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Maximum Sampling Speed	20 MS/s	20 MS/s	20 MS/s
Record Length	4K/1K (selectable)	4K	4K
Peak Detect	100 ns	100 ns	100 ns
Save Reference Memory	One, 4K Three, 1K	One, 4K	One, 4K
Vertical Resolution	8 bits 10 bits (AVG mode) 12 bits (AVG mode over the bus)	8 bits 10 bits (AVG mode)	8 bits
CRT Readout/Cursors	Yes	Yes	No
GPIB/RS-232-C Options	Yes ($750)	Yes ($500)	Yes ($500)
Battery-Backed Memory (save 26 waveform sets)	Yes (inc with GPIB/ RS-232-C)	No	No
Warranty	3 year on labor and parts, including the CRT		
Price	$4995	$3995	$2995

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CIRCLE 92 ON FREE INFORMATION CARD

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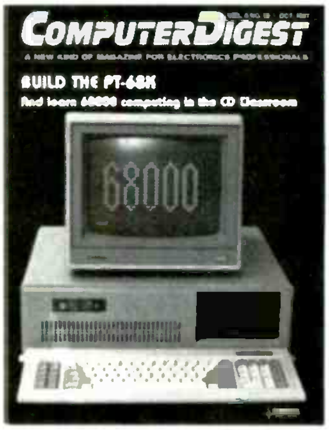

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Alexander Graham Bell experimented with light beam communications back in the 1880's. The technology of the day prevented his success then, but now, thanks to the availability of low-cost lasers, experimenters can apply their energies to that fascinating topic. This month, we'll show you a simple listening device that will let you use modulated laser light for communications over distances of several hundred feet or more. It can even be used to secretly listen in on conversations. To find out more about light-beam communications, turn to the story on page 39.

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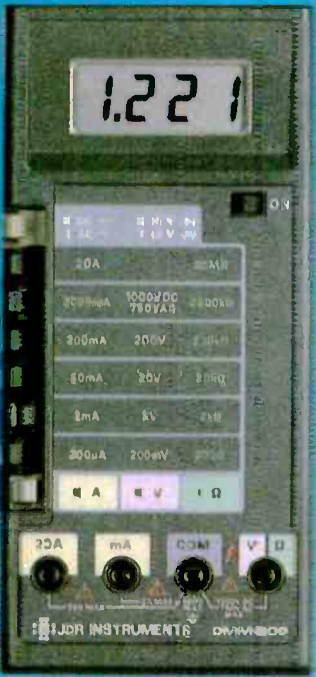

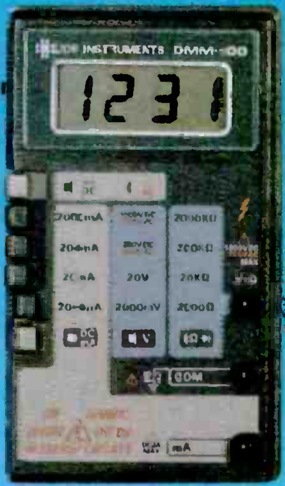

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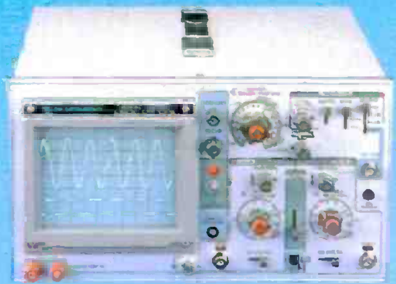
- DC current: 2mA — 2A, 4 ranges
- Fully over-load protected
- Input impedance: 10M ohm
- 130 x 75 x 28mm, weighs 195 grams



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GUEST EDITORIAL

Another attack on home taping

Consumers will soon have the advantages of digital sound quality in a compact cassette tape format, but the usefulness of the technology is threatened by special interest legislation that would prevent home recording of records, tapes or compact discs.

The new technology is known as *D*igital *A*udio *T*ape (DAT) recording and, like compact-disc technology, it uses electronic pulses to store and play back sound, offering the public much-higher quality than is possible on conventional analog recording equipment. In particular, the DAT will create a market for pre-recorded audio cassettes that sound as good as compact discs.

The recording industry is urging Congress to enact legislation that would require DAT recorders to incorporate anti-taping systems that would make it impossible for consumers to record most prerecorded or broadcast material, including material they have purchased and are recording for their personal use. The anti-taping IC is activated if the source material is recorded with a notch inserted in the high frequencies. The notch, which may be audible to a listener and could distort the music, would trigger the IC to stop the recording.

The legislation, HR 1384, sponsored by Rep. Waxman (D-CA) in the House of Representatives, and S 506, by Senator Gore (D-TN) in the Senate, would discourage consumers from buying this high-potential technology. Historically, consumers have accepted new recordinng technology only when it has offered them the chance to make tapes themselves. The anti-taping chip, however, would prevent home taping of notched source recordings and of tapes or records for use in car stereos and portable players.

DAT has extra advantages in that DAT tapes can be made much smaller than conventional cassette tapes, and they can store huge amounts of information -- nearly one gigabyte (one billion bits). The information storage capability gives DAT enormous potential in connection with personal computers.

Although recording companies claim that they would produce higher-priced recordings without anti-taping notches, it is highly questionable how many would be available, or at what price. Furthermore, research now shows that the anti-taping encoding process interferes even with sound quality on DAT playback.

Anti-taping legislation runs directly counter to the Supreme Court's "Betamax" decision, which held that consumers have a right to record aired material for their personal use. Just as that Supreme Court decision did not stop sales of prerecorded video tapes from topping five billion dollars, there is no evidence that home DAT recording will in any way limit the profits of the recording business.

The recording industry is plain wrong in stating that DAT recorders can make perfect copies of prerecorded material through conventioal analog inputs. The DAT is simply a better tape recorder, with tremendous portable applications, and will make people even more interested in buying music.

This latest assault by the recording industry on home taping is contrary to the intent of Congress and to Supreme Court precedent. Congress protected the right to tape during five years of debate. The recording industry's anti-consumers, anti-technological attack should be rejected once again.

Home Recording Rights Coalition
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VIDEO NEWS

DAVID LACHENBRUCH,
CONTRIBUTING EDITOR

• **Wireless is hot.** No, not Marconi's type of wireless, but wireless control and reception devices are big these days. Almost every TV manufacturer has introduced a wireless remote control that will work with the same brand of VCR, audio equipment, or both, and several have developed remote hand-held units that can "learn" other brands by facing them off with other remote units in a sort of bad-day-at-Black-Rock situation.

Wireless stuff got hotter at the recent Consumer Electronics Show in Chicago. CL9, the company started by Apple Computer co-founder Steve Wozniak, showed a universal remote control that could be taught whole sequences of commands, to be executed at a single keystroke. The controller, which costs $199, can perform as many as 260 series of tasks, has 16 keys, and 16K program memory. It can accomplish such tasks as turning on a VCR, setting it to record a specific channel, rewinding the tape and turning the machine off at one keystroke, for example. Coming in the future are computer and telephone interfaces—one of which would make it possible to program a VCR by phone.

Another hot wireless product was a hi-fi stereo speaker system using only house wiring for connection. To be marketed by Recoton for about $250 including amplified speakers, it can carry stereo sound to any room of the house via the AC wiring system and is claimed to have Compact Disc fidelity. Future models will be designed to accommodate name-brand speakers. Many years ago, General Electric's "Portasound" wireless AC speakers were all the rage, but they were killed off with the introduction of stereo. Now Recoton has updated Portasound in stereo and hi-fi.

Now you can edit your videotapes without even touching your VCR—by using Videonics' wireless editor. It's a complete editing system with a wireless hand-held alphanumeric keypad which is aimed at a high-speed microcomputer with 256K RAM as its main memory. Two VCR's are required—one of which can be a camcorder. Utilizing on-screen commands and prompts, the system guides the user through the process of editing, making titles, and captioning. More sophisticated add-ons will become available, but the basic system lists for less than $500.

Infrared wireless headphones are coming onto the American scene—none too early. They've been a fixture in Europe for many years. You merely plug the IR transmitter into the headphone jack of the TV or stereo and to a power source.

• **Personal video.** In its efforts to popularize the 8mm-Video format, Sony has adopted a new approach. Calling the format "personal video," the company is emphasizing 8mm's small size and ability to be built into miniaturized equipment. Two new products introduced by Sony are "the world's smallest" complete VCR with tuner and timer, designed to be easily attached to any TV set and moved from room to room, and a "desk set" combination VCR and 5-inch color TV. Scheduled for introduction next year is a 2.7"-LCD color-TV and VCR combination that is about the size of a paperback book. A companion color camera, small enough to fit in a pocket, was also shown.

• **Up in the air.** A completely new airborne video system is being offered to the airlines. As introduced at the Paris Air Show, each seat has its own individual 4-inch flat CRT built into the back of the seat in front of it. Passengers have their choice of at least three video programs, can pass the time by playing seven different video games, watch local TV or live closed-circuit TV showing takeoff and landing from the pilot's cabin, listen to one of 18 mono or nine stereo channels of digital audio. They also can use the interactive keypads and screens in front of them to order meals and drinks, purchase duty-free items and get safety instructions in multiple languages. Developed jointly by Sony and Sundstrand Data Control, the *A*irborne *C*abin *S*ervice and *E*ntertainment *S*ystem (ACSES) uses 8mm videotape for video and audio programs, and is expandable for the addition of further new features. There's no word on when you'll find it on an airplane. Its unveiling was the first indication that Sony had developed a color version of its flat Watchman picture tube. **R-E**

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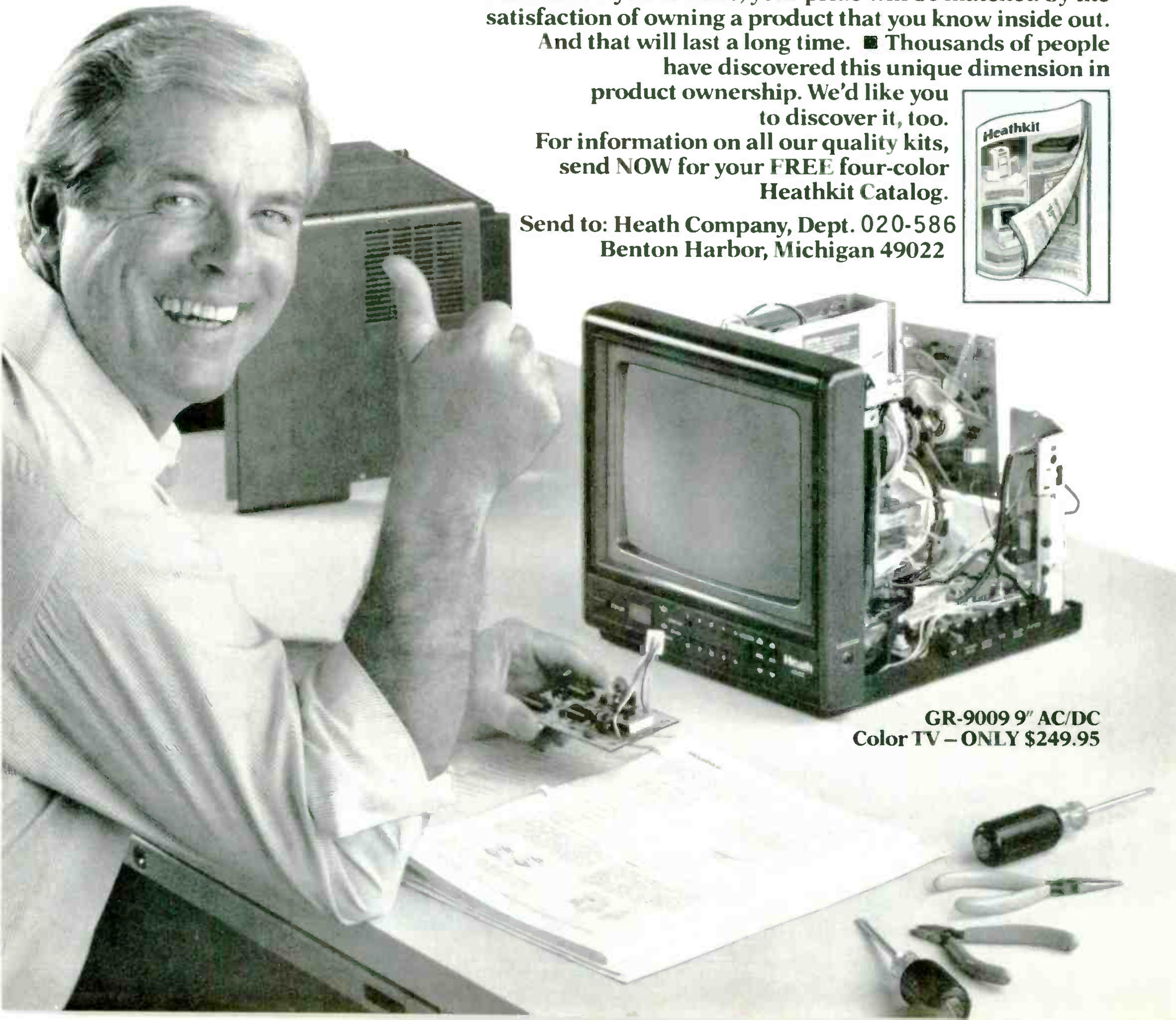

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MORE ON MOTORS

In selecting questions for this column, we try to choose those that will interest the greatest number of readers and provide what we feel is the most practical answer when there may be two or more possible solutions to a problem. At times we consult professionals and experts before preparing a reply; but, unfortunately, the expertise of experts and professionals is often governed by their experience and familiarity with the question, and recently we got some "not-so-expert" opinions. So...we apologize for the less-than-expert replies to a couple of inquiries and will now try and set the record straight.

In an early inquiry on reversing electric motors, we pointed out that there are many types of motors and suggested that the reader take the motor to a motor repair shop and have a technician install a reversing switch. In a follow-up on the question (See "Ask R-E" in the April 1987 issue), we mentioned the possibility of reversing a motor by shifting the pole and field coil assemblies to the opposite sides of the brush-holder center-line.

Reader Edward T. Smith, of Brogue, PA adds that a simpler and more practical solution is to switch the leads connected to the brush holders. Interchanging those leads reverses the current through the armature, so the torque and the direction of rotation are also reversed.

Now for what we hope will be the final word on the subject of reversing motors:

Single-phase, split-phase motors have a main winding fed directly from the AC powerline and an auxiliary winding that is fed a current that is out of phase with that in the main winding. The two windings may be electrically equal. In this case, the phase shift is generally produced by an inductor or a capacitor in series with the auxiliary winding. The usual single-phase, split-phase motor can be reversed by reversing the connections to either the auxiliary winding or the main stator winding.

In the single-phase capacitor motor (Fig. 1-*a*), the main and auxiliary windings are electrically similar. One winding is fed directly from the AC powerline and the other is fed through the capacitor. The position of the switch selects between the forward and reverse directions of rotation by switching the series capacitor from one winding to the other.

In some split-phase motors, the "start" winding has many turns of fine gauge wire; the "run" winding has fewer turns of a much heavier gauge wire. The phase difference in the magnetic fields causes the armature to rotate. The motor easily is reversed by reversing the connections to one of the windings.

In the capacitor-start motor (Fig. 1-*b*), the main or "run" winding is directly across the AC powerline and the auxiliary or "start" winding is fed through a capacitor and centrifugal switch that opens when the motor comes up to speed. For forward rotation, the start winding, switch, and the capacitor are in a series string from the midpoint of the main winding to one side of the powerline. For reverse operation, the switch returns the start-winding assembly to the other side of the powerline.

The shaded-pole induction motor (Fig. 1-*c*) is usually a low-torque low-speed type used for

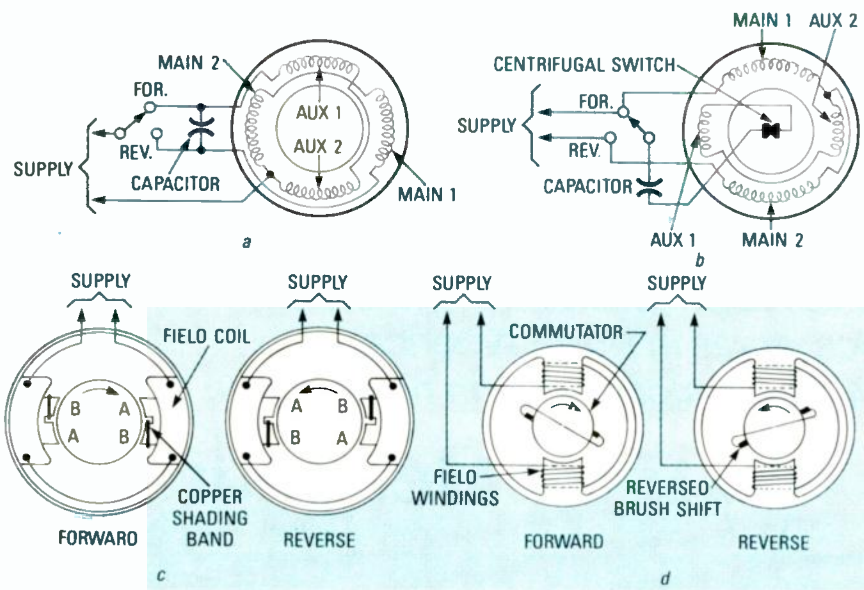

FIG. 1

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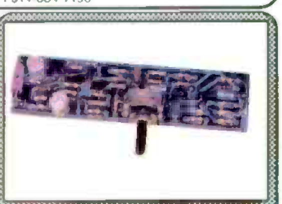

TSM 9 $14.00
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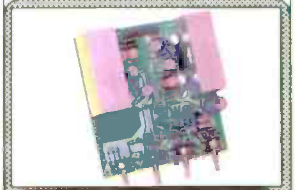

TSM 67 $39.74
STEREO AMPLIFIER 2X40W PEAK POWER SENSITIVITY INPUT 47K/300mV, OUTPUT 2.5/8Ω. VOLUME, BALANCE, BASS, TREBLE, CONTROLS, POWER SUPPLY 12V D.C. 3/4 A.

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TSM 68 $22.66
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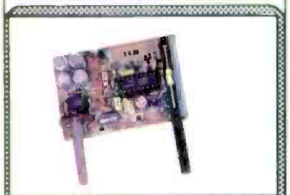

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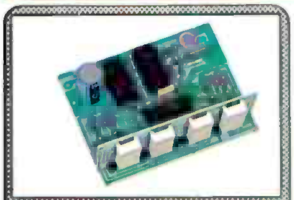

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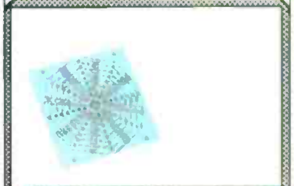

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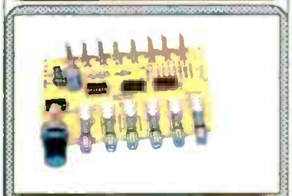

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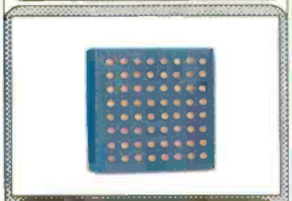

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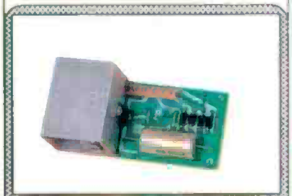

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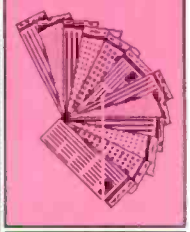

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- OD 860mm, I 094mm, A 198mm — Transfert sheet $2.00 each
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pumps and fans. Power generally ranges from around ⅓ to 1/30 horsepower. It has copper bands short-circuiting or "shading" a portion of each pole face. The magnetic flux "peaks" first in the unshaded portion, then it peaks in the shaded portion; the electrical effect being a rotation from the unshaded to the shaded pole piece. The motion of the rotor follows the rotating field.

Reversing a shaded-pole motor is generally a mechanical operation. Rotate the wound stator-coil assembly 180° in the case or turn it end-for-end with respect to the rotor. Special types of shaded-pole motors have been designed so as to be electrically reversible; they can usually be identified by instructions on a plate affixed to the motor's case.

The basic repulsion-induction motor (Fig. 1-*d*) has a slotted armature with windings connected to a commutator. The brushes are connected together and the armature is excited by pulsating currents in the stator winding. That type of motor is reversed by rotating the set of brushes through a small angle around the armature centerline. The brush positions for forward and reverse directions of rotation may be marked on the motor's frame; another technique might be to limit the brush positions using stops.

RHOMBIC ANTENNA IMPEDANCE

In the "Ask R-E" column of August 1986 you supplied information for a matching section for the 600-ohm impedance of a VHF rhombic antenna. Now, the article "Rhomboids for TV reception" (May 1957, page 86) gives the impedance of a rhombic antenna as 800 ohms. That figure is also given in the *The ARRL Antenna Book*. Why the discrepancy?—H.L.E., Cedar Rapids, IA.

A number of factors enter into the design of a rhombic antenna: tilt angle, antenna height, and the length of each leg. The *maximum output* design gives maximum radiation of signals in a desired direction and maximum response to signals arriving from that direction. Other designs are used to meet special conditions where height, leg length, or tilt angle may be dictated by local conditions. Of course, all variations in design can have an effect on the antenna's input impedance.

When a conventional single-wire rhombic is used over a 3:1 frequency range, its input impedance ranges from a maximum of about 830 ohms to a minimum of 700 ohms. When used over a frequency range of 4:1, the input impedance drops to a minimum of 580 ohms. In some authoritative references, we find:

"The transmission line can sometimes be designed to have a characteristic impedance the same as...the (rhombic) antenna input resistance, or vice versa in some cases. A 600-ohm two-wire balanced feeder gives a line of reasonable cross-section, but becomes less reasonable for higher (line) impedances. For this reason, rhombic antenna and feeder are designed for a value of 600 ohms for a majority of applications."—Jasik's *Antenna Engineering Handbook*.

"If the broad frequency characteristics of the rhombic antenna are to be fully utilized, the feeder system used with it must be similarly broad. This practically dictates the use of a transmission line of the same characteristic impedance as that shown at the antenna input terminals, or approximately 750–800 ohms. The spacing required for an 800-ohm line is rather awkward, also, rather small wire must be used. Both these considerations are disadvantageous mechanically, and the radiation from the line tends to be comparatively high at frequencies, because of the wide spacing. On the whole, the best plan is to connect a 600-ohm line directly to the antenna and accept the small mismatch which results."—*Antennas and Antenna Systems,* War Department Technical Manual TM 11-314.

"A 600-ohm line connected to the antenna feedpoint is perhaps the most convenient means of feeding the antenna."—*Antenna Systems,* Air Force Manual 52-19.

One thing that is often overlooked is that at frequencies where the rhombic's input impedance is 800 ohms and the feedline impedance is 600 ohms, the standing-wave ratio is a low 1.33 to 1, and the line loss compared to a perfect match will be negligible. R-E

LETTERS

SCA ERRORS

In the article, "Build This SCA Receiver," in the August 1987 issue of **Radio-Electronics**, the Parts List has R42 at 22K and R37 and R38 at 10K. The schematic has R42 at 4.7K and doesn't show R37 and R38 at all. They appear to be in series with pin 13 of IC1. The Parts List also says that C27 is not used, while the schematic shows that it is in the line between Q2 and Q6.

G. L. McDONALD
Auburn, WA

Resistors R37 and R38 are 10K units; as you surmised, those are the unmarked resistors at pin 13 of IC1. Resistor R42 is 4.7K, as shown in the schematic; the Parts List is incorrect. Also, capacitor C27 is a 0.01-μF ceramic disc as shown in the schematic.

In addition, a ground symbol is missing in the schematic; it should be added at the junction of R23, R25, and C21.

Finally, if you have trouble finding the National LM3189N used for IC1, an RCA CA3189E or CA3089E can be used in its place; the latter one should be the easiest to find.
—Rudolf Graf and William Sheets

MORE ON SCA

I enjoyed "Build this SCA Receiver"in the August 1987 issue very much. I want to use the unit to receive data for input into my computer, as mentioned on page 41. Some of those transmissions are at 19.2 kilobaud, so the SCA audio bandwidth must be high enough to not distort the transmission waveform.

The article states,"SCA is not a high fidelity service; its audio-response bandwidth is limited to about 5000 Hz." Is that an FCC limitation, or an arbitrary one to eliminate noise? I'm concerned that the 12-dB-per-octave low-pass filter on the output of the LM565 (R56/C45-R57/C46) will cause waveform distortion of any digital-data transmission.

If there is an FCC restriction, the bandwidth will be limited at the transmitter, and I don't have to worry. I do want to receive the signal exactly as transmitted, however.

What is the FCC bandwidth restriction on SCA transmissions? And what component value changes, if any, are necessary to receive digital-data exactly as transmitted, without waveform distortion caused by a restricted bandwidth?

I believe the authors were wrong in their statement. "The signals are FM with ± 7.5 kHz deviation *maximum*." According to the FCC's December 1984 amendment, section 73.319 (d)(2), for stereo FM plus an SCA and nothing else (the most common SCA situation) the following applies:

"During stereophonic program transmissions, modulation of the carrier by the arithmetic sum of all subcarriers may not exceed 20% referenced to 75 kHz modulation deviation..."

The maximum used to be 10 % (7.7 kHz) but now it's 20 percent (15 kHz)—and 30 percent for monaural and SCA-only transmissions. That error brings up a possible design error in the SCA receiver's circuit. If the designer's thought the maximum allowable deviation was noticeably less than what actually might be encountered, might the circuit distort more than it was designed for when it gets a true max-

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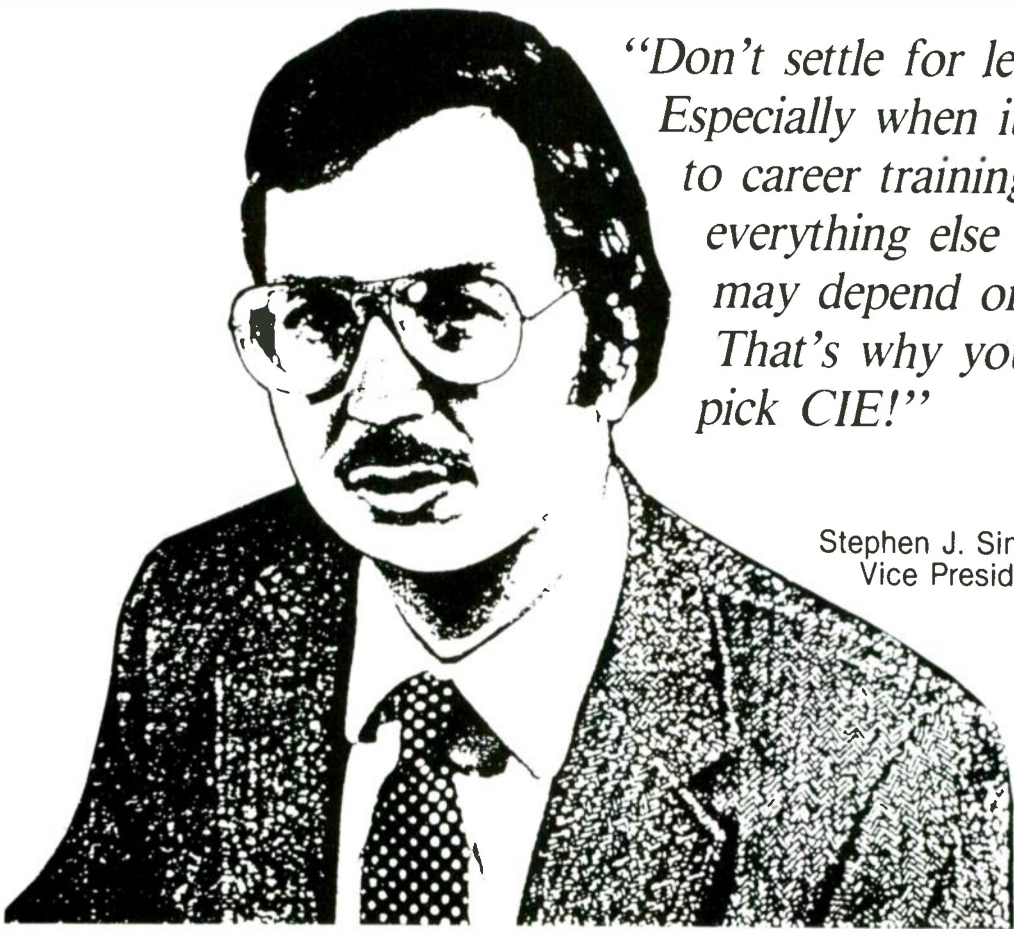

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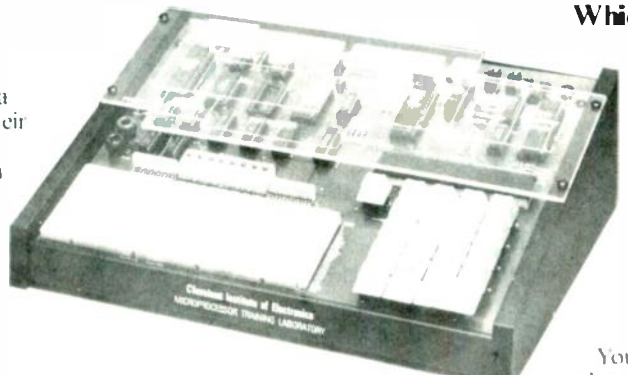

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imum signal? The output of LM565 and 2N3565 are the two possible overload points. What deviation was the circuit designed for, and what component changes are necessary for the true maximum possible SCA signal levels? Also, do you know where I could get a list of stations with SCA digital data transmissions?

I look forward to using the SCA receiver.

PETER SKYE
Glendale, CA

We were not aware of the change in the FCC rule when we wrote the article. Our object was to receive SCA music and speech transmission. The 565 PLL will lock and follow any signal up to ±60% of the design frequency depending on external components. We refer you to National Semiconductor's LM565 data sheets for more details.

The circuit was designed to handle the ±10% deviation (7.5 kHz). It does better than that on the bench, but we can not guarantee that you, too, will receive better performance.

If you find that the lowpass filter distorts the waveform, you can try removing it. However, you may find that that results in unacceptable noise levels. In that event, try experimenting with smaller levels of filtering.—Rudolf Graf and William Sheets

COMPUTER FLEA MARKET

There will be 80 sellers of hardware, software, printers, disk drives, supplies, books, and more at the Computer & Hi-Tech Flea Market on Saturday, November 21, 1987. It will be held at the Veterans Memorial Building, 4117 Overland Avenue, Culver City, CA from 10 AM to 5 PM. There will be ample free parking, and the admission charge is $2.00.

For those wishing to set up and sell at the fair, information can be obtained by calling (213) 276-1577.

MICHAEL J. FLAHERTY
303 North La Peer Drive
Beverly Hills, CA 90211

R-E ROBOT

I was disappointed to see that Clifford King was not credited as the co-author of the article on the RCL Robot Command Language ("R-E Robot," August 1987). Mr. King designed and wrote the RCL, then wrote the article describing it. I offered only general guidance in terms of the purpose of the program and the overall direction of the article. Without Cliff King's consulting group's—Micro-K Systems—offer of software support at the inception of the robot project, I doubt if I would have started the project at all.

As you know, it's not the hardware that is the bottleneck in the design and utilization of robots. It is the software. The RCL that Micro-K developed took over 4 man-months of solid effort and the results are outstanding.

Thank you for correcting the oversight and printing this information.

STEVEN E. SARNS
Vesta Technology Inc.

continued on page 25

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&				
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EQUIPMENT REPORTS

Mondo-Tronics Space Wings Robotics Kit

New wing-flapping technology

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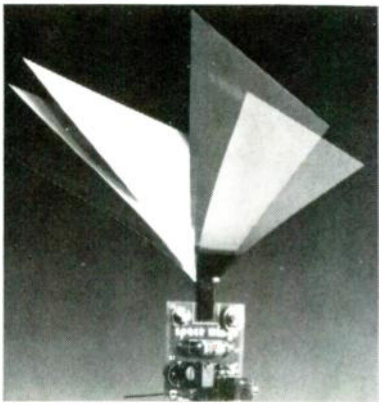

ROBOTICS IS A DIFFICULT HOBBY TO GET started in because it requires a knowledge of so many disciplines ranging from electronics to mechanics. Beginners to the hobby are often discouraged because building even a simple moving robot can be a complex project. We recently found, however, what might be the world's simplest robot project—*Space Wings* from Mondo-Tronics (20090 Rodrigues Avenue #I, Cupertino, CA 95014).

Calling *Space Wings* a robotics project might be stretching the truth a little bit. Usually we would consider a pair of wings that flap a dozen times or so per minute more of a novelty item than a robot. But this kit is worth mentioning because of its use of *BioMetal* wire.

Shape-memory alloys

BioMetal wire is an alloy of titanium and nickel that contracts when an electrical current passes through it. In some ways, it is very much like a human muscle. We have seen demonstrations of robotic arms using *BioMetal* wire, whose movements seem eerily human-like. The nickel-titanium alloy of which *BioMetal* is made is known as a *shape-memory alloy*. Such alloys undergo a reversible change in their crystal structure at certain temperatures.

BioMetal is different from other, similar alloys in that it has a more uniform crystal structure. That helps to make its behavior more consistent and predictable and makes its usable lifetime much longer. More important, the uniform structure makes electrical heating of the wire practical because "hot spots" don't develop. For more information on *BioMetal*, contact its manufacturer, Toki America Technologies, Inc. (18662 MacArthur Boulevard, Suite 200, Irvine, CA 92715).

Building the kit

Space Wings uses *BioMetal* wire to move a pair of Mylar wings. A 555-timer circuit controls the current through the wire. Each time current flows, the wire contracts and pulls down the "V" where the wings meet. The kit is very easy to build. After all, the entire circuit consists of the 555 timer IC, two resistors, a capacitor, a transistor, some hardware, and, of course, the *BioMetal* wire. The simplicity, however is a disadvantage in this case. The instructions recommend the use of a 3-volt, 200-mA transformer that is available at Radio Shack, and notes that "higher current outputs can adversely affect the performance" of the kit "and reduce its operating lifetime." We think it would have made sense to include current limiting on the board.

In conclusion, *Space Wings* makes an interesting conversation piece. It also gives you a chance to play with shape-memory alloy wire. Since education is its only real practical use, we feel the company should have done a better job at it. All that is included on the properties of the wire—the most exciting part of the kit—is a list of specifications that are not explained. Also, although the building instructions are clear and concise, there is no circuit explanation. That's inexcusable. Despite those complaints, we still liked *Space Wings*, and its $19.95 price. **R-E**

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CIRCLE 71 ON FREE INFORMATION CARD

continued from page 20

CAR RADIOS

I finished building the converter described in "New Life for Old Car Radios" (**Radio-Electronics,** June 1987), but found it lacking. However, I noted great improvement after I tied the bottom of L2/C1 to ground and eliminated C3. There's no cost in giving that a try, especially if you are using a variable capacitor (C1) that has the rotor connected to the chassis after mounting.

Thanks for a great magazine and projects such as that one. They're greatly appreciated.

I. GRISWOLD
Douglas, AZ

FLIP-FLOPS

I enjoyed your article, "Working with Flip-Flops," in the June 1987 issue of **Radio-Electronics.** I am a graduate of a technical school (digital and microprocessor technician), and have accumulated a good selection of books on digital electronics. I found that article to be the most comprehensive treatment of the topic that I have seen, and very enlightening. I'm sure there are many other **Radio-Electronics** readers who have had very intensive courses in electronics, or who are making the transition from analog to digital, who find areas in their understanding of the basics a bit sketchy.

May I offer a suggestion? I would like to see Ray Marston do an article, or a series of articles, on switching techniques used in digital circuits. He might start with the use of pull-up and pull-down resistors and continue with transistor push-pull configurations and three-state devices to explain how highs, lows, and pulses may be applied in digital circuitry. It could be accompanied by schematics of typical circuitry currently used, for example, in microprocessor applications.

Thank you for the fine articles I receive each month; **Radio-Electronics** continues to be the biggest bargain in my bookcase.

ED JOHNS
West Topsham, VT

R-E

New Products

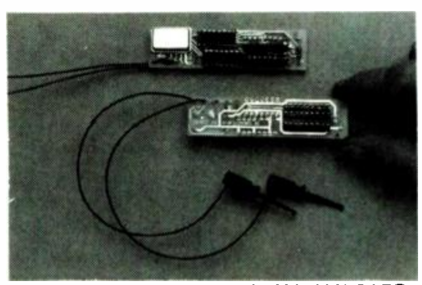
CIRCLE 10 ON FREE INFORMATION CARD

ELECTRONIC STILL CAMERA. The model *VS-101*, is capable of recording images and playing them back on a standard TV set. It requires no chemical processing for development and printing, but records to and plays back from special magnetic disks (video floppies) for viewing of photographs immediately after they are taken.

The camera weighs only 2.1 pounds, and has a high-resolution auto-exposure system with lock function. It can operate at a high speed, up to five frames per second. Up to 50 frames for recording/playback are possible on a single floppy disk; a built-in erase function permits multiple reuse of the disk.

The model *VS-101* has a suggested retail price of under $1000.00.—**Casio, Inc.,** 15 Gardner Road, Fairfield, NJ 07006.

ACCELERATOR BOARD, the *PC-BANDIT*, is designed for the IBM PC, PC-XT, and PC compatibles. It



CIRCLE 11 ON FREE INFORMATION CARD

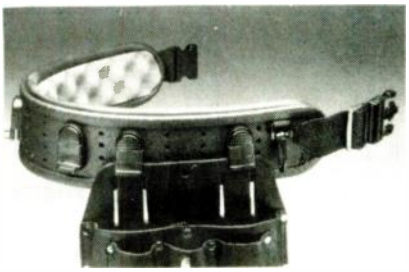
requires no expansion slot; the *PC-BANDIT* uses the computer's current 8284 clock IC position, and provides additional clocks with its own clock IC. The user then connects two leads from the *PC-BANDIT* board: one to the DMA chip to retain proper DMA function, and the other lead to the motherboard to provide speed selection.

Instead of an externally-mounted switch box, the board uses software to toggle between speeds, and is compatible with certain

BIOS hot-key sequences. That makes it easy to choose between the accelerated rate or the standard 4.77-MHz speed of the 8088 CPU. No other utilities are necessary for the board to function properly.

Depending on the application, *PC-BANDIT* boosts the PC's processing speed as much as 60 percent. It is priced at $69.95.—**Prism Electronics, Inc.,** 14682 NE 95th Street, Redmond, WA 98052.

EQUIPMENT BELT, the *Transporter 2000*, is designed for comfort by allowing its load to be evenly distributed around the entire waist of the body, and transfers that weight to the bone structure.

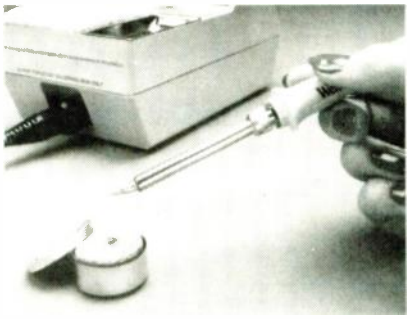


CIRCLE 12 ON FREE INFORMATION CARD

In addition to the comfort of the convoluted foam interior and the anti-slip moulding, the belt uses clip buckles that accommodate practically any kind of tool bag or other equipment-holding apparatus

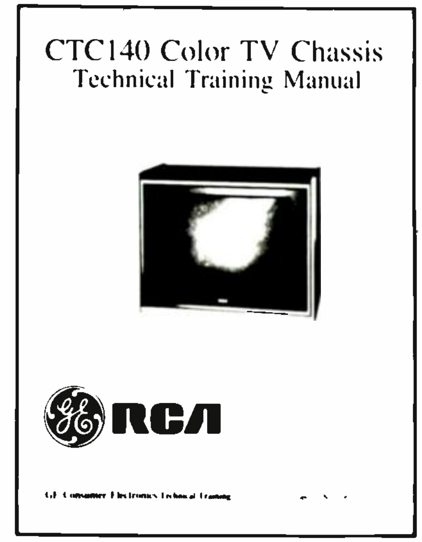
The *Transporter 2000* is priced at $49.95.— **Transport Technics,** 8909 Complex Drive, #F, San Diego, CA 92123.

TINNER/CLEANER, the *TTC1*, is a device for cleaning and re-tinning soldering iron tips. The tinner/cleaner is a small block of electronics-grade solder powder and chemicals compacted into the



CIRCLE 13 ON FREE INFORMATION CARD

You are only one manual away from knowing how the new technology in RCA's CTC 140 color TV chassis operates and how to service it!



Some servicers were expecting tomorrow's high-tech color TV chassis to have a lot of technician-obsoleting, expensive black boxes . . . The CTC 140 is a high-tech color TV chassis, but it doesn't have any black boxes. It is a state-of-the-art unitized chassis with advanced technology that can be easily and economically serviced by professional consumer electronic technicians . . . As a professional technician you need to learn how the new technology in the CTC 140 operates and what strategies we recommend you use to proficiently service it. That's why you should buy and carefully read the CTC 140 Color TV Chassis Technical Training Manual. Its price of $19.95 is an excellent investment in professional upgrading . . . And to make the learning easier, we've included the companion Technical Training Workbook content at no extra charge. You get both the manual and the workbook information in one manual for only $19.95.

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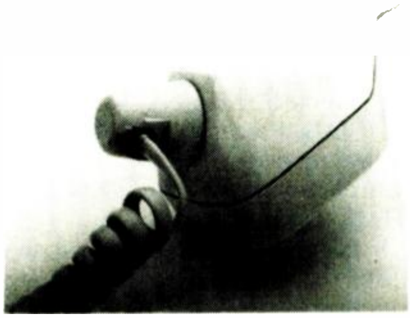
shape of a thick disc. It is packaged in a metal container complete with lid and self-adhesive pad on the underside, so that it can easily be attached to any convenient surface.

A single wipe of the iron tip across the *TTC1* block immediately cleans, wets, and tins the tip. It will remove even tin/iron intermetallic layers that form on iron plated tips and resists rosin-based fluxes. The chemicals it contains are non-corrosive and have a low evaporation point, so that nothing except solder remains on the tip after tinning.

TTC1 blocks are supplied in cartons of ten; the price is $3.95 each.—**Multicore Solders,** Cantiague Rock Road, Westbury, NY 11590.

TELEPHONE ACCESSORY, the *TWISSTOP,* is a modular telephone-cord rotary connector. It allows the telephone handset to rotate freely without twising the cord. Installation is simple. *TWISSTOP* clips quickly and easily into the standard modular telephone-handset jack.



CIRCLE 14 ON FREE INFORMATION CARD

TWISSTOP is available in a variety of colors, including almond, white, black, and clear, and can be imprinted with a logo or message; it is priced at $5.95.—**Telcor, Inc.,** 88 Hillside Road, Chester, NJ 07930.

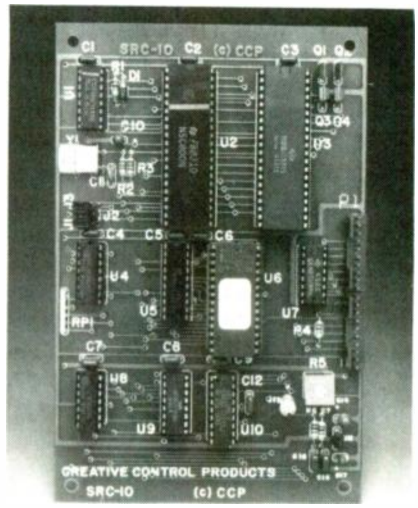
PRINTER BUFFER BOXES. The model *BX-64,* the model *BX-128,* and the model *BX-256,* are capable of storing up to 256K bytes of data for printing.

