You can rummage through the pile with the arrow keys, bring a note to the top or bury it at the bottom, delete it from memory, edit it with cut-and-paste commands or date and time stamps, or save or load a note pile to disk. If you'd rather not write your own notes, you can capture an ASCII or WordStar file or take a snapshot of the underlying application screen (first 78 columns), trim or edit that note as you like, then paste it into another application—with a carriage return, space, or down arrow after each line, fitting into either a word processor or spreadsheet.

Tornado Notes encourages you to make disorganized, disordered reminders because it's wickedly fast at retrieving notes from RAM as you type a search string. This narrows the pile as your text grows more specific, finally popping up the one note that contains "electronics" if you haven't already pressed Enter to scan those matching "elk," "elephant," and "elector." You can winnow the new pile in a second (and/or) search.

A "forms" command turns your notes into database records, the tab key moving among fields labeled "Name," "Address," or whatever, but I prefer Tornado's free-form searching speed, even if looking for contacts in New York (NY) also finds "Call Danny about tickets" and "Ask if anyone reads PC Papers." Tornado Notes is genuinely, as its package says, "a new idea," a wonderfully fast, handy replacement for the scraps of paper we all accumulate every day.

Any bad news? While Tornado's the neatest program I've seen in months, you might appreciate Micro Logic Corp.'s 30-day money-back guarantee. Cute little menus teach you the program in minutes, but the manual is skimpy—saying that you can use your word processor to edit a note file, for instance, without a hint about the cryptic numbers and format codes therein.

I had mixed results with a common pop-up problem, calling Tornado from graphics programs—easily returning to

```
 JumpStart (tm) Copyright 1986 Ascent, Inc. Version 1.0          10:40

Name     : Working breakfast with C. Snedeker        [ APPOINTMENT BOOK ]
Date     : 02/16/87
Time     : 09:30 AM                                  Monthly Calendar
Duration: 01:15                                      Add Appt
Work     : (203)555-8092                             Search/Edit Appts
Home     : (   )   -                                 Print All Appts
Other    : (   )   -                                 Print Calendar
Comment  : Discuss the Celtics

 February  1987                            02/16/87 Memo:
   S    M    T    W    T    F    S
   1    2    3    4    5    6    7     AM  12 ....  1 ....  2 ....  3 ....
   8    9*   10   11*  12   13   14          4 ....  5 ....  6 ....  7 ....
   15   16*  17   18   19   20   21          8 ....  9 ..*- 10 ---. 11 ....
   22   23   24   25*  26   27   28    PM  12 ....  1 ....  2 ....  3 ....
                                             4 ....  5 ....  6 ....  7 ....
                                             8 ....  9 .... 10 .... 11 ....
  F1           F3           F4                     F7    F10     ESC
 Help         Dial         Edit                   Calc  Accept  Quit
```

Fixed-form information: the rigid but practical JumpStart.

Microsoft Word on a Tandy 1000, but

aren't using their PCs and want some ... threatening, somewhat useful desk ... e's an ASCII text editor with ... and-paste commands, and a ... e utilities to guide you through ... ame, and delete functions. ... index-card-style, disk-search- ... s book and an appointment ... shows a monthly calendar and ... dule. A financial calculator ... rent variables for standard in- ... interest, depreciation, and ... ulas.

... that JumpStart doesn't work. ... keep track of a bunch of things ... d it has some sharp printing op- ... t transcribe your data in calen- ... hone-list form. But I can't im- ... least experienced user staying ... It makes DeskMate, the begin- ... ckage shipped free with Tandy ... rs or copies of DOS, look like ... ny.

... Start lets you type and scan your ... , but doesn't sound an alarm or ... se alert you to appointments. The ... or can plot 12.6-percent interest ... r years, but can't add or subtract ... four-function calculator. And ... ing seems to take 20 keystrokes— ... ressing < Enter > a few times to ... hrough menus, you're obliged to ... < F10 > (Accept). The < F2 > (Choices) key is a help when you're prompted to enter a filename for disk jobs, but an outrage when you'd rather type YES or NO for "Dial 1?" in a phone-number macro.

Except for its communications module, JumpStart isn't an alternative to real software like Reflex or Enable, or even a decent rookie kit. For executives with shiny micros on their desks, it's an alternative to leaving the computer turned off. **ME**

Ascent Inc.
190 Sobrante Way, Suite 201
Sunnyvale, CA 94086
408-720-9200

Micro Logic Corp.
P.O. Box 174, 100 Second St.
Hackensack, NJ 07602
201-342-6518

English-Language Broadcasts

BY GERRY L. DEXTER

Note: This list of English-language broadcasts was accurate at the time of compilation, but stations often make changes in the hours and frequencies of their broadcasts with little advance notice. Hundreds of broadcasts are aired in English on the shortwave broadcast bands every day, many of them directed to an audience in North America. This is a representative sampling of Winter 1987 broadcasts. Some broadcasters air only a part of their program in English during a given hour, or may run the English segment into the following hour. Times are UTC. Numbers in parentheses indicate a starting time in English in that many minutes past the hour.