The model *BX-64* buffers up to 64K of data; the model *BX-128* buffers up to 128K of data, and the model *BX-256* buffers to 256K of data. All three boxes are microprocessor-controlled printer-buffers/interface-converters, which accept data at very high rates from a host of computers and simultaneously feed that data to your printer at the printer's slower data-acceptance rate. The host computer is then free to process other data during printing, because the data transfer to the buffer box is accomplished very rapidly.

CIRCLE 15 ON FREE INFORMATION CARD

The suggested retail price for the model *BX-64* is $169.95; the model *BX-128* costs $209.95, and the model *BX-256* sells for $259.95.—**Chenesko Products, Inc.**, 21 Maple Street, Centereach, NY 11720.

REPEATER CONTROL BOARD, the model *SRC-10*, is a smart, low-cost, low-power, self-contained microprocessor-based repeater controller. All repeater functions have been incorporated onto a 4" × 6" G-10 glass-epoxy PC board.



CIRCLE 16 ON FREE INFORMATION CARD

The model *SRC-10* controller provides up to 7 buffered auxiliary function-control outputs, which are selected remotely via a three-digit DTMF command. The controller responds with a function-complete tone after each valid DTMF command.

In addition to the function-complete tones, there are auxiliary-function tone responses to indicate an ON or OFF condition. Courtesy-tone responses are also available to indicate repeater or link COS activity. There is a lock command: When it is selected, the controller ignores all DTMF commands until the unlock command is received. That is effective against jammers.

With the optional model *PI-10/S* synthesizer board, the frequency and offsets of the link radio can be programmed remotely. After the frequency and offset is sent in serial format from the controller, it is converted into parallel outputs to interface with the link radio's frequency synthesizer. A read-back command can be used to verify the link frequency.

The model *SRC-10* with manual is priced at $149.00. The optional model *PI-10/S* synthesizer board costs $39.00.—**Creative Control Products**, 31285 Bunting Avenue, Grand Junction, CO 81504.

COMMUNICATIONS CORNER

Light makes the perfect wire.

HERB FRIEDMAN,
COMMUNICATIONS EDITOR

YEARS AGO, BECAUSE ONLY A HANDFUL of circuits were needed to design almost all communications equipment, there was a logical progression to electronics technology, and it was possible to make an accurate guess as to what would come next. Today, the field of electronics is so fragmented that, more often than not, a manufacturer has no idea what's being developed by a competitor around the block. More important, the competition might be leapfrogging what is otherwise accepted as the leading edge of technology, and suddenly an entire technology becomes obsolete. It's as if someone had already perfected a 20-meter SSB (*S*ingle *S*ide*B*and) transceiver and the beam antenna while Marconi was still waiting to hear the spark signal from his transmitter located in England.

Just such a leapfrogging situation is happening today to the development of a national consumer communications network. Recently, there has been much ado about such a network in which the same wires used for the telephone would also provide digital access to a wide variety of services, such as on-line information and database, cable and pay-per-view TV, hi-fi stereo music, school-at-

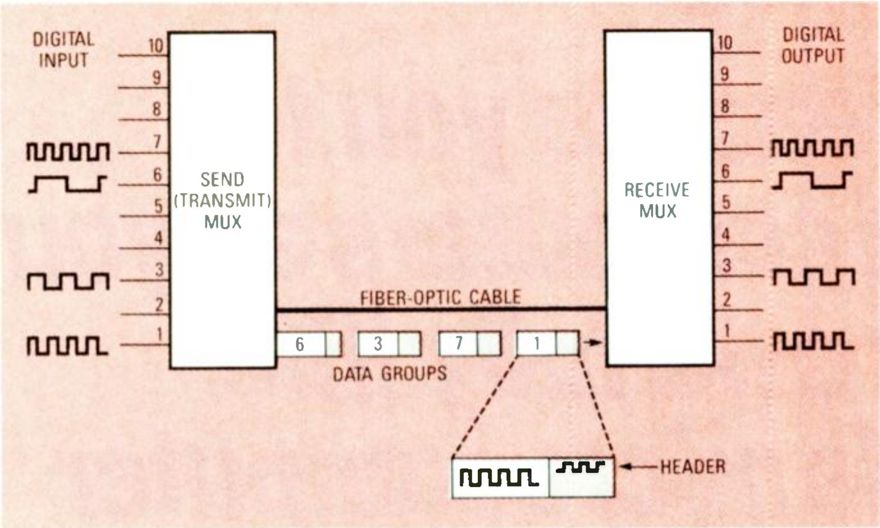


FIG. 1

home, picturephone, dial-up computer-to-computer communications, and just about anything else that's imaginable.

A multi-mode world of home-and-office communications is possible because we can now easily digitize any kind of signal—voice, music, TV, the printed word—and anything that's digitized can be sent down a line and restored to its original form or structure at the receiving end. The only problem with the idea is that many of the people doing the high-tech work in digitizing signals are talking in terms of metallic-wire lines—existing telephone and cable-TV wiring. In my view, putting digitized signals on a metallic-wired system is like putting spoilers on an underpowered sports car. It will look great, and it might be fun to drive, but it won't be a better car.

Fiber optics

In the world of modern communications systems we rarely talk in terms of metallic wires; rather, the term "wiring," if used at all, refers to fiber optics. Not esoteric fiber systems that connect cities with other cities or teleports, but a stretch of fiber filament from one office to another perhaps fifty feet away, or from home to the telephone switching center.

All other considerations aside, a major advantage of fiber-optic communications is speed. For example, a conventional fiber-optic office system that is presently available from AT&T will easily handle data communications at 200 megabits per second. You're not going to do that with conventional wires, and that's the cheap system. Even higher speeds, to 1 gigabit/sec, are possible by using laser transmitters.

But why would you, or anyone else, want so high a data rate for conventional use? Because the faster we can push data through a line the greater the number of signals that can be multiplexed. Ignoring the overhead loss—the bits needed to encode the individual digital signals—ten different 20-megabit signals could be sent through a 200-megabit system, and even 20 megabits is unusually fast for consumer applications.

How it's done

Figure 1 shows a simplified fiber-optic communications system. On the left we have a sending (transmit) MUX; MUX is shorthand for several terms having to do with multiplexing, such as *multiplex* and *multiplexer*. On the right we have a receiving MUX, which separates the signals and also restores the bits and pieces of a MUXed signal to the form it was n when it was input to the sending MUX—its original digital form.

The sending MUX looks at the incoming lines in order and strips off a single data block, or whatever data or bit group that it's designed for. The MUX affixes a header (digital code) representing a specific data source to the front of the block. (Line 1 has its own header, Line 2 its own, etc.) The transmit

continued on page 103

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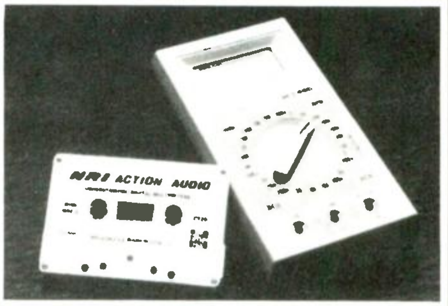

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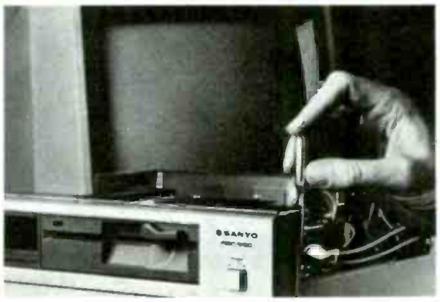


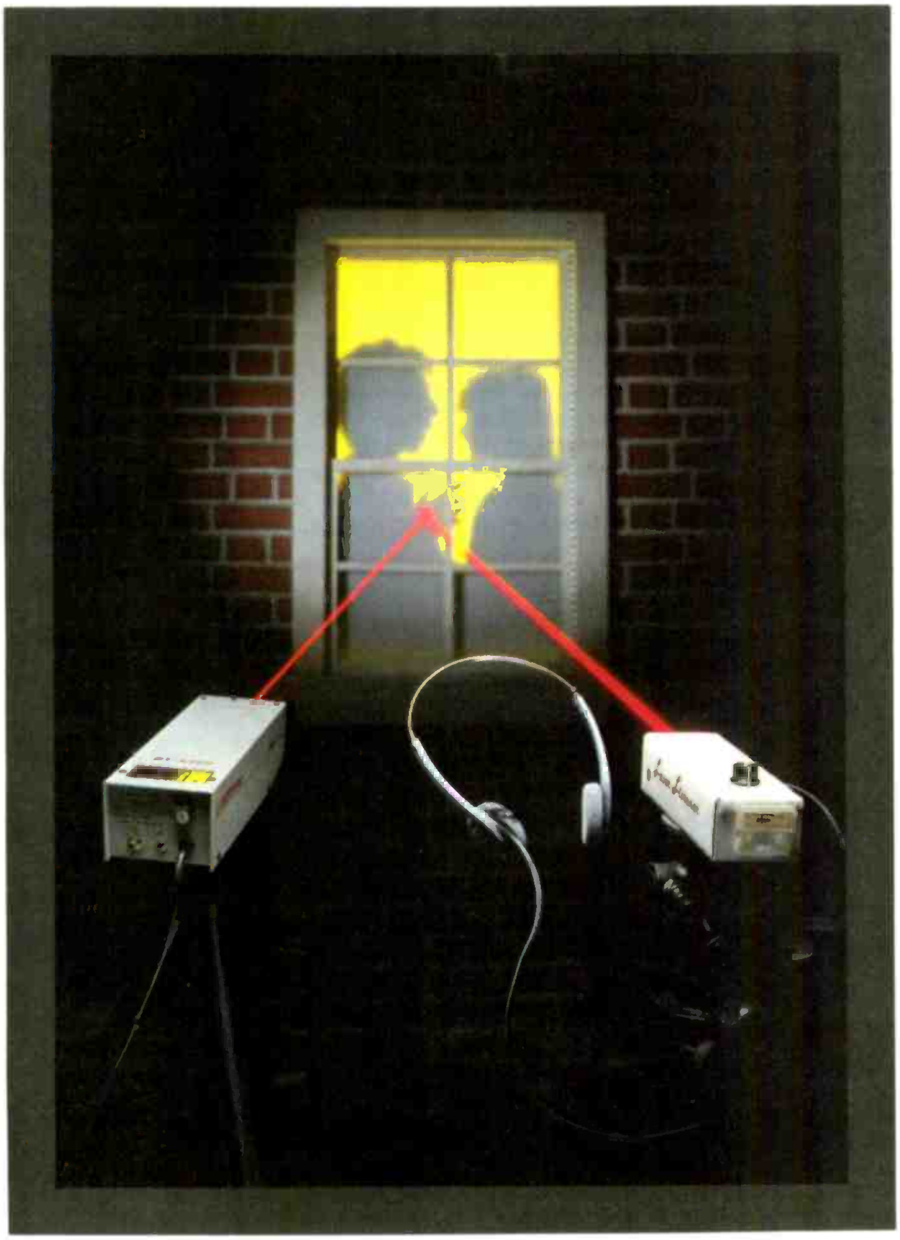
Next, you install the disk drive. You learn disk drive operation and adjustment, make a copy of MS-DOS operating disk and begin your exploration of the 8088 CPU.

Using the monitor, you focus on machine language programming, an indispensable troubleshooting tool for the technician. You continue by learning BASIC language programming.

LASER LISTENER

Use a light beam to listen in to anything, anywhere, any time.

RICHARD L. PEARSON



BREAKING AND ENTERING TO PLANT A LISTENING device is one way to "bug" a room. Unfortunately, it can earn someone a long jail term too. A better and safer way to bug a room is to use a laser beam to eavesdrop on a window from across the street.

The sound waves generated by nearby conversation will cause the glass in a window to vibrate very slightly. If a laser beam is bounced off the window, its reflection will be modulated by the vibrations. All that's needed to hear what is being said is a demodulating device that extracts the audio from the reflected laser beam. That technique is used by sophisticated "surveillance experts," but you can easily duplicate that feat by using a hobbyist's laser and the inexpensive Laser Listener demodulator shown in Fig. 1. If you need something a little more sophisticated, it can be made part of the riflescope aimed laser-bug system that is shown in Fig. 2.

Early light-wave communications

Communication using a modulated beam of light isn't a new idea. In the 1880's, Alexander Graham Bell experimented with something he called a *photophone*: a device that modulated a beam of sunlight. It had a mouthpiece that concentrated sound energy on a reflecting diaphragm, which, in turn, modulated a beam of sunlight that was aimed at the diaphragm. When a remote receiver con-

WARNING

Extra precautions must be taken because of a laser beam's intense concentrated energy. Among other factors, the hazards presented depend on the power density, the frequency of the beam, and the time of exposure. Guidelines have established the classification of lasers. A brief description of the classification is as follows:

Class I: Low-power beam. Not known to produce any biological injuries to the eye or skin,

Class II: Reserved for visible-light lasers only. They are limited to less than 1-milliwatt output. Eye damage will result if stared into for longer than 1 second. The normal blink response of the human eye will provide protection. Eye damage will occur if the beam is viewed directly by optical instruments. Direct (specular) reflection, as from a mirror, should be considered to be the direct beam. Diffuse reflection of the light may be viewed.

Class III: Instantaneous eye damage will occur if exposed to the direct beam.

Class IV: Both direct exposure or direct and diffuse reflections will produce eye damage. Exposure of the skin to the beam is hazardous. The beam is considered to be a fire hazard.

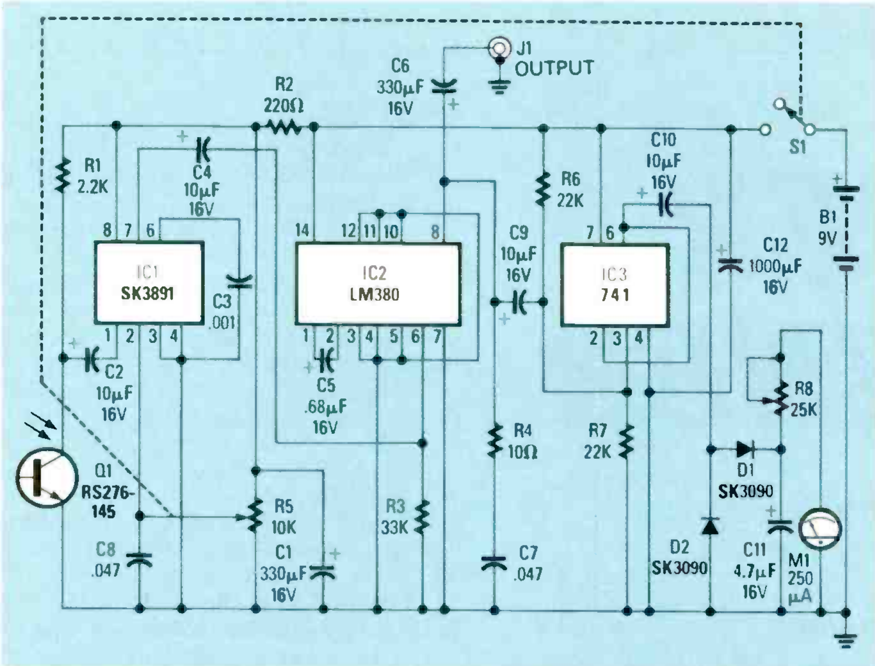


FIG. 1—THE LASER RECEIVER has extremely high gain, so be sure to keep the wiring of Q1 and IC1 separated from IC2's output and the connections to J1.

sisting of a photovoltaic cell and a sensitive earphone was positioned in the beam, the voice could be heard clearly from the receiver. The aiming problems presented by the movement of the sun, and the interruptions due to clouds and night, probably prevented the commercial exploitation of the device.

But by using coherent light—such as that produced by a continuous-wave laser—the principles used by Bell's device may again be applied in a meaningful way. After all, terrestrial lasers aren't influenced in any way by sunlight or clouds. And perhaps more important, unlike acoustic sound-detection devices, lasers aren't usually subject to interference originating between the sound source and the receiver.

For example, remote sound-pickup devices in the form of directional microphones have been available for many years. Unfortunately, any sound generated between the listener and the sound source usually renders the device useless because the interference is heard at the receiver, and it can be even louder than the source. On the other hand, lasers are not sensitive to sound of any kind between the source and the receiver. However, lasers may be subject to other kinds of interference: For example, AC-powered incandescent lights can produce a hum; gas discharge devices such as fluorescent, mercury, sodium vapor, and neon lights might produce a buzz; and direct sunlight might swamp the laser detector device. Also, where unusually long distances are involved, air currents can add flicker to the laser beam, which on windy days can result in a noise that is similar to that of blowing into a microphone. (But even though sensitive to some kinds of electrically-generated noise, laser-listening devices have an advantage: They can seemingly hear through walls or closed windows, and even selectively monitor only one window of a building from several hundred feet away.)

Commercially-available laser sound pickups use a laser device having an output in the infrared region. Because infrared is below the visible portion of the light spectrum, it cannot be seen by humans. However, some commercial devices have a power output rating as high as 35 milliwatts. **At such a power level there is clear potential for eye damage if someone in the target area unknowingly stares into the beam, or if the laser is operated carelessly by the user.**

Laser basics

Although the details underlying the generation of laser light are beyond the scope of this text, an understanding of some of the characteristics of a laser beam as compared to ordinary light will be helpful in assembling a laser-listener system.

Light is considered to be comprised of packages of energy particles called *photons*. However, light is also electromagnetic radiation and behaves like radio waves, although at a much higher frequency. The perceived color of visible light is determined by the radiation's wavelength, which is usually given in *micrometers* (one micrometer = 10^{-9} meters). The shorter wavelengths are perceived as violet, the longer wavelengths as red. The spectrum below the visible portion is called *infrared*; the spectrum above is called *ultraviolet*.

The light emitted by a conventional incandescent or fluorescent source contains a wide range of frequencies, and the photons are emitted randomly and spontaneously in all directions. On the other hand, in a laser light source the photons are released in one direction, at one frequency, making the laser light highly directional and pure in color. (An analogy would be to liken ordinary light to the white noise, while the laser is likened to a sinewave—a single pure tone.) Since all of the light emitted by a laser is coherent (has the same frequency), constructive or destructive interference occurs when two beams of laser light meet at the same place and time (Fig. 3).

As shown in Fig. 3-a, the beams cancel each other when out of phase (destructive interference). As shown in Fig. 3-b, the

FIG. 2—FOR LONG-RANGE USE the laser and the receiver should be combined into an integral unit so both are aimed together. The telescopic signal provides precision aiming on the target.

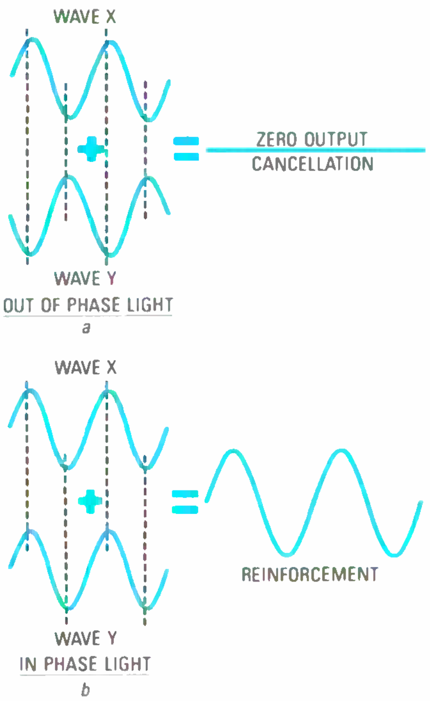


FIG. 3—SINCE LASER LIGHT IS COHERENT, reflections can both cancel and reinforce the direct beam.

beams are additive when in-phase (constructive interference). It is the interference between the beams that enables the movement of any reflecting surface to be sensed by a device called an *interferometer*. An interferometer is a beam splitter—usually a piece of partially-mirrored glass—that deflects only a small part of a beam aimed through the glass. As shown in Fig. 4, it can be used to reflect both the source and reflected laser beams so that their phasing or amplitude can be compared by a receiver.

The major problems with using interferometry for eavesdropping is that only a part of the laser's energy is directed at the target, limiting the working range, and the interferometer is sensitive to the diffusion of the sound target's reflections caused by tremors in the mountings of the interferometer, the laser, and the reflective target. For super-snooping, a direct reflection from the target is preferred because the collimated nature (parallelism) of laser light also allows modulation of the beam to occur just as Bell's photo-phone modulated the sunlight.

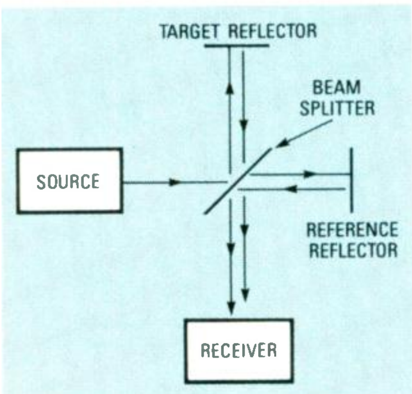


FIG. 4—AN INTERFEROMETER DIVERTS part of the laser to the target. Its chief advantage is that it can sense any kind of movement at all four points: the source, the reflector, the target, and the receiver.

The prototype's laser

Regardless how we choose to eavesdrop, we must start out with a laser, so we'll cover the prototype laser-bug's laser unit first. It's a Heathkit model *ETS-4200* Laser Trainer, a Helium Neon (HeNe) unit having an output power of 0.9 milliwatts. It has a beam divergence of 1.64 milliradians, which produces a spot of light 1½-inches in diameter at 200 feet. Although 0.9 milliwatts doesn't appear to be much power, **it can cause extreme eye damage if allowed to shine or be reflected directly into the eye, or if viewed directly through any optical device such as a telescope, binocular, etc. The beam may be safely viewed only if projected onto a non-reflective surface such as a white sheet of paper.**

If you want to keep costs at rock-bottom, or just want the excitement of a complete home-brew project, another alternative is to assemble the helium-neon laser shown in the June 1986 issue of **Radio-Electronics**. Also, if you want to build a laser from your own design, helium-neon tubes are often available from "surplus" distributors.

The receiver

The Laser Listener's receiver is relatively easy to build and adjust. It is designed to drive a 4–20-ohm headphone or speaker, which permits just about any high-fidelity or Walkman-type headphone to be used for monitoring. The circuit shown in Fig. 1, uses a photo transistor (Q1) for a sensor, and has a meter (M1) that indicates the relative signal strength of the reflected laser beam. Because the meter responds only to the amplitude modulation of the reflected laser beam, it is unaffected by ambient light and the relative intensity of the laser beam. An adjustable polarizing light filter can be installed in front of Q1 to avoid swamping of the phototransistor by very high ambient light.

Phototransistor Q1 is an inexpensive type usually called an *IR detector*, which means that it is specifically sensitive to infrared light. Tests comparing the unit specified in the parts list with other less readily-available and more-expensive devices show no measurable differences in performance in the prototype receiver. No base connection is used for Q1 because the reflected laser light controls the collector current. The audio signal developed across collector load-resistor R1 is coupled by C2 to voltage-controlled attenuator IC1, which has a greater than 30-dB gain variation; It serves as both a preamplifier and as an electronic volume control.

Resistor R2 and capacitor C1 decouple (filter) the power supply voltage to Q1 and IC1. Be sure to take extreme care not to eliminate or accidentally bypass the filter because that will cause unstable operation. The gain of Q1 and IC1 is too great to permit non-decoupled operation from the power supply.

The output from IC1 is fed through C4

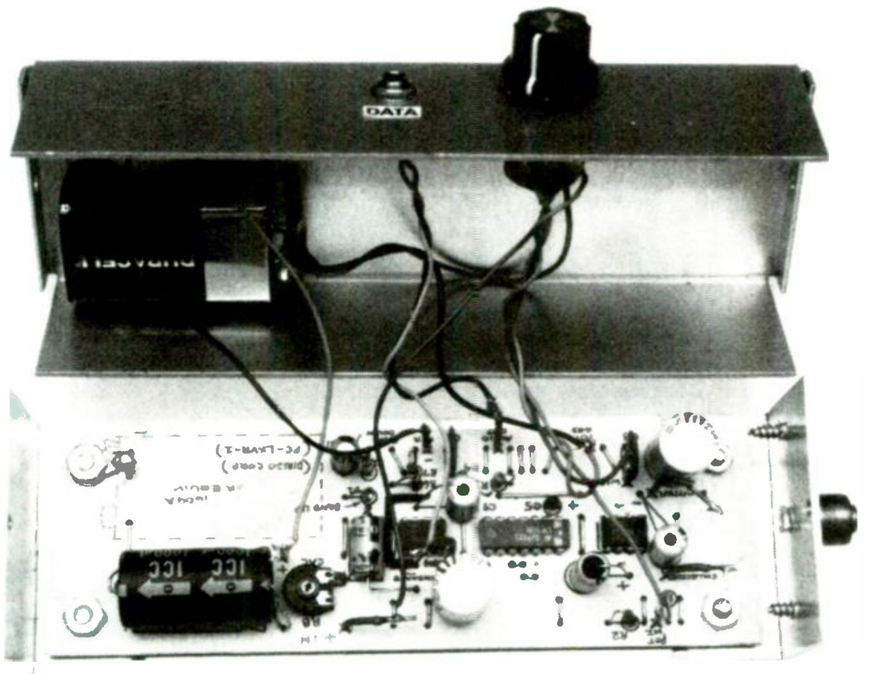


FIG. 5—A COMPONENT-POSITION TEMPLATE cemented to the pre-drilled PC board will simplify assembly.

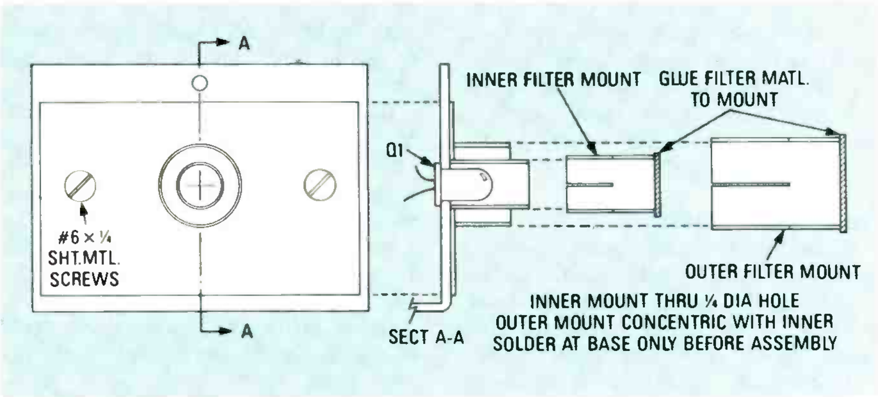


FIG. 6—THE OPTICAL ATTENUATOR assembly fits directly over phototransistor Q1. The front is painted white to help in aiming the reflected laser beam.

to amplifier IC2. Resistor R4, and capacitors C5 and C7, tailor IC2's frequency response and ensure stable operation with varying drive levels and output loads.

The output of IC2 is split into two paths: One goes to output-jack J1 via C6; the other feeds voltage-follower IC3, which drives the meter circuit consisting of D1, D2, C11, R8, and M1. The time constant created by the values of R8, C11, and M1's DC resistance was selected to provide a comfortable damping of the meter pointer's gyrations. The value of C11 may be varied to change the pointer's response. Increasing the value of C11 provides a smoother response; decreasing C11's value will cause the pointer to more closely track the variations in the laser beam's modulation.

Construction

The prototype receiver was assembled on a modified Radio Shack type *276-170* pre-drilled PC board, which has strips of copper foil on the underside that connect the component mounting holes. (A board with a parts-placement template in place, as shown in Fig. 5, is available from the source given in the Parts List.) Nothing about the layout is critical as long as you follow the usual precaution of keeping the input and output connections reasonably separated.

Check your parts layout against the foil strips on the underside of the board. If it appears that any will be too long, cut them to size before mounting any components. Cut each foil strip exactly as long as needed so that a foil carrying the input signal doesn't end up running adjacent to an output connection.

For best results when making connection to the foils, use a small pencil-tipped soldering iron and .040 diameter rosin-core solder. If your layout requires jumpers between component mounting holes, use #22 solid, bare wire. Insulated jumpers are #22 solid, insulated wire. Connections between the copper foils should be #18 insulated wire because it's a precise push-fit for the holes in the specified prototyping board.

The enclosure is a 6½ × 2⅛ × 1⅝ inch aluminum cabinet. Phototransistor Q1 protrudes from one end of that enclosure and is mounted with a dab of household cement. Position Q1 correctly before gluing it in place and be very careful to not get glue on the surface of the lens. Do not use cyanoacrylate-based instant glue because it might cloud the transistor's plastic lens. Output-jack J1, gain-control potentiometer R5, and the meter are mounted on the side of the cabinet so as to encourage the user to face at a right-angle to the source of the laser light, thereby lessening the chance of looking directly into the reflected beam.

The board is mounted in the enclosure with four ¾ inch 6–32 machine screws. Use ⅛ inch insulated spacers between the board and the enclosure to insure adequate clearance between the enclosure and the board's foil side. A ground lug located at one mounting screw is soldered to the circuit-board's ground foil to provide the ground connection between the board and the cabinet. The connections between the board and the panel-mounted components can be #18–22 stranded, insulated wire.

Optical attenuator

The optical attenuator assembly, for which construction details are shown in Figs. 6 and 7, mounts over phototransistor Q1. Figure 6 shows how it's installed over Q1; Fig. 7 shows the individual details for each component in the assembly. The front of the assembly is painted flat white

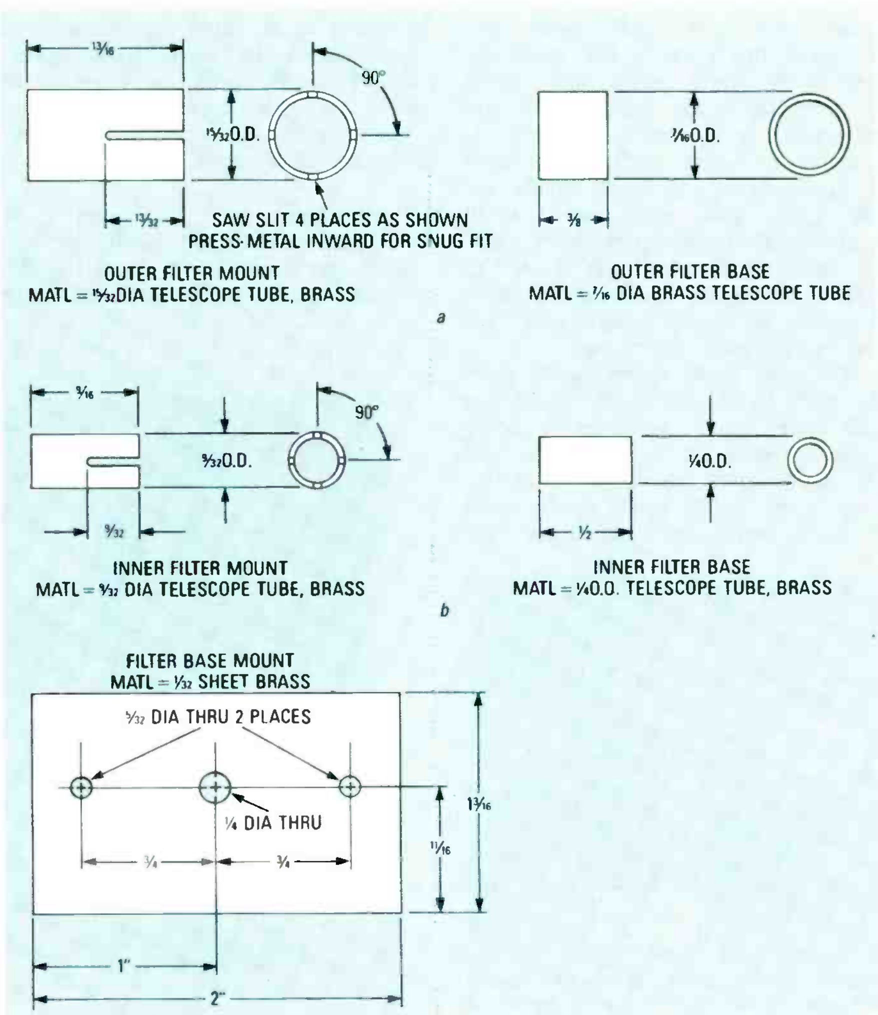


FIG. 7—All PARTS OF THE OPTICAL ATTENUATOR are made from brass sheet or tubing. Both the inner and outer filter bases are soldered to the brass mounting plate.

so that the reflected laser beam can be easily seen. The attenuator is built in such a way that the phototransistor can see the laser beam directly, or through a combination of one or two polarizing filters. When both filters are in place, rotation of the large-diameter filter-mount will cause a gradual decrease in light transmission (to almost total blockage within 90° of rotation), which allows the receiver to be used over a wide range of light intensities without swamping the photo detector. Figure 8 shows the installed assembly and the two filters.

The attenuator has an inner filter and an outer filter made from brass telescopic tubing. Each filter consists of two sections: a filter base that is soldered to small mounting plate made from brass sheet (the painted target), and a filter mount that slips over the base. Polaroid filters cut from neutral-tint polarized sunglasses are cemented to one end of each filter mount to complete the attenuator. When complete, the entire optical attentuator's mounting plate is secured on the enclosure over phototransistor Q1.

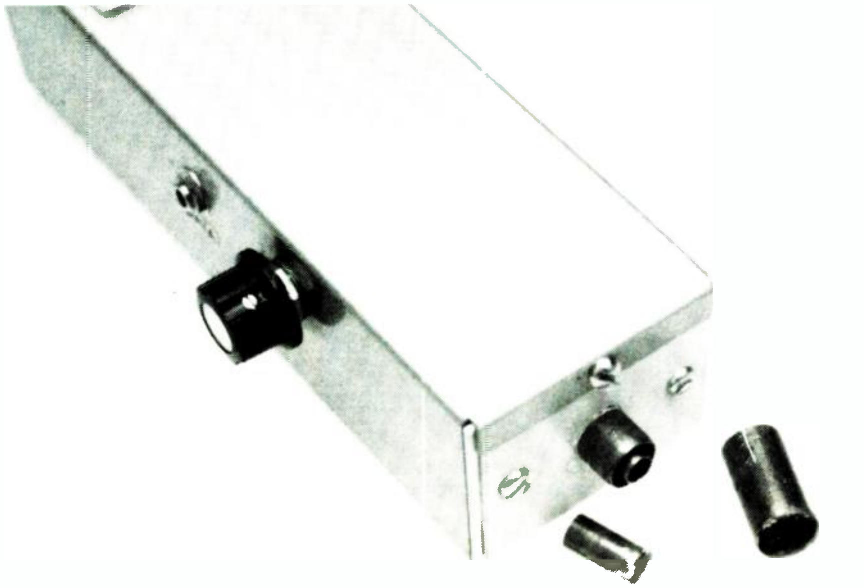


FIG. 8—THE ATTENUATOR'S mounting plate is installed directly over photoresistor Q1. The inner and outer filters are slipped into position when needed.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
R1—2200 ohms
R2—220 ohms
R3—33000 ohms
R4—10 ohms
R5—10,000 ohms, miniature potentiometer with SPST switch
R6, R7—22,000 ohms
R8—25000 ohms, trimmer potentiometer
Capacitors
C1, C6, C9, C10—330 µF, 16 volts, electrolytic
C2, C4—10 µF, 16V volts, electrolytic
C3—0.001 µF, 50 volts, ceramic disc
C5—0.68 µF, 16 volts, Tantalum
C7, C8—0.047 µF, 50 volts, ceramic disc
C11—4.7 µF, 16 volts, electrolytic
C12—1000 µF, 16 volts, electrolytic
Semiconductors
IC1—SK-3891 attenuator
IC2—LM380 audio amplifier
IC3—LM741 op-amp
Q1—TIL414, NPN phototransistor (Radio Shack *276-145* or equal)
DI, D2—SK-3090 germanium diode, or equivalent
Other components B1—9-volt transistor-radio type battery
J1—miniature phone jack
M1—250 µA meter, panel mounting
S1—SPST switch, part of R5
Miscellaneous—Cabinet, Pre-drilled PC board, brass sheet and tubing, wire, solder, etc.
The following is available from Dirijo Corp., Box 212, Lowell, NC 28098. A drilled prototype-board with a component layout overlay in place, model *LXVR-1*. $4.50 plus $2.50 postage and handling. NC residents please add appropriate sales tax.

Testing

We advise that a small speaker be used rather than headphones for the initial tests; then, if a wiring error or a defective component has created an audio oscillator rather than an amplifier, your ears will not be assaulted by a high-level tone or squeal.

With the volume control fully counterclockwise and power-switch S1 set to *off*, install the battery and connect the speaker. Turn the unit on and point it toward a source of daylight (not direct sun). Advance the volume control to maximum. Correct operation is indicated by a frying noise that sharply diminishes when the light is blocked. The meter-sensitivity control, R8, should then be set so that the meter's pointer just begins to move off the zero calibration. Decrease the gain and point the receiver toward an AC-powered light source, such as an incandescent or fluorescent light, or even an LED driven by an audio oscillator. Those sources should produce a loud hum or tone. Sound will be heard if the LED is driven from an audio amplifier at the correct level. If everything checks OK, assemble the enclosure.

Remote sound detection

To use the receiver as a remote sound pickup, you will need a laser and a reflective surface that sound waves will cause to vibrate; the receiver must be positioned so it can "catch" the direct reflection of the laser beam (Fig. 9). A particularly effective reflector for experimental use is a small piece of mirror (about ¼ × ¼ inch) cemented to the center of a speaker cone (see Fig. 10). There is no connection made to the speaker. The movement of the speaker cone caused by sound waves is transferred to the mirror-reflector, which in turn modulates the laser beam.

Due to the varying reflectivity and distances of the targets, the intensity of the light falling upon the detector may vary considerably from setup to setup. That will be readily apparent if the collector voltage of Q1 is measured while the illumination level on Q1 is adjusted. At some point of increasing illumination, the collector voltage will fall sharply and the audio output from the receiver will drop or disappear. The small-diameter polarized filter should then placed over Q1. If more light attenuation is required, slip the large-diameter filter in position and rotate it for maximum sound output.

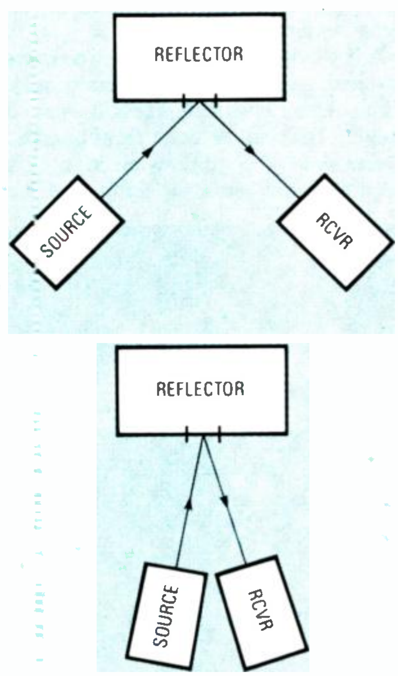


FIG. 9—A WIDE RANGE of reflection angle is possible. The laser source and the receiver can even be at the same location.

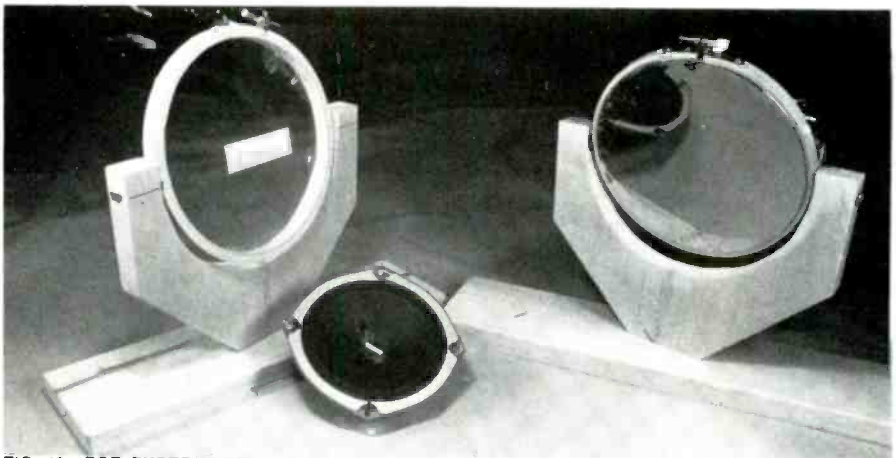


FIG. 10—FOR EXPERIMENTAL USE, an effective reflector can be made by gluing a small piece of mirror to the center cone of a speaker. Also shwon are Mylar, at left, and glass, at left, reflectors.

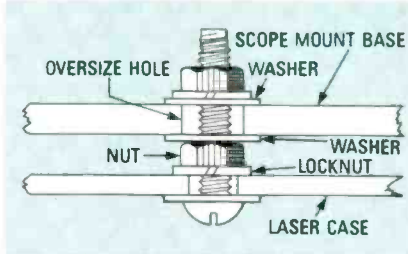


FIG. 12—DETAIL FOR THE RECEIVER mounting plate. An oversize hole mounting base allows coarse adjustment of the scope assembly. Use an oversize washer on both sides of the hole, and a lockwasher at the laser's case.

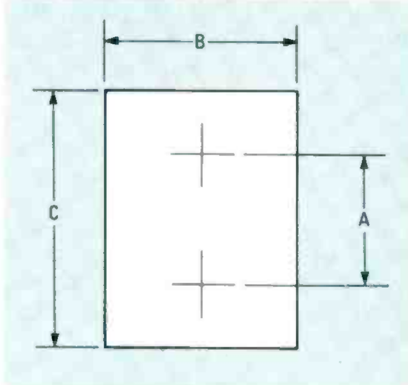


FIG. 13—THE AIMING TARGET for the scope/laser assembly should be made of dull-finish paper or cardboard. Dimension "A" is the measured distance between the laser beam and the optical center of the scope. Dimensions "B" and "C" are whatever you think will be convenient. The aiming cross-marks should be made with a soft pencil or a medium-point marking pen.

Thin is in

The thinner and more responsive to sound the reflective medium is, the greater the laser bug's sensitivity. Most window panes will work. Moving the beam to different spots on the glass can make a dramatic difference in the sensitivity.

For testing, no additional optics are needed for the receiver. Set up any convenient reflector—the mirrored speaker, or even an embroidery hoop holding plastic wrap or Mylar film (see Fig. 10)—aim the laser at the reflector, and then position the reflector so that the beam bounces back to the receiver. If you speak in the room, or play a radio or a tape recorder, the sound will be heard in the receiver's headphones. Another test can be done by modulating the laser with a 1-kHz tone while having an assistant move the target reflector for maximum tone reception—as indicated by maximum volume in the highest meter reading.

A non-adjustable target, such as a window pane, requires that the operator select a site where a direct reflection can be caught. That can be done from hundreds of feet away if conditions are right. Use the modulated beam for setup, and then remove the modulation to listen in. Double-pane glass and storm windows tend to greatly reduce sound transmission to the outer glass. It is possible, however, to aim through the glass to an object within the room, such as the glass front of a china cabinet or a hanging picture. The returned reflection is usually modulated.

At long range

At ranges greater than 100 feet or so, or when a high ambient light level obscures the reflected beam, a means must be provided to accurately aim the receiver to the reflected laser. As shown in Fig. 11, the receiving unit of our prototype laser-bug system uses a telescopic gunsight; and that assembly is, in turn, mounted directly on the laser housing as shown in Fig. 2 so both the laser and receiver can be aimed as a single unit.

The design of a combination receiver and laser mounting bracket will depend on the particular laser and scope that's being used. In general, the mounting bracket should be sturdy and have provisions for coarse elevation and azimuth adjustments; all gun scopes have provisions for fine adjustments. The adjustment details for the prototype mount are shown in Fig. 12.

The scope-to-laser alignment is done in two stages. First, the distance from the center of the laser beam to the center of the scope is measured and used as the spacing for the cross marks of the target shown in Fig. 13, which is made from dull, white cardboard. Then, the target is taped to a wall about 50 feet away from the laser assembly. Next, with the scope's cross-hair adjustments at the center of their range, position the laser beam at the center of the *lower* cross. Looking through the scope, adjust the scope's mounting bracket so that its cross-hairs are close to being centered on the target's *upper* mark. Making sure that the laser beam stays centered on the lower mark, tighten the mounting bracket's nuts and use the scope's fine adjustments for the final alignment. In this instance, the diffuse reflection of the laser beam from the card should present no eye hazard.

When using the laser/scope assembly, remember that at a range of under 300 feet you must compensate for the aiming error introduced by the offset between the scope and the laser beam centerlines.

Again, let us stress that under no circumstances should the laser beam or its direct reflection be viewed through optical devices of this type because severe damage to the eye can result. R-E

FIG. 11—AT LONG DISTANCES, a telescopic gun sight is used to accurately aim the receiver. That assembly is then strapped to the laser, as shown in Fig. 2, so that both units can be aimed together.

DIGITAL AUDIO TAPE

The audio-tape format of tomorrow is here today.

BRIAN C. FENTON, MANAGING EDITOR

GET READY FOR THE NEXT REVOLUTION IN audio. *Digital Audio Tape* (DAT) is on its way! Just as the compact disc is replacing the LP, you can expect DAT to replace the conventional audio cassette.

Just imagine audio tape with a frequency response that is flat from 2 Hz to 22 kHz. Imagine making your own hiss-free recordings with a dynamic range better than 96 dB. (Compare that to the 50–60 dB dynamic range of a standard cassette tape with noise reduction!) DAT is coming, and you should be ready for it.

Actually, digital audio tape has been around quite a while. As long as a decade ago, devices were available that would allow digitized audio to be recorded on VCR's. But they were a far cry from the dedicated DAT format we'll be discussing. The new generation was first demonstrated a year ago at the Japan Audio Fair, and then at the January 1987 Winter Consumer Electronics show. But all the DAT decks shown in this country were "prototypes only." No one would even discuss marketing plans.

Finally, this June, Marantz announced at the Summer Consumer Electronics Show that they would bring DAT machines into the U.S. as early as this fall. That hasn't happened yet, and the future of DAT could be in jeopardy thanks to some controversy in the industry regarding an anti-copy system that may be implemented—and even required by the U.S. government—in all DAT machines. We'll get to that issue later. First, let's see what the advantages of the new digital audio tape are.

Is digital better?

When audio tape moves across a tape head, the magnetic particles in the tape pick up and retain the magnetic field created in the head gap. When you play the tape back, you should, of course, hear a duplicate of the signal that was used to create the magnetic field. But in the real world, things aren't that simple. The transfer characteristics of audio tape, shown in Fig. 1, are non-linear. As a result, the recorded signal is a distorted version of the input.

There is a way to decrease the distortion—by creating a bias field to force the audible signal into the linear portion of the transfer characteristics. The results aren't perfect but, as cassette sales indicate, they certainly are adequate for many people.

Digital audio tape cassettes also use magnetic tape, and that magnetic tape also has a non-linear transfer characteristic. But as you can see in Fig. 1-b, a digital signal—which has only two discreet values—is not affected by the tape's non-linearity.

But how can an analog audio signal be

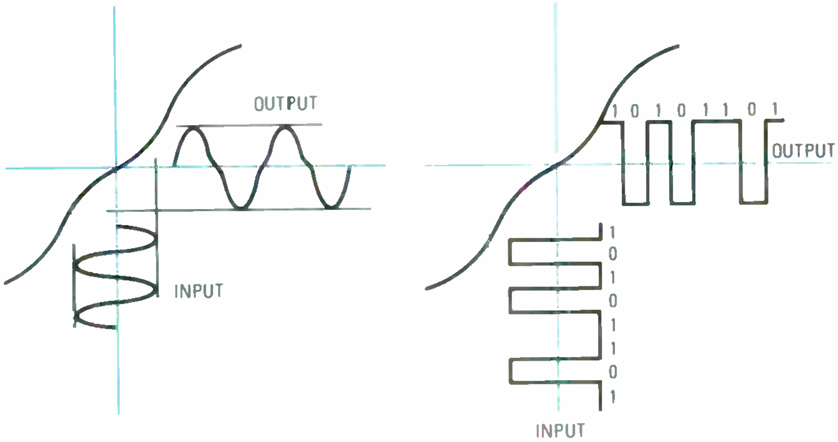


FIG. 1—THE NON-LINEAR CHARACTERISTICS of audio tape cause distortion in the recorded signal (*a*). However, since digital signals contain only two values, they are not affected by the non-linearity.

replaced by a string of digital data—which consists of only ones and zeros? It's done by *digital sampling*. An analog signal is sampled at a given rate, and the value of the sample is assigned a number. Figure 2 shows the process.

It might seem strange that a staircase-like signal could accurately represent a smooth analog signal. But if the sampling rate is fast enough, and if a sufficient number of bits is used to represent each sample, the results are excellent. If you've ever heard a compact disc—which also uses digital sampling—you know just how good the results can be.

DAT vs. CD

Both DAT and CD use 16-bit *P*ulse-*C*ode *M*odulation (PCM), but each uses a different sampling rate: 48,000 samples/second for DAT, and 44,100 samples/second for CD. Because of the different sampling rate, it is impossible to make a direct digital-to-digital recordings of a CD. In fact, that's precisely why a different rate was chosen.

Pre-recorded digital tapes are recorded with the same sampling rate as CD's are. But tapes you record at home are recorded at the higher rate. The DAT player can play back either tape, but can record only at the higher sampling rate. You *will* be able to make direct digital-to-digital copies of tapes you record yourself, but not of CD's or pre-recorded tapes.

In terms of sound quality, DAT and CD compare equally. Each format, however, has its own outstanding features—and its own inherent problems. The most obvious advantage DAT has over CD is that consumers can make their own recordings. It's no secret, however, that research is underway to create a recordable CD format. We have quite a few years to wait before that happens though.

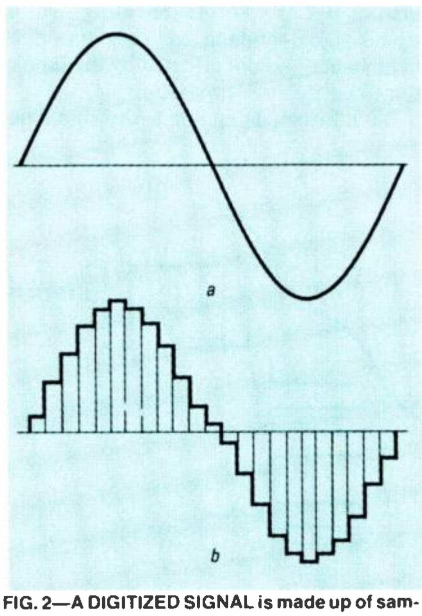


FIG. 2—A DIGITIZED SIGNAL is made up of samples of an analog signal.

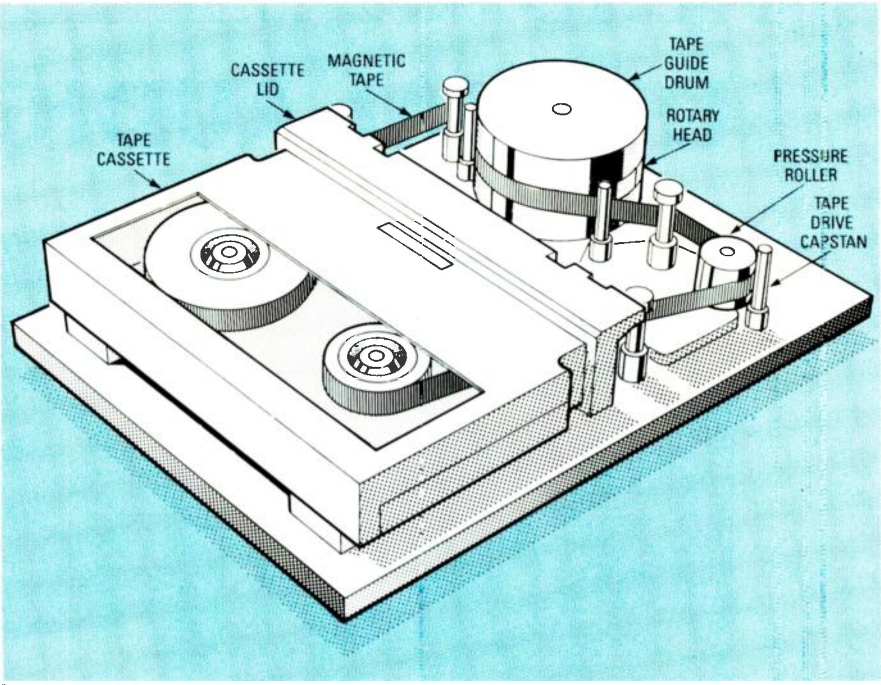


FIG. 3—A DAT-TRANSPORT MECHANISM. When the cassette is inserted into the DAT machine, the protective cover opens, and the tape is wrapped around a rotary-head drum.

Another advantage DAT has is its long playing time—the maximum length of a standard digital audio tape is two hours, while the maximum length of a CD is about an hour.

Speaking of pre-recorded tapes, you can be sure that recording companies will release many titles once the anti-copy issue is settled. Will pre-recorded material sell? Yes, because DAT has some playback advantages over CD's—especially in automobiles. The DAT package is smaller and much easier to handle than a CD. The tapes also fit easily in a shirt pocket, and will probably be very popular in personal portable players. The package provides a self-closing protective cover for the tape, which is important in the dirty auto environment. Perhaps more important is that the playback mechanism is much less subject to vibration problems than CD players, so it will be easier to produce portable and automotive players.

CD technology, of course, has some important advantages over DAT. The CD is a non-contact technology. Nothing but a beam of laser light comes in contact with the disc during playback, so playing a disc doesn't wear it out. DAT tape, on the other hand, wraps 90 degrees around a drum that spins at a speed of 2000 revolutions per minute, limiting its lifetime.

CD players feature fast track-access. In less than one second, you can access any random track. DAT, of course, offers only sequential access. While fast-forward and fast-rewind are indeed fast—about 20 seconds for each hour of tape—the access speed will never match that of CD.

The mechanics of DAT

Figure 3 shows a basic DAT transport mechanism. In some ways, it similar to the tape transport mechanism in a VCR. One significant difference is that the tape wrap is only 90 degrees. That helps keep tape wear down, and it is one of the reasons that the rapid fast forward and reverse functions are possible.

The DAT tape head rotates at 2000 rpm,

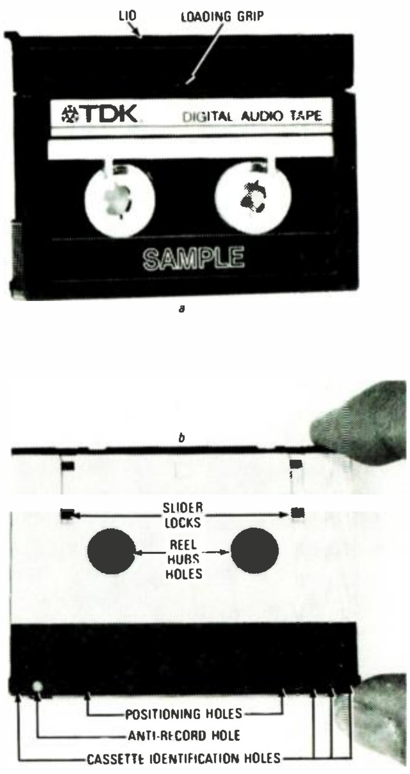


FIG. 4—THE DAT CASSETTE provides a dust-free enclosure for the tape. A series of holes on the bottom of the cassette identify the tape type, and whether the tape is pre-recorded.

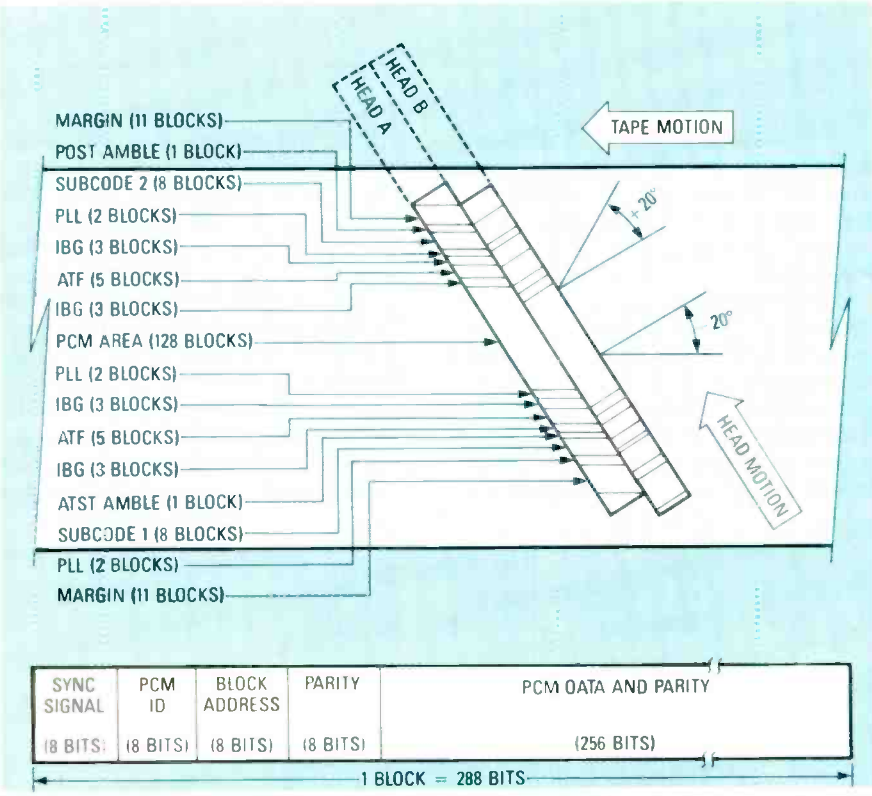


FIG. 5—THE DIGITAL DATA on the tape are a lot more than simple digital representations of audio signals. There are a huge number of "housekeeping" bits as well (*a*). A block of PCM data is shown in *b*. Subcode blocks are similar to PCM blocks, except for identity words that tell the DAT player that the PCM data is a subcode, and which subcode it is.

and the tape is pulled from the reel at about 0.8 cm/second. That creates an apparent tape speed of 10 feet per second, which is how so much data can be crammed onto such a small cassette.

The DAT cassette—which is about half the size of a standard compact cassette—is shown in Fig. 4. It has a lot in common with a video cassette. A hinged lid protects the tape from dust and fingerprints. A slider covers the hub holes when the tape is not in use, and keeps tape slack to a minimum. Data and reference holes are included to automatically instruct the DAT player what tape type and thickness is used, and whether the tape is pre-recorded. There is also a hole to prevent accidental erasure.

When a cassette is inserted into the recorder, the sliders move so the hubs can be accessed. The lid opens, and the tape is wound around a rotary head.

What's on the tape

A digital audio tape recording contains a lot more than the audio signals. Organizing the data so that it can be played back requires a lot of overhead.

Figure 5 shows how the audio tracks are placed on the tape and how individual tracks are organized. Note that crosstalk

(Continued on page 77)

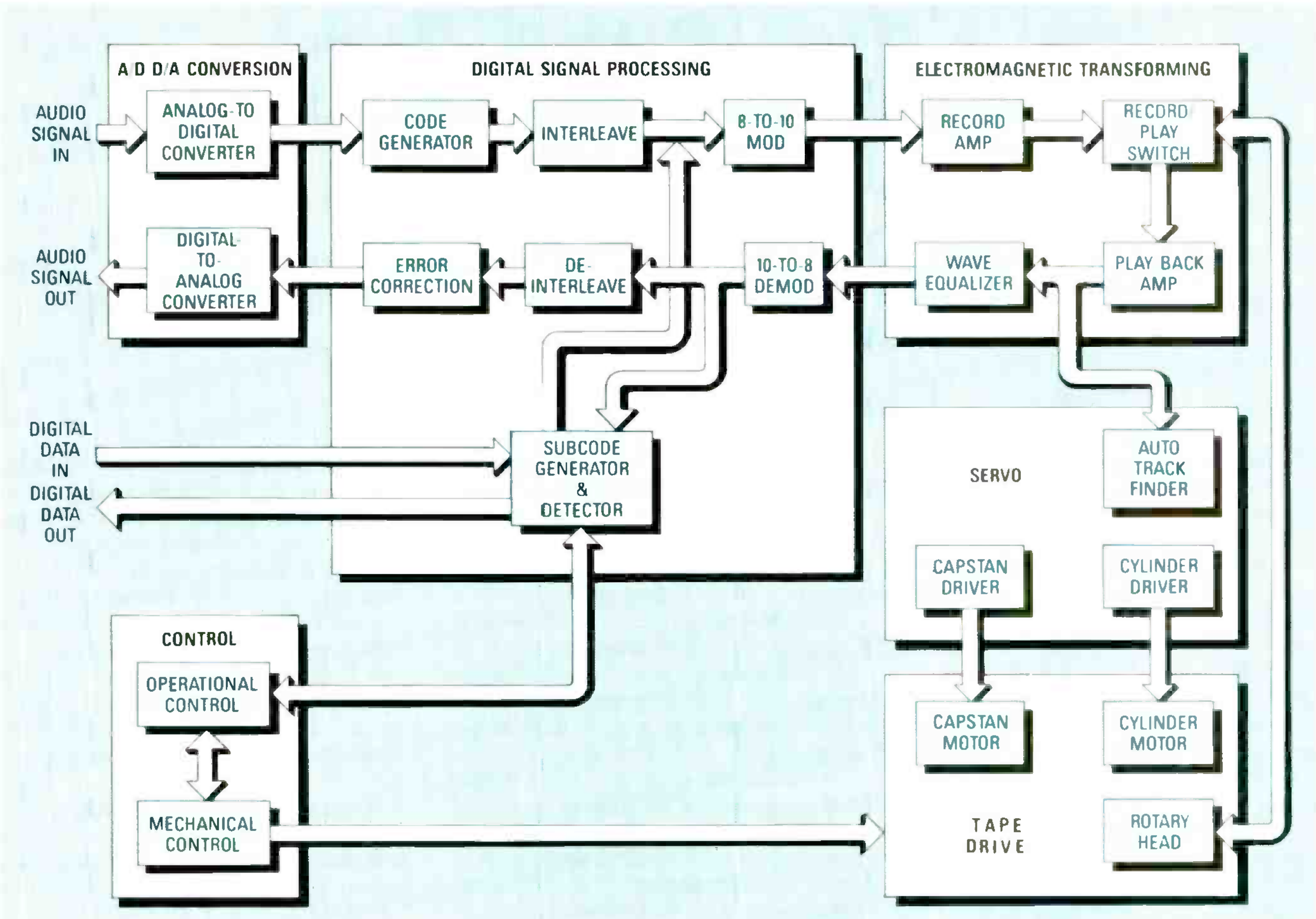


FIG. 6—A DAT PAYER/RECORDER. Note how the player will record direct digital inputs, and will output digital data directly. However, you will not be able to make direct digital-to-digital copies of any pre-recorded material because of differences in the sampling rates used.

VIDEO EFFECTS GENERATOR

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Part 2

THE VIDEO PALETTE IS built on two printed-circuit boards: a "main" board and a "special-effects" board. The main board contains the video-signal splitting and recombination (summing amplifier) circuits. The special-effects board contains the circuits for the solarizer, posterizer, inverter, and the power supply.

Circuit Description

Refer to Fig. 10, the schematic of the main board, and Fig. 11, the schematic of the effects board. Transformer T1, diodes D5 and D6, and capacitors C52 through C55 form two half-wave rectifiers supplying +8-volts DC to regulator IC12, and −8-volts DC to regulator IC13.

A 1-volt peak-to-peak negative-sync video signal at input jack J1 is coupled through C1 to the video amplifier consisting of R2, R3, R78, IC1, and C2. Switch S4 can bypass C1 if DC coupling is necessary. Terminating-resistor R1 can be switched across the input by switch S1 to provide a 75 ohm termination. Trimmer potentiometer R78 sets the amplifier's output level.

At least 0.5-volt peak-to-peak video is necessary for proper operation. IC1 is an LM318, a video op-amp. Resistor R3 provides feedback and C2 provides frequency compensation for IC1. Resistors R18 and R19, together with capacitors C3 and C4, provide ±5 volts to IC1 and serve as decoupling networks, reducing video cross-talk through the power-supply wiring. About 2 to 3 volts of inverted (positive sync) composite video appears at IC1 pin 6.

Inverted composite video is fed directly from IC1 to IC2, an analog switch, and through R4, C5, and Q1 to the sync-separator system. Transistor Q1 is normally non-conducting, because bias generated across R5 keeps Q1 cut off except during positive sync tips. Negative sync pulses appear at Q1's collector. Resistor R6 provides a collector pull-up for Q1. Resistors R7 and R8 couple the sync pulses to Q2. Resistor R9 is the collector load for Q2. Resistors R10 and R11, and capacitors C6 and C7 form an integrator network that extracts vertical timing pulses from the composite sync at the collector of Q2. Capacitor C8 couples the timing pulses to Q3, which squares and shapes the timing pulses. The negative-going vertical sync pulses are used to trigger dual-multivibrator IC4.

Pulses at the collector of Q1 trigger dual-multivibrator IC3; the two sections of IC3 are connected as two cascaded monostable multivibrators. Resistors R79 and R14, and capacitor C9 determine the pulse width of the first section—about 53 microseconds. Resistor R80 and R15, and capacitor C10 determine the pulse width of the second section—about 10 microseconds. A positive-going pulse appears at IC3 pin 10. By proper adjustment of R80, the pulse can be made coincident to, and the same width as, the horizontal-blanking pulse. It's the same with the vertical-sync pulses at the collector of Q3 trigger IC4. Both sections of IC4 function identically to IC3. Resistors R81 and R16, and capacitor C12, determine the pulse width of the first section—nominally 16 milliseconds. Resistors R82 and R17, and capacitor C13, determine the pulse width of the second section. By proper adjustment of R81 and R82, the pulse appearing at IC4 pin 10 can be made coincident with the vertical-sync interval of the video-input signal. A negative pulse at IC4 pin 9 cuts off IC3 (horizontal gating) during vertical-retrace intervals. The horizontal and vertical gating pulses are summed across R20. Diodes D1 and D2 DC-isolate IC3's and IC4's outputs from each other. The pulse across R20 is nominally +5 volts; it is low during line scan and high during sync intervals. It is fed to pin 9, the control lead, of video switch IC2.

Since IC2 pin 9 is low, during line scan intervals the normal video containing luminance and chroma from IC2 pin 4 appears at pin 5. Inductor L1, and capacitors C16 and C17 form a lowpass filter, while C15, R22, and L2 form a highpass filter. Resistors R23 and R24 terminate the

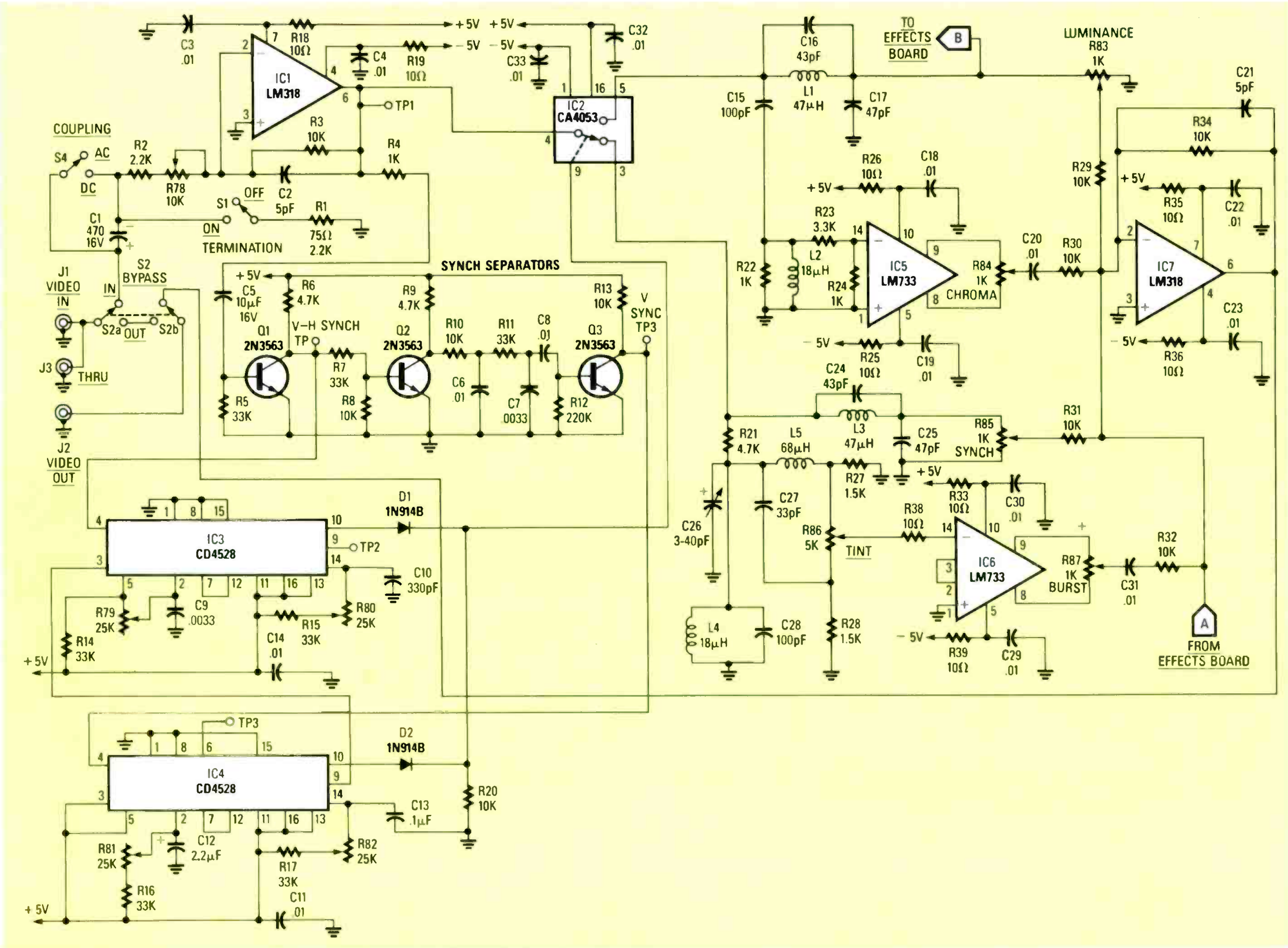

FIG. 10—THE MAIN BOARD provides the video input and output connections and the basic picture processing. Analog switch IC2 separates the sync from the chroma and luminance components.

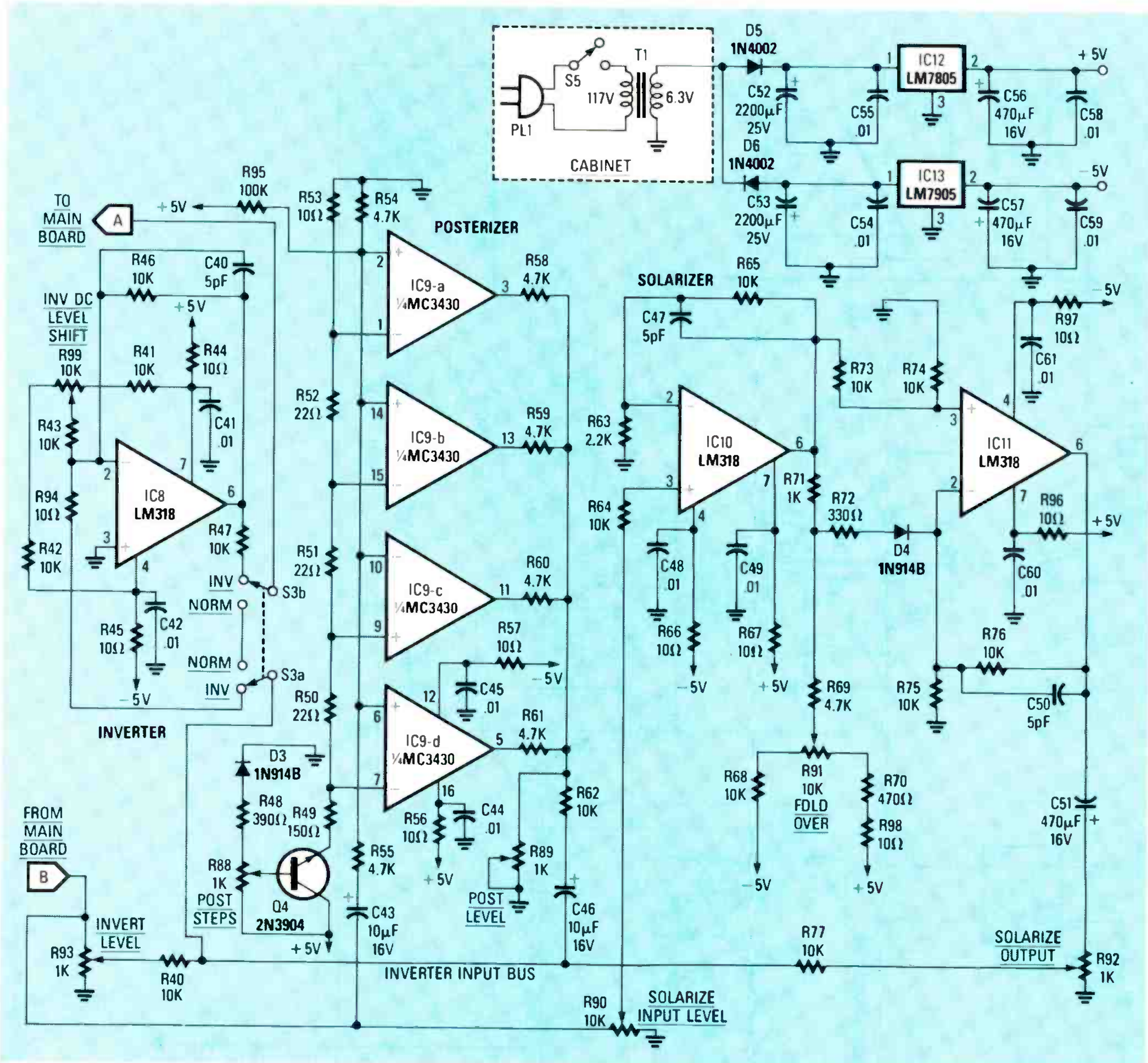

FIG. 11—THE EFFECTS BOARD provides the analog effects: posterization, solarization, and inverted video. The power supply is also built on the effects board.

highpass filter. The luminance gain control, R83, terminates the lowpass filter. Video from R83's wiper goes through R29 to summing amplifier IC7. Chroma amplifier IC5 has a nominal gain of 10. (The chroma signal appears at an equal level, 180° out of phase, at IC5 pins 8 and 9.) Resistor R84 is the chroma-level control. Depending on R84's setting, either positive or negative chroma signal can be supplied to IC7 through R30.

During sync intervals, IC2 pin 9 is high, so sync, burst, and blanking appear at pin 3. Capacitors C24, and C25, and L3 form a lowpass filter, feeding sync and blanking to R85, the sync-level control. The wiper of R85 feeds summing amplifier IC7 through R31. Resistor R21, capacitors C26 and C28, and L4 are used as a burst take-off filter. Trimmer capacitor C26 is adjusted so that the tint-control circuit—L5, C27, R27, R28, and R86—produces correct tints when R86's wiper is centered. The burst from R86's wiper goes to burst amplifier IC6, which has a gain of 100 to compensate for the loss in the tint control circuit. Potentiometer R87 controls the burst level.

Adding effects

Processed video from the effects board is fed to summing amplifier IC7 at pin 2. In addition to summing the various video-signal components, IC7 re-inverts the video so that it appears as 1-volt peak-to-peak with negative sync (nominal NTSC) at video output jack J2. Depending on the settings of the the palette's controls, up to 2 volts of video is available when the unit is terminated by 75 ohms.

As shown in Fig. 11, the effects board receives its video input across R93. Video (luminance) is applied to the posterizer circuit through C43 and R55. Resistor R54 provides a ground return for IC9's comparators. Transistor Q4 provides an adjustable reference bias for the posterizer. Resistor R48 and diode D3 provide temperature compensation of the reference voltage. The comparator outputs are summed across level control R89 and flow through the inverter input bus to S3-a, the INVERT-NORMAL switch.

The solarizer, which was discussed in Part 1 (see **Radio-Electronics**, page 41, September 1987), consists of IC10 and IC11. Amplifier IC10 has a gain of four; its input signal is taken from R90's wiper through R64. The output, which has an amplitude of up to 4-volts peak-to-peak, appears at IC10 pin 6. Potentiometer R91 is the "foldover" control; resistors R68 and R71 limit R91's effective range for

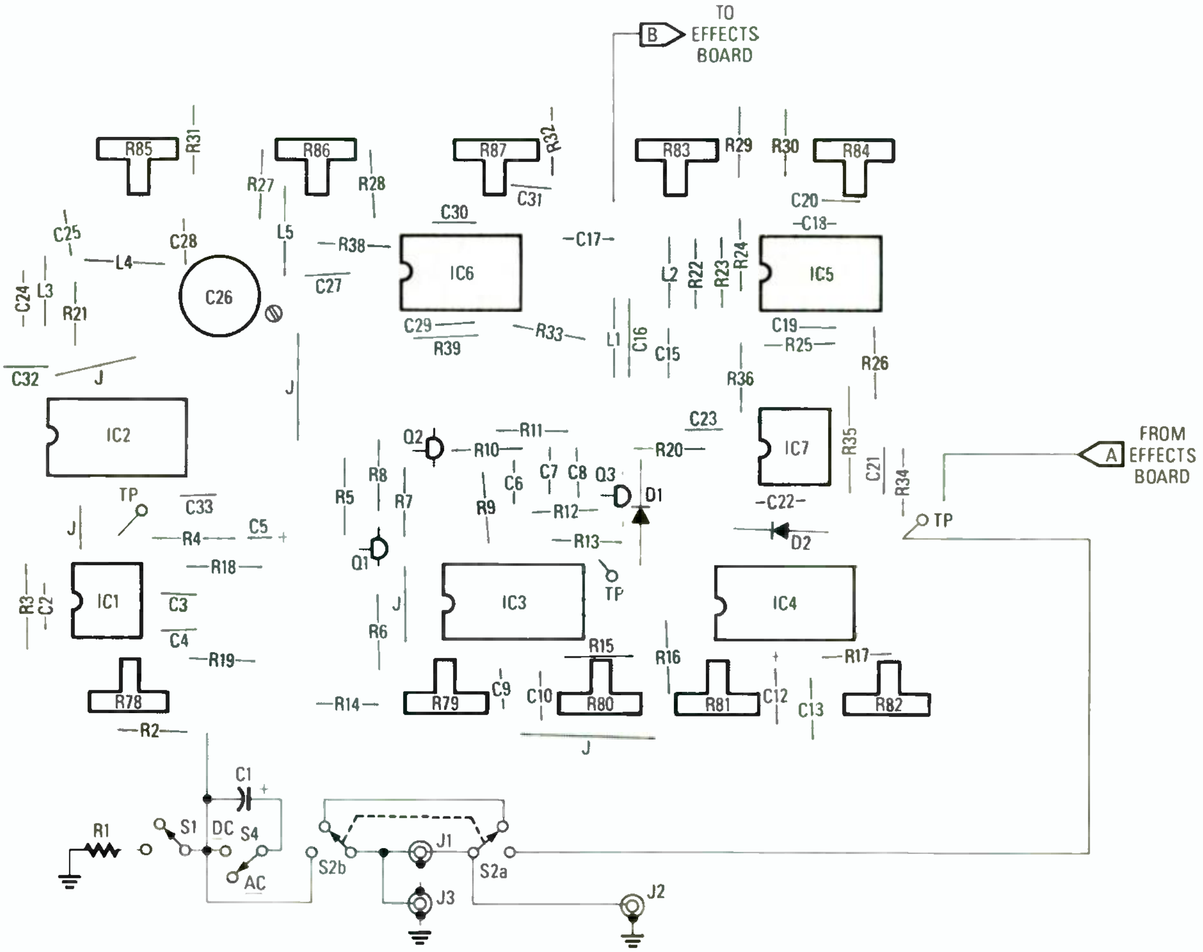

FIG. 12—INSTALL THE MAIN BOARD COMPONENTS in the order given in the text. While IC sockets aren't specified, their use is suggested. They make troubleshooting easier if you have any problems.

PARTS LIST—MAIN BOARD

All resistors are ¼-watt, 5% unless otherwise noted

R1—75 ohms
R2—2200 ohms
R3, R8, R10, R13, R20, R29–R32, R34—10,000 ohms
R4, R22, R24—1000 ohms
R5, R7, R11, R14–R17—33,000 ohms
R6, R9, R21—4700 ohms
R12—220,000 ohms
R18, R19, R25, R26, R33, R35, R36, R38, R39—10 ohms
R23—3300 ohms
R27, R28—1500 ohms
R37—not used
R78—10,000-ohm trimmer potentiometer
R79–R82—25,000-ohm trimmer potentiometer
R83, R84, R85, R87—1000-ohm potentiometer
R86—5000-ohm potentiometer

Capacitors

C1—470 µF, 16 volts, electrolytic
C2, C21—5 pF, silver mica
C3, C4, C6, C8, C11, C14, C18, C19, C20, C22, C23, C29–C33—0.01 µF, ceramic disc
C5—10 µF, 16 volts, electrolytic
C7, C9—0.0033 µF, Mylar
C10—330 pF, silver mica or NPO ceramic disc
C12—2.2 µF, 10 volts, Tantalum
C13—0.1 µF, Mylar
C15, C28—100 pF, silver mica
C16, C24—43 pF, silver mica
C17, C25—47 pF, silver mica
C26—3–40-pF trimmer
C27—33 pF, silver mica
C34–C39—Not used

Semiconductors

IC1, IC7—LM318 wideband op-amp
IC2—CD4053 analog multiplexer/demultiplexer
IC3, IC4—CD4528 dual monostable multivibrator
IC5, IC6—LM733 differential video amplifier
Q1, Q2, Q3—2N3565 NPN transistor
D1, D2—1N914B small-signal diode

Other components

J1, J2, J3—Coaxial jacks, see text
L1, L3—47 µH
L2, L4—18 µH
L5—68 µH
PL1—Power plug
S1, S4, S5—SPST switch
S2, S3—DPDT switch
T1—6.3 volts, 300 mA

Miscellaneous—Wire, solder, cabinet, mounting hardware, knobs, etc.

easier operation. Solarized video is fed through C51 to solarizer output level control R92, whose wiper feeds the inverter input bus through R77. Unprocessed video luminance is also fed to the bus from inverter level control R93.

Similar circuits

Switch S3-a selects the inverter circuit consisting of IC8 and its peripheral components. You may have noticed by now that the circuits using the LM318 are all very similar; hence we are not discussing them in detail except where significant differences are encountered. Resistors R87, R41, R42, and R53 feed an adjustable DC bias to IC8 to maintain correct DC-baseline levels when inversion is used. Resistor R47 feeds inverted output through S3-a to summing amplifier IC7, which is located on the main board. As in the other amplifier circuits using the LM318, a 10,000-ohm feedback resistor (R46) and a 5-pF shunt capacitor (C40) are used to set the gain and provide frequency compensation.

Construction

You can build the video palette from scratch using the PC-board patterns provided in PC Service. Also, a kit of

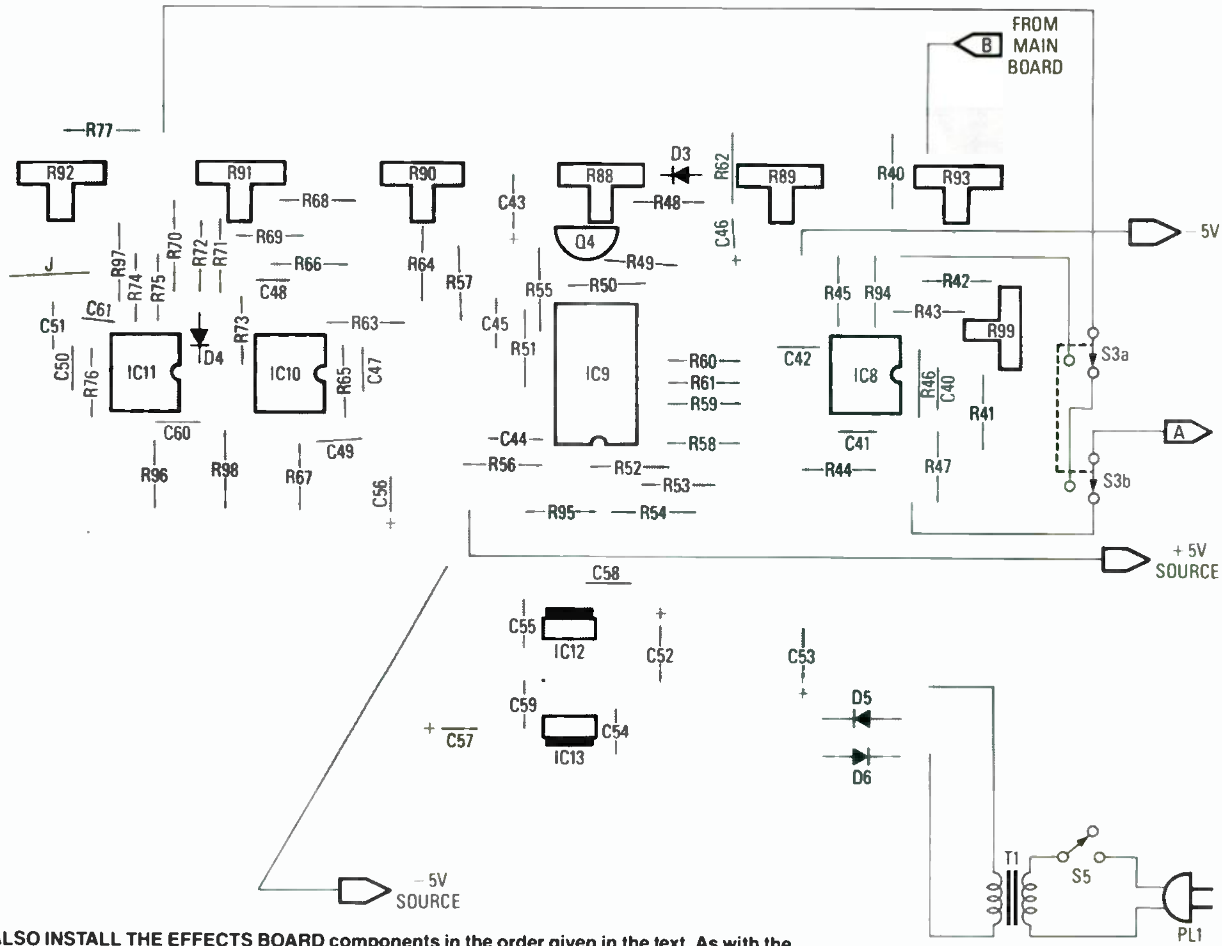

FIG. 13—ALSO INSTALL THE EFFECTS BOARD components in the order given in the text. As with the main board, IC sockets are suggested to simply troubleshooting.