Time	Station/Country	Frequencies
0000	Radio Canada International	5960, 9755
	Radio Baghdad, Iraq	11750
	Kol Israel	5885, 7465, 9435
	Vatican Radio (50)	6015, 9605, 11845
	Radio Tirana, Albania	7065, 9750
	BBC, England	5975, 6005, 6120, 6175, 7325, 9410, 9515, 9590, 9915
	RBI, East Germany	6080, 6125, 9730
	Radio Beijing, China	15445
	RHC, Cuba	6100, 6140
	Radio Moscow	7115, 7175, 7185, 9600, 9720, 9865
	Spanish Foreign Radio	6055, 9630
	BRT, Belgium (30)	9830, 9925
	Radio Portugal	9680
0100	Radio Canada International	9535, 11845, 11940
	DW, West Germany	6040, 6085, 6145, 9545, 9565, 11785
	RAI, Italy	5990, 11800
	Voice of Nicaragua	6015
	Radio Tirana, Albania	7120, 9750
	HCJB, Ecuador	9870, 11910, 15155
	Radio Netherlands	6020, 9895
	Voice of Greece (30)	7430, 9395, 9420
	Radio Austria International (30)	9770
0200	Radio Budapest, Hungary	6025, 6110, 9520, 9835, 11910
	Radio Polonia, Poland	6095, 6135, 7145, 7270, 9525, 11815, 15120
	Radiobras, Brazil	11745
	Kol Israel	5885, 7465, 9435
	Radio Japan	15195, 15420
	Voice of Free China	5985, 9680, 9765, 11740, 11745, 11825
	Radio Kiev, Ukraine SSR	7165, 7175, 7205, 11790, 13605, 15180
	Radio Belize	3285
	Radio Prague, Czechoslovakia	5930, 7345, 9540, 9740, 11990
	RAE, Argentina	9690, 11710
	Swiss Radio International	9725, 9885
	Radio RSA, South Africa	5980, 6010, 9615
	Radio Bucharest, Romania	5990, 6155, 9510, 9570, 11810, 11940
	Radio Cairo, Egypt	9475, 9675
	Radio Sweden	9695
0300	DW, West Germany	9545, 9565, 9640, 9735
	Radio Polonia, Poland	6095, 6135, 7145, 7270, 9525, 11815, 15120
	Radio New Zealand (45)	9620, 11780
	Radio Tirana, Albania	7120, 9750
	Radio Netherlands (30)	6165, 9590
	RBI, East Germany	6080, 9730
	Radio Portugal	9565
	Voice of Turkey	9560
	HRVC, Honduras	4820
	TIFC, Costa Rica	5055
	TWR, Netherlands Antilles	9535
	Radio France International (15,45)	7135, 9535, 9790, 9800
	Voice of Greece (40)	7430, 9420
0400	Radio Botswana	4820, 7255
	Radio Japan	9505
	Voice of Nicaragua	6015
	TGNA, Guatemala	3300
	Swiss Radio International	6135, 9725, 9885
	Radio Baghdad, Iraq	11750
	Radio France International (15,45)	6055, 6175, 7135, 9535, 9550, 9790, 9800
	Radio Austria International (30)	6155, 9755
0500	DW, West Germany	5960, 6120, 6130, 9700
	Radio Netherlands (30)	6165, 9590
	Radio Lesotho	4800
	TWR, Netherlands Antilles	9535

Time	Station/Country	Frequencies
	Kol Israel	7465, 9009, 9435, 9860
	RBI, East Germany	9500, 11960
	RHC, Cuba	6090, 6100, 6140
	Radio Nigeria	7255
0600	Radio Canada International	6140, 7155, 9740, 11775
	HCJB, Ecuador	6230, 9870, 15155
	GBC, Ghana	3366, 4915
	CRFX, Canada	6070
	BBC, England	5975, 6175, 7150, 9510, 9600
	Swiss Radio International	6165, 9535, 9870
0700	Voice of Free China	5985
	ELWA, Liberia	4760
	Radio Bucharest, Romania	11940
	CHNX, Canada	6130
	Radio Moscow	7290
0800	Solomon Is. Broadcasting Service	5020, 9545
	HCJB, Ecuador	6130, 9745, 9845, 9860
	BRT, Belgium	9880
	KTWR, Guam	11735
	KYOI, Saipan	15190
	Radio Australia	5995, 9580
	TWR, Monaco	7105
0900	Radio Australia	9580, 9655
	Radio Afghanistan	4450, 6085, 15255, 17665
	Radio Korea, South Korea	7275
	KNLS, Alaska	11850
	Radio Japan	9675, 11955
	Radio Singapore	5010, 11940
1000	Radio New Zealand (30)	6100, 9620
	Radio Norway (Sunday)	9590, 15175, 15185, 15230
	Voice of Vietnam	9840, 12035
	BSKSA, Saudi Arabia	11855
	Radio Australia	9580, 9655, 9770
	Radio Netherlands	6020, 9650
1100	Radio Pyongyang, North Korea	9750, 9977
	NBC, Papaua, New Guinea	4890
	Radio Pakistan	15605, 17660
	Radio Finland	11945, 15400
	Radio Japan	9675
	SLBC, Sri Lanka	11835
	Voice of Vietnam	9840, 12035
	Radio Beijing	9535
	Radio Korea, South Korea	15575
	TWR, Netherlands Antilles	11815
	VOIRI, Iran	15084
1200	Radio Canada International	9650, 11855, 11955, 15440, 17820
	Voice of People of Kampuchea	9695, 11938
	Radio Pyongyang, North Korea	9600, 9715
	Radio Tirana, Albania (30)	9515, 11960
	HCJB, Ecuador	11740, 15115, 17890
	Radio Finland	11945, 15400
	Radio Tashkent, Uzbek SSR	9600
	Radio Ulan Bator, Mongolia	12015
	KYOI, Saipan	11900
	RAE, Argentina	15345
	All India Radio	11620
	Radio Austria International (30)	6155, 11915, 11955
	Radio Bangladesh	15525
	Radio Sweden (30)	9565, 11940
1300	Radio Norway (Sunday)	6040, 9590, 15300, 15305, 17775
	Radio Canada International	9715, 11955
	Radio Finland	15400, 17800
	BRT, Belgium	15590, 17590
	HCJB, Ecuador	15115
	Radio Beijing, China	9730, 11660, 11755
	UAE Radio, United Arab Emirates (30)	11955, 17775
	Voice of Vietnam (30)	10040, 15010
1400	Radio Norway (Sunday)	11860, 15300, 15305
	Radio Finland	15400, 17800
	Radio Japan	9695
	Radio Sweden	11785, 15345
	All India Radio	11810, 15335
	HCJB, Ecuador	15115, 17890
	Radio Korea, South Korea	9750, 15575
	Radio Moscow	9655, 11840
1500	HCJB, Ecuador	11740, 15115, 17890
	Radio Veritas, Philippines	9570
	TWR, Guam	9870
	BBC, England	15260, 17775

COMMUNICATIONS . . .

FM BROADCAST STATION CLASSES & FREQUENCIES

Channel No.	Frequency	For Class	Channel No.	Frequency	For Class
201	88.1 MHz	†	251*	98.1 MHz	B-C
202	88.3 MHz	†	252*	98.3 MHz	A
203	88.5 MHz	†	253*	98.5 MHz	B-C
204	88.7 MHz	†	254*	98.7 MHz	B-C
205	88.9 MHz	†	255*	98.9 MHz	B-C
206	89.1 MHz	†	256*	99.1 MHz	B-C
207	89.3 MHz	†	257*	99.3 MHz	A
208	89.5 MHz	†	258*	99.5 MHz	B-C
209	89.7 MHz	†	259*	99.7 MHz	B-C
210	89.9 MHz	†	260*	99.9 MHz	B-C
211	90.1 MHz	†	261*	100.1 MHz	A
212	90.3 MHz	†	262*	100.3 MHz	B-C
213	90.5 MHz	†	263*	100.5 MHz	B-C
214	90.7 MHz	†	264*	100.7 MHz	B-C
215	90.9 MHz	†	265*	100.9 MHz	A
216	91.1 MHz	†	266*	101.1 MHz	B-C
217	91.3 MHz	†	267*	101.3 MHz	B-C
218	91.5 MHz	†	268*	101.5 MHz	B-C
219	91.7 MHz	†	269*	101.7 MHz	A
220	91.9 MHz	†	270*	101.9 MHz	B-C
221	92.1 MHz	A	271*	102.1 MHz	B-C
222	92.3 MHz	B-C	272*	102.3 MHz	A
223	92.5 MHz	B-C	273*	102.5 MHz	B-C
224	92.7 MHz	A	274*	102.7 MHz	B-C
225	92.9 MHz	B-C	275*	102.9 MHz	B-C
226	93.1 MHz	B-C	276*	103.1 MHz	A
227	93.3 MHz	B-C	277*	103.3 MHz	B-C
228	93.5 MHz	A	•278*	103.5 MHz	B-C
229	93.7 MHz	B-C	279*	103.7 MHz	B-C
230	93.9 MHz	B-C	280*	103.9 MHz	A
231	94.1 MHz	B-C	281*	104.1 MHz	B-C
232	94.3 MHz	A	282*	104.3 MHz	B-C
233	94.5 MHz	B-C	283*	104.5 MHz	B-C
234	94.7 MHz	B-C	284*	104.7 MHz	B-C
235	94.9 MHz	B-C	285*	104.9 MHz	A
236	95.1 MHz	B-C	286*	105.1 MHz	B-C
237	95.3 MHz	A	287*	105.3 MHz	B-C
238	95.5 MHz	B-C	288*	105.5 MHz	A
239	95.7 MHz	B-C	289*	105.7 MHz	B-C
240	95.9 MHz	A	290*	105.9 MHz	B-C
241	96.1 MHz	B-C	291*	106.1 MHz	B-C
242	96.3 MHz	B-C	292*	106.3 MHz	A
243	96.5 MHz	B-C	293*	106.5 MHz	B-C
244	96.7 MHz	A	294*	106.7 MHz	B-C
245	96.9 MHz	B-C	295*	106.9 MHz	B-C
246	97.1 MHz	B-C	296*	107.1 MHz	A
247	97.3 MHz	B-C	297*	107.3 MHz	B-C
248	97.5 MHz	B-C	298*	107.5 MHz	B-C
249*	97.7 MHz	A	299*	107.7 MHz	B-C
250	97.9 MHz	B-C	300*	107.9 MHz	B-C

†For classes of noncommercial educational stations and their definition, see FCC Rules and Regulations, Paragraph 73.504.
*In Hawaii, the band 98 to 108 MHz is allocated for nonbroadcast use, and the frequencies 98.1 to 107.9 MHz will not be assigned in Hawaii for use by FM broadcast stations.

Time	Station/Country	Frequencies
	Radio Australia	9580
	Voice of Indonesia	11790, 15150
	Voice of Greece (40)	11645, 15630
1600	Radio Pakistan	11675, 15595, 17660
	Radio Norway (Sunday)	9510, 11925, 17840