PARTS LIST—EFFECTS BOARD

All resistors are ¼-watt, 5% unless otherwise noted
R40–R43, R46, R47, R62, R64, R65, R68, R73–R77—10,000 ohms
R44, R45, R53, R56, R57, R66, R67, R94, R96–R98—10 ohms
R48—390 ohms
R49—150 ohms
R50–R52—22 ohms
R54, R55, R58–R61, R69—4700 ohms
R63—2200 ohms
R70—470 ohms
R71—1000 ohms
R72—330 ohms
R95—100,000 ohms
R99—10,000-ohm trimmer potentiometer
R88, R89, R92, R93—1000-ohm potentiometer
R90, R91—10,000-ohm potentiometer

Capacitors
C40, C47, C50—5 pF, silver mica
C41, C42, C44, C45, C48, C49, C54, C55, C58, C59, C60, C61—0.01 µF, ceramic disc
C43, C46—10 µF, 16 volts, electrolytic
C51, C56, C57—470 µF, 16 volts, electrolytic
C52, C53—2200 µF, 25 volts, electrolytic

Semiconductors
IC8, IC10, IC11—LM318 wideband op-amp
IC9—MC3430 high-speed comparator
IC12—LM7805 +5-volt regulator
IC13—LM7905 –5-volt regulator
Q4—2N3904, NPN transistor
D3, D4—1N914B small-signal diode
D5, D6—1N4002 silicon rectifier

Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804: Main PC board $12.50; main and effects PC boards $25.00; main PC board and all parts that mount on the board $49.95; main and effects PC boards and all parts that mount on the boards $84.95. (The effects board is sold only in conjunction with the main board.) Add $2.50 for postage and handling per total order. NY State residents add appropriate sales tax.

parts that includes the PC boards and all board-mounted parts is available from the source listed in the parts list. Knobs, switches, jacks, plugs, case, etc., are not supplied with the parts kit. A suitable cabinet is the Radio-Shack *270-274*.

If you decide to etch your own boards, use single-sided .031 or .062 phenolic material, or fiberglass-epoxy G-10 (preferred). Figures 12 and 13 show the parts placement for the boards.

Stuff the PC boards in this order: resistors, inductors, capacitors, controls, transistors, IC's. The lengths of the interconnecting wires aren't critical, but they should be as direct as possible. The palette's input and output connections should be coax when possible. To reduce both stray capacitance and induced 60- or 120-Hz pickup, the leads carrying video signals to and from the effects board should be dressed away from grounded metal and the power-supply leads.

The shafts for all the front-panel controls should be strain relieved. That can be done by passing them through holes in the front of the cabinet that are about .005" larger than the shaft diameter, which is nominally ¼". If desired, bushings can be used around the shafts.

The front panel has eleven controls, a pilot light (if installed), and three switches; don't crowd its layout or it will be hard to use unless you have very small hands. RCA-phono, HF, BNC, or F-type video connectors are suggested for the external connections. Switches can be of the mini-

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ature type which use a ¼" mounting hole. At this point, check your wiring and PC boards for correct component insertion and pin orientations, unwanted solder bridges, and completeness. If any wiring or assembly errors exist, correct them before proceeding farther.

Alignment

Alignment is simple. If possible, use an oscilloscope having a bandwidth greater than 5-MHz. While a scope does make the initial alignment easier, do not let the lack of a scope discourage you, because final "tweaking" will be found easiest to do by watching the picture. If a scope isn't available, simply observe the effects of your adjustments on a TV monitor; we'll tell you what to look for.

Prepare the video palette for alignment by setting R78, R79, R80, R81, R82, and R99 so that they are in the center of their range (midway). Then connect the video palette as shown in Fig. 14.

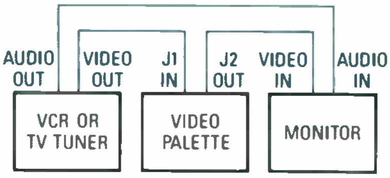


FIG. 14—USE THIS KIND OF HOOKUP for checking and aligning the video palette. A TV-tuner signal source can originate in the VCR, or use an integral TV-tuner device.

Next, connect the ground lead of a 20,000-ohm/volt (or higher) VOM that is set to read about 10-volts full scale to the main board's ground foil; then apply power to the video palette. *Very quickly* check the voltages across C56 and C57—they each should be 5 volts (C56 has its negative lead grounded, and C57 has its positive lead grounded). Then *very quickly* check for the following voltages on the indicated pins of IC1, IC7, IC8, IC10, and IC11:

Pin 6: 0-volts (±0.5 volts OK)
Pin 7: +5 volts
Pin 4: –5 volts

Make the following checks on IC5 and IC6:

Pin 5: +5 volts
Pin 6: +5 volts
Pin 8: 0 volts (± 1 volt OK)
Pin 9: 0 volts (± 1-volt O K)

Then, with no signal input to J1 or J3, check IC1, IC3, and IC4 for:

Pin 10: 0 volts
Pin 9: +5V volts
Pin 16: +5 volts
Pin 8: 0 volts

Also check IC2 for:

Pin 7: –5 volts
Pin 16: +5 volts

Check IC9 for:

Pin 16: +5 volts
Pin 12: –5 volts

Check Q1 for:

Collector: +5 volts
Base: 0 volts

Check Q2 for:

Collector: 0 volts
Base: +0.6 volts

Check Q3 for:

Collector: +5 volts
Base: 0 volts

Check Q4 for:

Collector: +5 volts
Base: +2–5 volts (depends on setting of R88)
Emitter: 0.6 volt less than base

Nothing should get hot—if anything does, there is a problem that must be corrected before proceeding any farther.

If the test signal is provided by a VCR that can output a tuner signal instead of a tape signal, use the tuner signal because it has better stability.

The main board

If an oscilloscope is available, you can check your adjustments using the photographs shown in Figs. 15 through 26 as a general—not an exact—reference. Each figure shows the vertical sensitivity and sweep rate used to obtain the trace.

Apply a 1-volt peak-to-peak negative-sync NTSC video signal to J1 (Fig. 15). Close S1 to provide a 75-ohm termination for the video source. Open S4 so that the video source is AC-coupled to the palette. Set S2 to its IN position. Adjust R78 for 3-volts peak-to-peak at IC1 pin 6 (Fig. 16). Notice that the signal at pin 6 is inverted. Check Q1's collector for negative-going pulses (Fig. 17). Transistor Q3's collector should also show negative-going pulses (Fig. 18), although because of their short duration they may be hard to see on a scope with screen brightness.

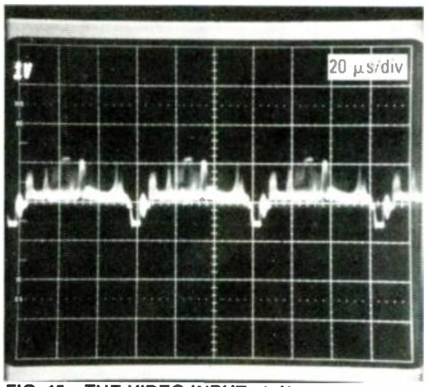


FIG. 15—THE VIDEO INPUT at J1.

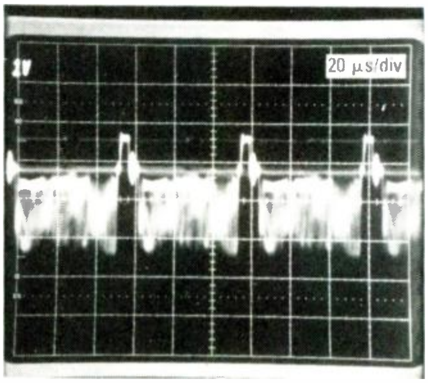


FIG. 16—INVERTED VIDEO AT IC1, pin 6.

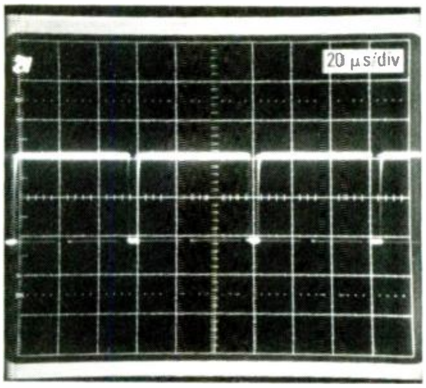


FIG. 17—NEGATIVE PULSES at Q1's collector.

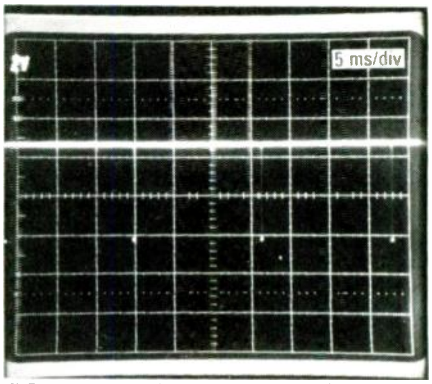


FIG. 18—THE NEGATIVE PULSES at Q3's collector might be difficult to observe.

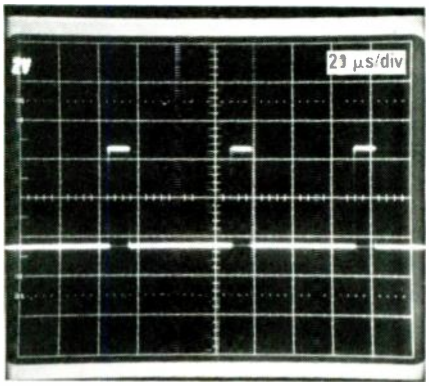


FIG. 19—THE SCOPE DISPLAY should resemble this at IC3 pin 7.

Adjust R79 for a nominal 53-microsecond negative-going pulse at IC3 pin 7 (Fig. 19). Then set R80 for a nominal 10-microsecond positive-going pulse at IC3 pin 10 (Fig. 20). Next, adjust R81 for a negative-going 16-millisecond pulse at IC4 pin 7 (Fig. 21). Then adjust R82 for an approximate 600-microsecond positive-going pulse at IC4 pin 10. If there is no pulse, tweak R81 until a narrower pulse is obtained (Fig. 22). Note that a 600-microsecond pulse will not be generated if the 16-millisecond multivibrator is set for too long a pulse.

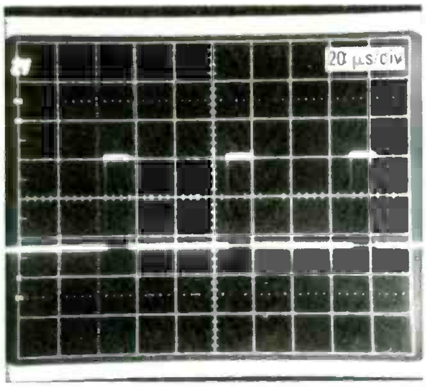


FIG. 20—THE SCOPE DISPLAY AT IC3, pin 10 resembles the display at pin 7.

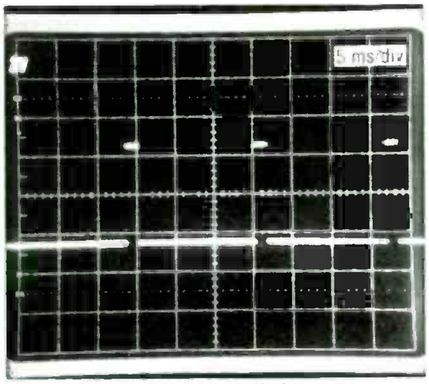


FIG. 21—THE DISPLAY FROM IC4 pin 7.

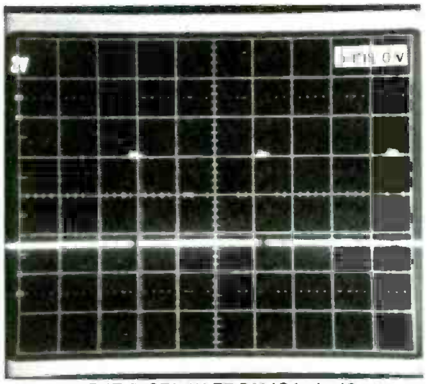


FIG. 22—THE DISPLAY FROM IC4 pin 10 resembles that of pin 7.

Aligning by monitor

If a scope isn't available, make the following adjustments and use a TV monitor to observe their effect.

1. Set R83, R85, R86, and R87 to their mid position. You should see a black-and-white, or a weak color image on the monitor. Set all the effects-board controls for minimum resistance (*off*).

2. Adjust R79—you will see a "transition" on the right and/or left side of the screen. That is caused by IC2 switching the video through the sync channels. If instability is noticed on the monitor, adjust R85 for maximum stability. Adjust R79 and R80 to move the transitions just off the right and left edges of the screen so they are unseen during normal viewing. The picture may roll vertically—that is OK for now.

3. Adjust R81 and R82 for a stable, vertically-locked picture. When those controls are properly set there should be no "transitions" at the top or bottom of the picture.

4. With all effects controls still set for minimum resistance, set S2 to OUT to bypass the video palette and adjust the TV monitor for a normal picture. Then set S2 to the IN position and check that each control does what it's supposed to do.

- Resistor R83 should vary the picture contrast (luminance).
- Resistor R85 should vary the picture brightness. (When R85 is toward minimum, the picture should lose its sync.)
- Resistor R87 may vary the color saturation and reverse the colors (burst).
- Resistor R84 should operate in a similar manner to R87 (chroma).
- Resistor R86 should vary the tint. Adjust C26 to produce normal tint when R86 is set to its mid position.

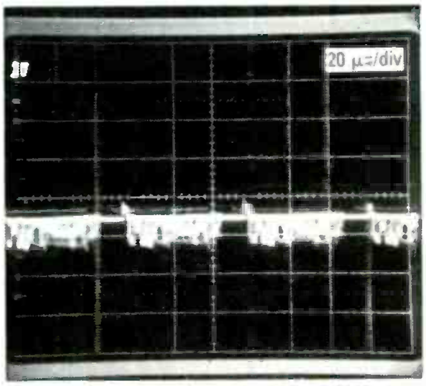


FIG. 23—THERE IS NO SYNC at IC2 pin 5.

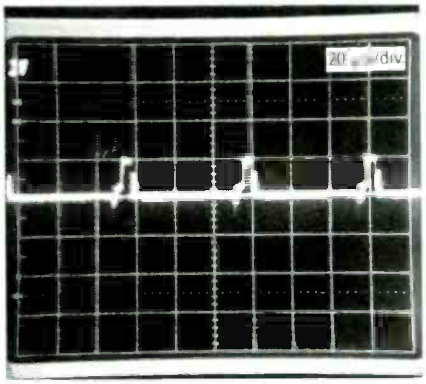


FIG. 24—THERE IS NO VIDEO at IC2 pin 3.

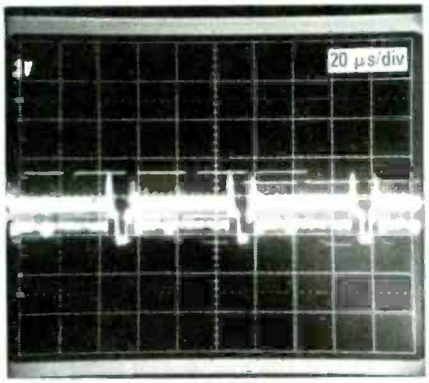


FIG. 25—AN INVERTED VIDEO OUTPUT has the picture information going negative.

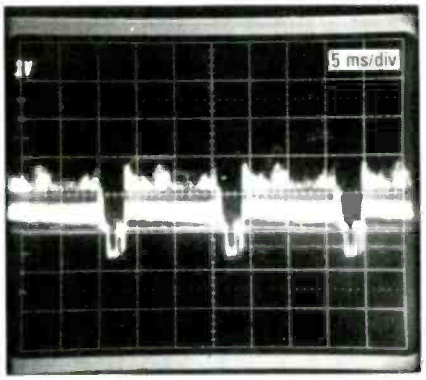


FIG. 26—A NORMAL VIDEO OUTPUT looks like this on your scope.

If you are using a scope, you can place the scope on IC7 pin 6 and observe the effect of each control on the video signal.

5. Set up R83 through R86 for a normal TV picture. Then set R83 to minimum. (All effects-board controls should be at zero again.) You should see a plain raster with only splotches of color, or on a black and white monitor, just a raster with only a very weak, faded picture.

6. Set inverter switch S3 to NORMAL. The picture should return as you adjust R93 clockwise.

7. Set S3 to its INVERT position. A negative picture should be seen.

8. Adjust R99 for a satisfactory negative picture. (You may have to touch-up R85 on the main board first.) When R99 is properly adjusted, R85 can be left alone. Now set S3 to its NORMAL position.

9. Rotate R93 fully counter-clockwise. Set R88 and R89 to their mid position. Observe the effect on the TV picture. You should see a posterized image—it will be obvious. Then adjust R88 and R89 and take note of their effect on the picture. Finally, return R88 and R89 to zero (full counter-clockwise).

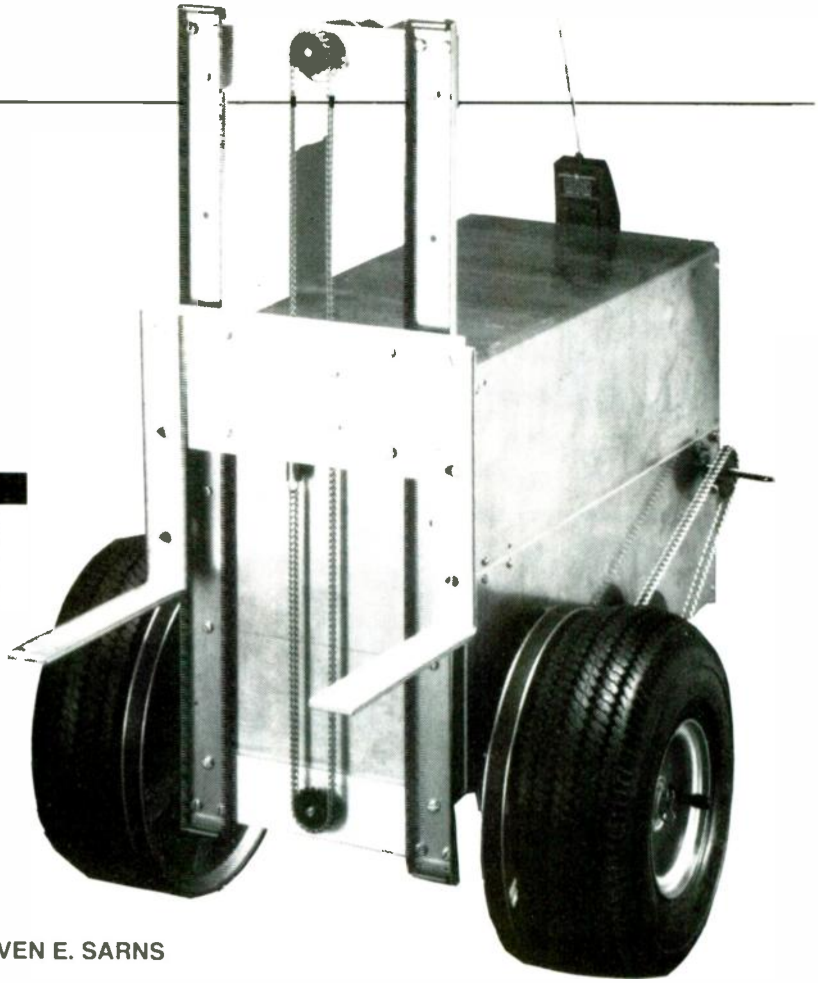
10. Set R90 and R92 to approximately their mid position and then slowly adjust R91—you will see the solarization effect. Adjust R90 and R92 for the best or the desired effect, although R85 may have to be readjusted at some settings.

11. Set S3 to both its NORMAL and INVERT positions and observe the solarization effect (as in step 10).

If you have some form of instability or an undesired effect that we haven't mentioned, the following scope checks will help your track down the problem. Check for *video only* at IC2 pin 5 (Fig. 23); *sync only* at IC2 pin 3 (Fig. 24); *normal video* at output jack J2 when S3 is set to NORMAL (Fig. 25); *inverted video* at J2 when S3 is set to INVERT (Fig. 26).

That completes the alignment and checkout. The rest is up to you. A few hours of just plain experimentation is the best way to learn what the video palette can do. **R-E**

R-E ROBOT



Adding the arm, and the electronics to control it.

STEVEN E. SARNS

Part 11

IF YOU'VE BEEN FOLlowing this series, by now you have no doubt noticed that our robot does not have a traditional multi-jointed robotic arm. In its place is an "arm" that resembles a fork lift.

There are several reasons why that approach was chosen. First, it allows our robot to lift loads up to 10 pounds—multi-jointed arms usually are limited to lifting loads of one pound, or less. Second, our design is relatively inexpensive to implement. Third, few tasks actually require multi-jointed dexterity to get the job done—tasks performed with a multi-jointed arm often deteriorate into programming exercises. When we considered those factors, our design seemed to be the obvious way to go.

Of course, some tasks do require some measure of dexterity. For those, a pincher add-on for the lift has been designed; part of that pincher is shown in Fig. 1. The pincher will be described in detail in a future installment of this series. For now, let's concentrate on the basic fork-lift design.

Mechanical overview

Our intention was to provide a rugged and reliable workhorse unit. The lift assembly has been designed to lift 10-pound loads from floor level to the top of a 32-inch-high table at a rate of 3 inches-per-second. The overall height of the assembly described is 43 inches. Exactly the same construction techniques can be used to build smaller (or larger) lifts.

Linear ball-bearing slides are used for the lift to preserve the efficiency of the system. Because of the way cantilever loads are coupled to the bearings, friction

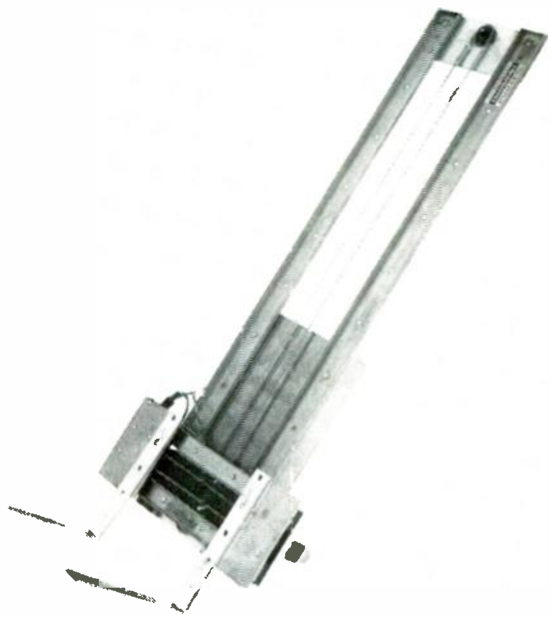


FIG. 1—THIS FORK-LIFT DESIGN can do almost as much as a multi-jointed arm, but with higher lifting capacity and at a lower cost. For greater dexterity, the pincher shown can be added. That pincher, part of which is shown here, will be described in detail in an upcoming installment of this series.

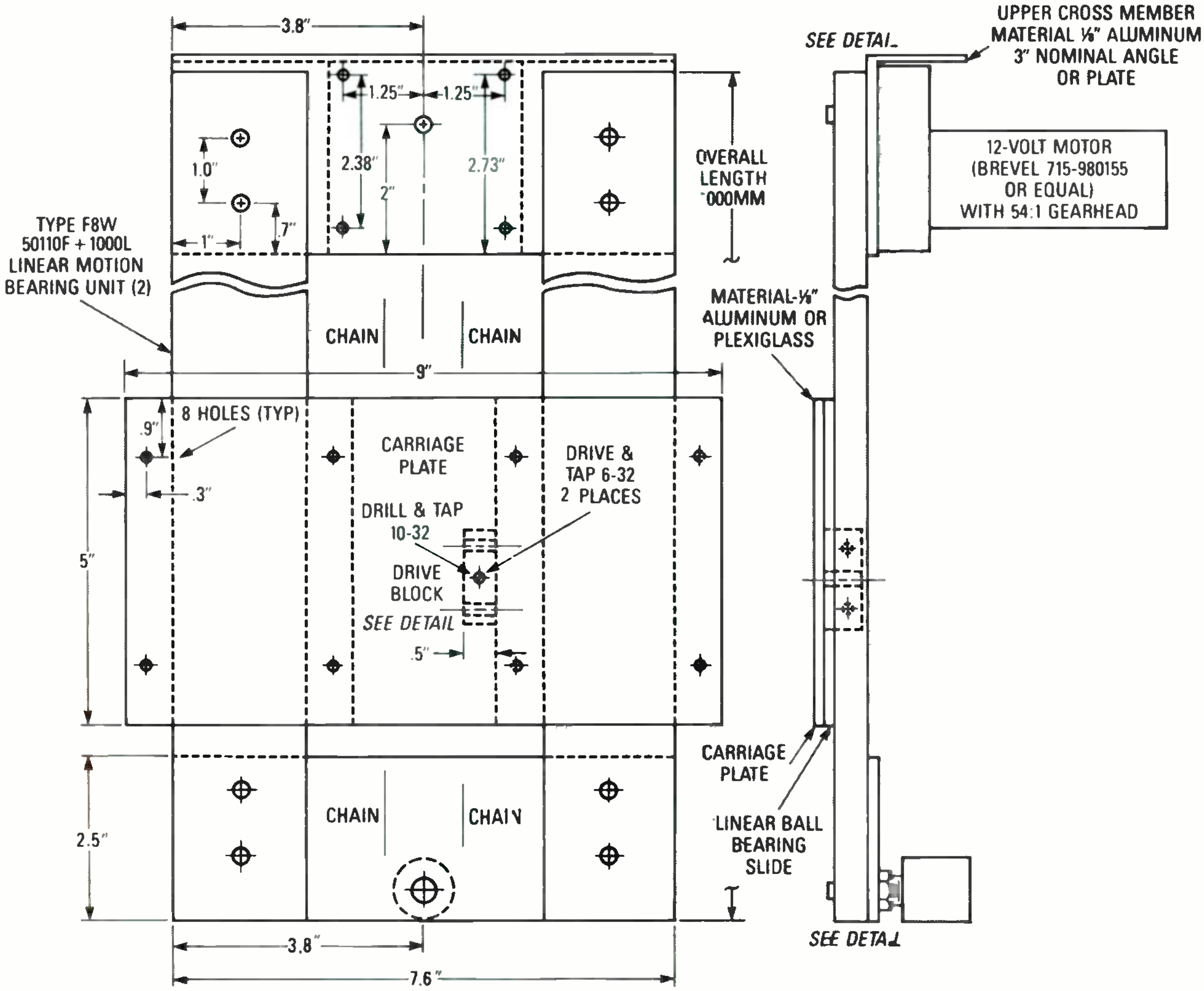


FIG. 2—THE ROBOT ARM can be fabricated using the mechanical drawings shown here.

could cause the required lifting force to become several times the total weight of the load on the lifting forks if sliding bearings were used. That would reduce the lifting capacity significantly. A chain drive is used to handle forces of 10 to 20 pounds without slipping and without any uncertainty about the lift position. The steel ladder-chain used is rated at 55 to 90 pounds tensile load. The drive motor is mounted at the top so that the lifting load is applied to its shaft and bearings directly (a ball-bearing version of that motor is desirable for heavy use). A potentiometer used for position-sensing is placed at the bottom of the chain loop as an idler; when it is mounted there, little load is placed on the potentiometer.

As with the rest of the robot project, the mechanical and electrical details cover our implementation of the arm. There are many other ways that the same results could be achieved. If you wish to change the design to accommodate a specific application, to incorporate an improvement, or to use components you have on hand, you may do so.

Note that much of the mechanical design of the arm can be credited to Spectron Engineering, and they provided the prototype on which this article is based. Further, Spectron is offering for sale the complete arm assembly. See the Sources box for more information.

Electronics overview

The electronics required to operate the arm are quite straightforward. We will use the robot's RERBUS expansion bus to communicate to a quasi-analog servo positioner. All the computer must do is to write the desired position of the arm to the servo circuit and that circuit will do the rest. The servo circuit also allows the computer to read back the position of the arm for analysis and direct control.

Arm design

The heart of the arm is the two linear ball-bearing slide units. Those are 1000-mm long, with approximately 35 inches of travel available. Our first task is to select the ladder chain-and-sprockets that move the carriage along those linear slides. We must select a sprocket for the potentiometer that will allow at least 35 inches of chain travel in ten turns of the sprocket, or 3.5 inches-per-turn. The ladder chain is ¼-inch pitch. Expressing 3.5 inches in terms of pitch length:

$$3.5 \text{ inches} \times 4 \text{ teeth/inch} = 14 \text{ teeth (exactly)}$$

In other words, if our potentiometer sprocket has 14 teeth, in 10 turns it will displace 35 inches of chain. We select the next larger sprocket, 15 teeth, resulting in a total chain travel of:

$$15 \text{ teeth} \times 0.25 \text{ inches/turn} \times 10 \text{ turns} = 37.5 \text{ inches}$$

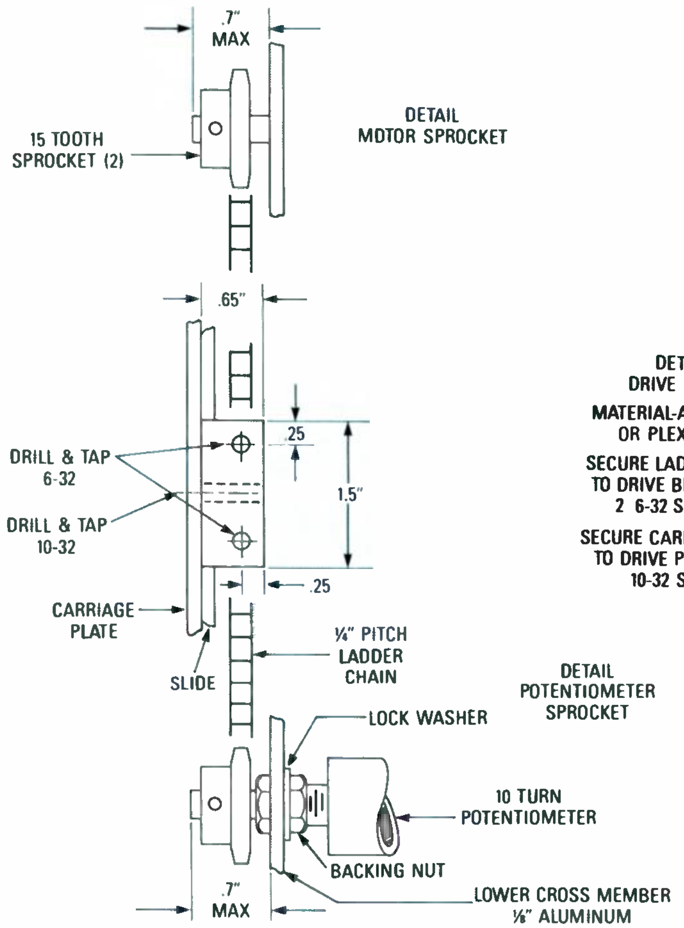


FIG. 3—THIS DETAIL DRAWING shows the ladder-chain drive system.

The extra 2 inches of chain travel will not be used and gives us a margin of error (± ¼ turn) in the event of some misalignment of the potentiometer sprocket during the assembly.

The motor used to drive the chain is any small DC motor with an attached gearhead. The motor may be rated from 12- to 36-volts DC. Using a motor rated at 12 volts will produce approximately twice the rated output, and using one rated at 36 volts will produce approximately ⅔ rated output. The only problem with using under-rated motors is heat build-up. Overheating should not be a problem if your applications call for a low duty cycle—the motor is never on for long, and is off most of the time. Assuming 3000 rpm and a 65:1 gearhead, the lifting speed will be:

(3000 rpm/60-sec/min)/65 = 0.77 rev/sec at sprocket

We can choose the lifting speed by selecting the sprocket size for the motor:

0.77 rev/sec × 10 teeth × 0.25 inch/tooth = 1.9 inch/sec

Other speeds can be calculated by plugging in the appropriate sprocket size. For instance, using a 15-tooth sprocket will give us a lifting speed of 0.77 × 15 × 0.25 = 2.9 inches-per-second, or 15 teeth × 0.25 inches/tooth = 3.75 inches-per-revolution.

Note that as you increase the lifting rate, the lifting capacity (in pounds) will be decreased. We have selected the 15-tooth design for more load capacity.

PARTS LIST

All resistors ¼ watt, 5%, unless otherwise noted
R1–R7, R9—100,000 ohms
R8—220 ohms
R10—47,000 ohms
R11—1 ohm, 1 watt
R12—10,000 ohms, 10-turn linear potentiometer
Semiconductors
IC1—DAC0832 digital-to-analog converter
IC2—74LS138 decoder
IC3—LM324 quad op-amp
IC4—UDN2952W motor driver
D1, D2—1N914 diode
Other components
J1—26-conductor ribbon-cable connector
TS1—5-position terminal strip
MOT1—12-volt motor with attached gearhead (see text)
Miscellaneous: Perforated construction board, wire, solder, mechanical components (see text), etc.

SOURCES

The complete arm assembly can be purchased from Spectron Engineering, 1342 West Cedar Ave., Denver, CO 80223; (303) 744-7088. The cost is $300 plus $8 shipping. Colorado residents add appropriate sales tax. The assembly includes the following: two 1000-mm linear-bearing assemblies, two cross members, carriage plate, robot end cover, drive block, chain, motor, sprockets, 10 turn potentiometer, servo positioner, cables, and connectors.

Stock Drive Products, Division of Designatronics, Inc. 2101 Jericho Turnpike, New Hyde Park, NY 11040, (516) 328-0200, can supply the 15-tooth ¼-inch pitch sprocket (part number 6T7-2515) and the ¼-inch ladder cabin (part number 6C88-25). Contact them directly for pricing, shipping, or other information.

The 1000-mm linear ball-bearing slides are manufactured in Japan by T.H.K. Ltd. They can be purchased from Bearing Engineers, Inc., 6009 Bandini Blvd., Los Angeles, CA 90040; (213) 754-9660. Contact them directly for pricing, shipping, and other information. Ask for part number FBW 50110F+1000L.

The Brevel motor, part 715-980155, can be purchased from Johnstone Supply, 930 Wyandot, P.O.Box 4605, Denver CO 80204; (303) 573-5626. Contact them for pricing and shipping. **R-E**

Turning our attention to the motor, the 15-tooth sprocket has a chain radius of approximately 0.5 inches. In order to lift 10 pounds, we will require a motor whose shaft can deliver a torque of 0.5 inches × 10 pounds = 5 pound inches.

We have chosen a Brevel 715-980155 gearhead 12-volt motor. The motor will be run at 24 volts, but that is not a problem because the motor will be subjected to a low duty cycle. The motor has a starting torque rating of 40 pound inches, which means that it can lift 40 pound inches/0.5 inches = 40 pounds. Its running torque is rated at 13 pound inches at 40 rpm, which means it can lift 26 pounds at a lifting speed of (40 rev/min/60 sec/min) × 3.75 inches/rev = 2.5 inches/second.

We can assume that the motor will deliver approximately twice the calculated performance if we run it at 24 volts. However, the servo circuit will limit the current drawn by the motor to approximately one ampere. That effectively limits the lift torque to about 10 pounds.

Arm construction

The arm can be built following the plans shown in Fig. 2; details for several sections of that drawing are shown in Fig. 3. The upper and lower cross-members can be made from aluminum plate, channel, or angle extrusion. Note that channel or angle form-factors are stronger than that of flat plate in resisting twisting

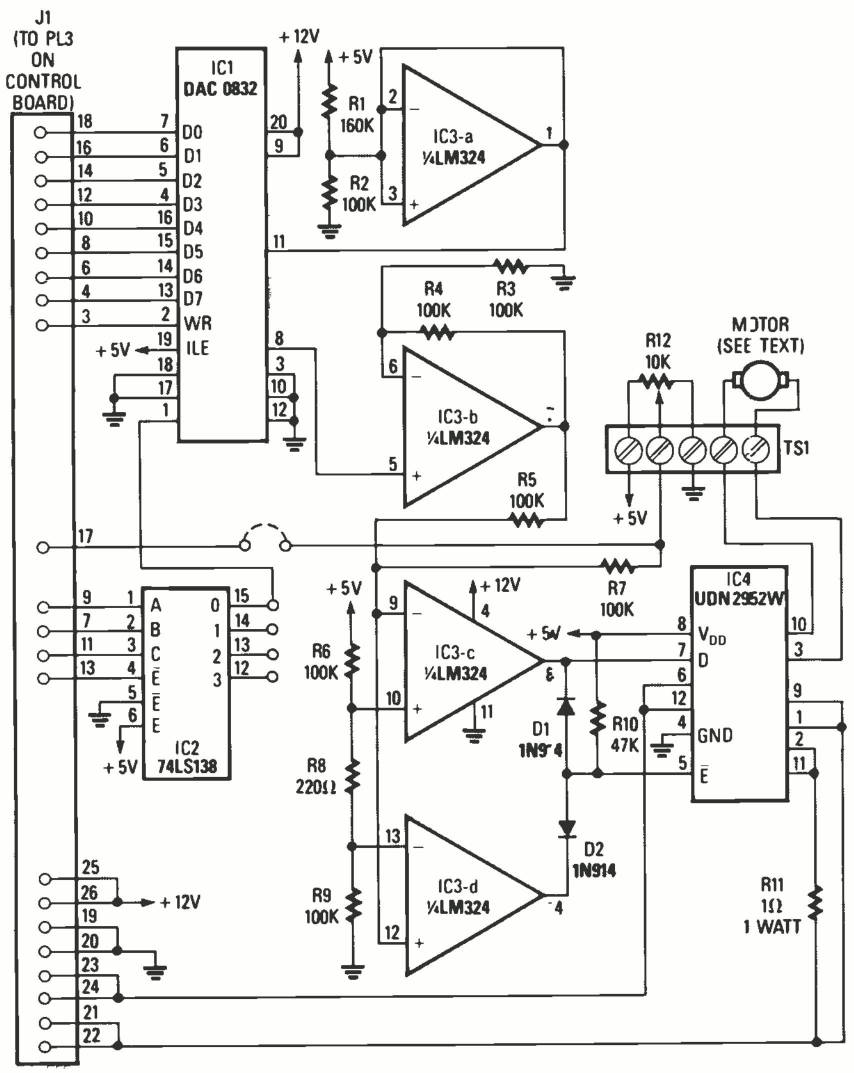


FIG. 4—THE SERVO CONTROLLER positions the carriage plate without RPC supervision.

forces imposed by off-center loads and provide additional mounting surfaces for future projects. Mount the motor on the upper cross-member so that the shaft is offset to the top, and secure it to the face of the cross-member using 10-32 flat head screws. The potentiometer should be mounted at the bottom of the lower cross-member. When mounting, use double nuts or extra washers so that the mounting bushing extends only 1/16-inch beyond the mounting nut. Installing the motor and potentiometer as described will allow for the maximum possible travel of the linear bearings with a minimum overhang of the cross-members.

The cross-members are mounted to the back of the linear bearing tracks. Those tracks are part of the 1000-mm linear bearing assemblies, which can be purchased from the company mentioned in the Sources box; they are also provided with the complete arm assembly that was mentioned previously.

Next, mount the carriage plate to the front of the sliders with 10-32 screws. The carriage plate should slide over the entire length of the tracks and overlap the motor mount in the end position. If the carriage plate jams, correct the problem by readjusting the mounting screws. Note that the type of slide bearings used in this assembly may bind somewhat, particularly when unloaded. But under load, the bearings provide low friction and long operating life.

The sprockets should now be mounted on the motor and potentiometer. They are positioned with the hub outward so that the working load is kept close to the bearings. The set screws on the sprockets have a bad habit of working loose, so seal them after installation with nail polish, *Loctite*, etc.

Check to be sure that the carriage clears the sprockets and shafts of the motor and potentiometer. Install washers behind the carriage plate to move it away from the sprockets if you have an interference problem. In some instances, you may have to saw off the ends of the motor and potentiometer shafts to achieve clearance.

Next, turn the potentiometer fully clockwise. Use a piece of tape to hold it in that position until the chain installation is complete. Note that if the potentiometer is not positioned properly the full carriage travel will not be available; or worse, the potentiometer stops can be damaged if the full power of the motor is applied to them. Thread the chain over the motor and potentiometer sprockets, open it, remove enough links so that it is the correct length, and reassemble the chain. Move the carriage all the way to the top of the assembly and attach it to the chain via the drive block. Be sure to thread the chain so that it is inside the block; i.e., closer to the centerline.

An alternate to closing the chain into an endless loop is to connect the ends using a spring. Doing so serves to eliminate backlash from chain slack and lessens the load on the potentiometer. However, under heavy loads, the spring may allow the chain to become slack, allowing slippage at the sprockets. Although usually that is not a problem, slippage can be eliminated entirely by not using a spring.

The lifting tines of the fork lift are formed using 8- to 10-inch steel L-brackets. You will probably need to drill some extra holes to allow you to mount the bracket to the carriage plate. If you wish, you can add the holes in such a way to allow the brackets to extend below the slide bearings and reach the floor. Mount the tines to either the outer or inner row of carriage-plate holes to accommodate the width of your anticipated loads.

Attach a 26-conductor ribbon cable to the RERBUS interface on the control board, and lead the cable out through the bottom of the robot's body. Finish up by mounting the arm assembly on the robot's end cover using four 6-32 screws. In our implementation, we split that end cover into two sections to allow for easy access to the fastening nuts and the electronics package, which is mounted on the forward bulkhead.

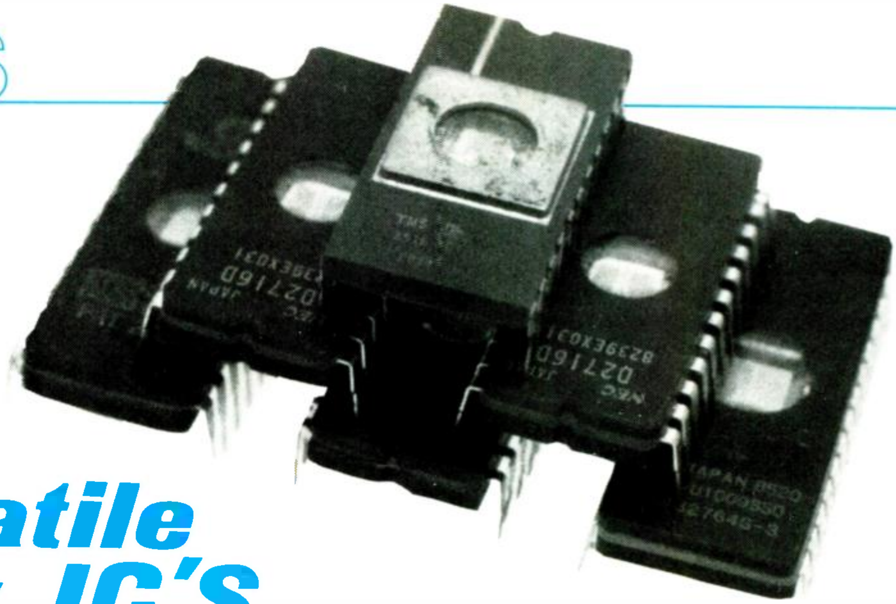
Arm electronics

The control system for the arm is straightforward. Once notified of the final position for the carriage plate, the system will move the plate to that position without further attention from the *R*obotic *P*ersonal *C*omputer (RPC).

A schematic of the control system is shown in Fig. 4. After determining where the carriage plate should be positioned, the RPC writes a position value into the *D*igital-to-*A*nalog *C*onverter (DAC). The quasi-analog servo system takes over and begins slewing the motor toward the selected position. When the voltage fed back from the potentiometer is equal to the voltage output from the DAC, the system knows that the selected position has been reached and the motor is turned off. All during that time the computer is free to begin analyzing the next required motion.

continued on page 74

Two IC's that retain their content's with few hassles—and no batteries!