Time	Station/Country	Frequencies
	Voice of Vietnam	10040, 15010
	UAE Radio, United Arab Emirates	11955, 15300, 15320
	BSKSA, Saudi Arabia	11855
	Radio France International	11705, 17620, 17795
1700	Radio Surinam International (30)	17775
	BBC, England	9740, 15070, 15260
	Radio Norway (Sunday)	9655, 11925, 15310
	Radio Moscow	9580, 9640, 9705, 9775, 9885, 11840, 12030
1800	Radio Canada International	15260, 17820
	Radio Kuwait	11675
	BRT, Belgium	15510
	Radio Nigeria	15120, 17800
	RHC, Cuba	11795
	Voice of Greece (40)	11645, 15630
1900	Radio Afghanistan	9665, 11880
	Radio Canada International	11945, 15260, 15325, 17820, 17895
	Radio Norway (Sunday)	11865, 15310
	BBC, England	12095, 15070
	HCJB, Ecuador	15270, 17790
	VOIRI, Iran (30)	9022, 11930
2000	Radio Algiers, Algeria	9640, 15215, 17745
	Radio Budapest, Hungary	9835, 11910
	Radio Moscow	12030, 12050, 15425
	Radio Cairo, Egypt	15375
	Voice of Nigeria (30)	11770
	All India Radio (45)	9910, 11620
2100	Radio Damascus, Syria	7455, 9950, 12085
	Radio Netherlands	9540, 9715, 9895
	Radio Japan	9675, 11815
	RHC, Cuba	11725, 17885
	Voice of Nigeria	15120
	Radio Yugoslavia	6100, 7240, 9620
	HCJB, Ecuador	15270, 17790
	Kol Israel	9435, 9815, 9860, 12080
2200	Radio Norway (Sunday)	9605, 11930
	Radio Vilnius, Latvian SSR	7165, 7400, 9800, 11750, 11860, 15100
	Voice of Turkey	9560
	BBC, England	5975, 6120, 6170, 6175, 7325, 9590, 9915
	Radio Moscow	7400, 9610, 9720, 9820, 9880, 12030, 13665, 15425
	Kol Israel (30)	7410, 9435, 9815, 9860
	CBCNQS, Canada	9625, 9755, 11720
	Swiss Radio International (30)	9590, 9885
	Radio Yugoslavia	6100, 7240, 9620
2300	Radio New Zealand (45)	11780, 15150
	Radio Kiev, Ukraine SSR (30)	7205, 9685, 11790, 13605, 15180
	RBI, East Germany	6080, 9730
	Radio Japan	9695, 11705
	Voice of Turkey	9560
	Radio Prague, Czechoslovakia	9630
	Radio Luxembourg	6090

LETTERS • • • *(from page 5)*

home computers designed to work with TV receivers. The switch's toggle is pushed to either the DIRECT position, which is near the direct input, to the VCR (or whatever else is labeled), which is near the associated input connector. Also, to be technically correct, the PREMIUM and NORMAL positions on A/B switch 1 in Fig. 5 should be transposed.

Cass R. Lewart

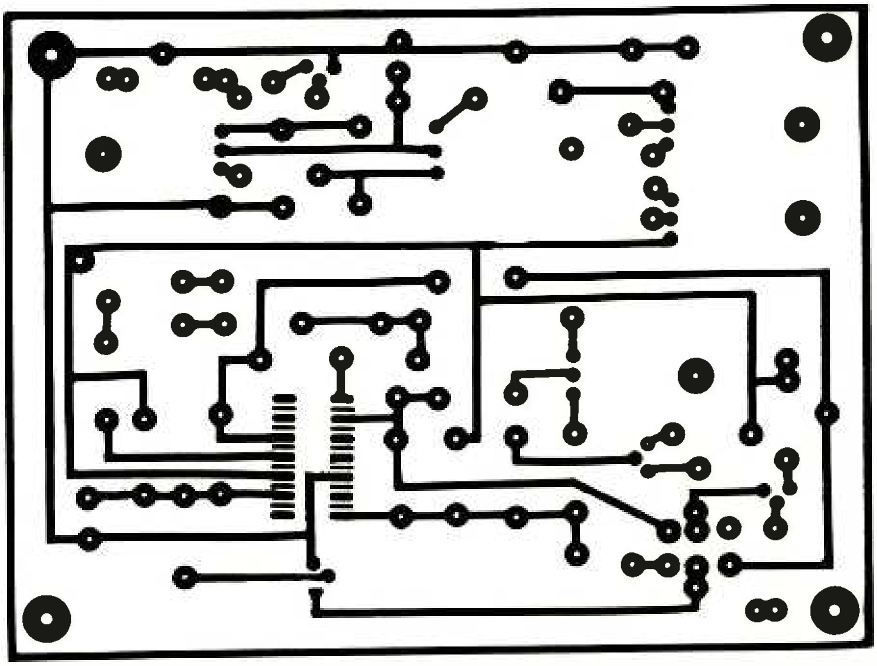
• Builders of the "CASS/RS232 Adapter" (Dec. 1986) should make the following corrections: In Fig. 1, the polarity of *D2* should be reversed; in Fig. 3, the "K" at the top of *R5* should be at the top of *D1*, and the top of *C3* should be labeled with a "+" sign.

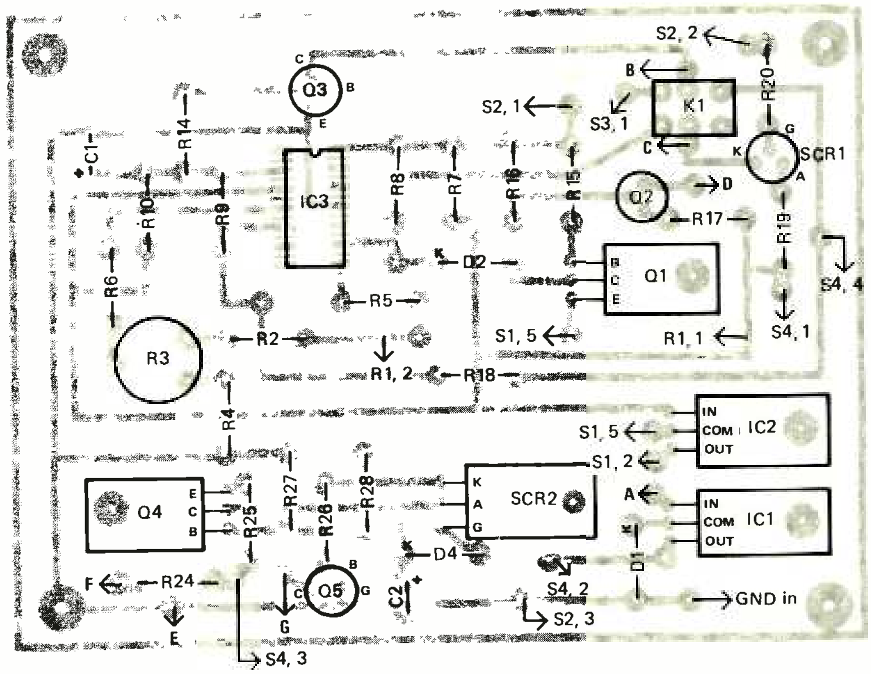
Duane M. Perkins

• The printed-circuit board etching-and-drilling and wiring guides that appeared in my "Ni-Cd Recycler" (Oct. 1986) had two errors. Here is the revised artwork.