Non-Volatile Memory IC'S

ROBERT GROSSBLATT

IF YOU HAD TO SINGLE OUT ONE AREA IN the semiconductor industry as the most competitive, it would have to be the memory market, because the advances made in electronics invariably put increased pressure on memory designers to produce IC's that are faster, smaller physically, have denser storage, and are easier to use.

Unfortunately, it's a lot easier to build a wish list than it is to build an IC. As a result of the market pressure, memory development split into two separate parts, each with different design goals. One group aimed at increased storage capacity while the other tackled the problem of permanence. The result of the dichotomy has been the production of two very different kinds of memories: volatile and non-volatile.

By using a single-transistor storage cell, address multiplexing, and geometries of under 2 microns, 256K-bit DRAM's are now so commonplace that their price in single units is less than $3. Unfortunately, although DRAM's (*Dy*namic RAM's) may be able to store a lot of data in a small package, they're not the easiest chips to use. Because only one transistor is used for storage, data has to be refreshed every 2 milliseconds, and any application using DRAM's must have refresh circuitry. Address multiplexing may cut down the size of the package, but it means that external gating has to be used to properly address the IC. And it goes without saying that permanent—non-volatile—data retention is completely impossible.

Although the designers who tackled the problem of volatility wanted to keep storage capacity as large as possible, they also wanted to make sure it was permanent as well. The first consequence of a decision to make non-volatility a design goal was to concentrate on the development of CMOS static RAM's. The inherent low-power requirements of CMOS technology meant that non-volatility could be faked by using a small battery to provide standby power. That approach produced the *5101*, a 256 × 4 RAM that could be toggled into a "sleep" mode, in which it would retain data at a current drain measured in the low microamps. Modern versions of that design, such as the *6264*, have the same kind of low-power data-retention feature, but the amount of storage capacity has been increased to 64K bits (8K × 8).

Non-volatile memory

But standby batteries are a poor substitute for real permanence. Battery life is often an unknown variable and even a modern lithium cell can't be considered absolutely reliable when the temperature or other operating parameters are outside predefined limits. True non-volatility in a read/write memory first appeared in the late 1970's in the form of EPROM's (*E*rasable *P*rogrammable *R*ead *O*nly *M*emories). The early IC's were hard to use, required several voltages, and had the nasty habit of self-destruction if they weren't used exactly according to specifications.

As EPROM's developed, they became so reliable and easy to use that they began replacing bipolar PROM's as the memory of choice. Programming simplicity, second-sourcing, storage capacity, and cost-per-bit have made EPROM's an attractive answer to the problem of non-volatility. But EPROM's still have major drawbacks—they can only be bulk-erased (cells cannot be erased individually), and erasure has to be done by narrow-band ultra-violet light (about 2500 Angstroms).

Electrical erasure

EEPROM's (*E*lectrically *E*rasable *P*rogrammable *R*ead *O*nly *M*emories) appeared on the market at about the same time as EPROM's but never became as popular in the consumer market. Although they have several major advantages over EPROM's, they're more than twice as expensive. The best way to think of an EEPROM is as an EPROM that can be erased in-circuit under program control. Although there are some restrictions in erasing and programming an EEPROM, the fact that it can be done at all makes them an interesting solution to many circuit and design problems.

Storage in an EEPROM is much the same as it is in an EPROM—a charge stored on a polysilicon floating gate. What makes the EEPROM different is the way charges are either moved to, or taken from the cell. Figure 1 is a representation of an EEPROM storage cell. The three separate gates are completely surrounded

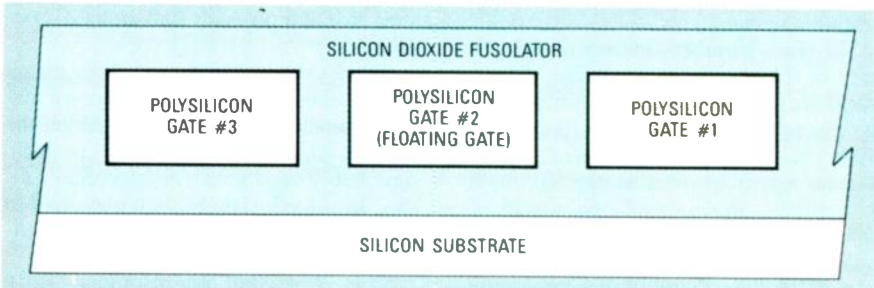


FIG. 1—A FLOATING-GATE EEPROM is built on a silicon substrate. The gates are insulated by silicon dioxide.

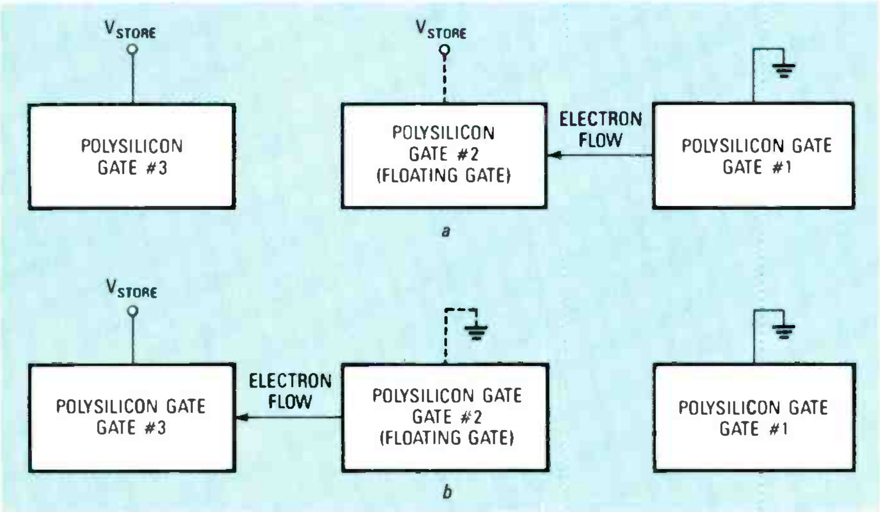


FIG. 2—HOW AN EEPROM'S FLOATING GATE is charged is shown in *a*. The discharge is shown is *b*.

by silicon dioxide to make sure that they're totally insulated from both the silicon substrate and each other. Any electron that gets caught on the floating gate will stay trapped there until a sufficiently large amount of energy forces it to move through the silicon dioxide. In an EPROM, the energy comes from bombarding the gates with doses of ultraviolet light. If sufficient photons hit the cell, the energy level will increase to the point where the trapped electrons will be excited enough to leave the gate and migrate through the insulator.

It's also possible to force electron migration by applying a high electric field. If the field is strong enough, the electrons will tunnel through the silicon dioxide—a phenomenon first described by Fowler and Nordheim in 1928. The Fowler-Nordheim tunneling is the basic principle used to store and remove charges from the isolated gates in EEPROM cell.

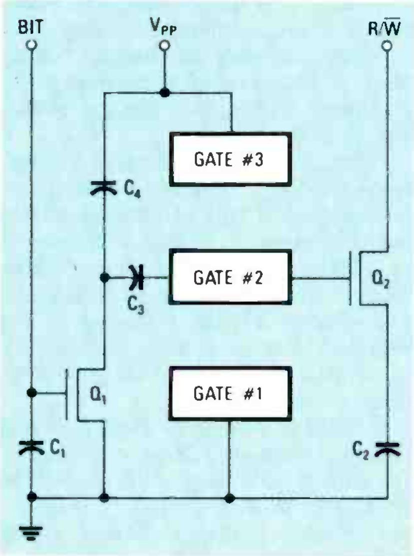


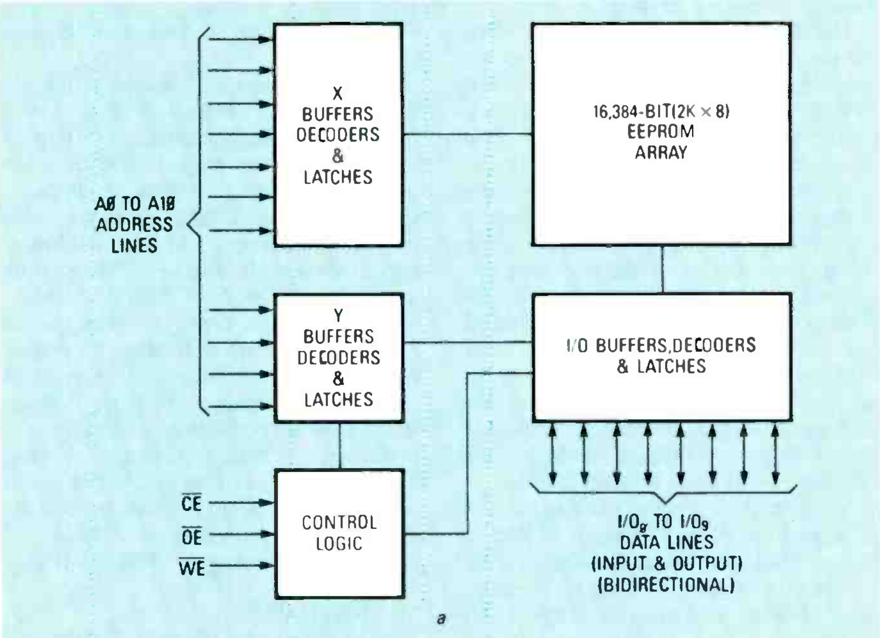
FIG. 3—TO WRITE TO AN EEPROM the R/W line is held low. It is held high for a read.

Figure 2 shows what happens when you write to an EEPROM cell. If gate 3 is tied to a large enough voltage, and gate 1 is grounded, Fowler-Nordheim tunneling will take place and electrons will migrate through the silicon-dioxide insulator from gate 1 to gate 2 (the floating gate), causing it to be charged negatively. The applied electric field causes the gates and insulating material to act as if two capacitors were present there—one between gate 1 and gate 2, and the other between gate 2 and gate 3.

In order to discharge the floating gate, it must be held near ground when the programming voltage is applied. Since gate 1 is also tied low, the electrons will move from gate 2 to gate 3 and the negative charge will be removed from the floating gate.

It takes more than the structure that we just discussed to produce a working EEPROM cell. A means must be added to steer the charges to the floating gate, and switching circuitry has to be added to let the cell's operation be handled by external control signals. Figure 3 shows an operational cell. Notice that the floating gate is only capacitively connected to the rest of the circuit.

The two lines that control the data written to the cell are the BIT line and the V_{PP} line. If a low is put on the BIT line and the programming voltage is applied to V_{PP}, Q1 turns off and floats the junction of C3 and C4. Since their combined capacitance is made to be much larger than the effective capacitance between gate 1 and gate 2, the floating gate (2) will follow the programming voltage and Fowler-Nordheim tunneling will take place, causing a negative charge to accumulate on the floating gate. If the BIT line is held high when V_{PP} is



$\overline{CE}$	$\overline{OE}$	$\overline{WE}$	MODE	IO	POWER
L	L	H	READ	D_{OUT}	ACTIVE
L	H	L	WRITE	D_{IN}	ACTIVE
H	X	X	STANDBY	Hi Z	STANDBY
X	L	X	STANDBY	—	—
X	X	H	STANDBY	—	—

b

FIG. 4—THIS IS THE BLOCK DIAGRAM for an X2861A 2K × 8 EEPROM.

applied, the C3/C4 junction will be grounded, and since C3 is much larger than the effective capacitance between gate 2 and gate 3, the floating gate will be held near ground as well. The electrons will migrate from the floating gate to gate 3 and leave the floating gate with a positive charge.

The process of adding and removing electrons to the floating gate is never 100% efficient. As a result, each write operation leaves the floating gate less able to retain a stored charge. That is an inherent characteristic of the storage mechanism, and although it can be minimized, it can't be eliminated altogether. Most EEPROM's are guaranteed to be able to successfully perform 10,000 write operations without any noticeable degradation of data storage—and that's a lot of writes.

One voltage source

Like the early EPROM's, early EEPROM's were multivoltage components and needed support circuitry to work properly. V_{PP} (about 21 volts) had to be generated independently, latches were needed to hold the data and address lines stable during addressing, and strict timing was needed to read or write data. But just as with most IC families, considerable improvements have been made. Figure 4 is a functional diagram of a modern EEPROM, Xicor's *2816A*, a 2K × 8 memory that incorporates all the features found in modern EEPROM's.

The first thing you should notice is that the pin configuration is the same as the industry-standard pinout for the *2716* EPROM. As you would expect, the read-cycle timing is also similar to the *2716*, so the *2816* is socket-compatible with the EPROM. A more interesting comparison is that the 2816 is both pin and socket compatible with the *6116* 2K × 8 static RAM. Since the Xicor part only uses a 5-volt supply, it's possible to literally replace a *6116* with a *2816*. The EEPROM will use more power than the low-power *6116*, but that's not a high price to pay for real non-volatility. And the amount of current needed by the *2816* can be reduced to 50 mA by bringing the CE line high if the chip isn't being used by the system.

Since the 21-volt programming pulse is generated internally and a pair of latches in the IC hold the data and address during a write, the operation of the IC is essentially identical to that of a static RAM. All of the IC's timing is done automatically by internal circuitry, and the outputs three-state whenever the chip is busy, leaving the bus free for other purposes. You can get a better idea of how the chip works by examining the truth table, shown in Fig. 4.

EEPROM's are currently available with the same capacity found in the more popular EPROM's, including the 1-megabit (256K × 8) size. And even the power-consumption problem is being solved. Since EEPROM's store their charges on a floating gate that is capacitively coupled to the rest of the chip, EEPROM's are perfectly suited to being made with CMOS technology. Xicor, and other companies such as Seeq and National Semiconductor, are starting to deliver sample quantities of CMOS EEPROM's.

Since it's so easy to write to an EEPROM, they are well-suited for power-failure protection. A small circuit can watch the powerline, and if the voltage falls below a predetermined level an automatic write is done to save system data. The restriction as to the number of writes would seem to be a problem, but the answer can be found in an offshoot of EEPROM technology— NOVRAM's.

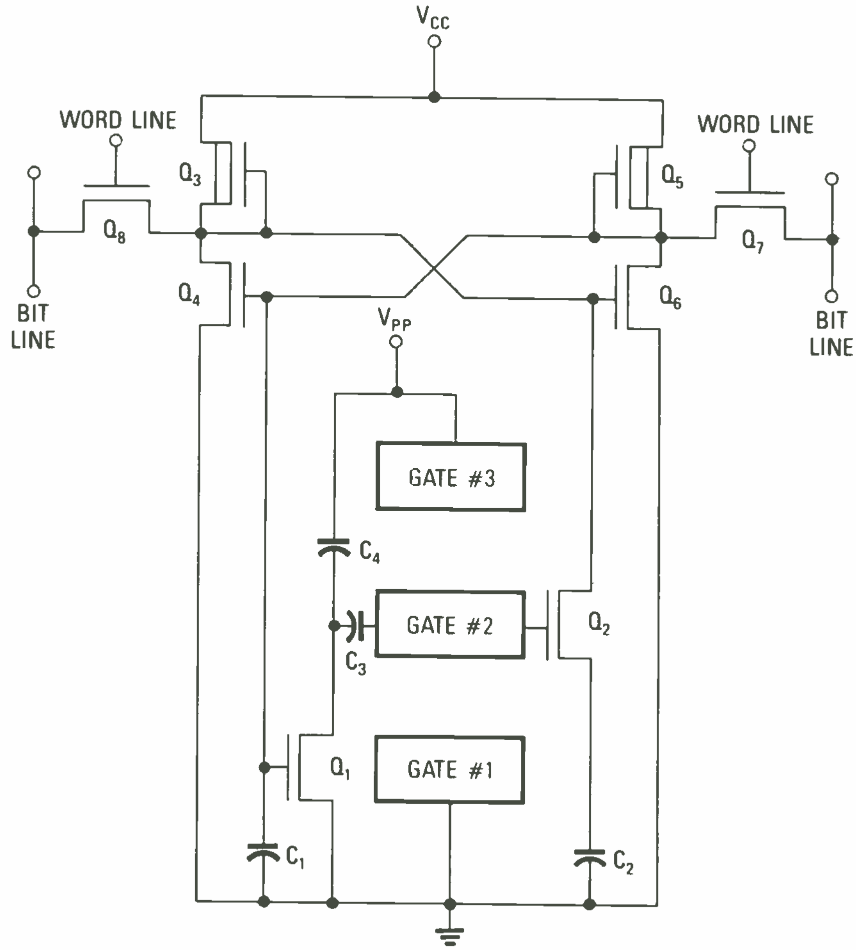


FIG. 5—A NOVRAM CELL SCHEMATIC. Transistors Q3–Q8 form a conventional static-RAM cell.

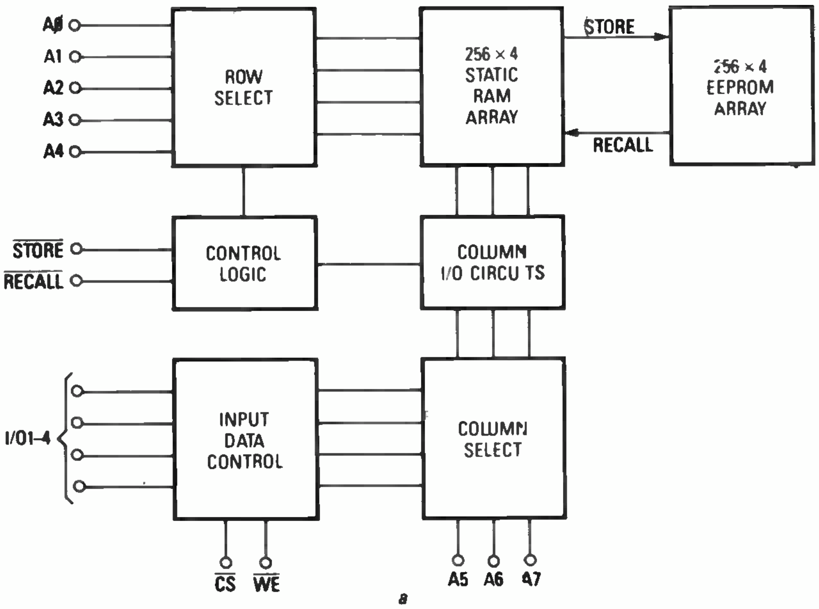
The NOVRAM

*NO*n-*V*olatile *RAM*'s (NOVRAM's) are also known as *shadow RAM*'s. Their construction can be understood from Fig. 5. The EEPROM cell we described earlier is linked to a regular static RAM cell. The six transistors in the standard static RAM cell, Q3–Q8, link to the two-transistor EEPROM cell. In that way, each static RAM cell is backed up, or shadowed, by an EEPROM cell. The advantage of using a NOVRAM—as opposed to an EEPROM—in a working circuit has to do with speed and write cycles.

EEPROM's, just like EPROM's, are not particularly fast parts. Even the fastest EEPROM has about a 10-millisecond write cycle, which is made a bit more bearable because of the EEPROM's internal latches. A write may be slow but at least it won't tie up the system bus. Any application that has to write data faster than that will have to take some other route for emergency data-backup. And of course, there are only a certain number of guaranteed write cycles over the normal lifetime of the IC.

Those problems are solved, at a price, by NOVRAM's. Data can be written to the static-RAM half of a NOVRAM at much higher speeds. A typical NOVRAM has a 300-nanosecond write time and, of course, there are an unlimited number of writes. After all, the front end of the NOVRAM is ordinary static RAM, so it's no surprise that it operates at microprocessor speeds.

The EEPROM part of the NOVRAM can only be accessed in one of two ways. The static-RAM image can be dumped to the EEPROM with a STORE command, and the data in the EEPROM can be loaded in the static RAM with a RECALL command. A block diagram of Xicor's



a

CS	WE	RECALL	STORE	I/O	MODE
H	X	H	H	Hi-Z	NOT SELECTED
L	H	H	H	D_{OUT}	READ
L	L	H	H	D_{IN} HIGH	WRITE A "1"
L	L	H	H	D_{IN} LOW	WRITE A "0"
X	H	L	H	Hi-Z	RECALL
H	X	L	H	Hi-Z	RECALL
X	H	H	L	Hi-Z	STORE
H	X	H	L	Hi-Z	STORE

b

FIG. 6—THE BLOCK DIAGRAM and truth table for a X2212 NOVRAM.

2212, a 256 × 4 NOVRAM is shown in Fig. 6-*a*; its truth table is shown in Fig. 6-*b*.

The larger size of a NOVRAM cell compared to an EEPROM cell means that NOVRAM's will have smaller storage capacities. In addition, their cost per bit is going to be much greater. Which one you should use will depend on your application. In general, EEPROM's are better suited for off-line work and NOVRAM's are fast enough to work as an on-line component. If you plan on doing a lot of reads with only occasional writes, EEPROM's are your best bet; but if you have to write data frequently you should look into NOVRAM's. Even though it will take more IC's to build up to the required memory size, they will still be more cost-effective than a handful of regular memory IC's.

Snapshots and DIP's

Two ideal uses for a NOVRAM are for system snapshots in the event of a power failure, and as replacements for DIP switches. The circuit shown in Fig. 7 is one approach for the design of a power-loss trigger device for a snapshot circuit. It operates on DC, but can be adapted for use with an AC-powered circuit.

A trigger device such as the one in Fig. 7 is needed because the STORE input of NOVRAM's such as Xicor's *22xx* family wants to see a negative TTL trigger pulse at least 100-nanoseconds long. As soon as the pulse is received, an automatic STORE operation transfers the static RAM image, bit for bit, into the EEPROM. The write to EEPROM takes 10-milliseconds, so any detection circuit that produces the STORE pulse has to tread a fine line. If it has too high a trip point there's a good chance of producing spurious pulses, and if it's set too low there won't be enough time for the NOVRAM to complete the STORE. Since the minimum operating V_{CC} for a

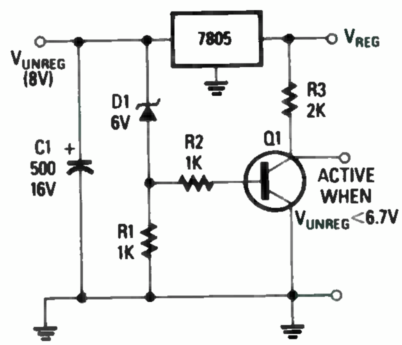


FIG. 7—A DC POWER FAILURE detector that can be used for a NOVRAM snapshot circuit.

NOVRAM is 4.5 volts, the STORE has to be triggered at a voltage level that can guarantee a 10-millisecond delay before V_{CC} drops to 4.5 volts.

The values shown in Fig. 7 assume a 5-volt regulator being fed an unregulated 8 volts. The trip point is set to be 6.7 volts by a 6-volt Zener diode and the 0.7-volt base-emitter drop in the transistor. The filter capacitor (C1) helps slow down the voltage drop in the event of a failure.

If you want to put together a circuit that

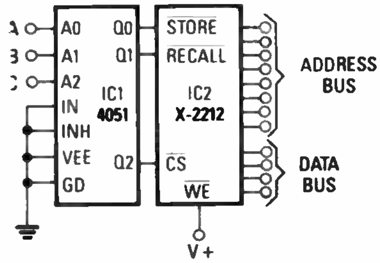


FIG. 8—A NOVRAM DIP SWITCH requires a single decoder. NOVRAM's are available that can emulate 4096 mechanical DIP switches.

will do the same thing for an AC-powered supply, you can detect the zero crossing on the AC-line and feed that to a missing-pulse detector. An easier way would be to use the circuit in Fig. 7. Even if your application has no use for a regulated DC voltage you can still use it to power the NOVRAM, and just think of the regulator and the associated components as part of the detection circuit.

Using NOVRAM's in place of DIP switches eliminates a potentially noisy and troublesome mechanical component with an IC. As an added benefit, fewer external parts are needed as well. As shown in Fig. 8, a single decoder (IC1) is all that's needed to set up a NOVRAM as an electronic DIP. The three NOVRAM control pins are connected to the outputs of a 4051 one-of-eight decoder set to operate in the digital mode. Using only three of the 4051's output ports—Q0, Q1, Q3—will let the system access any one of the switch settings stored in the NOVRAM. Since Xicor makes NOVRAM's as large as 512 × 8, (the *X2004*), you can pack 4096 separate DIP switches in a single IC; more if you use additional IC's.

Although EEPROM technology has been around for more than 10 years, cost, complexity, and capacity have forced them to take second place to the more popular EPROM's. That may change in the near future as manufacturers continue to refine EEPROM fabrication methods and produce new IC's whose utility, reliability, and versatility compensate for the dwindling differences in cost.

Many mail order houses now stock EEPROM's and NOVRAM's. It's well worth your time to get your hands on some parts and their data sheets, and start learning just how useful those IC's can be. **R-E**

WORKING WITH TRIACS AND SCR's

Twenty-eight practical SCR and Triac circuits.

RAY MARSTON

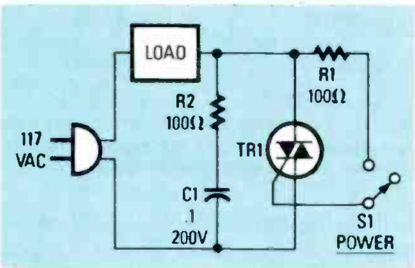


FIG 1—AC POWER SWITCH, AC triggered.

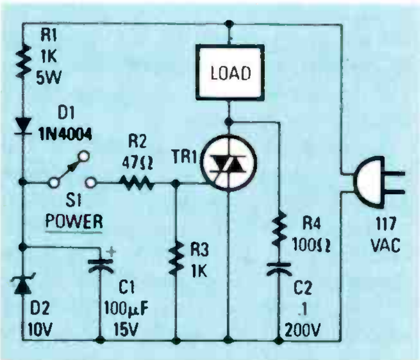


FIG 2—AC POWER SWITCH, DC triggered.

LAST TIME WE DISCUSSED BASIC SCR AND Triac theory, paying particular attention to the principles of synchronous and asynchronous triggering. (See **Radio-Electronics**, September 1987.) This time we'll present a number of practical circuits for which the user need only select an SCR or Triac having suitable voltage and current ratings. Let's start off by looking at several Triac circuits that can be used to control some line-voltage-powered devices.

Asynchronous designs

As explained last time, a Triac may be triggered (turned on) either synchronously or asynchronously. A synchronous circuit always turns on at the same point in each half-cycle, usually just after the zero-crossing point, in order to minimize RFI. An asynchronous circuit does not turn on at a fixed point, and the initial current surge generated during turn-on at a non-zero point of the AC cycle can generate significant RFI. Triac turn-off is automatically synchronized to the zero-crossing point, because the device's main-terminal current falls below the minimum-holding value at the end of each half-cycle.

Figures 1–8 show a variety of asynchronous Triac power-switching circuits. In Fig. 1, the Triac is gated on (whenever S1 is closed) via the load and R1 shortly after the start of each half-cycle; the Triac remains off when S1 is open. Note that the trigger point is not line-synchronized when S1 is closed initially; however, synchronization is maintained on all subsequent half-cycles.

Figure 2 shows how the Triac can be triggered via a line-derived DC supply. Capacitor C1 is charged to +10-volts DC (via R1 and D1) on each positive half-cycle of the line. The charge on C1 is what triggers the Triac when S1 is closed. Note that all parts of the circuit are "live," and that makes it difficult to interface to external control circuitry.

Figure 3 shows how to modify the previous circuit so that it can interface with external control circuitry. Switch S1 is simply replaced by transistor Q2, which in turn is driven from the photo-transistor portion of an inexpensive optocoupler. The LED portion of the optocoupler is driven from a 5-volt DC source via R4. Opto-couplers have typical insulation potentials of several thousand volts, so the external circuit is always fully isolated from the line.

Figure 4 shows an interesting variation of the previous circuit. Here the Triac is AC-triggered on each half-cycle via C1, R1, and back-to-back Zeners D5 and D6. Note that C1's impedance determines the magnitude of the Triac's gate current.

The bridge rectifier composed of D1–D4 is wired across the D5/D6/R2 network and is loaded by Q1. When Q1 is off, the bridge is effectively open, so the Triac turns on shortly after the start of each half-cycle. However, when Q2 is on, a near-short appears across D5/D6/R2, thereby

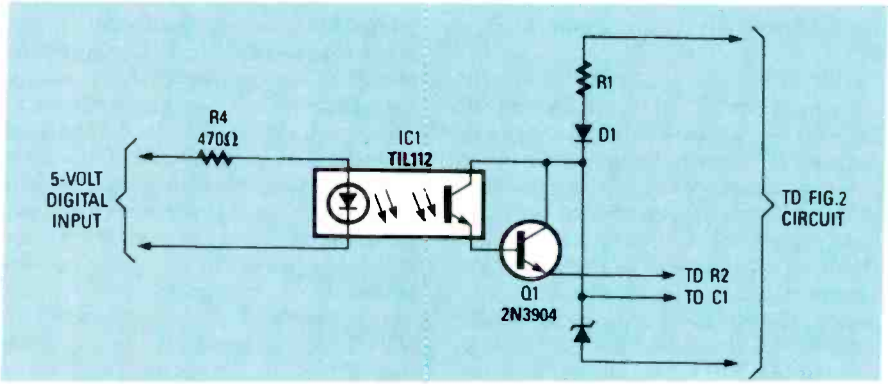


FIG 3—OPTICALLY ISOLATED AC power switch, DC triggered.

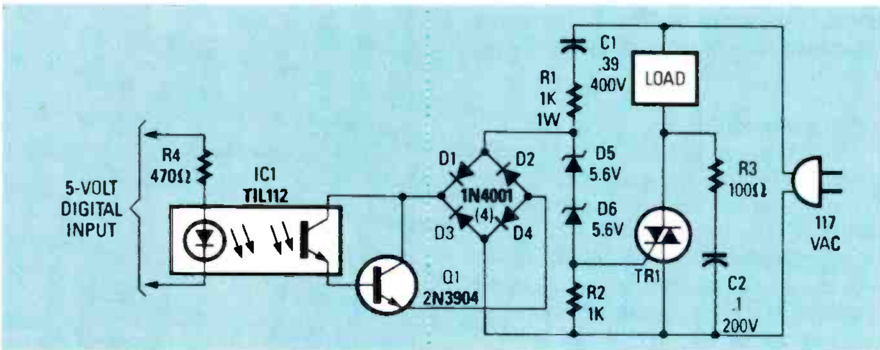


FIG 4—OPTICALLY ISOLATED AC power switch, AC triggered.

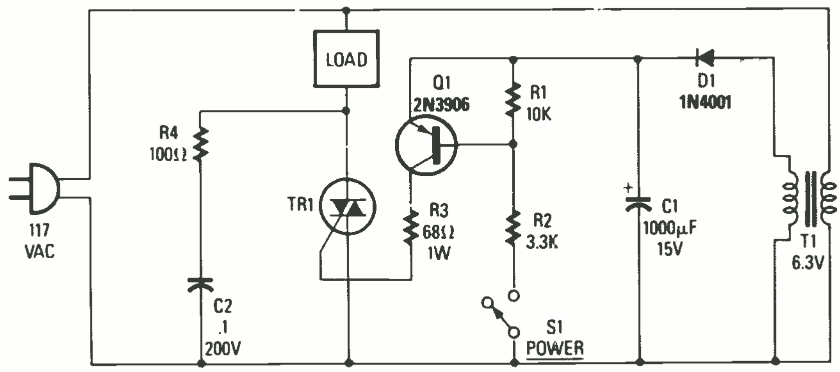


FIG 5—AC POWER SWITCH with transistor- aided DC triggering.

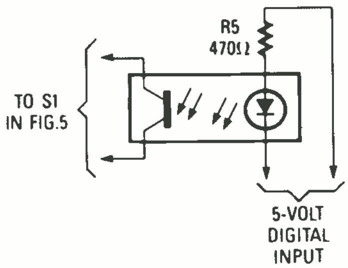


FIG 6—TRIGGER THE PREVIOUS CIRCUIT with an optocoupler.

inhibiting the Triac's gate circuit, so it remains off.

Figures 5 and 6 show several ways of triggering the Triac via a transformer-derived DC supply and a transistor-aided switch. In the Fig. 5 circuit, Q1 and the Triac are both turned on when S1 is closed, and off when it is open. In practice, of course, S1 could be replaced by an electronic switch, enabling the Triac to be operated by heat, light, sound, time, etc. Note, however, that the whole of the Fig. 5 circuit is "live." Figure 6 shows how to modify the circuit so that is is suitable for use with an optocoupler.

To complete this section, Figures 7 and 8 show several ways of triggering a Triac from a fully isolated external circuit. In both circuits, triggering is obtained from an oscillator built around unijunction transistor Q1. The UJT operates at a frequency of several kHz and feeds its output pulses to the Triac's gate via pulse transformer T1, which provides the desired isolation. Also in both circuits, S1 can easily be replaced by an electronic switch.

In the Fig. 7 circuit, Q2 is wired in series with the UJT's main timing resistor, so the UJT and the Triac will turn on only when S1 is *closed*. In the Fig. 8 circuit, Q2 is wired in parallel with the UJT's main timing capacitor, so the UJT and the Triac turn on only when S1 is *open*.

Synchronous designs

Figures 9–18 show a number of power-switching circuits that use synchronous triggering.

Figure 9 shows the circuit of a synchronous line switch that is triggered near the zero-voltage crossover points. The Triac's gate-trigger current is obtained from a 10-volt DC supply that is derived from the network composed of R1, D1, D2, and C1. That supply is delivered to the gate via Q1, which in turn is controlled by S1 and the zero-crossing detector composed of Q2, Q3, and Q4.

Transistor Q5 can only conduct gate current when S1 is closed and Q4 is off. The action of the zero-crossing detector is such that either Q2 or Q3 turns on whenever the instantaneous line voltage is positive or negative by more than a few volts, depending on the setting of R8. In either case, Q4 turns on via R3 and thereby inhibits Q5. The circuit thus produces minimal RFI.

Figure 10 shows how to modify the previous circuit so that the Triac can only turn on when S1 is open. In both circuits note that, because only a narrow pulse of gate current is sent to the Triac, average consumption of DC current is very low (one milliampere or so). Also note that S1 can be replaced by an electronic switch, to give automatic operation via heat, light, time, etc., or by an optocoupler, to provide full isolation.

A number of special-purpose synchronous zero-crossover Triac-gating IC's are available, the best-know examples being the CA3059 and the TDA1024. Both devices incorporate line-derived DC power-supply circuitry, a zero-crossing detector, Triac gate-drive circuitry, and a high-gain differential amplifier/gating network.

Figure 11 shows the internal circuitry of the CA3059, together with its minimal external connections. AC line power is applied to pin 5 via a limiting resistor

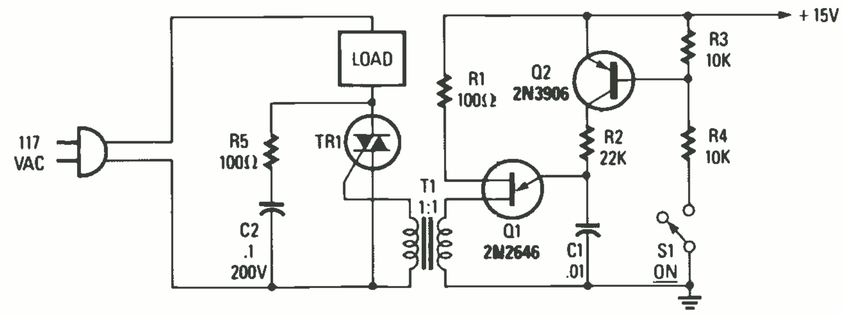


FIG 7—TRANSFORMER-COUPLED AC power switch. The Triac turns on when S1 is closed.

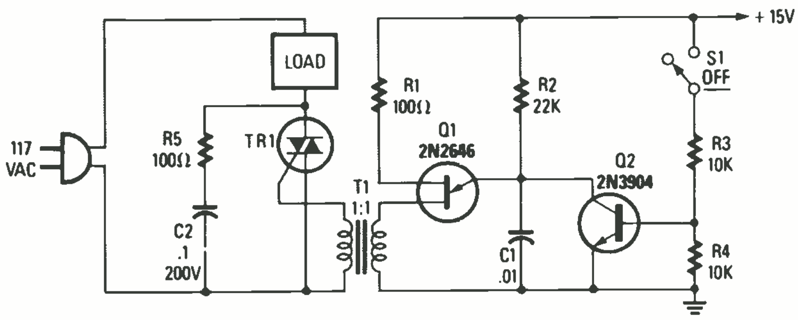


FIG 8—ISOLATED-INPUT AC power switch. The Triac turns on when S1 is open.

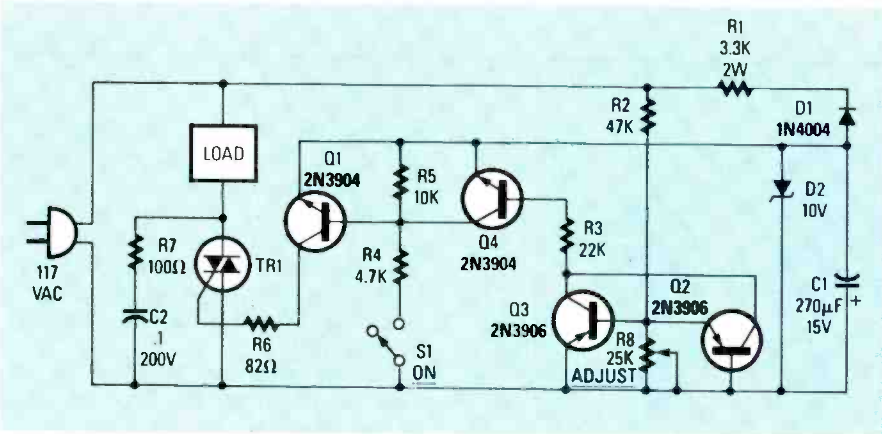


FIG 9—ZERO-CROSSING synchronous line switch. The Triac turns on when S1 is closed.

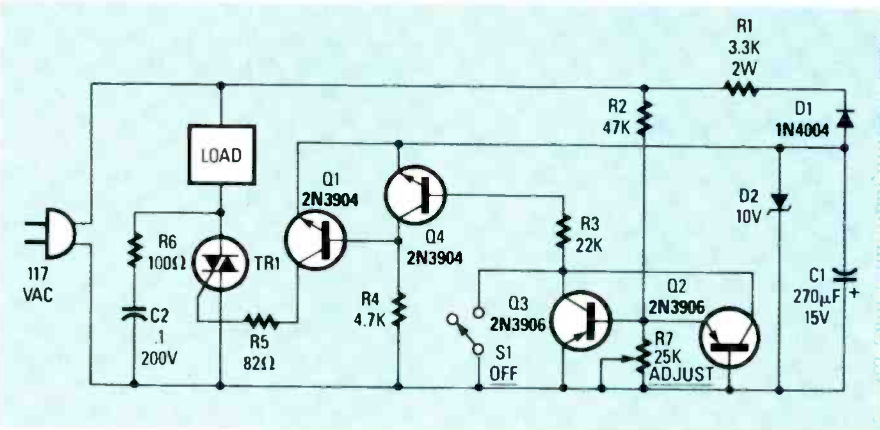


FIG 10—ALTERNATE synchronous line switch. The Triac turns on when S1 is open.

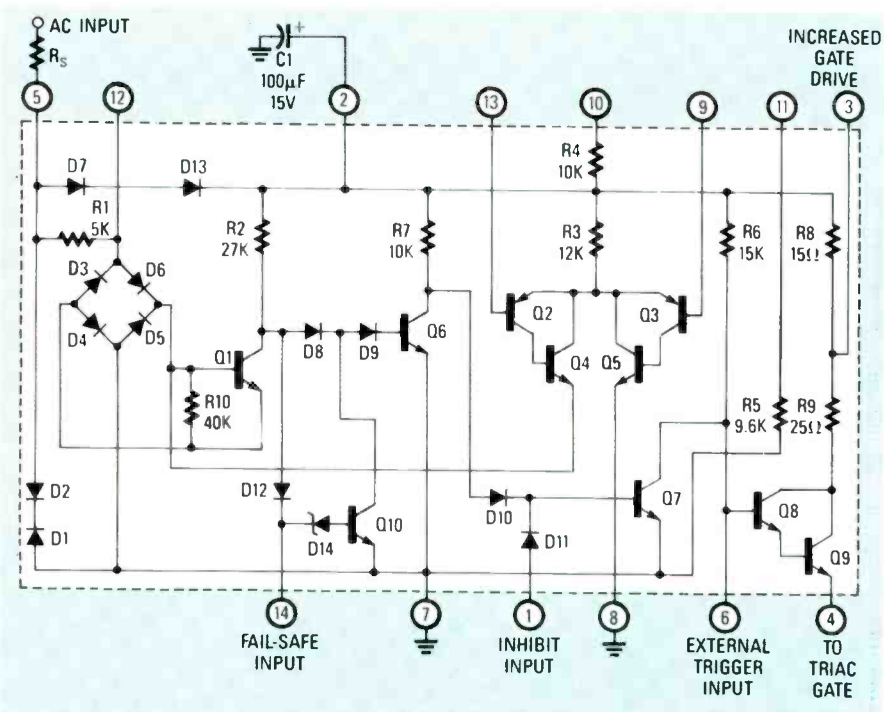


FIG 11—THE CA3059'S internal circuit and necessary external components.

(R_S), which should have a value of 12K at 5W for 117-volt use. Diodes D1 and D2 function as back-to-back zeners that limit the potential on pin 5 to ±8 volts. On positive half-cycles, D7 and D13 rectify that voltage and generate 6.5 volts across external capacitor C1. That capacitor stores enough energy to drive all internal circuitry. It also provides adequate drive to the gate of the Triac, and a few mA of current are available for powering external circuitry.

Bridge rectifier D3–D6 and transistor Q1 function as a zero-crossing detector, with Q1 being driven to saturation whenever the pin-5 voltage exceeds –3V. Gate drive to an external Triac can be provided (via pin 4) from the emitter of the Q8/Q9 Darlington pair; that current is available only when Q7 is off. When Q1 is on (i. e., the voltage at pin 5 exceeds –3V), Q6 turns off through lack of base drive, so Q7 is driven to saturation via R7, so no current is available at pin 4.

The overall effect is that gate drive is available only when pin 5 is close to zero volts. When gate drive is available, it is delivered as a narrow pulse centered on the crossover point; the gate-drive current is supplied via C1.

The CA3059 incorporates several transistors (Q2–Q5) that may be configured as a differential amplifier or a voltage comparator. Resistors R4 and R5 are externally available for biasing the amplifier. Q4's emitter current flows via the base of Q1; the configuration is such that gate drive can be disabled by making pin 9 positive relative to pin 13. The drive can also be disabled by connecting external signals to pin 1, pin 14, or both.

Figures 12 and 13 show how the CA3059 can provide manually-controlled zero-voltage on/off Triac switching. Each circuit uses a switch (S1) to enable and disable the Triac's gate drive via the IC's differential amplifier. In the Fig. 12 circuit, pin 9 is biased at $V_{CC}/2$ and pin 13 is biased via R2, R3, and S1. The Triac turns on only when S1 is closed.

In Fig. 13, pin 13 is biased at $V_{CC}/2$ and pin 9 is biased via R2, R3, and S1. Again, the Triac turns on only when S1 is closed. In both circuits, S1 handles maximums of 6 volts and 1 mA. In both circuits C2 is used to apply a slight phase delay to pin 5 (the zero-voltage detecting terminal); that delay causes gate pulses to be delivered after the zero-voltage point, rather than straddling it.

Note that, in the Fig. 13 circuit, the Triac can be turned on by pulling R3 low, and that it can be turned off by letting that resistor float. The circuits shown in Fig. 14 and Fig. 15 illustrate how that ability can increase the versatility of the basic circuit. In Fig. 14, the Triac can be turned on and off by transistor Q1, which in turn can be activated by any low-voltage circuit, even CMOS devices. And Fig. 15 shows how to use the circuit with an optocoupler.

Figure 16 shows how the Signetics TDA1024 can be used in a similar circuit to provide optically coupled zero-voltage Triac control.

To complete this section, Fig. 17 and Fig. 18 show several ways of using the

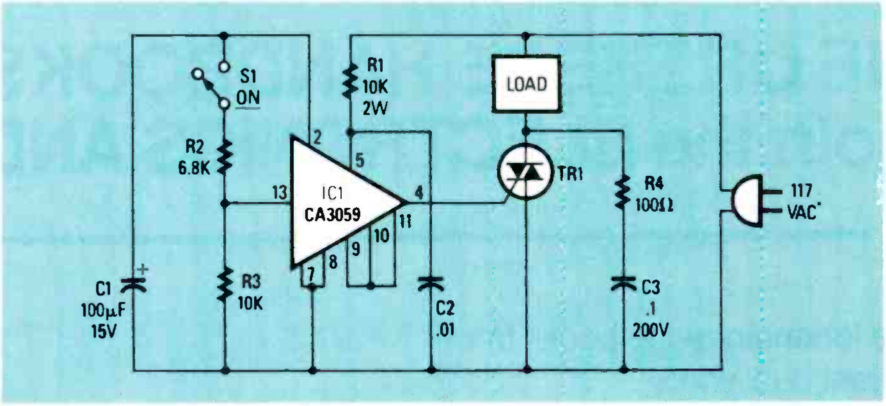


FIG 12—ZERO-VOLTAGE line switch built from the CA3059.

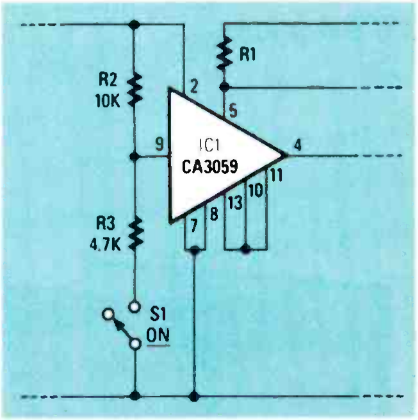


FIG 13—ALTERNATE CA3059 zero-voltage switch.

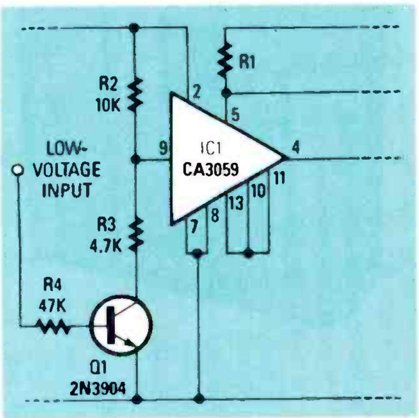


FIG 14—TRANSISTOR-CONTROLLED CA3059 switch.

CA3059 so that the Triac operates as a light-sensitive dark-operated power switch. In both designs the IC's built-in differential amplifier is used as a precision voltage comparator that turns the Triac on or off when one of the comparator input voltages goes above or below the other comparator input voltage.

Figure 17 is the circuit of a simple dark-activated power switch. Here, pin 9 is tied to $V_{CC}/2$ and pin 13 is controlled via the R2–R5 resistive string. In bright light, photocell R4 has low resistance, so the voltage at pin 9 exceeds that at pin 13, and the Triac is disabled. In darkness, the photocell has a high resistance, so the pin 13 voltage exceeds that at pin 9, and the Triac is enabled. The circuit's switching point is set with R3.

Figure 18 shows how a degree of hysteresis or "backlash" can be added to the previous circuit. Doing so prevents the Triac from switching in response to small changes (passing shadows, etc.) in ambient light level.

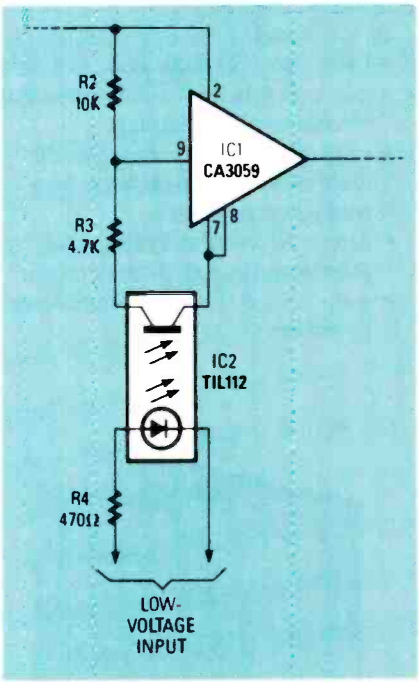


FIG 15—OPTICALLY COUPLED CA3059 switch.

Electric-heater controllers.

A Triac can easily be used to provide automatic room-temperature control by using an electric heater as the Triac's load, and either thermostats or thermistors as the thermal feedback elements. Two

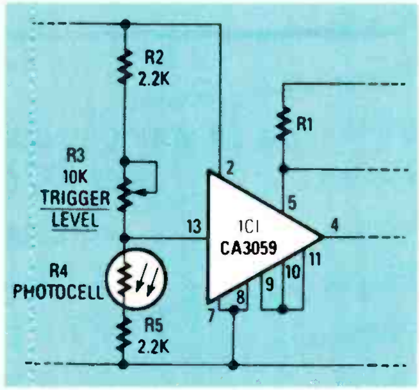


FIG 17—DARK-ACTIVATED zero-voltage switch.

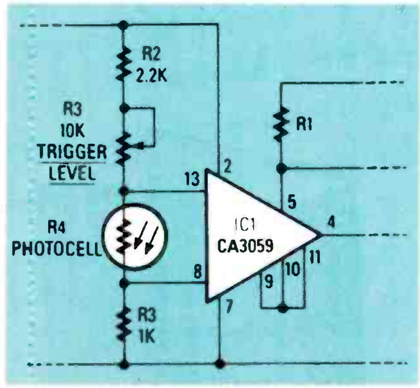


FIG 18—DARK-ACTIVATED zero-voltage switch with hysteresis.

methods of heater control can be used: automatic on/off power switching, or fully automatic proportional power control. In the former case, the heater turns fully on when room temperature falls below a preset level, and it turns fully off when the temperature rises above that level.

In proportional power control, the average power delivered to the heater is automatically adjusted so that, when room temperature is at the preset level, the heater's output power self-adjusts to precisely balance the thermal losses of the room.

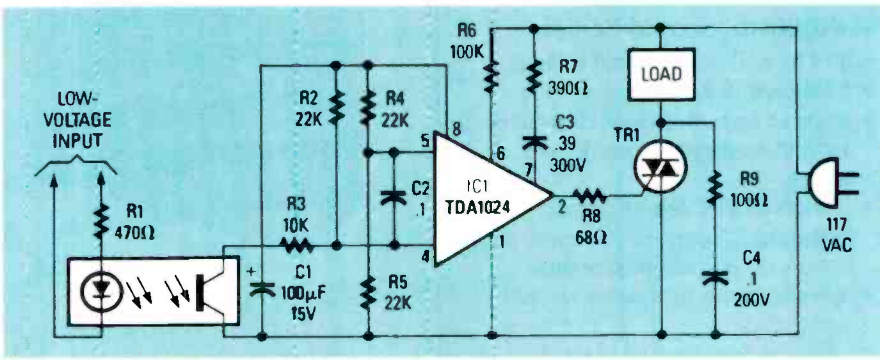


FIG 16—OPTICALLY COUPLED TDA1024-based zero-voltage switch.

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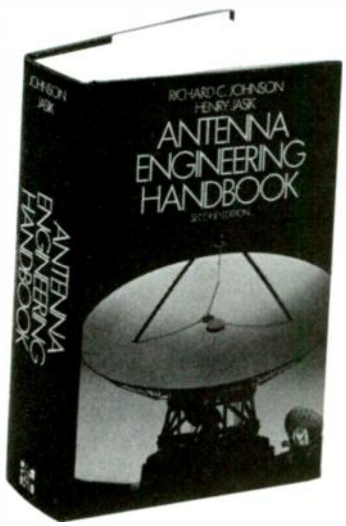

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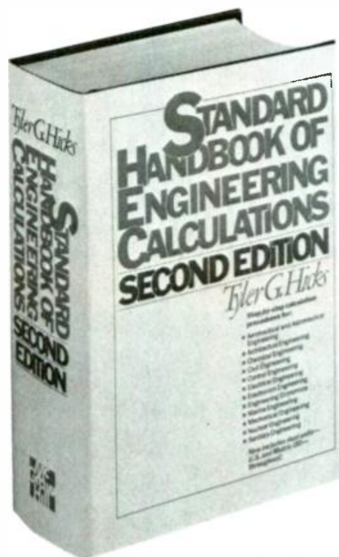

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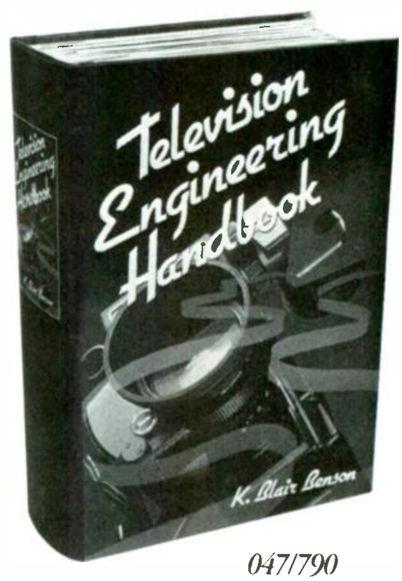

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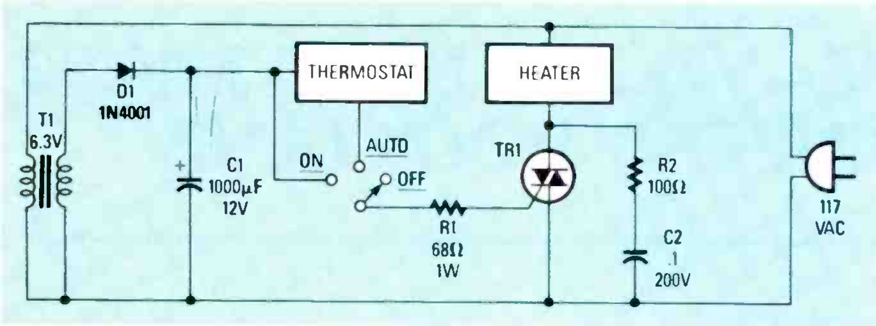

FIG 19—THERMOSTAT-SWITCHED heater controller.

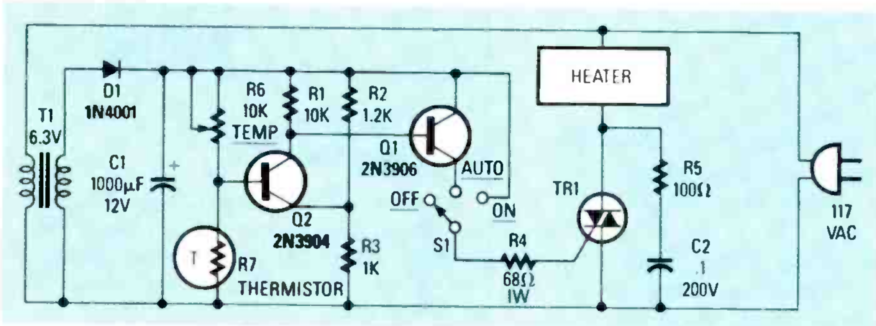

FIG 20—THERMISTOR-SWITCHED heater controller.

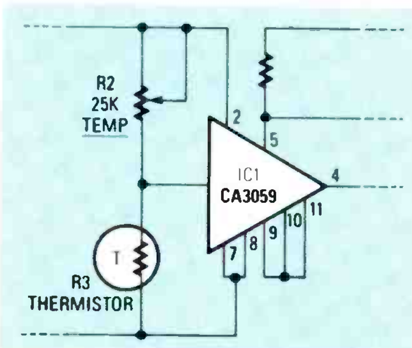

FIG 21—HEATER CONTROLLER with thermistor-regulated zero-voltage switching.

Because of the high power requirements of an electric heater, the circuit must be carefully designed to minimize RFI generation. The designer's two main options are to use either continuous DC gating or synchronous pulsed gating. The advantage of DC gating is that, in basic on/off switching applications, the Triac generates zero RFI under normal running conditions; the disadvantage is that the Triac may generate very powerful RFI as it is turned on. The advantage of synchronous gating is that no high-level RFI is generated as the Triac turns on; the disadvantage is that the Triac generates continuous low-level RFI under normal running conditions.

Figures 19 and 20 show several DC-gated heater-controller circuits. In both cases the DC supply is derived via T1, D1, and C1, and the heater can be controlled either manually or automatically via S1. The Fig. 19 circuit is turned on and off by the thermostat, depending on its temperature.

The Fig. 20 circuit, on the other hand, is controlled by *N*egative *T*emperature *C*oefficient (NTC) thermistor R7 and transistors Q1 and Q2. The network composed of R2, R3, R6, and R7 is used as a thermal bridge, and Q2 acts as the bridge-balance detector. Potentiometer R6 is adjusted so that Q2 just starts to turn on as the temperature falls to the desired level. Below that level, Q2, Q3, and the Triac are all fully on; above that level all three components are cut off.

Because the gate-drive polarity is always positive, but the Triac's main-terminal current alternates, the Triac is gated alternately in the + I and + III quadrants, and gate sensitivity varies tremendously between them. (See our discussion of gate sensitivity in the September issue.) Consequently, when the temperature is well below the preset level, Q1 is driven fully on. Therefore, the Triac is gated on in both quadrants, so it provides full power to the heater. However, when the temperature is very close to the preset value, Q1 is driven on "gently," so the Triac is gated in the + I mode only, and the heater operates at half maximum power drive. The circuit thus provides fine temperature control.

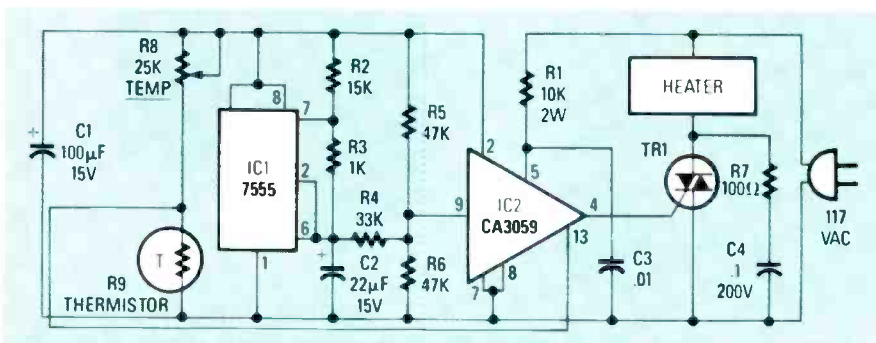

FIG 22—HEATER CONTROLLER with precision temperature regulation.

Synchronous circuits

Figure 21 shows how a CA3059 can be used to build a synchronous thermistor-regulated electric-heater controller. The circuit is similar to that of the dark-activated power switch of Fig. 17, except that the thermistor (R3) is used as the sensing element. The circuit is capable of maintaining room temperature within a degree or so of the value set by R2.

To complete our discussion of heater controllers, Fig. 22 shows the circuit of a proportional heater controller that is capable of maintaining room temperature within 0.5°C. In that circuit a thermistor-controlled voltage is applied to the pin-13 side of the CA3059's comparator, and a repetitive 300-mS ramp signal, centered on $V_{CC}/2$, is applied to the pin-9 side of the comparator from astable multivibrator IC1.

The action of the circuit is such that the Triac is synchronously turned fully on if the ambient temperature is more than a couple of degrees below the preset level, or is cut fully off if the temperature is more than a couple of degrees above the preset level. When the temperature is within a couple of degrees of the preset value, however, the ramp waveform comes into effect and synchronously turns the Triac on and off once every 300 mS, with a *M*ark/*S*pace (M/S) ratio that is proportional to the temperature differential.

For example, if the M/S ratio is 1:1, the heater generates only half of maximum

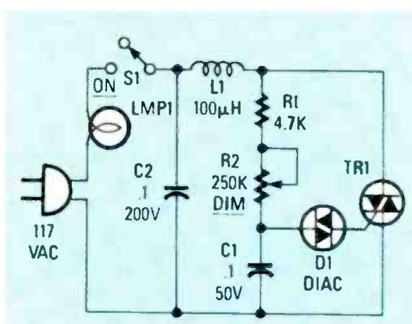

FIG 23—SIMPLE LAMP DIMMER.

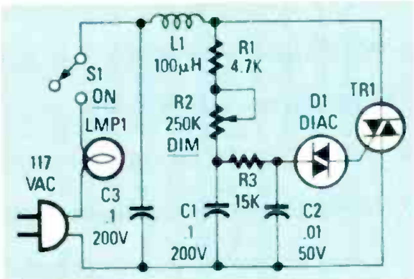

FIG 24—IMPROVED LAMP DIMMER with gate slaving.

power, and if the mark/space ratio is 1:3 it generates only one quarter of maximum power. The net effect is that the heater does not switch fully off, but generates just enough output power to match the thermal losses of the room precisely. As a result, the circuit provides very precise temperature control.

Lamp-dimmer circuits

A Triac can be used to make a lamp dimmer by using the phase-triggered power-control principles discussed last time. In that type of circuit, the Triac is turned on and off once in each line half-cycle, its M/S ratio controlling the mean power fed to the lamp. All circuits of that type require the use of a simple LC filter in the lamp's feed line to eliminate RFI.

The three most popular methods of obtaining variable phase-delay triggering are: (1) Diac plus RC phase-delay network; (2) line-synchronized variable-delay UJT trigger; (3) special-purpose IC as the Triac trigger.

Figure 23 shows the circuit of a Diac-triggered lamp dimmer. A defect of that type of design is that it suffers from considerable control hysteresis or backlash.

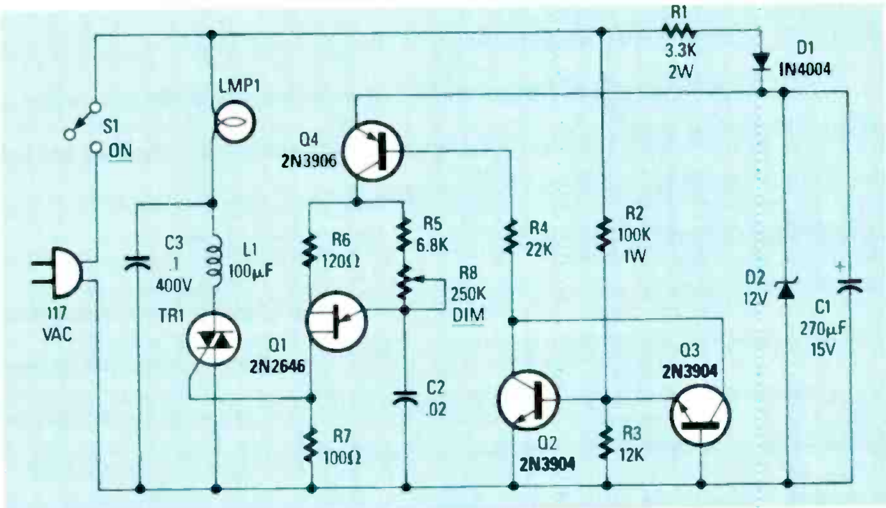

FIG 25—UJT-TRIGGERED zero-backlash lamp dimmer.

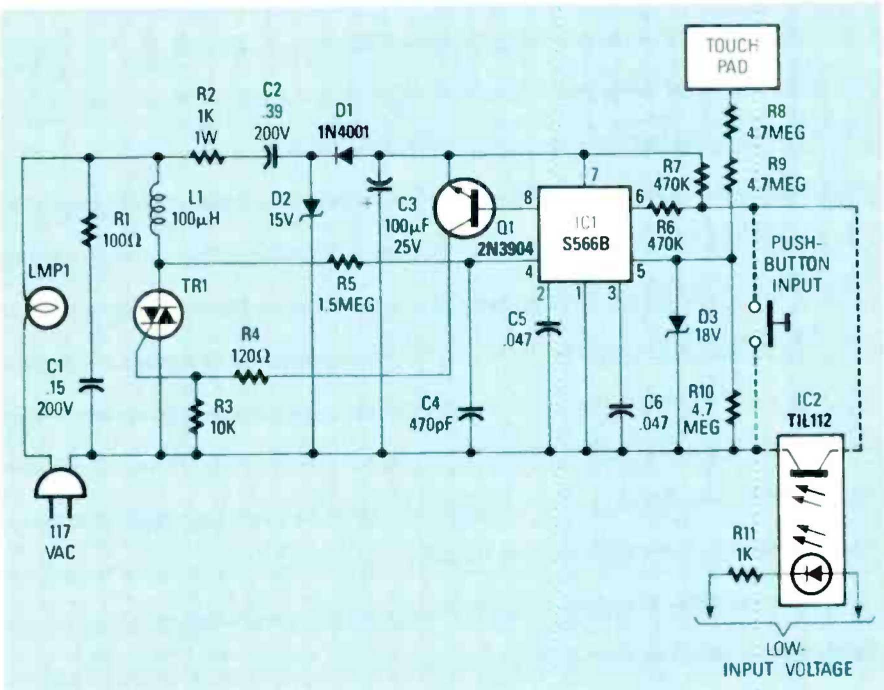

FIG 26—SMART LAMP DIMMER controlled by a Siemens S566B.

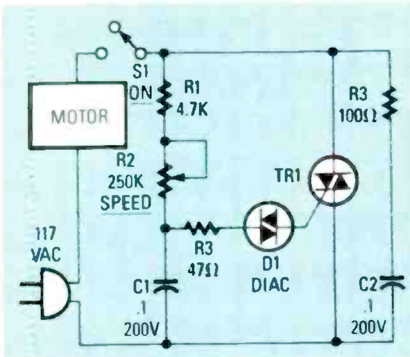

FIG 27—UNIVERSAL-MOTOR light-duty speed controller.

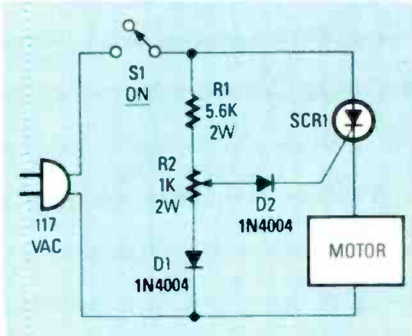

FIG 28—SELF-REGULATING UNIVERSAL-MOTOR heavy-duty speed controller.

If the lamp is dimmed by increasing the R2's value almost to maximum, the lamp will not go on again until R2 is reduced to about 80% of the former, at which it burns at a fairly high brightness level. Backlash is caused because the Diac partially discharges C1 each time the Triac fires.

Backlash can be reduced by wiring a 47-ohm resistor in series with the Diac, to reduce its effect on C1. An even better solution is to use the gate-slaving circuit shown in Fig. 24, in which the Diac is triggered from C2, which "copies" C1's phase-delay voltage, but provides discharge isolation through R3.

If backlash must be eliminated altogether, the UJT-triggered circuit shown in Fig. 25 can be used. The UJT (Q1) is powered from a 12-volt DC supply built around Zener diode D2. The UJT is line-synchronized by the Q2-Q3-Q4 zero-crossing detector network, in which Q4 is turned on (thereby applying power to the UJT) at all times *other* than when line voltage is close to zero.

So, shortly after the start of each half-cycle, power is applied to the UJT circuit via Q4, and some later time (which is determined by R5, R8, and C2), a trigger pulse is applied to the Triac's gate via the UJT.

Figure 26 shows how a dedicated IC, the Siemens S566B "Touch Dimmer," can be used to build a smart lamp dimmer that can be controlled by several devices simultaneously: a touch pad, a pushbutton switch, or an infrared link.

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WORKING WITH TRIACS

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The IC, which provides a phase-delayed trigger output to the Triac, provides both on/off and proportional output control.

To do so, the S566B incorporates conditioning circuitry that recognizes a brief input as a "change stage" command. In addition, a sustained input causes the IC to go into the ramp mode, in which lamp power slowly increases from 3% to 97% of maximum. After reaching maximum, it ramps downward to a minimum of 3%, and then again reverses.

The touch pad used with the circuit may be simple strips of conductive material; the operator is safely insulated from the line voltage via R8 and R9.

Universal motor controllers

Domestic appliances are usually powered by a series-wound universal electric motor, so-called because they can operate from either AC or DC power. In operation, that type of motor produces a back EMF that is proportional to the motor's speed. The effective voltage applied to that type of motor is equal to the applied voltage minus the back EMF. That results in some self-regulation of motor speed, because an increase in motor loading tends to reduce speed and back EMF, thereby increasing the effective applied voltage and causing motor speed to try to increase to its original value.

Most universal motors are designed to provide single-speed operation. A Triac-based phase-control circuit can easily be used to provide that type of motor with fully-variable speed control. A suitable circuit is shown in Fig 27.

That circuit is useful for controlling lightly-loaded appliances (food mixers, sewing machines, etc.). However, heavy-duty tools (electric drills and sanders, for example) are subject to heavy load variations, and therefore require a circuit like the one in Fig. 28.

An SCR is used in that circuit as the control element; it feeds half-wave power to the motor, which results in a 20% or so reduction in available speed and power. However, during the half-cycles when the motor is off, its back EMF is sensed by the SCR and is used to adjust the next gating pulse automatically.

The network composed of R1, R2, and D1 provides only 90° of phase adjustment, so all motor power pulses have a minimum duration of 90° and provide very high torque. At low speeds the circuit goes into a "skip-cycling" mode, in which power pulses are provided intermittently, to suit motor-loading conditions. The result is that the circuit provides particularly high torque under low-speed conditions. **R-E**

R-E ROBOT

continued from page 59

Even if the motor encounters resistance, it will continue to move in the necessary direction until the voltage outputs from the potentiometer and the DAC are equal. Later on, if the carriage plate encounters enough resistance to move it away from the selected position, in either position, the drive circuit will return the carriage plate to the selected position as soon as it is able to, without further action by the computer.

The circuit we used to accomplish all that is surprisingly simple. As shown in Fig. 4, a DAC0832 DAC configured in the voltage mode is used to output the desired analog position. One section of an LM324 quad op-amp buffers the output of the DAC, while another multiples a 2.5-volt reference voltage by two, resulting in a 0- to 5-volt output range. Two other sections of the LM324 are used to compare the output of the DAC to the output of the position-sensing potentiometer; the output of the potentiometer corresponds to the actual position of the carriage plate. When the voltage from the potentiometer is exactly equal to the output from the DAC, but *opposite* in sign, with respect to the 2.5-volt reference, the circuit shuts down the motor. A small dead band is introduced into the comparator circuit to insure that the motor is not forced to oscillate about its target position. A single 74LS138 address decoder is used to enable and disable the circuit.

The entire control circuit, minus of course, the potentiometer and the motor, can be mounted on a small (2 × 2.5 inches) piece of perforated construction board; the layout is not critical. When finished, the circuit board can be mounted near the potentiometer using double-sided foam tape or standoffs.

Software

Note that the use of a 15-tooth sprocket results in more chain travel in 10 turns of the potentiometer than the linear ball-bearing slide can achieve. That means that it is possible to program positions that are beyond the travel limits of the carriage plate. If that is done, the motor will continue to turn after the ball-bearing slide has hit a stop. Therefore, the values for the limits of travel must be determined experimentally, and the software set up to disallow values greater than those limits.

The RERBUS interface that is used to communicate with the arm electronics is controlled by two digital ports so that all timing problems vanish. We must write the data to one port and use the other port to set up our address and control signal. We will create two Forth words to do that: XPC@ and XPC!

```
:XPC@ (address — data)
   DUP ( save copy of address )
   80 OR ( set WRITE high )
   BF AND ( set READ low - active )
   130 PC@ ( get the data from 130 )
   SWAP ( get the old address )
   C0 OR 140 PC! ; ( both strobes high )
:XPC! (data address —)
   SWAP 130 PC! ( write data to port )
   DUP ( save a copy of addr )
   40 OR ( set READ strobe high )
   7F AND ( set WRITE strobe low )
   140 PC! ( write addr and cntrl )
   C0 AND 140 PC! ; ( both strobes
   high )
```

Those two words are direct analogies of the Forth words PC@ and PC!, which fetch and store bytes to ordinary ports.

Notes

The mechanical aspects of the arm are easily modified to suit your needs. If you wish to do so, here are some design factors to keep in mind. When considering whether to increase the arm's lifting capacity, remember that the capacity must be consistent with the design of the robot. It's pointless to design an arm that lifts 100 pounds with ease if lifting such a weight will cause the robot to topple forward.

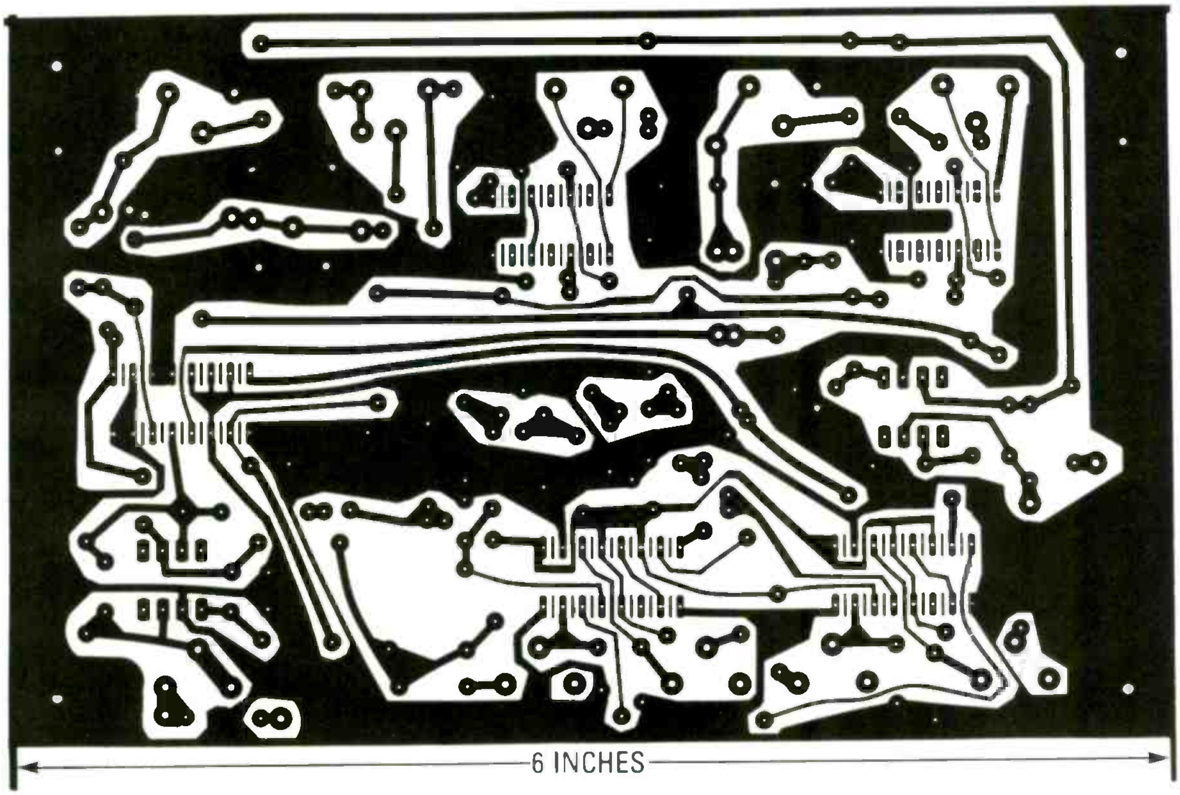
The steel ladder chain is rated at 90 pounds yield strength. Allowing for a 50% safety factor (highly recommended) means that you can use the ladder chain to lift to about 45 pounds. If your requirements call for loads that are greater than that, you will have to use a different style of chain (for example, riveted ¼-inch roller chain).

The motor and gearhead are the governing factors for lifting capacity and speed. The lift motor should draw no more than 3 amps, the rating of the connecting ribbon cable. Use of a worm-gear style gearhead would improve the design because then the load could not back drive the motor.

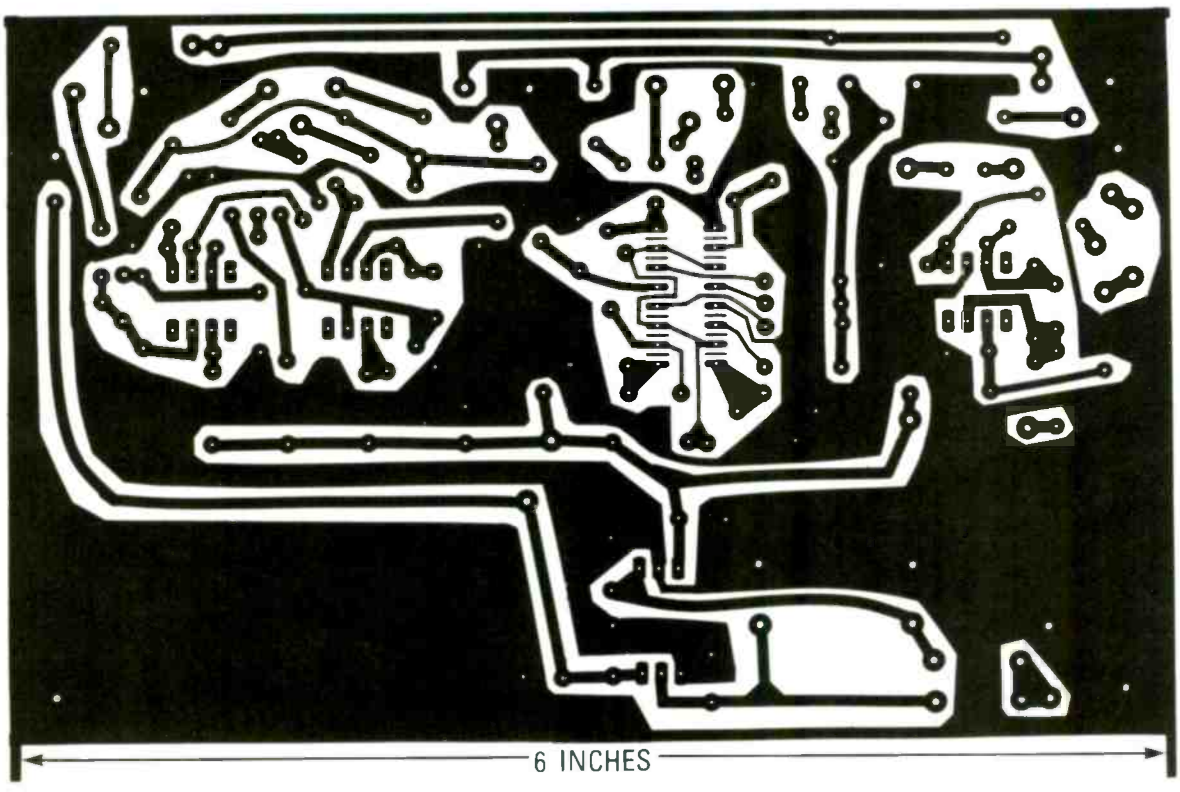
The orientation of the linear ball-bearing slides deserves some consideration. Building the lift assembly is easiest when the slides are oriented as described in this article. However, greater loading capacity would be achieved if the slides were mounted on aluminum angle and rotated 90°. That would allow the use of less costly FBW3590NF series linear bearings instead of the FBW50110F series specified. While the FBW3590NF series is only available in 800-mm maximum lengths, several sections could be joined together to yield any overall length desired.

The Brevel motor specified comes with mounting holes for a shaft encoder. That means that we could use the same position sensing scheme as the main motor (shaft encoder and quadrature decoding). That would allow for greater accuracy when positioning the carriage plate. See Part 7 in the July 1987 issue of **Radio-Electronics** for more information. **R-E**

PC SERVICE



THE VIDEO-EFFECTS GENERATOR main board.



THE EFFECTS BOARD for the video-effects generator.

PC SERVICE

DIGITAL AUDIO TAPE

continued from page 47

from adjacent tracks is eliminated by reversing the azimuth on each head.

Each track contains 196 *blocks* of data, with each block containing 288 bits. There are three types of data stored on the tape: 1) The music signal that is digitally coded using PCM. 2) Subcodes, which provide various information about the tape in the playback mode. 3) An *Auto*matic *T*rack *F*inder (ATF) signal.

The largest group of blocks is contained in the PCM area. The structure of a PCM block is shown in Fig. 5-b. Along with the PCM music signal, each block contains a synchronizing signal, a code that identifies it as a PCM block, a block address, and parity information.

The structure of the sub-code blocks is similar. The main difference between the two blocks is the identity data. The subcodes are used mainly for the convenience of the user during playback. They can contain such information as the tape's table of contents, including the location of each selection. They can be used to designate the beginning of a selection, or they can instruct the machine to skip over areas of a tape.

Along with music and subcode signals is an Automatic Track Finder (ATF) signal that helps the head accurately trace recorded tracks in the playback mode. It controls the head-to-tape positioning, and thus eliminates the need for a control head and a tracking-adjustment knob such as those found on VCR's.

The other overhead—margin, PLL,—help the DAT player keep track of where it is. The subcodes can provide info such as the selection's index number, length, etc. They facilitate such tape-deck features as direct-tune selection, track repeat, length of selection, etc.

Now let's see how all that information gets onto the tape. As the block diagram in Fig. 6 shows, the analog signal to be recorded is first digitized. In the next step, the overhead is added—all the codes that are needed to keep track of the data flow in the playback mode. The order that the data are placed on the tape is interesting. The data are *interleaved*. In other words, the position of the left-channel and right-channel information are alternated on adjacent tracks. That is very important for error correction. We won't discuss error correction in detail, except to point out that since the data rate of DAT is about 2.4 megabits per second, you can be sure that some of the data will be in error—either from manufacturing defects, dirt, or any number of reasons. Error correction allows many of the errors to be inaudible during playback.

After the interleave block does its job, the data are converted from 8 bits to 10 bits. The 10-bit modulation helps the DAT recorder keep better track of timing information. Of course for playback, the process is reversed by the 10-to-8 modulator.

The subcode generator and detector are used to decode the subcode channel, which is a low-capacity channel that can be used for storing information ranging from track length to perhaps a transcript of the information on the tape. The subcodes can also be used to control some of the DAT deck's functions. For example, some decks may allow you to program repeat-track functions, or auto-shutoff after a certain number of plays, etc.

The politics of DAT

Digital audio tape is an exciting technology. But not everyone is excited about it. The recording industry is terrified that if consumers have access to digital recording, sales of all pre-recorded material will be hurt.

The recording industry wants to incorporate an anti-copy system that cuts a notch in *all* pre-recorded software—tapes, CD's, LP's etc.—that would be recognized by a DAT recorder, shutting the recorder down.

The hardware manufacturers point out, however, that past events don't lead to the conclusion that DAT will hurt the sales of any pre-recorded media. They note that each new recording format has opened up new markets and sales for the recording industry. The hardware manufactures are convinced that the consumers are ready for—and in fact demand—better quality. To back up that argument, they point to the explosive sales of CD's and CD players, and are happy to remind you of the initial skepticism that the Recording Industry Association of America, or RIAA, had of the CD format.

While the RIAA is convinced that an anti-copy system must be incorporated in DAT so that sales of pre-recorded DAT tape and CD's wont' be affected, the hardware manufacturers point out that pre-recorded cassettes actually outsell LP's, and that direct digital-to-digital copies cannot be made of either CD's or pre-recorded DAT's because of the different sampling rates used.

The issue seems to be whether consumers can be trusted to use DAT technology responsibly. That raises another question: is making a copy of a CD or LP for personal use responsible, or is it piracy?

Not only is the anti-copy system an affront to the rights of consumers to make home recordings, it is not inaudible, as the recording industry claims. That is not just our opinion: In May of this year, 200 recording industry executives met to press their demands that the CBS *Copycode* system be manditory for all new recordings. Engineers and music critics were brought to the studios of Thorn-EMI to demonstrate that *Copycode* doesn't affect the reproduction of music.

However, the music critics *were* able to hear the effects of *Copycode*. They noted subtle effects, especially on high piano notes. If the industry goes ahead with the use of *Copycode*, those who take their music most seriously will be the ones affected most. That certainly is not a good marketing strategy. The people most likely to buy a new and better recording technology—especially in its early stages before prices come down—are the people who take their music seriously.

The RIAA's insistence that an anti-copy system be used has so far kept DAT out of this country. Some companies have insisted that if the bill is passed they simply comply with the law and bring in DAT machines incorporating the anti-copy system. We don't believe that is very likely, and many potential DAT manufacturers agree. Would you buy a digital tape recorder if you couldn't make your own tapes—for your own personal use? We wouldn't either.

For more on the political arguments surrounding DAT, see our guest editoral on page 4 from the Home Recording Rights Coalition. **R-E**

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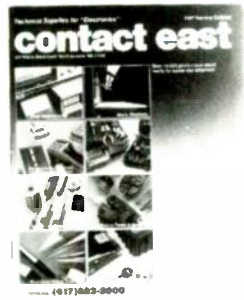

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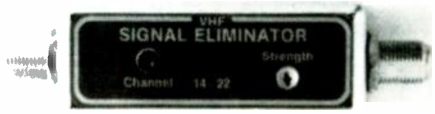

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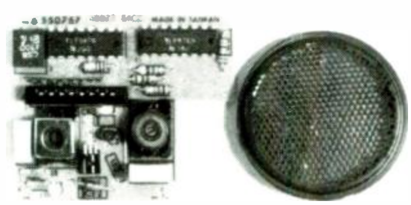

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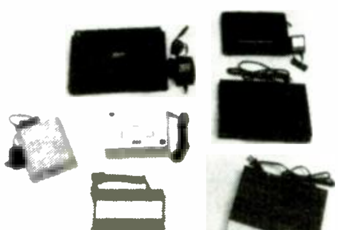

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SATELLITE TV

The international connection, part 2

LAST TIME, WE SAW THAT SOME COUNtries, under pressure from the United States, have acted to prevent reception of U.S. satellite signals outside of this country. However, some countries have resisted such pressure.

Some feel that national laws are for the country where the laws are enacted, and those governments see little reason to allow a U.S. law to be applied in Bermuda, or a French law to be applied in Switzerland, for example. The U.S. seems to be slowly reacting to that point of view, and recently there have been proposals to correct that situation.

Many countries, such as Jamaica, are very dependent upon cordial relations with the United States. The Caribbean, as an example, now benefits from a U.S.-aid program called the Caribbean-Basin Initiative. Countries that meet certain legislated provisions of the program can ship products into the U.S. with no or very low duties. A firm manufacturing ceramic figurines in the Dominican Republic, for example, is permitted to bring its products to the U.S. marketplace at a duty-advantage. That is important to that firm and its 100 employees

Under the proposed legislative changes, a country that does not cooperate with policing the unauthorized use of American "intellectual" property, such as movies, would be disqualified from the program's benefits.

That is a strong weapon in the hands of U.S. programmers who seek to force foreign governments to shut down unauthorized users of their programming. A country that resists the intrusion of U.S. laws into its territory on philosophical grounds, or feels intimidated by its large North-American neighbor would think twice about not cooperating with U.S. officials applying U.S. laws when local jobs and commerce are at stake.