Any reader who has made his own board can easily rectify the errors by cutting traces, installing a ground wire for IC3 and moving two wires. Readers who purchased boards from R&R Associates can obtain revised boards by writing to the company.

Peter A. Lovelock





Combo VCR

• With reference to Samsung Electronics' new VHS/8 Combo VCR mentioned in your September issue, is this unit in production and where can I purchase one? I called the "FREE 8-mm VIDEO INFO" number listed in the October issue, but they don't have a listing on it yet or Samsung's address for my inquiry.

James R. Wall
Amarillo, TX

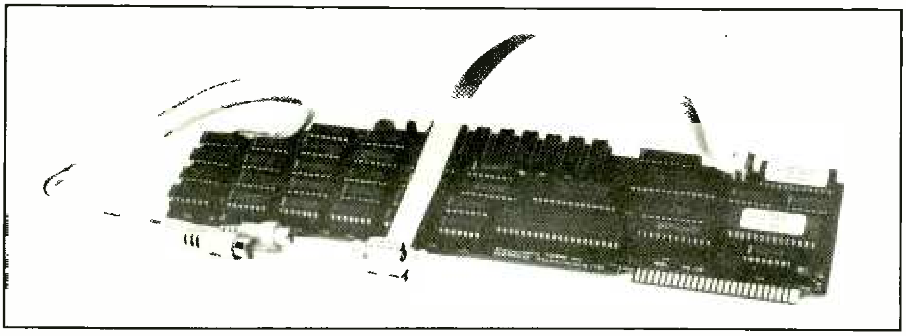
It was reported that the company planned to produce the combo machine, but we haven't heard anything since. Their address is: Samsung Electronics America, 301 Mayhill St., Saddlebrook, NJ 07662.—Ed.

Flying High

• In "An Experimenter's Aviation-Band Receiver" (September 1986), Fig. 1 shows the values of *C4* and *C7* to be 2,000 and 200 pF, respectively, while the Parts List lists the values of both capacitors as 2,000-pF. Which is correct? I note also in Fig. 1 only three leads for *Q1*, but Fig. 4 shows four leads going into holes in the pc board. Why the discrepancy? Finally, on another matter, what is the size of the powdered-iron toroid core used for *T1*?

Joseph A. Corbeil
Chicopee, MA

To answer your questions in the order stated: The Parts List correctly gives the value of both capacitors as 2,000-pF. The fourth lead on Q1 is a shield that connects internally directly to the transistor's case. if Q1 is plugged into the pc board with its tab exactly as shown, all four leads will be properly connected into the circuit. The No. T-25-0 toroid core specified is commonly available from electronic parts dealers; it has an outer diameter of about 0.5"—Ed.



configurable for most popular dot-matrix printers and interface cards. A Quality Print Mode (160 dots/inch) and full 11″ × 14″ printouts are supported on printers that have these capabilities.

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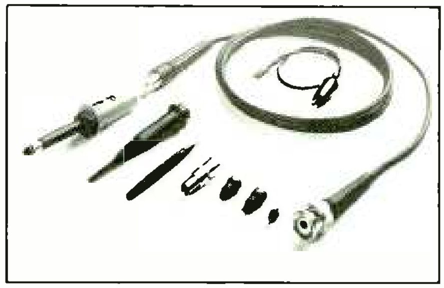
CIRCLE 11 ON FREE INFORMATION CARD

Plug-in Oscilloscope Probes

HHSmith (Manasquan, NJ) has two new series of probes that can be used with any oscilloscopes, the OP1000 Series standard modular and the OP2000 Series professional modular. The probes utilize a "plug-in" module concept that permits interchanging with Tektronics, Philips, Hewlett-Packard, Hameg and other oscilloscopes that have an input impedance of 1 megohm shunted by 15 to 47 pF capacitance. Both Series have slender low-capacitance cable for optimum transient response, special cable lengths, head modules and various levels of attenuation.



Specified bandwidths are 20 to 100 MHz for the OP1000 Series and 15 to 250 MHz for the OP2000 Series. The OP2000 also has a compensation box on a BNC-end that permits use with wide end scopes. A complete set of accessories is available for both probe Series.

CIRCLE 12 ON FREE INFORMATION CARD

BOOKS

First Book of Modern Electronics Projects, Edited by Art Salsberg. (Howard W. Sams, Soft cover, 165 pages. $12.95.)

This large-format (8½" × 11") book contains the most popular construction projects from the pages of *Modern Electronics* magazine. Original authors upgraded their work and corrected glitches where they had occurred. The book is arranged in a very logical manner, consisting of eight sections. It starts off with a discussion of the basic "tools" needed for project and kit building and gives tips on buying components and parts. Following this come details for fabricating printed-circuit boards without chemicals and for making professional-appearing front panels.

Succeeding chapters provide full plans for building more than 20 projects. These are: Home Electronics, Audio/Video Electronics, Security Electronics, Telephone Electronics, Computers, Test Equipment and Electronic Designing. Among the projects featured are a touch-sensitive light controller; a device that cuts the cost of operating a gas or oil heating system; a "Surround-Sound" Audio Enhancer; gas and microwave leakage detectors; a power controller for a computer system; a low-cost digital logic probe; a telephone security system; a thermometer accessory for voltmeters, and much more. All projects are accompanied by a Parts List, many with kit-availability information. Many of the construction projects include actual-size etching-and-drilling guides for fabricating pc boards, and all are fully illustrated with schematics, drawings and photos.

A fitting conclusion is the "Electronic Design" chapter. Here a bevy of articles provides the reader with information on how to go about designing his own projects, using practicable examples such as employing logic devices to create a "smart" water pump controller.

Coupled with in-depth "how it works" discussions for each project presented, this book is actually an exciting, hands-on electronics course for both digital and analog circuits. Building the useful electronic devices detailed in the book, most of which are either not available commercially or substantially lower in cost, caps the inviting theory behind them.

Antennas—Selection and Installation by Alvis J. Evans. (Radio Shack. Soft cover. 112 pages. $3.95.)

Anyone who is experiencing reception problems for broadcast or satellite TV, FM radio, CB radio, shortwave and amateur radio, or mobile cellular telephone communications is well advised to add this book to his library. This practical guide can solve a wide variety of common reception problems. In addition to telling the reader how noncommercial antennas work and how to select and install them, it gives valuable practical information on how to deal with electrical noise and interference. The text is handled in a relatively nontechnical manner so that readers who have no knowledge of radio theory can understand and apply the information. Many drawings and photos support the clearly written copy, too. Considering the value of the information it contains and its unusually low price, this book is a double bargain.

NEW LITERATURE

Quartz Crystal Catalog. New from Jan Crystals is a 12-page catalog that lists the company's full line of quartz crystals for communications and special applications. Each crystal is grouped according to use and is fully described by frequency, tolerance, maximum drive level and holder. All listings also include prices. For a free copy of Cat. No. 30, write to: Jan Crystals, P.O. Box 06017, Ft. Myers, FL 33907.

Information Brochure on 8-mm Video. The 8 MM Video Council has a 12-page booklet that answers the most-asked questions about the 8-mm video recording format. Using a Q&A approach, it explains what 8-mm video is, discusses its evolution and compares and contrasts it with other video formats. Compatibility of formats, product and software availability and present/future applications of the 8-mm medium are also addressed. For a copy of the "8MM: The New Video Generation" booklet, send a stamped, self-addressed envelope to: Video Booklet Offer, 8MM Video Council, 99 Park Ave., New York, NY 10016.

Analog Panel Meter Note. A 4-page article that explains the details of selecting the right analog panel meter for a given application is available from Simpson. Detailed explanations and illustrations are included for construction details and materials, pointer types, pivot and jewel mechanisms, sensitivity, accuracy, tracking accuracy, temperature compensation, response time, etc. For a copy, write to: Simpson Electric Co., 583 Dundee Ave., Elgin, IL 60120-3090.

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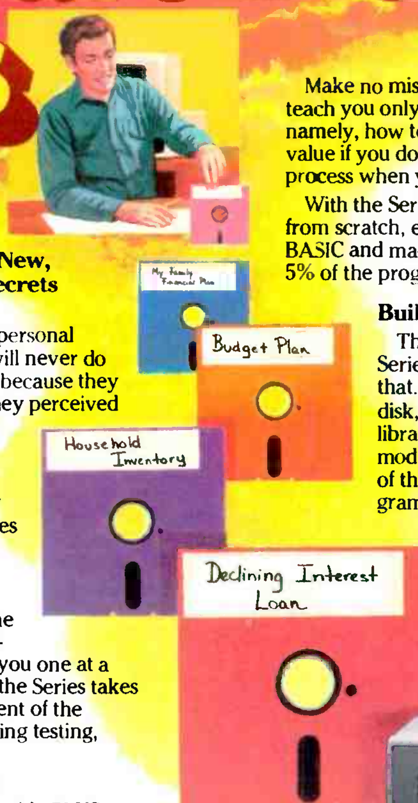

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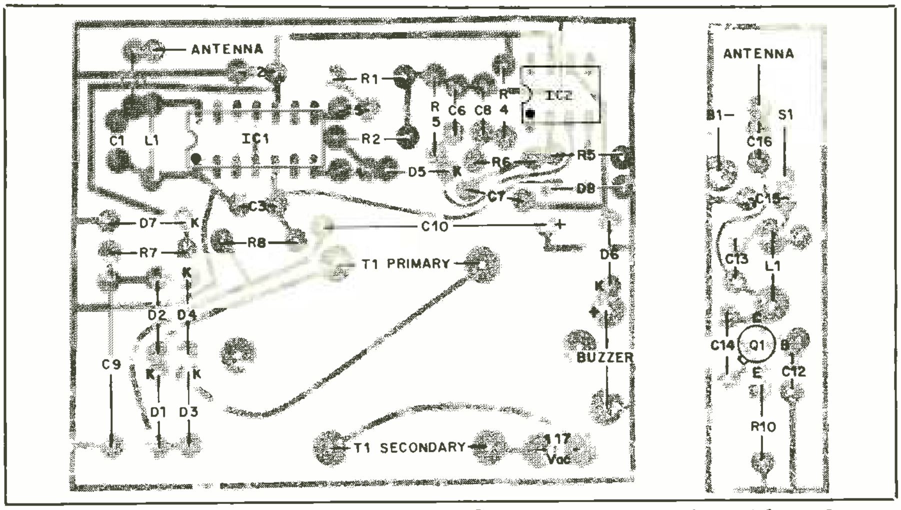

Fig. 6. Wiring guides for receiver (left) and transmitter (right) boards.

between closely spaced conductors on the bottom of the board, especially between the IC pads. Do not install the antenna wire and buzzer yet.