The United States has reasons beyond the economic well being of its satellite-TV programmers for restricting the reception of domestic satellite TV. Indeed, if economics were the only factor, it might seek to allow such reception. Currently, we have about 50% more available satellite channels or transponders than we have fulltime users. That means that many satellite channels are under-used. Naturally a satellite manufacturer such as GTE or RCA would like to see all channels/transponders put to maximum use to realize the maximum possible revenue.

If the U.S. market for transponders is not as large as the supply of transponders, and the satellites coverage extends beyond our borders, why not offer those transponders for rent or sale to firms located outside of the United States? Technically, that is illegal.

Domestic vs. international

The U.S. is a party to various international agreements that define the operation of satellites. Those agreements have created two general categories of satellites: domestic and international. Domestic satellites can only be used to transmit signals to the country that operates it. That means that a U.S. satellite, like one of the Satcom series, can only transmit programming to U.S.-located receiving sites; a Canadian satellite, like a member of the Anik series, can only transmit programming to Canada (the Anik-E, scheduled for launch in 1990 is shown in Fig. 1); and so on.

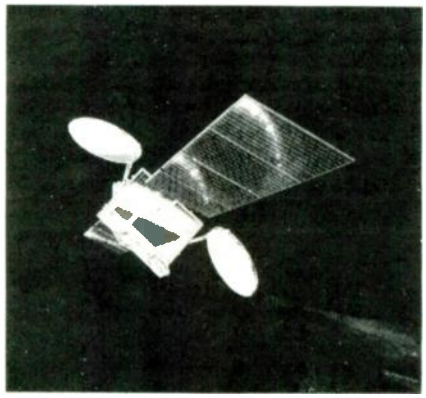


FIG. 1

International satellites, on the other hand, are operated by international organizations and can only be used to transmit signals from one country to another; they can't be used to beam a signal from a country back to a site within the same country. The two international satellite organizations are Intelsat and the U.S.S.R.-sponsored Intersputnik.

However, international accords tend to be warped with time, and nearly a decade ago Intelsat began renting satellite transponders to countries such as Brazil, who in turn used those transponders for service wholly within their borders. More recently, nations have rented unused transponders on domestic satellites to their neighbors.

For instance, Indonesia has allowed their neighbors access to unused transponders on board their Palapa satellites. Further, un-

der pressure, various U.S. satellites have been rented part or full-time on a transponder by transponder basis for service that was clearly international in scope.

Most recently, a U.S. firm has created a data-processing operation within a free-trade zone near Montego Bay, Jamaica. The operation processes credit-card orders for U.S. customers. Those customers dial an 800 number in the U.S. and are linked to the Jamaican site via satellite.

Dialing for dollars

That last example brings us to an important point: Video is not the only signal delivered by satellite. And while the U.S. is enacting new, more restrictive legislation aimed at curbing distribution of television programming to other countries, the same thing isn't happening in the fields of data and voice communications. There, free-wheeling agreements and regulations are replacing the restrictive rules of yesteryear.

That is happening because of pressures from satellite owners or from firms who see satellites as a link to potential revenue sources outside of the United States. As a result, the distinction between domestic and international satellites in that field is blurring rapidly.

Interestingly, some of the impetus behind the changes has come about due to reception of U.S. programming by those outside of this country. Much of that programming is advertiser supported, and many of the advertisements offer products that can be ordered by dialing a toll-free 800 number. That's no problem for viewers in the U.S., but formerly those numbers could not be dialed from other countries. Since many of the products can not be purchased locally in Latin America, the Carribean, etc., there was considerable demand for such products. Hence, a great deal of potential revenue was lost.

That was until the creative marketing genius of U.S. telephone companies got into the act. Now, thanks to their urging, a service known as USA Direct is in place. For a charge, that service lets those in the Carribean region bypass the local telephone systems and tie in directly to the U.S. telephone system, including access to 800 numbers. The net result is lower cost per call for the users, more volume for the telephone company, and more business for mail-order companies. Eventually, 800 service may even be extended to that region, allowing totally toll-free ordering of products.

As you can see, our government is sending confusing signals to the rest of the world. On one hand, new legislation seems to be saying that we want to restrict the exportation of American "culture" via satellite. But we seem to have no objection to U.S. business using the "satellite expressway" to expand into global markets. The developments that come about because of that will be interesting to watch. **R-E**

AUDIO UPDATE

Magnetically shielded loudspeakers

LARRY KLEIN
AUDIO EDITOR

THE GROWING POPULARITY OF AUDIO/video systems has produced a plethora of components, accessories, and adapters, all intended to facilitate the marriage of the two media. From a technical point of view, one of the more interesting of the newly created audio/video components is the magnetically shielded speaker system. The purpose of the magnetic shielding is to prevent the stray magnetic-flux field normally emitted by a speaker's magnet from impinging on the video monitor's picture tube. Because the electron beams inside the picture tube are controlled magnetically, any extraneous magnetic influences can have an adverse effect on the picture.

Preventing flux influx

In my youth I worked for an electronic-kit company as a test-instrument troubleshooter. The oscilloscopes I serviced were primitive devices by today's standards, but they had the virtue of being easily fixed when something went wrong. One of the things that went wrong in the customer's kits was trace distortion caused by magnetic radiation from the scope's power transformer. The fix was simple enough: A 3- by 5-inch piece of thin sheet steel was bolted to the scope's chassis in the magnetic path and then bent until the trace distortion was no longer visible. What I installed was not a magnetic *shield* but rather a magnetic *deflector*, which brings us to a rather interesting topic—the "shielding" techniques available to the manufacturers of video-ready speakers.

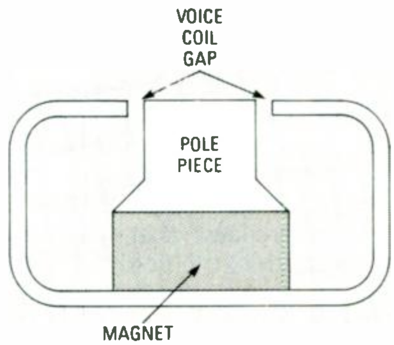


FIG. 1

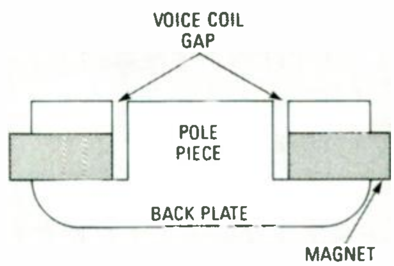


FIG. 2

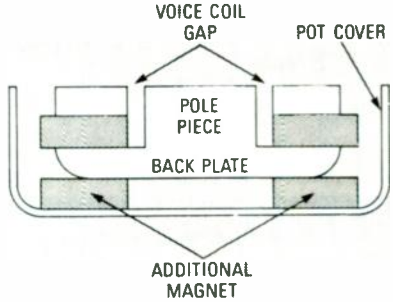


FIG. 3

Internal shielding

At a time when all speakers used Alnico magnets, shielding was a simple proposition. The Alnico magnet was in the form of a cylindrical "slug" surrounded on two sides by a heavy metal yoke. See Fig. 1. The yoke was actually part of the magnetic circuit that concentrated the magnet flux in the voice-coil gap. The inherent magnetic leakage from such a structure is quite low, but today the high cost of Alnico magnets has pretty much eliminated them from speaker use in favor of ceramic-ring magnets. The ceramic magnet is usually in the form of a flat-sided ceramic doughnut that surrounds the pole piece as shown in the cross-section view in Fig. 2. If you've ever handled a ceramic-magnet speaker you know that there is extensive magnetic leakage from the exposed outer edges of the ceramic-magnetic ring.

External shielding

External shielding in the form of a judiciously placed ferrous-metal cover can be effective with small speakers with low-flux magnetics such as are found in many conventional TV sets. However, when such shielding is applied to larger, better quality speakers, problems occur. Although it can be effective in suppressing magnetic leakage, the shielding diverts a substantial part of the available flux away from the voice-coil gap, which can result in an unacceptable loss of damping and efficiency.

Magnetic deflection.

The technique used to produce today's better "magnetically shielded" speakers uses no shielding at all! As illustrated in cross-section view in Fig. 3, a second, fairly hefty ceramic-ring magnet is installed piggyback at the rear of the speaker so that its magnetic polarity is opposite to that of the main magnet. An iron housing (a "pot" in speaker-designer jargon) is part of the additional assembly and its purpose is to focus the magnetic field of the second magnet so as to divert the stray leakage-flux back toward the main magnet. It does that so effectively that an additional benefit occurs—there is an increase in the magnetic flux appearing in the voice-coil gap.

In effect, it is as though the main magnet were made more powerful. Adding an extra magnet is not a cheap solution to the flux-leakage problem, however, because the magnet is the most expensive part in most speakers.

To digress for a moment: Do *not* assume that a more effective or heavier magnet is always desirable in a speaker system. An excessively strong magnet can electronically overdamp a woofer, thus inhibiting its voice-coil/cone movement at low frequencies. Overall mid-frequency efficiency will be increased, but at the expense of low-bass performance. A knowledgeable designer juggles (trades off) efficiency, bass performance, and cabinet size to achieve the specific results he (or the marketing department) wants.

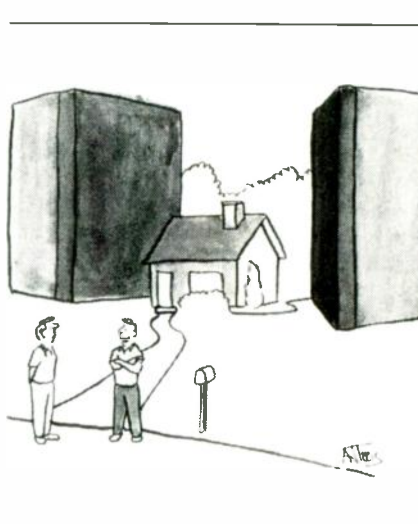
Video psychoacoustics

There's an important question that no one seems to be asking about shielded video speakers: Is it a product category that is really needed? For several years I've been using a pair of small B&W *LM-1* car speaker systems with my Proton video monitor. The speakers are driven directly by the low-powered stereo amplifier built into the Proton unit, which sits between them.

There's no effect on the picture as long as the *LM-1's* are spaced a foot or so away from the screen. That is not surprising, since magnetic fields are subject to the "inverse square law." That means that the strength of the field decreases in proportion to the *square* of the distance (rather than linearly) as you move away from its source. If you double the distance, you get a quarter of the field strength. It's easy to move the speakers to where they won't cause any trouble, considering how comparatively weak the stray magnetic field is to start with.

It seems to me that with a full audio/video system you *don't* want to install stereo speakers that close to the TV screen—or each other. In other words, the normal ground rules of stereo-speaker spacing apply whether the program source is audio or video, stereo or mono. Assuming that your speakers are correctly wired in phase, a normal 5- or 6-foot spread between them won't cause problems with imaging or centering with mono programs. Despite what some recent Japanese literature seems to imply, the human eye, ear, and brain combination is remarkably accommodating in placing the apparent source of a sound where the eyes say it should be. If you've ever watched television while listening through headphones, you know how easily the brain is able to shift the apparent location of the sound to the screen.

There's no technical reason *not* to buy a good audio/video speaker if for reasons of decor or silliness you simply must place them cheek-to-jowl with your monitor. But the odds are that some less-expensive conventional speakers, properly installed, will sound just as good. **R-E**



"I finally found the perfect speakers!"

VOL. 4 NO. 10 OCT. 1987

ComputerDigest

A NEW KIND OF MAGAZINE FOR ELECTRONICS PROFESSIONALS

BUILD THE PT-68K

And learn 68000 computing in the CD Classroom

A GERNSBACK PUBLICATION

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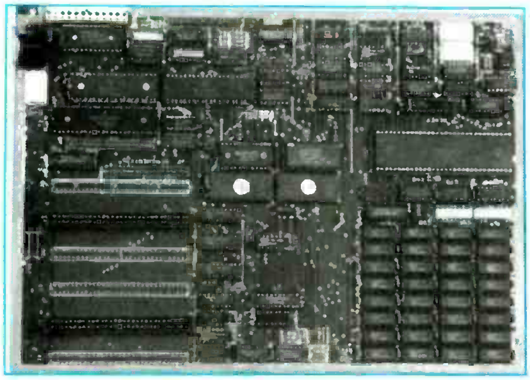

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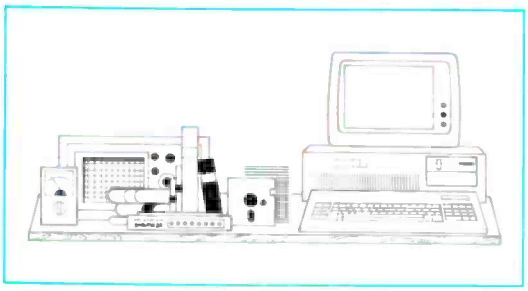
Breathe new life into your 64



87 EDITOR'S WORKBENCH
Hardware: The Option Board
Software: Mite
In Brief: PCED, Cruise Control, KSH-1

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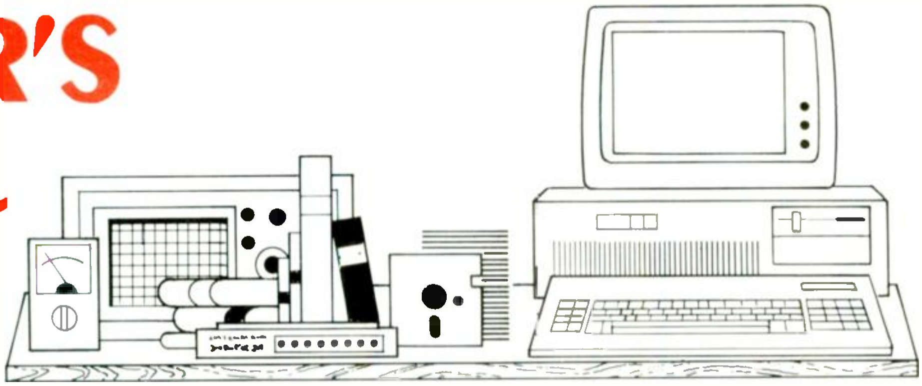


Introducing the Computer Digest Classroom: Build your own 68000 computer.

In the August issue (see Editor's Workbench, p. 63), we announced a new 68000 computer system custom-designed for readers of **Computer Digest.** The PT-68K is now a reality; the price is still $200 for a minimal system—and it's available in a number of configurations. (Turn to page 90 for more information.)

We'll be publishing a series of articles on the design of the PT-68K. The series assumes knowledge of basic electronics and basic digital logic, and it assumes that you have basic construction skills. By following the series from beginning to end, you'll learn in detail about one of today's most popular microprocessors, the 68000; that knowledge will surely aid you as you make your career in electronics.

Every effort has been made to make the PT-68K as economical as possible, so it makes extensive use of IBM PC clone components (keyboard, case, power supply, video adapter, monitor, etc.) wherever it is possible.

Our author wrote a similar series of articles on an earlier member of the Motorola family of microprocessors for a now-defunct computer magazine; his disk-operating system is used on various computers in many countries around the world, and he is a practicing teacher who is familiar with the needs of the computer neophyte. So he is well-qualified to be Headmaster of the Computer Digest Classroom.

Central Point Software: The Option Board

Mention the words "copy protection" and you're sure to start an argument, because there are as many good reasons for a programmer to protect his program as

there are for a consumer to back it up. Both sides have reasonable arguments, so there's a constant war between the two. And when a new copy-protection scheme shows up, it's only a matter of time before someone figures a way around it.

There are several good programs available for the IBM PC that can defeat most copy-protection schemes, but in the final analysis they all share a common weakness, because no matter how sophisticated their algorithms, they all have to use the PC's disk-control IC, the NEC PD765.

A smart programmer can take advantage of that IC's known quirks in a copy-protection scheme. Since some of those peculiarities cause unreliable reads and writes, it can be difficult for copy-protection software to be sure that the data it thinks it sees is what's really on the disk.

The Option Board (Central Point Software, Inc., 9700 S.W. Capitol Hwy. #100, Portland, OR 97219) plugs into a standard expansion slot and provides the ultimate backup system for the PC. It gets around the limitations of the PD765 disk controller by using its own hardware to read and write the disk. The Option Board's control software makes it simple to copy a disk, and Central Point also supplies you with a very powerful track and sector editor.

Installation consists simply of installing the board in an unused expansion slot, plugging your computer's disk-drive cable into the board, and then using the supplied cable to connect the Option Board to your disk controller. Then you're ready to run the software and put the board to work.

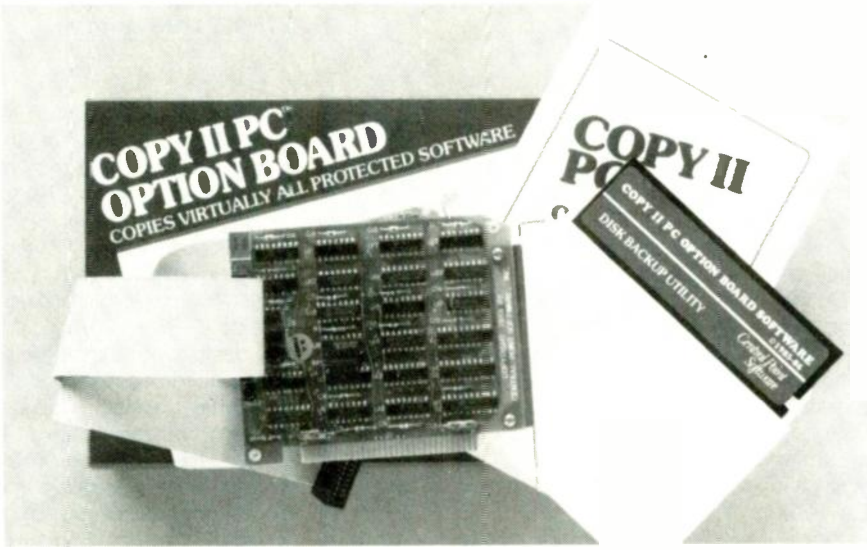


FIG. 1—The Option Board.

The software

Even though the Option Board is connected between your standard disk controller and your disk drives, it is transparent to the system until the supplied software wakes it up. That software consists of two programs: TC, a disk copier, and TE, a disk editor. Both programs are as uncomplicated as possible; their commands are straightforward and all options are displayed on-screen

Copying a disk with TC is easy. You set the source and destination drives, the number of sides, and the range of tracks to copy through a menu. You can also maintain the track lengths, copy "weak bits," verify each write, and keep the copy's track alignment the same as the original's. All options can be specified on the command line when you run the program, but it's much easier to pick and choose from the menu.

One of the first things you'll notice when running the program is that, even with 640K of RAM, only 26 tracks are read at a time. Software-only copiers can read more data at a time because they read only the *data* bytes from a track; the Option Board, on the other hand, reads the entire track into memory, including the data headers, address headers, and the gap bytes that DOS puts there when the disk is formatted. In other words, TC loads a complete image of each track, whereas a software-only copier loads only data. By reading and writing whole track images, the Option Board can easily handle any protection scheme that relies on a non-standard disk format.

The success of any disk copier depends to a great extent on the assumptions it makes when it reads a disk. The greater the number of things it expects to find, the easier it is to fool. The Option Board makes very few assumptions about disk format so it has a much better chance of making a successful copy, and since it can't be confused by non-standard disk formatting, you can use it to copy disks written by other computers—even Apple disks! It's a real testament to the design of the Option Board that it knows how to read them at all.

The disk editor

The full power of the Option Board becomes evident when you use TE, the disk editor. You can get a track dump of both Apple and IBM disks—no mean accomplishment. The board can distinguish between regular bytes and sync bytes, and highlights the latter on the screen display to make them stand out. You can use the editor to take a bit-level cruise through the disk and change anything you find there. One extra-nice feature of the editor is that it will recalculate the CRC's for you when you write new data to a track. That is important because it is very difficult to do by hand, and if you get it wrong, the disk will be unreadable by DOS.

Examining a track dump can tell you a lot about how the disk was formatted. If you know what you're doing, you can figure out how the directory is organized, how files are written, and how the data is stored; invaluable information if you're trying to rescue a crashed disk. Being able to identify single- and double-sided disks simplifies the process of data conversion.

The manual hand-holds the user through the process of installing and using the board. There's a small section on how standard disks are formatted, but you'll have to go elsewhere if you want to learn about copy protection. Since there's absolutely no technical description of the Option Board itself, you won't be able to write software to use it. Central Point Software is keeping the board's circuitry to itself. That makes sense because knowing everything the board *can* do means you also know everything it *can't* do, and that's something the copy-protection people would love to find out.

Conclusion

If you have a substantial investment in copy-protected software, or if you really want to get into the nitty gritty of disk formatting, the Option Board is for you. It's much more powerful than software-only disk copiers and, at $100, is only slightly more expensive. It's an impressive piece of hardware; the more you use it the more valuable it becomes.

MYCROFT LABS' Mite

We all have our own special use for home computers, but sooner or later everyone wants to get on-line and explore. Telecommunications lets you tap into a whole new world of information. Everything from extended data bases, to airline guides, to remote bulletin boards is only a phone call away—if you have the hardware and software to do it.

Once you've decided on the hardware half of RS-232'ing, you still need software to make it work, and this is where things can get very bewildering. There are probably as many terminal programs available on the market as there are word processors and choosing the one that is best for you can be a confusing business. You need software that is easy to use, yet powerful

Mycroft Labs (P. O. Box 6045, Tallahassee, FL 32314) has been marketing successive versions of Mite since the late seventies so the current release is the result of nearly 10 years of development. If you're an old hand when it comes to RS-232 stuff, you'll find that Mite has every feature you could conceivably want and if you're just learning what on-line means, you'll find the program so intuitively organized that you'll be getting around it in no time at all.

Although Mite started out in the CP/M world it was rewritten from scratch in 8086 assembler to run on the PC. This means it can cross directories and follow paths that might be set before the program is run. And it's tightly written as well - because Mite weighs in at a mere 51k, you could run it on a machine with as little as 128k. The small size of the program becomes more impressive as you become more familiar with it and realize how powerful it is.

The most basic function of any terminal software is the uploading and downloading of files. Mite can do simple, non-protocol transfers of text but has the ability to handle four different types of binary transfers as well. XMODEM, YMODEM, KERMIT, and Mite's own protocols are fully supported—in both single and batch mode—and XMODEM can be set for either checksum or CRC error checking. All Mite commands can be issued in two ways. The first is by running through a series of menus while in command mode, and the second method is by typing a user-definable fly key in terminal mode, and then typing the command and appropriate argument, (e.g., SEND [filename], DIR [drive]:, PATH [directory]) When you're first getting started with Mite it's much simpler to issue commands from the menu but as you get more familiar with the program, you'll take advantage of the speed and convenience of remaining in terminal mode and using the fly key.

If you get stuck, Mite's extensive online help is only a keystroke away. You can get an explanation of any of the commands by pressing the question mark and the first letter of the command. If you're in command mode you'll get a full description of any of the commands on the screen. In terminal mode the help key will give you a commented list of the available commands. In either mode however, the help is well planned—it's complete without being obtrusive.

Mite can be automated as well. You can preprogram up to 10 macro strings to give you a one-key logon to dialup services, simplify the search command strings used with on-line data bases and, in general, make your time a lot more efficient—and that's nothing to sneeze at when you're on-line at more than 25 bucks an hour. Macros can be up to 61 characters long, and there are six special macro characters that perform functions such as making the macro stop executing until a particular character is received or linking to another macro

If you're really into automating things, you can learn how to use MORSE, the programming language that's built into Dyna-Mite, Mycroft Lab's top of the line product. It's a BASIC-like language that lets you create programs that control operations while you're online. It has over 30 built-in commands such as LET, PRINT, GOTO, GOSUB, DIAL, HANGUP, IF, THEN, etc., and will also accept any of the standard Mite commands. The extensive vocabulary gives you the ability to create programs to automate the handling of electronic mail, do conditional searches through online data bases, or simplify an overly complex online procedure so it can be done by any inexperienced user. MORSE is to Mite what batch files are to DOS. Programmability is not just unique to Mite—other software, both commercial and shareware, have this feature. As far as power goes, MORSE falls about in the middle of the pile. It is, however, extremely easy to use and even someone who's just starting out will have no trouble at all writing programs after ten minutes with the manual.

Mite's documentation is packaged in a 5 × 8 looseleaf binder and it has all the information you need to find your way around the program as well as a good discussion of what you can find in the larger dial-up services such as Compuserve and The Source. If it means anything to you, Arthur C. Clarke is a Mite user and he has written a book called *Mite For Morons* that will show even the most inexperienced user how to use the program.

There are two PC versions of Mite: Maxi-Mite and Dyna-Mite. The difference between them is extended terminal emulation and the MORSE language interpreter. Maxi-Mite costs $50 and Dyna-Mite costs $100, so if you're not interested in the extra goodies you can save the 50 bucks, but the addition of MORSE alone is worth the investment. If it were a stand-alone program, it would cost more than Dyna-Mite and you'd still need terminal software.

There's even a way to try out Mite for nothing. Mycroft Labs has put a version, called Mini-Mite, in the public domain. It has a lot of the bells and whistles, (but not MORSE, of course), and it can do XMODEM protocol as well as ASCII uploads and downloads. Look for it on your local BBS and, if it's not there, Mycroft Labs will send the whole thing to you on a disk, (including a small manual file), for a minimal charge of about $15.

For all us 8-bit lovers, Maxi-Mite is available in CP/M and there are overlays for a mind-boggling number of terminals. If you need a good terminal package for CP/M, the 50 bucks you spend for Maxi-Mite will turn out to be the best software investment you ever made. And that, of course, goes for the PC version as well. Mite meets every one of the criteria you should look for in software. It's powerful, well seasoned, actively supported, and reasonably priced.

If you need telecommunication software Mite will provide you with a lot of power without doing too much damage to your wallet.—*Bob Grossblatt*

K SOFTWARE HOUSE, RESIDENT SCIENTIFIC CALCULATOR

Certainly, a memory-resident calculator is no ground-breaking product. However, like people, calculators are not all created equal, and not all calculate equally well. For many people, the typical "four-banger" (add, subtract, multiply, divide) included with programs like SideKick, PolyWindows, etc. is sufficient. But engineers often need transcendental functions, programmability, etc.

If you use a scientific calculator and a PC, the KSH-1 calculator can make life much easier for you. It has all the functions of the HP-11c it's modeled on, the ability to store programs on disk, and an attractive screen display (color or mono). See Fig. 2. It'll never get lost in a stack of papers on your desk; nor can anyone walk off with it.

You use the cursor-control keys (or a mouse) to move a blinking reverse-video bar to the screen locations that correspond to various keys. Just press Return, and the function at that location will be executed.

Like the original, most keys actually perform three different functions: the default function, an F function (listed above the key) and a G function (listed below the key). F and G functions are available by pressing the F or G key of your PC's keyboard, followed by Return.

The KSH-1 includes several features not included in the original. To mention just a few, you can convert numbers among several bases (decimal, of course, as well as binary, octal, and hexadecimal). In addition, by pressing F8, the contents of the X, Y, Z, and T resisters are displayed on screen.

The KSH-1 comes with an informative manual containing usage hints and sample programs. The program is very easy to install, and, at $49.95, is a bargain. Contact the K Software House, Rt. 2 Box 83B1, Unionville, TN 37180.

REVOLUTION SOFTWARE, CURSOR CONTROL

Keyboard and screen control has never been a strong-point of the MS-DOS operating system. Numerous add-in memory-resident programs purport to correct some deficiencies, but they tend to conflict with one another or other programs.

Along comes Cruise Control, a program that emerged as a by-product of another project. You use it to control cursor speed while moving through a spreadsheet, browsing a text file, etc. It has an automatic repeat (whose rate may be adjusted on the fly) for hands-free browsing. Repeat is applied to all the usual keys (excluding Control, Alt, the shift keys, NumLock, etc.)

In addition, Cruise Control has an auto-

continued on page 95

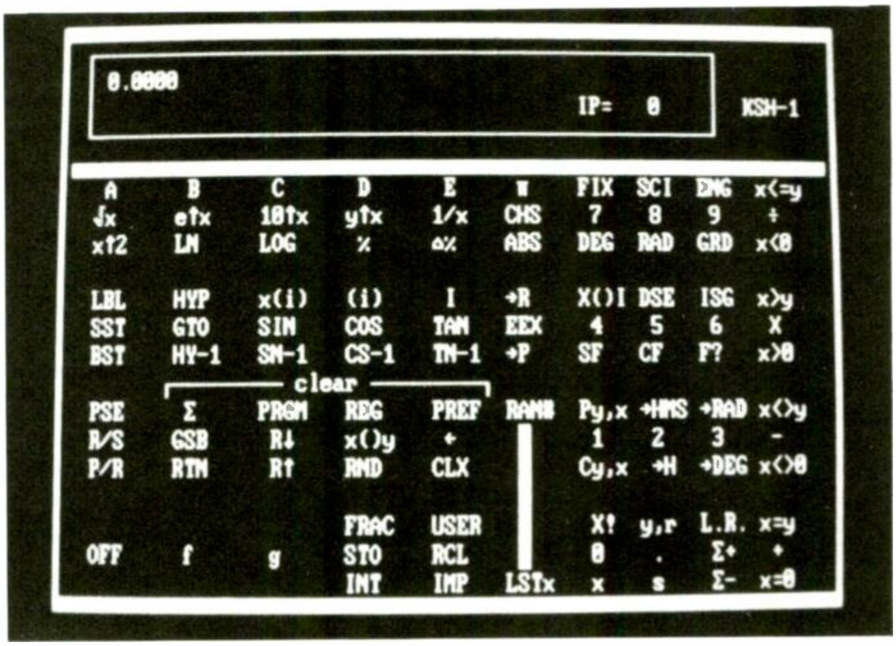


FIG. 2

BUILD THE PT-68K

LEARN 68000 COMPUTING IN THE CD CLASSROOM

PETER STARK, STARK SOFTWARE SYSTEMS CORPORATION

The two major microprocessor manufacturers today are Intel and Motorola. Although Intel processors are better known (mainly due to their use in the IBM PC line), astute users agree that Motorola's 68000 family of microprocessors is more powerful and easier to use. When you look at heavy-duty number-crunching machines, you will find the 68020 used more often than any other.

We were tempted to use the 68020 in the computer described here (hereafter called the PT-68K), but were put off by the $200 price of that one IC alone. So we settled for its slightly slower cousin, the 68000, which is used in various computers made by Atari, Commodore, Apple, in many laser printers, as well as in industrial controllers and scientific workstations.

The 68000 is roughly in the middle of the 68000 family of microprocessors; the 68008 is below it, and the 68020 is above it. A fourth processor, the 68010, is theoretically faster than the 68000, but the 68000 can run at faster clock rates and so is just about equal in overall speed. You can plug a 68010 into the PT-68K, but you probably won't notice any difference—except in price.

System overview

In its simplest form, the PT-68K runs at a clock rate of 8 MHz. With minor changes, it can run at 10 MHz; if that's not fast enough, you can also run it at 12 or possibly 16 MHz. Naturally, faster models will cost more. In addition, you won't be able to use the 68010 at the higher clock rates.

Almost all necessary system components are contained on the PT-68K's printed-circuit board. A fully built-up board contains the 68000 microprocessor and support circuitry; one megabyte of dynamic RAM (main memory); 4K of battery-backed static RAM; 32K of ROM (containing BASIC, a machine-language debugger, and a link to the disk-operating system); four serial ports; two parallel ports; floppy-disk interface for up to four drives; sound interface for a speaker; a clock/calendar IC; expansion connectors for memory and a hard disk controller; IBM PC keyboard interface; interface connectors for additional clone-compatible I/O boards.

You can communicate with the PT-68K using an RS-232 terminal or any computer running a communications program functioning as a terminal (perhaps an IBM PC or clone, an Apple, or a Commodore). Or you can plug an IBM keyboard and monochrome adapter card directly into the PT-68K and the computer will use them for input and output.

What about software? First of all, the 68K contains 32K of permanent memory containing two programs that will let you use the computer right away, even if your system does not have disk drives or a full complement of memory. The first program is called *HUMBUG;* as shown in Table 1, it has thirty commands that allow you to enter machine-language programs into memory, dump memory contents, test memory, fill memory,move memory, serch memory, start and stop programs, single-step or breakpoint them, and more. HUMBUG also provides a number of useful subroutines to handle the screen and keyboard (or terminal), boot from disk (Winchester or floppy), etc.

In addition, HUMBUG's BA command places you into its ROM BASIC interpreter. The ROM BASIC is somewhat limited, but it does allow you to peek and poke in memory, do floating-point calculations, and run test programs. You can't save them, but a full disk BASIC should be available by the time you read this.

SK*DOS

After you add memory and a disk interface, HUMBUG allows you to boot SK*DOS, a disk operating system (DOS) developed specifically for individual users and small system manufacturers; it has been adapted to a variety of different computers in the U.S. and Europe.

SK*DOS comes with about forty utility programs, including an editor, an assembler, another version of BASIC, a game (Eliza), programs to read and write IBM PC disks, and RAM disk and disk cache programs (we will explain those terms later in this series). Also included is an emulator program that lets you run hundreds of programs developed for Motorola's 6809 processor. In addition, device drivers, and a number of other interesting and useful programs are also included.

SK*DOS requires at least one standard floppy-disk drive (single- or double-sided, 40- or 80-track, 3½- or 5¼-inch). SK*DOS itself can handle up to ten drives, but the PT-68K hardware will support only four. But you can also add one or two hard-disk drives to provide up to 128 megabytes of additional storage. And because the 68K will accept some IBM type hard-disk interfaces, you can do so relatively cheaply as well.

Unlike some disk operating systems which are unique to just one brand or type of computer, SK*DOS has been adapted to a number of different 68008, 68000, and 68020 computers in the United States and Europe. This means that software developed on other machines will run on your 68K system as well. For example, a number of inexpensive programs (a text processor, communications software, Edward Ream's screen editor, and Ron Cain's small C compiler, among others) are available through the SK*DOS Users' Group and from the **Radio-Electronics** BBS (300/1200, 8/N/1).

In addition, several members of the Users' Group are into Unix programming, and have converted Unix-like programs (such as Micro-EMACS and NRO) to run under SK*DOS. Last, as this article was being written, several commercial developers were working on larger programs including a full C compiler and a full Basic interpreter.

TABLE 1—HUMBUG COMMANDS

AD	- ASCII Dump	JU	- Jump to User program
AI	- ASCII Input	LO	- Load S1-S9 format
AO	- ASCII Output	MC	- Memory Compare
BA	- Basic	ME	- Memory Examine
BP	- Breakpoint Print	MO	- MOve memory
BR	- BReakpoint set/reset	MS	- Memory Store
CO	- COntinue	MT	- Memory Test
CS	- CheckSum	RC	- Register Change
FD	- Boot / Floppy Disk	RD	- Return to DOS
FI	- FInd 1-5 bytes	RE	- Register Examine
FM	- Fill Memory	SS	- Single Step
HA	- Hex and ASCII dump	ST	- STart single-step
HD	- Hex memory Dump	WA	- Boot / Winchester A
HE	- HElp	WB	- Boot / Winchester B
JS	- Jump to System program	!!	- Force reset

Educational value

The PT-68K will not be presented as an "appliance" computer that you plug in and use with no knowledge of what's going on under the hood. Rather, we are going to spend a great deal of time building the PT-68K section by section, testing and explaining as we go along. Due to its unique construction, you will be able to run machine-language and BASIC programs with a minimal system.

That approach has two big advantages. First, it allows us to spend time discussing and understanding what each section does. More important, though, is the fact that you can catch and fix a mistake or problem soon after it is made. At any stage, you will add just a few IC's, and that will simplify debugging, as well as give you a chance to really understand how various circuits work.

Of course, if you feel that you already possess the necessary expertise, you're free to purchase parts, build the computer, and get to work. Just make sure you *are* ready!

The bottom line

The PT-68K isn't being built by the millions in the Far East, so you can't expect it to be as cheap as a mass-produced PC clone. On the other hand, it is surprisingly inexpensive, partly because we use PC clone components wherever possible, and also because our motherboard contains much hardware that must be added to most computers on plug-in boards. To illustrate how clone components can save costs, an early prototype of the PT-68K—which did not have the PC bus slots—needed a $220 hard-disk controller. The current version allows you to use a standard Western Digital controller that costs about $90. Kit prices are summarized in the sidebar.

System overview

The block diagram in Fig. 1 shows the major sections of the PT-68K. In general terms, the diagram describes just about any computer, not just the PT-68K. At this point we won't define some of the terms we'll use (RAM, ROM, etc.) in much detail; a later installment will do so.

The heart of the diagram is the microprocessor, a Motorola 68000. It is driven by a clock, which is nothing more than a high-frequency oscillator that generates a squarewave. The clock synchronizes everything that occurs in the system. In the PT-68K, the clock will most likely be an 8-MHz signal, though it could go as high as 16 MHz.

In the PT-68K, two EPROM (Erasable Programmable Read-Only Memory) IC's contain the system software. Unlike RAM (Random-Access Memory) the contents of an EPROM is not lost when power is removed. When you purchase an EPROM, it is "empty" or erased. But the two PT-68K EPROMs have been programmed with HUMBUG and BASIC. The computer can read and use those programs, but it cannot erase or change them.

RAM (which should really be called RWM, for Read-Write memory—but have you ever tried to pronounce RWM?) is memory in which the microprocessor can store information and then read it back at a later time. Of course, the contents of RAM is usually erased when you turn the power off.

The PT-68K actually has two kinds of RAM: static and dynamic. Many computers use only one or the other, but we use both because each has its advantages. For large amounts of memory, dynamic RAM (DRAM) is cheaper and smaller—without DRAM, it would be impractical to provide one megabyte of memory at any reasonable cost. On the other hand, for small memories static RAM is the right choice because it is much simpler to design with, and therefore the support circuitry is easier to debug.

The minimal PT-68K has a small amount (4K) of static RAM that is contained in just two integrated circuits. Because the static-RAM circuitry is so simple, it will most likely work immediately with no problems. That RAM will allow you to run BASIC and HUMBUG. After the static RAM is working, you can add the DRAM, which consists of thirty-two 256K IC's, plus a batch of support IC's. If there is a problem with the DRAM, you can use HUMBUG to debug it. That kind of "bootstrapping" makes the building of a large system like the 68K from scratch practical.

There is another reason for providing static RAM; a special clock/calendar IC is plug-compatible with the RAM IC we use. So we need only unplug one of the RAM IC's and plug in the clock/calendar IC, a MK48T02, which provides not only a clock and calendar, but also some static RAM of its own, and a built-in battery to power the clock and RAM while the computer is off.

I/O interface

Although the block diagram in Fig. 1 shows just a single box labeled I/O Interfaces, the PT-68K's I/O is actually quite complex. It consists of two MC68681 DUART's that provide four serial interfaces, one 68230 parallel interface timer, a 1772 floppy-disk controller, keyboard interface, speaker interface, a number of extra support IC's, the PC interface circuitry, plus the interrupt circuitry, which allows I/O devices to interrupt the 68000 when they need it.

Some microcomputers provide DMA (Direct Memory Access) circuits. DMA is often used when the microprocessor has difficulty keeping up with disk drives and other relatively fast I/O devices. The 68000 has no problem keeping up with the disk drives, and DMA really complicates the computer (and increases its cost), so we chose not to use it in the PT-68K.

System buses

As Fig. 1 shows, the two main sets of connections between the microprocessor and the ROM, the RAM, and the I/O interfaces are the data bus and the address bus. The term *bus* is used to signify that a number of parallel wires are used to carry signals simultaneously.

The data bus is used to move data of any sort (numeric data, microprocessor instructions, or plain text) between the microprocessor, memory, and I/O devices. The arrowheads leading from and going to the various functional blocks in the block diagram show the direction that data may flow from various devices. For example, data can only flow out of ROM, but it can flow both into and out of RAM. The data bus is said to be *bidirectional* because data may flow either into or out of the microprocessor. The address bus, by contrast, is *unidirectional*, because address information only flows out of not into the microprocessor.

The PT-68K's data bus consists of 16 signals, each of which carries one binary digit (bit). Therefore, the 68000 can transfer an entire 16-bit number to or from memory all at once. Other microprocessors handle eight bits, 32 bits, and other values. As we will see, the 68000 handles numbers in 8-bit chunks (called bytes), 16-bit chunks (two bytes, or a word), and 32-bit chunks (four bytes, or a long word.) When transferring a byte, the 68000 uses only half of the data bus; when transferring a long word, it uses the data bus twice, transferring 16 bits at a time.

The number of bits on a data bus (also called the width of the bus) obviously has a bearing on speed: the wider the bus, the more bits that can be moved at a time, so the faster the computer runs. However, bus width is by no means the only factor limiting speed; the microprocessor's *internal* bus width is also important.

Early general-purpose microprocessors (including the 8080, the 6800, the 6502, and the Z80) have an eight-bit data bus and also handle most numbers internally in an eight-bit format. For that reason they are called eight-bit microprocessors.

The next generation of microprocessors (including the 6809 and the 8088) still have eight-bit external data buses, but 16-bit internal buses. That gives them extra power, but they are still bogged down by the slow speed at which they can transfer data to and from memory and I/O devices.

The next step includes the 8086, the 80186, and the 80286, processors which handle 16-bit numbers both internally and externally, and which are properly called 16-bit processors.

The 68000 is one step higher yet—it has a 16-bit external bus, but a 32-bit internal bus. The 68008 has the same 32-bit internal bus as the 68000, but an external width of only eight bits. That may appear to be a disadvantage, but in cost- and space-sensitive applications, the reduced width can be valuable, because fewer support IC's are necessary.

Last, at the top of the current pyramid are the 80386 and the 68020, both of which handle 32-bit numbers both internally and externally. They are true 32-bit processors.

Internal and external bus width are not the only factors that affect computer speed. A bus that's twice as wide doesn't necessarily mean a computer that's twice as fast, unless you consistently run

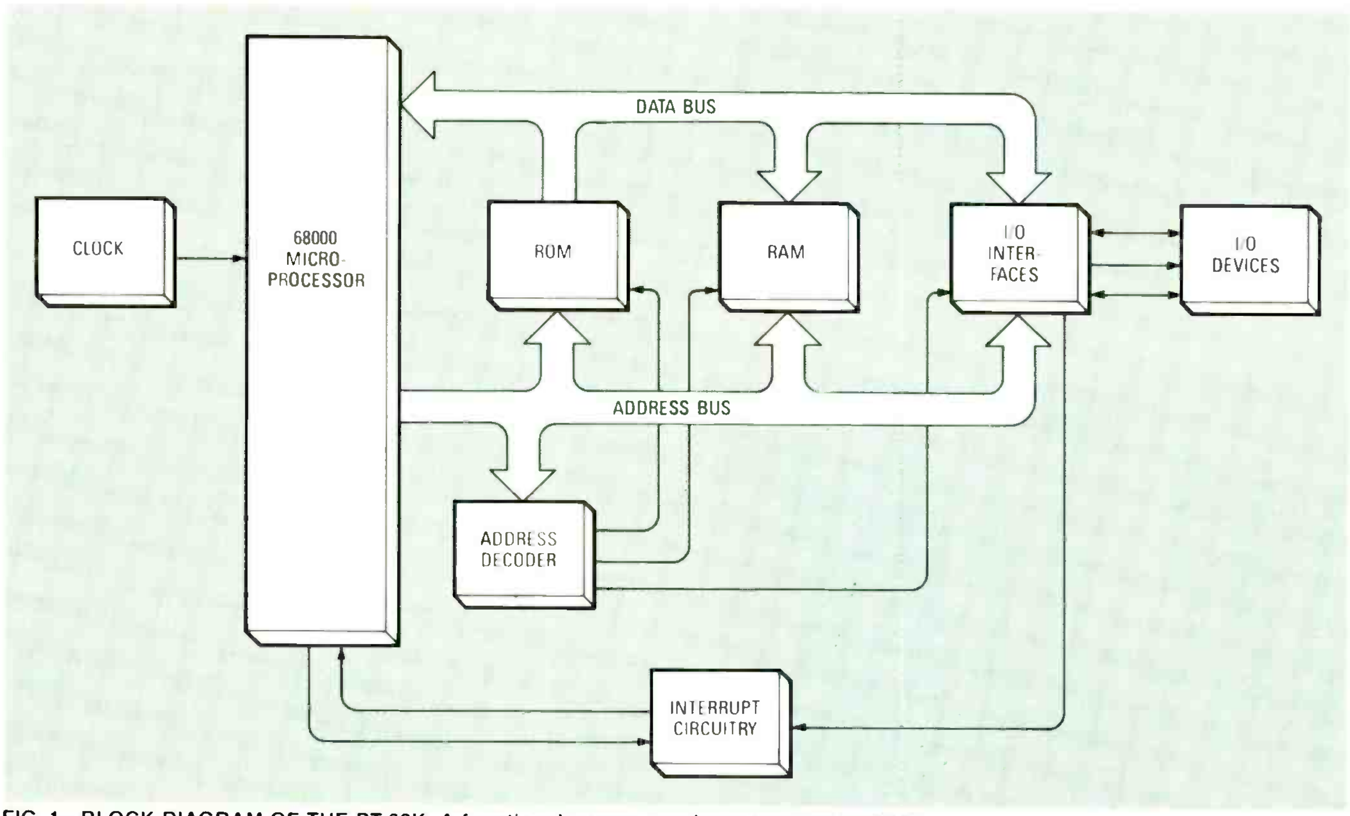


FIG. 1—BLOCK DIAGRAM OF THE PT-68K. A functional system can be assembled for $200.

programs that make full use of that width. For example, a program that uses many byte-oriented instructions may not operate much faster on a 32-bit bus than on a 16-bit bus.