Now wire the transmitter board exactly as shown in the right guide in Fig. 6, again taking care to properly orient the transistor. When installing *C13*, observe the same instructions as for *C1* above. Also note that the transistor has four leads, one of which is internally connected to the case. Be sure the emitter, base, collector and case (shield) leads plug into the appropriate holes in the board and that you solder to the ground plane those component leads that pass through holes from which no copper has been removed.

You can use a short length of stranded hookup wire for the transmitter's antenna to achieve the desired operating range. Start with an 18″ wire connected to the transmitter's board as shown in Fig. 5.

Since there is no restriction on the length of the antenna used for the receiver, you should use as long a stranded hookup wire as necessary to achieve maximum system sensitivity. Start with about a 36″-long wire, connecting it to the receiver board as indicated in Fig. 4.

It is possible to use a short insulated jumper wire connected from the antenna side of *C11* to one side of the ac line at the primary side of the power transformer in the power supply section to pick up the transmitter's signal. Make absolutely certain if you do this that *C11* is rated at at least 200 volts and preferably 1,000 volts, and make sure to insulate the antenna wire to eliminate any possibility of shock hazard. This arrangement takes advantage of the enormous signal-gathering power of your home's ac wiring. A disadvantage of this arrangement is that electrical noise on the ac power line is likely to periodically cause the receiver's beeper to sound when no one has pressed the transmitter's switch.

You can house the receiver and transmitter circuits in suitably sized plastic boxes. For the transmitter, which will normally be in a location near your front door that is accessible to any passerby, you might want to use a metal box that mounts on a wall, or mount the circuitry behind a more secure panel with only the pushbutton switch accessible. If you are planning on using the receiver as a portable unit that can be taken to different locations in and around your home as needed, a better box might be one of those plastic types with an aluminim front panel.

Mount the transmitter's battery close to the circuit board assembly. The receiver requires 117-volt ac power and must, therefore, be mounted in a location where line power is available if it is to be permanently mounted. In any event, the piezoelectric buzzer should be mounted on the front of the box so that its sound can be clearly heard.

Checkout and Use

The transmitter must be checked out first to set it to the desired frequency. You can do this with the help of a standard FM broadcast radio or receiver. Tune the latter to a "dead" spot on the dial near 88 MHz where there are no stations broadcasting.

Turn on your FM radio and tune it to a spot near 88 MHz where no station is broadcasting. All you should hear at this point is a steady rush of static. Move the transmitter away from the FM receiver as far as practical and press and hold its pushbutton switch as you tune *C13* with a plastic alignment tool until you hear the static coming from the FM radio.

Tune *C13* so that the transmitter's frequency is peaked to the setting of the FM radio. This is a very sensitive adjustment that takes a lot of patience to perform correctly. Be sure you peak the transmitter to the FM radio because there may be one or several false settings that are not at the correct frequency. If you set the transmitter to one of these false frequencies, you may not be able to get your Doorbell to work properly.

Caution: Under no circumstances should you set the transmitter to a frequency beyond 108 MHz. This portion of the radio spectrum is reserved for aircraft communications. The FCC Rules and Regulations strictly forbids transmitting of remote-control devices in the 108-to-130 MHz band!

When the transmitter has been tuned to the correct frequency, use it to tune the system's receiver. For this operation, you will need a plastic alignment tool and a sensitive dc voltmeter (a digital multimeter set to low ac volts will do) or an oscilloscope. If possible, have someone operate the transmitter across the room from where you are working on the receiver.

Connect the voltmeter or oscilloscope, set to its most sensitive range, across *R3* in the receiver. Have your helper press and hold the pushbutton switch on the transmitter as you adjust the setting of *C1* for maximum voltage across *R3*, as indicated by the voltmeter or oscilloscope. You may find that as you approach peak, the instrument will have to be set to a less-sensitive range.

As the voltage indicated exceeds 10 millivolts, the piezoelectric buzzer should sound. Continue adjusting *C1* until the indicated voltage has reached its peak. If you go beyond the peak indication, back off and stop at peak. This completes adjustment of the system.

To check operating range, vertically orient the receiver and transmitters and walk away from the receiver while holding down the pushbutton switch of the transmitter. If the resulting operating range is too great for your application, it is suggested that you reduce transmitter radiation by shortening its antenna in ½" increments at a time until the range is just right or perhaps just a bit better than you really need. You may have to peak the receiver after doing this if the transmitter's frequency is affected by the trimming.

There is an alternative way you can reduce the sensitivity of the system without having to trim transmitter antenna length. You can reduce the receiver's sensitivity by increasing the value of *R5*. This resistor sets the operating bias on *IC2*. By increasing the value of *R5*, you increase the transmitter signal strength required to set off the buzzer.

It is always best to set your remote Doorbell for the shortest satisfactory operating range. By doing this, you avoid interference with other transmitting and receiving equipment in your area. **ME**

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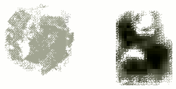

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MISCELLANEOUS

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ROBOTICS parts catalog for hobbyists, $2 (refundable). Alpha Robotics Inc., Box 21091, St. Paul, MN 55121.

ADVERTISERS' INDEX

PC Speed-Up Board *(from page 36)*

FAST. The last conductor picks up the +5-volt supply from the end of *R5* near *C1* (hole 4) and connects to *R6*, with the anode end of *LED1* connected to the other end of *R6*. Refer to Figs. 2 and 4.

Now, exercising safe handling procedures for MOS devices, carefully plug a *new* 8284 into the *U1* socket on the PCA board. Make sure you properly orient this IC, as shown in Fig. 4. Also make sure that no IC pins fold under or overhang the socket as you push it home. The 8284 for *U2* comes from your existing computer, as will be discussed next.

Installation and Use

Before doing anything else, "park" your hard-disk system (if you have one) and turn off power to the computer. Then remove the system unit's cover. Actual installation of the PC Accelerator is surprisingly easy. First, find the 8284 IC, which must be removed and plugged into the PCA's *U2* socket. (Exercise the same care as you did for *U1*.) If you have a Zenith Z-151 or Z-161, you'll find it on the separate CPU board. This is plugged into a bus, so you'll have to pull it out. In an IBM PC or XT, you'll find the 8284 on the motherboard close to the floppy-disk drive on the left (with the system unit's front facing you). With any other PC-compatible computer, refer to its technical or operating manual to locate the 8284.

If you're working with a CPU board you unplugged from the bus of a Zenith computer, protect it from any damage that might be caused by static electricity while handling it. To do this, place the board on a sheet of aluminum foil and touch the foil before handling the board. Leave the board on the foil during the entire time you're installing the PCA board. If you wish to, you can replace the 8088 CPU with a NEC V20-8 at this time.

Only the PC Accelerator circuit board installs inside your computer, plugging into the socket in which the 8284 was removed. The control box remains external for easy access to the FAST-NORMAL switch and the RESET pushbutton switch. Thread the PCA board into your computer through an open expansion card slot in the rear of the system unit and plug it into the empty 8284 socket. Be sure to use the proper orientation when you plug the PCA board into the vacated socket. That is, the upper-left of the board coincides with pin 1 of the 8284 socket in the computer. If you're modifying a Zenith computer, reinstall the CPU board by plugging it into the system bus once the PCA board has been installed.

Reassemble the computer's system unit. Your computer is now ready to run at both its originally designed 4.77-MHz speed or at the PC Accelerator's faster 6MHz.

When you turn on power to your computer, the LED on the external switch box should come on to indicate that high-speed operation is in effect. If your computer boots up as it should, you're ready to test it at this operating speed. If you installed the PC Accelerator board in a Zenith PC and get a timer or keyboard error during high-speed booting, there are two ways around the problem. One is to boot up at 4.77 MHz and then switch to the high-speed mode at the DOS prompt. The other is to use the ROM monitor to boot the computer. Use Ctrl-Alt-Ins to enter the monitor and then type < B > to initiate boot-up. IBM PCs appear to work properly in either mode.

You now have a faster computer for very little upgrade cost. If you install a V20-8 CPU as well as the PC Accelerator, your computer should work about twice as fast as it originally did for string manipulations, with an overall 40% increase when averaging all functions.

Thus, the PC Accelerator may be just what you want to breathe new life into your old PC, as it did to mine. And for little cost and effort. **ME**

Weird Music?

Now you can listen to music that's coursing through the AC wiring system of your home. It's exciting. It's soothing. It's vibrant. And, it's all around you.

By Drew Kaplan

No, I don't want you to listen to the 60 cycle hum of your AC power. No, I don't want you to listen to a 120 volt blast.

But, if you're like me you're going to find that this 'Weird Music' is really going to end musical frustration. And frankly, I've been frustrated.

As you might expect from reading my catalogs, I have 4 complete music systems in my home, and a very large collection of records, cassettes, open reel tapes and CDs.

One reason I'm frustrated is because I can't listen to my open reel tapes unless I'm at one of my two main systems.

And, if I'm on the patio, in the kitchen, or in the garage, I'm relegated to AM, FM or cassettes on a pocket stereo or portable.

And frankly, I've never taken the time to transfer all my albums, open reel tapes and CDs to cassettes. So, I haven't been able to listen to what I want where I want.

WELL, NO MORE

It may seem weird to plug a speaker into an AC outlet, but a new technological breakthrough has allowed me to listen to **any** music I choose from my best stereo, **anywhere** in my home.

The music (or speaking) is transmitted through the AC wiring in my home.

So, instead of running speaker wires all over my house, I just plug in a speaker wherever I want rich, room filling sound.

I really like it. I had always wanted to have wireless speakers in my living room because my wife hates having me run wires everywhere.

In the dining room, we can have uninterrupted music from one of my auto-reverse cassette decks 'piped in' while we entertain guests.

In the bedroom, now I can listen to my old open reel tapes. And in the garage, I can use the continuous programmable playback from my CDs. Of course, my system can transmit AM or FM too.

NOT STEREO AND PROBLEMS

It's not a perfect system. But, you'll be shocked by the magnificent rich sound.

And, installation consists of simply plugging its cable into the left and right tape jacks of your receiver and plugging in the AC power transmitter.

It will have no effect whatsoever on your stereo system.

NOTE: Don't worry about your tape jacks. Extra jacks are provided so you won't lose the use of your tape jacks.

But, it's not stereo. It combines the signals from the left and right channels and transmits a combined signal throughout your home's electrical system. So, you'll enjoy full rich music anywhere.

You can plug in as many 2-way speaker systems as you wish. And, you can plug them in anywhere in your home, **or office**, that you'd like vibrant, room filling music.

The 9½" X 4¾" X 6" speakers will knock your socks off with their rich full sound. A 4½" woofer combined with an acoustically designed cabinet really belts out the bass, while a 2½" tweeter easily matches the high frequency response of most traditional speaker systems.

A word about noise. You can virtually forget it. This system is virtually noiseless. It operates on VLF (Very Low Frequency) FM that is virtually unaffected by noisy motors and fluorescent lights.

It will, however, react to wireless intercoms and the BSR's X10 remote control system that we sell. But, the reaction is momentary and not too bothersome.

So, in short, although it's not stereo (you can put two speakers in a room), it's a fabulous sounding way to listen to your favorite music wherever you are.

IT'S PORTABLE

Installation of the speakers consists of simply plugging them in. Then you can adjust their On/Off volume controls.

Each even has a handle on the back so you can take them out to the garage, the patio or even to unattached barns.

As long as you're on the same side of the AC transformer (most houses are), virtually any plug in your home should be a source of your favorite vibrant music.

It's made by Universal Security and backed by their limited warranty.

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