Another factor that can affect overall system speed is the use of a cache. Both the 68020 and the 80386 use a cache, an area of memory within the IC itself that holds instructions or data that are loaded from main memory before they are needed. Older processors generally read data from main memory only at the instant it is needed, and main memory is invariably slower than memory inside the IC. However, the newer processors spend their spare time pre-reading a few bytes ahead of themselves, and store those bytes for possible future use. In that way they avoid having to wait for data or instructions to load from main memory. The 68000 and corresponding members of the Intel family have small caches, but they're too small to provide significant savings.

The address bus

The other major bus, the address bus, carries addresses. That is, in order to store data in memory, or read data from memory, the processor must specify exactly where in memory that data is located. That is done with a numeric address, sent out on the address bus. As stated earlier, the address bus is unidirectional. However, there is an important exception to that statement: A DMA controller may seize control and supply addresses instead of the microprocessor. A DMA controller allows extremely quick transfer of large amounts of data without involving the microprocessor. Transfers may occur from a disk drive (or other mass-storage device) to main memory, from main memory to a disk drive, or even from memory to memory. But because the PT-68K has no DMA circuit, we'll say no more about it.

The width of the address bus determines the maximum amount of memory a computer can have. If the bus had only three lines, for example, then each address would consist of just three bits. Each bit can be either Ø or 1, so there would be only eight possible addresses: ØØØ, ØØ1, Ø1Ø, Ø11, 1ØØ, 1Ø1, 11Ø, and 111. Hence the maximum number of addresses would be 2^3, or 8.

In general, the maximum number of addresses is 2 to the same power as the number of address lines. For example, most 8-bit microprocessors have 16 address lines, so the maximum number of addresses would be 2^{16}, or 65,536.

In electronics, the symbol K stands for multiples of 1000 (a 10K resistor, for example), but in computers, a K is 1024 (2^{10}). So 65,536 turns out to be exactly 64K (64 × 1024) locations.

Newer microprocessors have more address lines than their predecessors. For example, the eight-bit processors mentioned earlier have 16 address lines, for a total of 64K of memory. The 8088 and the 68008 each have 20 address lines, for a total of 1 megabyte. The 68000 and the 80286 each have 24 address lines, for a total of 16 megabytes. Last, the 68020 and the 80386 have 32 address lines for a total of four billion bytes of physical memory.

As you might expect, the mere width of the address bus is not the only thing that affects system performance. Consider the 20-bit

PARTS LIST

All resistors are ¼-watt, 10% unless otherwise noted.
R1–R6—150 ohms
R7—4700 ohms
R8–R10, R12, R13—10,000 ohms
R11—not used
R14, R15—330 ohms
R16—220 ohms
R17, R18—33-ohm 16-pin DIP package
R19—10,000-ohm 8-pin SIP package
R20, R21, R24, R26—2200 ohms
R22, R23—1 megohm
R25—33 ohms
Capacitors
C1, C2, C6–C62, C64, C67, C68—0.1 µF, disc, ceramic
C3, C4, C5—47 pF, disc, ceramic
C63—1 µF, 16 volts, tantalum
C65—10 µF, 16 volts, tantalum
C68—33 pF, disk, ceramic
Semiconductors
IC1—74LS245 octal bus transceiver
IC2—MC68230P8 peripheral interface/timer
IC3—3.68-MHz oscillator
IC4, IC10—MC68681 DUART
IC5—WD1772 floppy-disk controller
IC6, IC22, IC32—7406 open-collector hex inverter
IC7—74LS367 hex bus driver
IC8, IC29—1489 RS-232 receiver
IC9, IC30—1488 RS-232 driver
IC11, IC24, IC31, IC33, IC76—74LS175 quad D flip-flop
IC12—7442 BCD decoder
IC13, IC50—74LS74 dual D flip-flop
IC14, IC26, IC51—74LS32 quad 2-input OR gate
IC15, IC35—74LS00 quad 2-input NAND gate
IC16—74LS174 hex D flip-flop
IC17–IC19—74LS373 octal latch
IC20, IC27—27128 16K × 8 450ns EPROM
IC21—6116 2K × 8 400ns static RAM
IC23—74274 dual D flip-flop
IC25—74LS322 8-bit shift register
IC28—6116 2K × 8 400ns static RAM or MK48T02 clock
IC34—74LS138 3-to-8 line decoder
IC36—74LS30 8-input NAND gate
IC37—74LS10 triple 3-input NAND gate
IC38–IC45, IC53–IC60, IC67–IC74, IC80–IC87—256K 150ns dynamic RAM
IC46—74LS393 dual 4-bit counter
IC47—MC68000P8 microprocessor
IC48—74LS08 quad 2-input AND gate
IC49, IC77—74ALS74 dual D flip-flop
IC52—150ns delay gate
IC62, IC75, IC88—74LS257 quad 2-input multiplexer
IC61—74S373 octal latch
IC63—16L8 PAL
IC64—74LS139 dual 2-to-4 line decoder
IC65—74LS390 dual decade counter
IC66—74LS04 hex inverter
IC78—16-MHz oscillator
IC79—Optional 20- or 24-MHz oscillator
IC89—74LS148 8-to-3 line priority encoder
IC90—74LS164 8-bit shift register
IC91—555 timer
IC92—optional 14.313-MHz oscillator
Connectors
J1–J6—62-pin card edge connector (for IBM slots)
J7, J8—40-pin dual header strip
J9—5-pin DIN connector (for IBM keyboard)
J10a, J10b—6-pin power connector (IBM style)
J11, J12, J21, J22—6-pin dual header strip
J13—34-pin dual header strip
J14–J17—not used
J18—4-pin single header
J19, J20, J24, J25—3-pin single header strip
J23—2-pin single header strip
Other components: PC board, cabinet (PC, XT, or AT clone), power supply (135-watt minimum, PC or XT clone).

bus of the 8088 and the 68008, for example. Both processors can address a megabyte of memory, but the 68008 can do so in one continuous piece, whereas the 8088 splits that memory into 64K segments. Handling the segmenting greatly complicates a program, and that's why many programs written for the 8088 (Microsoft BASIC, for example) can only use 64K of memory at a time, whereas BASIC on the 68008 has no such limitation.

So the 68000 can easily handle programs and data that use up the entire 16 megabytes of memory—almost. The reason is that Intel and Motorola processors differ in the ways they handle I/O. In a Motorola-based computer, I/O devices connect to the processor in exactly the same way as memory does, and the result is that available memory space decreases slightly. So if a 68000 were to dedicate one megabyte of memory to I/O, there would be only 15 megabytes left for memory.

Intel processors do not have that limitation; they use the entire address range for memory, and they have a separate (usually smaller) set of addresses just for I/O. Some people claim that Motorola's sharing memory and I/O space is a disadvantage, but in practice it makes very little difference, because a given system seldom requires more than a few dozen (or perhaps a few hundred) I/O addresses, and that leaves plenty of space for memory. In fact, in most cases, a 68000 or 68020 has so much unused address space that we can afford to waste thousands—maybe even millions—of addresses on I/O without feeling the pinch.

A list of addresses in a computer and what they are used for is called a *memory map*. Table 2 shows the memory map of the PT-68K. As you can see, there is still plenty of memory left for expansion, probably much more than most of us would ever care to pay for.

Decoding memory

As Fig 1 shows, the microprocessor's address bus is split into two sections: part goes to the address decoder, and part goes to the ROM, RAM, and I/O interfaces.

The address decoder's job is to examine the address bus and route a given address to the appropriate circuit. For example, as Table 2 shows, the on-board dynamic RAM occupies addresses 000000 through 0FFFFF. Whenever the address decoder sees an address beginning with the hexadecimal digit 0, it recognizes that address as a RAM address, and sends a signal to the RAM that effectively says "Hey, you! This address is meant for you—get to work!" That signal is called an *enable* or *select* signal. If it goes directly to an IC, then it is called a *chip enable* or *chip select*, often abbreviated CE or CS.

The block diagram implies that there is just one address decoder, but in practice most computers split the function among two or more decoders, each of which services just one part of the computer. One reason is that circuit design is easier, but there is a second reason as well: different decoders deal with different parts of the address bus.

For example, to decode the dynamic RAM space, the address decoder need only look at the leftmost hex digit of the address, that is, the four leftmost bits, which must equal 0000 (a hex 0) for the RAM to go to work.

TABLE 2—PT-68K COMPUTER MEMORY MAP

Memory Range	Description
000000 - 0FFFFF	On-board RAM (1 megabyte)
100000 - BFFFFF	Expansion RAM (11 megabytes)
C00000 - DFFFFF	PC address-space slots (2 megabytes)
E00000 - F7FFFF	Unused (1.5 megabytes)
F80000 - F9FFFF	ROM (128K)
FA0000 - FBFFFF	PC I/O space slots (128K)
FC0000 - FDFFFF	Unused (128K)
FE0000 - FE3FFF	I/O Interfaces (16K)
FE4000 - FEFFFF	Unused (48K)
FF0000 - FF7FFF	Static RAM (32K)
FF8000 - FFFFFF	Unused (32K)

Note: Parts of some segments may not be used. For example, 32K is assigned to static RAM, but only 4K is actually installed.

The ROM-decode signal, by contrast, is derived from seven bits. The ROM occupies addresses F80000 through F9FFFF. The lowest address (F80000) begins with 1111100 and then continues with 17 zeroes; address F9FFFF also begins with 1111100 but then continues with 17 ones. All other ROM addresses also begin with the bits 1111100, but have different combinations of zeroes and ones at the end. So any address that starts with 1111100 applies to the ROM. Therefore, whenever the address decoder sees a 1111100, it sends an enable signal to the ROM.

Hands-on

The preceding serves as a brief introduction to the PT-68K, and it indicates the kind of material we'll be covering in future installments. Now we'll discuss some basics of construction. As discussed in the sidebar, the hardware is available in several configurations. If you want (and are able), you can purchase the parts, assemble the computer, and start using it. If, however, you're

PARTS AND PRICES

The following kits and components are available from Peripheral Technology, 1480 Terrell Mill Rd #870, Marietta GA 30067, 404-984-0742.

Basic Kit, PT1, $200. Contains all parts (except power supply and case) to build the basic 8-MHz PT-68K: double-sided solder-masked silk-screened PC board, MC68000 microprocessor, HUMBUG and BASIC EPROM's, clock oscillator, static RAM, two serial ports, power and signal connectors, IC sockets, resistors, capacitors, and all other components to make a functional system. Add $20 for the 10-MHz version, or $70 for the 12-MHz version. Please inquire about the cost of the 16-MHz version. The 8-MHz board can be updated later to 10 MHz; conversion to 12 or 16 MHz may be more difficult.

First 512K RAM, PT2a, $90. DRAM controller circuitry and first 512K of 150-ns RAM IC's with sockets, for 8 or 10 MHz. **Second 512K RAM, PT2b, $50.** 512K of dynamic RAM IC's with sockets, can be added at any time. DRAM prices are highly unstable at this time, so prices may vary.

Floppy-disk Controller, PT3, $100. Floppy-disk controller and all support IC's, connectors, IC sockets, and SK*DOS, which includes editor, assembler, BASIC, RAM disk, disk cache, and utility programs. Disk drives extra.

Parallel port and clock/calendar, PT4, $50. All parts and IC sockets included.

PC-compatible slots, PT5a, $40. Includes connectors, support IC's, and sockets for the first three bus slots and compatible keyboard. **Three additional connectors, PT5b, $10.** (The slots can be added at any time, but you may want to install them immediately if you have no serial terminal or computer that can act as a serial terminal.)

Full basic system, PT68K, $470. Includes all circuitry from kits PT1, PT2a, PT3, PT4, and PT5a, as well as the 10 MHz upgrade kit. You needn't purchase the full kit to get started; however we recommend that options be added in the order described. A bare motherboard with EPROM's and PAL is available for $170.

Other components can be obtained through the clone market or from Peripheral Technology: "Baby" AT cabinet, as shown in the accompanying photographs, $45; 150-watt power supply, $60; AT-style keyboard, $60; Samsung 1252G amber monitor, $90; Hercules-compatible monochrome text/graphics card, $50; Western Digital hard-disk controller card, $90; 80-track double-sided 720K floppy-disk drive, $120; 20 megabyte half-height hard disk, $295.

All orders add $5 shipping and handling. Heavy items (monitors, disk drives, etc.) extra. Georgia residents add applicable sales tax.

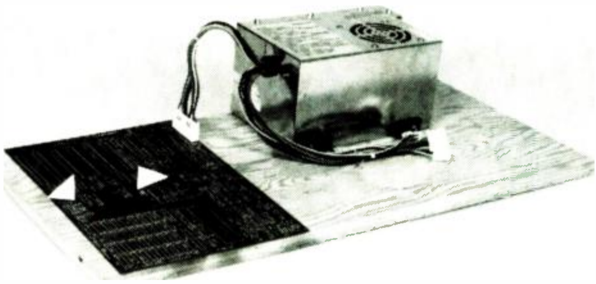


FIG. 2—MOUNT THE PT68K on a 12" × 24" slab of wood.

coming along for the educational ride, you'll want to follow the steps outlined below. You'll want to buy either the basic kit (PT1) or the full kit (PT-68K). The basic kit can be expanded to the same capabilities of the full kit, but with a smaller initial cash outlay. In addition, you'll want to obtain the following:

- A power supply. Almost any supply that can provide five volts at about five amperes will do; however, a PC clone supply is recommended because it provides ample power for adding disk drives and plug-in boards. It is also about as cheap as you can get, and it has a set of connectors that plug directly into the PC board without having to jury-rig some kluge.
- A 12" × 24" wooden board to mount the PC board and power supply so you can work on them easily. (See Fig. 2). Don't fasten the PC board to the wood; just hammer two thin brads into the wood so the board's mounting holes slip over them to prevent the board from sliding. The white markers in Fig. 2 indicate which holes to use. **IMPORTANT:** do not use any of the other 7 mounting holes yet. Those holes have a ground trace on the bottom of the board, and a + 5-volt trace on the top of the board; if you insert a metal screw or nail into the hole, you may short out the power supply and cause damage. When it is time to mount the board in the cabinet, you will use plastic hardware to avoid a short.
- A voltmeter, logic probe, or oscilloscope would be helpful, but is not essential. If none of those is available, you can build a simple LED-based logic probe right on the board. We'll show you how next time.
- Some thin wire, 30 gauge or so, will be needed for some of our experiments.
- Last, you need some simple hand tools: screwdriver, needle-nose pliers, diagonal cutters, and, above all, a good soldering iron, rated at no more than 45 watts. A pencil type iron rated 35 watts or so is good; a temperature-controlled low-voltage soldering station is better. In any case, don't use anything over 45 watts. Good soldering technique is extremely important in a project of this complexity.

When we get together next time, we'll start to build and test the PT-68K. R-E

EDITOR'S WORKBENCH

continued from page 89

dimmer that will blank your screen after a time period you select. And for privacy you can blank the screen at any time by pressing a key. Press any key to restore the screen.

You can use Cruise Control to insert the current time, date, or both, into your current enivronment, be it a word processor, a spreadsheet, or just about any other program. The characters flow into the program just as if you had typed them at the keyboard.

A help panel, shown in Fig. 3, that lists all available options, is availble at the DOS prompt. Four "strategies" (also changeable on the fly) help adapt Cruise Control to various environments.

Cruise Control has been part of our AUTOEXEC.BAT file since the day we received it. It uses only about 3K of RAM, and lists for $39.95 plus $3.50 shipping and handling, from Revolution Software, 715 Route 10 East, Randolph, NJ 07869.

COVE SOFTWARE GROUP, PCED

Several months ago (March 1987, page 95) we mentioned a little program called CED that we discovered on the PC-SIG CD-ROM. (The CD-ROM contains more than 10,000 public-domain programs for the IBM family of computers.) CED has now gone commercial; the new incarnation is called PCED (for Professional Command-line Editor). PCED includes all the features of CED (the most important of which are the ability to edit the current command line; the ability to call up previous ones, edit them, and re-execute them; and the ability to define synonyms for single or multiple DOS commands). In addition, PCED adds several new commands, including the ability to load and save its configuration file, the ability to be turned off temporarily, the ability to log every command executed by DOS in a disk file, and more.

CED had provisions for adding external pseudo-commands to DOS; PCED includes several such commands. For example, an optionally installable directory program allows you to get directory listings that are sorted in one of several ways. Another installable pseudo-command allows you to send codes out various communications ports, thereby allowing you to set up a printer, a modem, etc. At $35, PCED is a bargain. Order from the Cove Software Group (PO Box 1072, Columbia, MD 21044). R-E

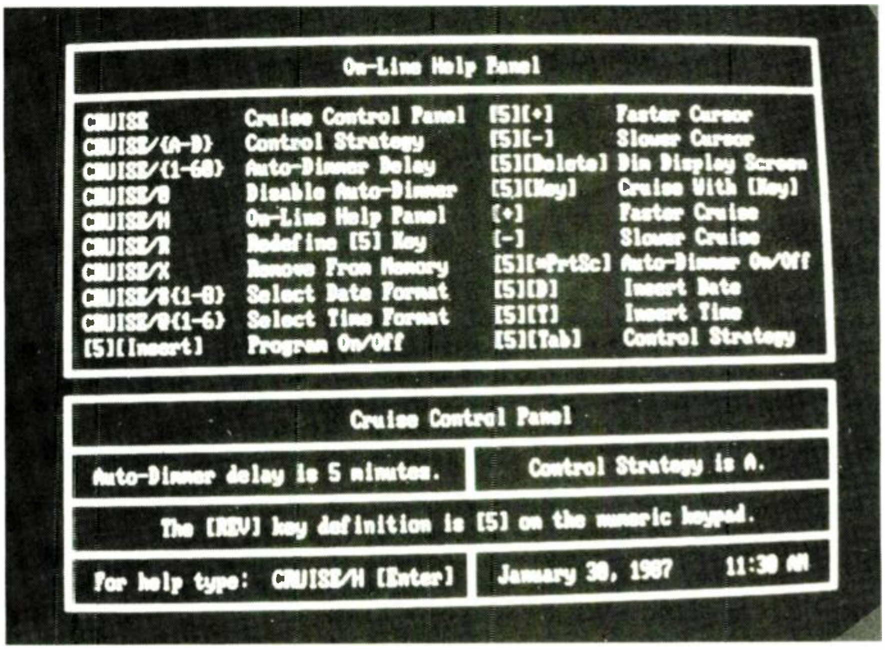
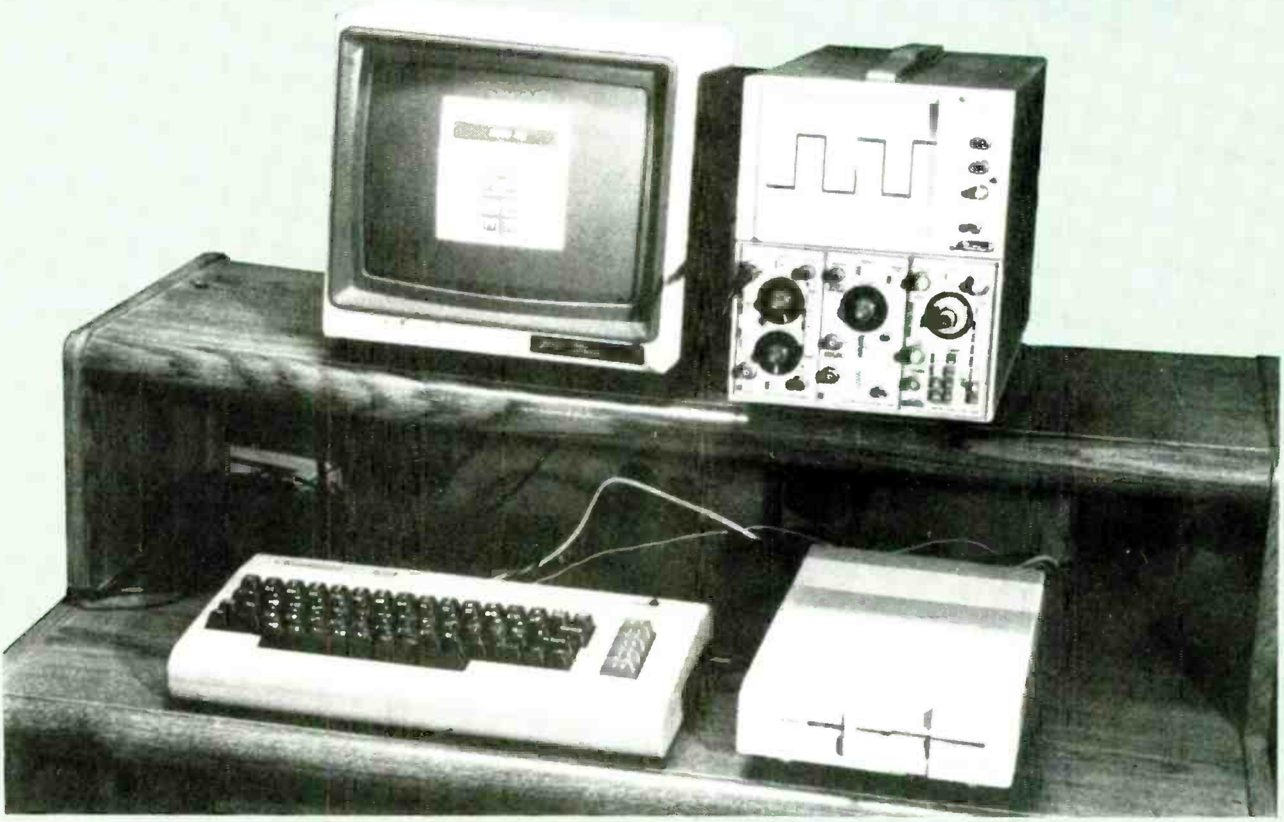


FIG. 3

COMMODORE PULSE GENERATOR



Only three components are needed to make a Commodore C64 into a pulse generator.

JIM BARBARELLO

If your test gear doesn't include a pulse generator it's probably because you just never got around to buying one. Of course, in a pinch you can always use a 555 timer and a few inexpensive components to assemble a quick-and-dirty squarewave or pulse generator. But for about the same cost you can build a simple device that will put your Commodore *64* to work as a stable, accurate source of squarewaves and pulses, and also provide a debounced one-shot trigger source to boot. Actually, the pulse generator consists of the hardware accessory and an accompanying BASIC program.

The software simulates a physical pulse generator. Its screen display combines a digital frequency indicator with a menu for eight functions that are available through the Commodore *C-64's* normal function keys. No calibration procedure is necessary because the pulse generator uses the computer's 1-MHz crystal-controlled clock for a time base. What you see on the screen is what you get.

Capabilities and limitations

The pulse generator can generate continuous squarewaves in the range of 15 Hz–500,000 Hz, or 1-microsecond width pulses with a repetition rate of 30 pps (*pulses per second*) to 1-million pps. A *one-shot* function produces a single 1-millisecond pulse on demand. All outputs vary between zero and about 4.3 volts.

The output frequency and waveform is determined entirely by the software. For those of you who might want to experiment with the circuit, we'll take time out to describe how the hardware device uses the Complex Interface Adapter (CIA) IC that drives the computer's user port. With that information and some BASIC programming skill, you can add features such as frequency sweeping, auto sequencing of discrete frequencies, and repetitive trigger pulses having a programmable interval.

The characteristics of the CIA IC require the output frequency to be equal to 500,000/N, where N is a whole number between 1 and 65535. For that reason, the pulse generator's output frequency isn't continuously adjustable. When you key in a desired frequency the software selects the closest value it can generate. As the frequency increases, the difference between the current and the next frequency value increases. For example, at 100 Hz the next value is 100.02 Hz; at 1000 Hz the next value is 1002 Hz, at 10,000 Hz the next value is 10,204 Hz. Considering that the pulse generator has crystal-controlled accuracy, good resolution in the audio range, and a construction cost of well under $10.00, its performance will adequate for many applications.

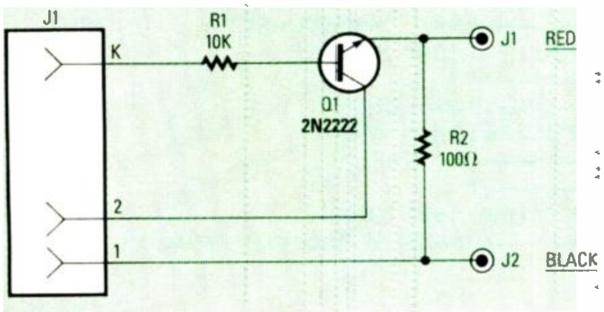


Fig.1—THE USER PORT INTERFACE uses only three components and a connector.

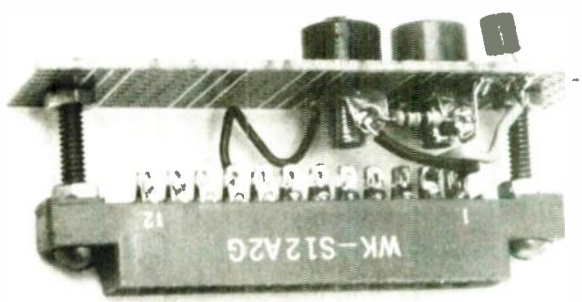


FIG. 2—ALTHOUGH THE LAYOUT ISN'T CRITICAL, try to approximate this layout to insure the interface will fit on the user port.

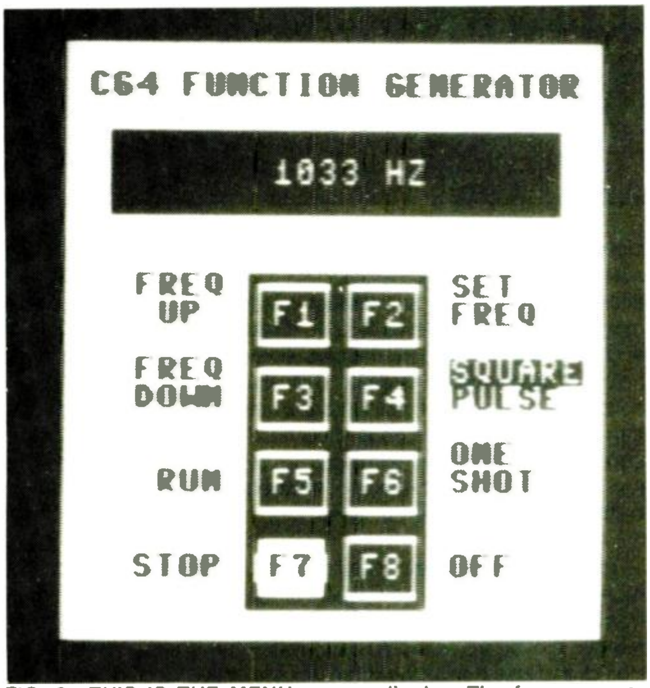


FIG. 3—THIS IS THE MENU screen display. The frequency or pulses-per-second of the output is shown in the rectangle near the top.

The CIA adapter

The Commodore *C-64*'s user port is connected directly to a 6526 CIA, which has two interval timers. The pulse generator uses the one called *Timer A*, which operates just like a standard countdown timer. Before starting, a number representing the count is loaded into the timer. When started, the count begins decreasing by one for each clock cycle. When the count reaches zero, the timer can either stop or reset and begin counting again. Memory locations 56580 and 56581 hold the low and high byte values (respectively) for the count. For example, a count of 1000 would have a high byte value of 3 (the integer part of the product of the count value divided by 256) and a low byte value of 232 (1000 less the high byte value times 256). With a clock rate of 1 MHz, the count can produce either 1000 alternating transitions per second (a squarewave with a frequency of 500 Hz) or 2000 pulses per second.

The value loaded into memory address 56590 controls most aspects of the timer A value of 2 sets the CIA for pulse output, a value of 3 begins pulse generation, a value of 6 sets the CIA for a squarewave output, a value of 7 begins squarewave generation, a value of 15 produces a single pulse whose width is determined by the value stored in memory locations 56580 and 56581.

Once the timer is in operation, it continues independent of the computer until one of the values in memory locations 56580, 56581, or 56590 are changed. Therefore, all control can be performed directly from the BASIC program by monitoring the contents of those locations.

The hardware interface:

The simple circuit shown in Fig. 1 interfaces the signal from the Commodore's user port to the outside world. Transistor Q1, which functions as a current amplifier, buffers the output from user-port connector J1's pin K (Port B6 of the CIA), an arrangement that allows the signal to drive circuits having current demands that would otherwise distort a direct output from the user port. All output signals appear at banana-type jacks J2 (signal) and J3 (ground).

Operating power is provided by the computer itself from the user port's pins 2 (+5 volts) and 1 (ground). The 100-mA maximum rating of the user port allows the circuit to easily drive a 50-ohm load.

Assembly

The circuit is so simple that a printed circuit board assembly isn't necessary. Instead, use a 1" × 3" piece of perforated construction

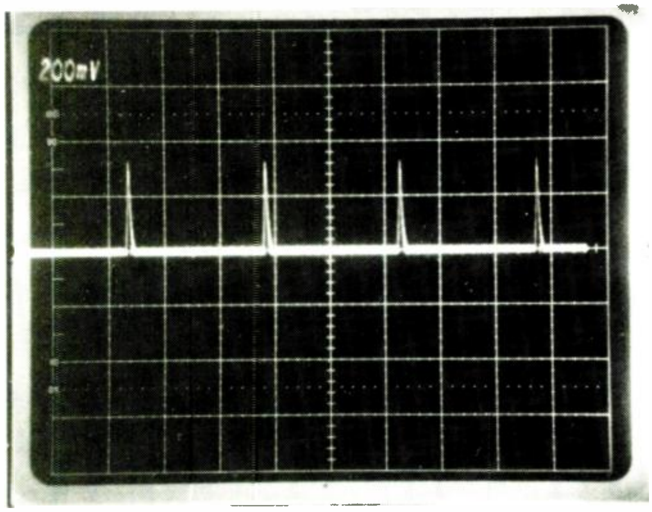


FIG. 4—THE WIDTH OF THE PULSE OUTPUT is so narrow that the signal is changed to a spike by conventional coaxial cable. Use low-capacitance cables and test leads.

```
10 GOSUB 3000:PRINT:F=500:SP=2:P$(1)=" PPS   ":P$(2)=" HZ    "
20 GOSUB 5000
30 COL=10:RO=9:GOSUB5050:PRINTB$" FREQ "W$"┌──┐┌──┐"B$" SET"
35 RO=10:GOSUB 5050:PRINTB$"  UP   "W$"|F1||F2|"B$" FREQ"
40 RO=11:GOSUB5050:PRINTB$"        "W$"└──┘└──┘"
50 RO=12:GOSUB5050:PRINTB$" FREQ "W$"┌──┐┌──┐"B$" "W$"SQUARE"
55 RO=13:GOSUB 5050:PRINTB$" DOWN "W$"|F3||F4|"B$" PULSE"
60 RO=14:GOSUB5050:PRINTB$"        "W$"└──┘└──┘"
70 RO=15:GOSUB5050:PRINTB$"        "W$"┌──┐┌──┐"B$" ONE"
75 RO=16:GOSUB 5050:PRINTB$"  RUN "W$"|F5||F6|"B$" SHOT"
80 RO=17:GOSUB5050:PRINTB$"        "W$"└──┘└──┘"
85 RO=18:GOSUB5050:PRINTB$"        "W$"┌──┐┌──┐"
90 RO=19:GOSUB 5050:PRINTB$" STOP "W$"|F7||F8|"B$" OFF"
95 RO=20:GOSUB5050:PRINTB$"        "W$"└──┘└──┘":GOSUB 500:GOSUB 4000
97 POKE 56590,6
100 CO=12:RO=5:GOSUB 5050:PRINT SP$
110 GET A$:IF A$="" THEN 110
120 G=ASC(A$):IF G<133 OR G>140 THEN 110
130 ON G-132 GOSUB 200,300,400,500,600,700,800,1000
140 GOTO 100
200 CO=17:RO=10:GOSUB 5050:PRINTB$"F1"
210 F=F-1
220 IF F<1 THEN F=1
230 GOSUB 4000:IF PEEK(197)=4 THEN 210
240 CO=17:RO=10:GOSUB 5050:PRINTW$"F1":RETURN
300 CO=17:RO=13:GOSUB 5050:PRINTB$"F2"
310 F=F+1
320 IF F>33334 THEN F=33334
330 GOSUB 4000:IF PEEK(197)=5 THEN 310
340 CO=17:RO=13:GOSUB 5050:PRINTW$"F2":RETURN
400 REM F5
410 CO=16:RO=15:GOSUB 5050:PRINT"▄▄▄▄":RO=16:GOSUB 5050:PRINTB$"▌F5▐"
420 RO=17:GOSUB5050:PRINT"▀"B$"▄▄"W$"▀"
430 RO=18:GOSUB 5050:PRINTW$"┌──┐":RO=19:GOSUB5050:PRINT"|F7|"
440 RO=20:GOSUB5050:PRINT"└──┘"
450 PT=PEEK(56590):POKE 56590,PT OR 1:RETURN
500 REM F7
510 CO=16:RO=18:GOSUB 5050:PRINT"▄▄▄▄":RO=19:GOSUB 5050:PRINTB$"▌F7▐"
520 RO=20:GOSUB5050:PRINT"▀"B$"▄▄"W$"▀"
530 RO=15:GOSUB 5050:PRINTW$"┌──┐":RO=16:GOSUB5050:PRINT"|F5|"
540 RO=17:GOSUB5050:PRINT"└──┘"
550 PT=PEEK(56590):CO=21:RO=16:GOSUB 5050
560 POKE 56590,PT AND 14:GOSUB 820:RETURN
600 REM F2
```

PARTS LIST

J1—12/24-pin card edge connector (mating connector for the C64's user port)
J2—Red banana jack
J3—Black banana jack
Q1—2N2222, NPN transistor
R1—10,000 ohms, ¼-watt, 10%
R2—100 ohms, ¼-watt, 10%
Miscellaneous: Perforated construction board, wires, solder, hardware.
NOTE: The 12/24-pin connector (J1) is available for $3.25 each, and the complete program with additional programming information is available on a Commodore-mode disk for $5.00 from B&BTC, RD#1, Box 241H, Tennent Road, Manalapan, NJ 07726. Add $2.00 postage and handling with each order. New Jersey residents must include appropriate sales tax.

board. Any kind of perforated board will do, but the kind having holes spaced at 0.1" intervals and foil pads on one side will make attaching the transistor and resistor easier. In addition to the board material, you will need two 6-32 × 1" round-head machine screws and six 6-32 nuts. Mount the two screws through the mounting holes located on either side of J1. If you're using a standard connector the screws will thread into the holes, making for firm fit. The threaded ends of the screws should be on the same side of the connector as the solder terminals. Secure each screw to J1 with a nut. Drill a hole on both ends of the board about ⅜" up from the bottom edge. Place one nut on each of the screws about 1/4" from the end of the screw.

Temporarily mount the board on the screws and then place one more nut on each of the screws, securing the board about ⅜" away from the ends of J1's terminals. When you are satisfied with the fit, remove the board, cut it to size, install the components on the board, and attach short wires for the connections to J1 pins 1, 2, and K. Reassemble the board to J1 and solder the three wires to the appropriate terminals. The finished unit should resemble the pro-

```
610 CO=20:RO=9:GOSUB 5050:PRINT"▄▄▄":RO=10:GOSUB 5050:PRINTB$"▌F2▐"
620 RO=11:GOSUB5050:PRINT"▀"B$"▀▀"W$"▀"
630 CO=0:RO=4:GOSUB 5050:PRINTBB$:PRINTBB$:PRINTBB$
635 CO=0:RO=23:GOSUB 5050:PRINT BL$:GOSUB 5050
640 CO=0:RO=23:GOSUB 5050:PRINT BL$:GOSUB 5050
650 INPUT"ENTER NEW FREQUENCY";F9$:F9=VAL(F9$):IF F9<15 OR F9>.5E6 THEN 640
660 GOSUB 5050:PRINT BL$:F=INT(.5E6/F9):GOSUB 4000
670 CO=20:RO=9:GOSUB 5050:PRINTW$"┌──┐":RO=10:GOSUB5050:PRINT"│F2│"
680 RO=11:GOSUB5050:PRINT"└──┘"
690 RETURN
700 REM F4
710 CO=21:RO=13:GOSUB 5050:PRINTB$"F4":CO=25:RO=12:GOSUB 5050
720 IF SP=1 THEN PRINTW$"SQUARE":RO=13:GOSUB5050:PRINTB$"PULSE":SP=2:GOTO 740
730 PRINTB$"SQUARE":RO=13:GOSUB 5050:PRINTW$"PULSE":SP=1
740 CO=21:RO=13:GOSUB 5050:PRINTW$"F4"
750 PT=PEEK(56590):IF SP=2 THEN POKE 56590,PT OR 4
760 IF SP=1 THEN POKE 56590,PT AND 11
770 GOSUB 4000:RETURN
800 REM F6
810 CO=21:RO=16:GOSUB 5050:PRINTB$"F6":GOSUB 5050
815 POKE 56580,232:POKE 56581,3:PT=PEEK(56590)
820 PT=PEEK(56590):POKE 56590,15
830 POKE 56590,PT:PRINT W$"F6":GOSUB 4000:RETURN
1000 REM** END
1010 PRINTCHR$(147):RO=12:CO=6:GOSUB5050:POKE 56590,0:POKE 56579,0
1020 PRINTCHR$(18);" GENERATOR OFF ";CHR$(146);" - PROGRAM ENDED."
1030 PRINT:PRINT:PRINT:END
3000 REM** FORMAT SCREEN=
3010 POKE 53280,6:POKE 53281,6:PRINTCHR$(147)
3020 B$=CHR$(05)+CHR$(18):BL$="          "+B$+"                              ":PRINTBL$
3030 PRINTTAB(8);CHR$(05);CHR$(18);" C64 FUNCTION GENERATOR "
3040 PRINTBL$:BB$="        "+B$+"  "+CHR$(146)+"                    "+B$+"  "
3050 PRINTBB$:PRINTBB$:PRINTBB$:W$=CHR$(146)
3060 FORI=1TO14:PRINTBL$:NEXT I:PRINT BL$
3070 BL$="                                        ":RETURN
4000 REM ** FORMAT/PRINT OUTPUT
4010 P$=LEFT$(STR$(1E6/(F*SP)),8):P=INT(VAL(P$))
4015 IF P=1E6 THEN P$="1000000":GOTO 4050
4020 IF P<1000 OR P>99999 THEN P$=LEFT$(P$+"     ",7):GOTO 4050
4030 IF P<10000 THEN P$=LEFT$(P$+"     ",5):GOTO 4050
4040 P$=LEFT$(P$+"     ",6)
4050 P$=P$+P$(SP)
4060 CO=16:RO=5:GOSUB 5050
4070 H=INT(F/256):L=F-H*256:POKE 56580,L:POKE 56581,H
4080 PRINT P$:RETURN
5000 REM* CURSOR CONTROL USING PLOT                    KERNEL ($FFF0)
5010 DATA 162,0,160,0,24,32,240,255,96,999
5020 A=49300:SC=A
5030 READ B:IF B<>999 THEN POKE A,B:A=A+1:GOTO 5030
5040 RETURN
5050 POKE SC+3,COL:POKE SC+1,ROW:SYS SC
5060 RETURN
```

totype shown in Fig. 2. Be sure to tighten all six screws firmly since you don't want the assembly to flex when you're installing it on the user port. Most 24-pin connectors make a very tight fit to the user port, so make sure all mounting nuts are tight. Finally, install the adapter to the user port.

The software:

The program listing is shown in Listing 1. It is a relatively long program, and if you feel that you're not up to keying in so large a program without making errors you can obtain the program on disk from the source given in the Parts List.

When you run the program, you'll get the screen display shown in Fig. 3. Note that the frequency, which always initializes at 1033 Hz, is displayed in the small dark rectangle at the top of the display. Below the frequency display area are representations of the computer's F1 through F8 function keys, with each key's function clearly labeled. On startup, F7 will be highlighted, indicating that the generator isn't running.

Pressing the F1 key once will increase the ouput frequency one interval. Holding the F1 key down will cause the frequency to continually increase. Similarly, the F3 key causes the frequency to decrease. When the frequency reaches its upper or lower limit, the display will freeze and you will have to reverse the direction of the frequency selection.

Press the F2 key to get to a desired frequency quickly. The F2 screen display will highlight, the frequency display area will clear, and the prompt Enter New Frequency? will appear. Typing any number between 15 and 500000 resets the frequency to the closest allowable value. Decimal numbers such as 100.56 are allowed, but commas are not (i.e., 500000, not 500,000). If a value outside the working range is entered, it will be ignored and the prompt will be repeated. The display area will then show the selected frequency in Hz or the corresponding pulse rate in pps—and remember, the pulse rate is twice the selected frequency in Hz.

The right function

On startup, the frequency is set to 1033 Hz and the SQUARE function of F4 is automatically initialized. Pressing F4 toggles the output between squarewave (Hz) and pulse (pps). Again, note that the pulse rate is twice the frequency.

Pressing F6 for ONE SHOT generates a single, 1-millisecond pulse. F6 must be released and then pressed again to generate a second pulse. Pressing F8 clears the screen, causes the screen to display the message GENERATOR OFF—PROGRAM ENDED, turns off Timer A, and removes any signal present from the base of Q1 (thus turning it off).

Scope displays

The level and waveform from the pulse generator can be affected by capacitive loading. The most common source of capacitive loading is using a long shielded cable to feed the output to another circuit, or to other test equipment. Normally, high test lead or cable capacitance affects only the higher frequencies. If excessive lead capacitance does exist, the resulting waveform will resemble a triangular wave rather than a squarewave, and the signal level will decrease by as much as 25%. For example, a 6400-Hz squarewave fed through a conventional coaxial-cable test lead had sharp rising and falling edges. However, the signal shown in Fig. 4 also started out as a perfect squarewave, but because its frequency is 500 kHz, the test lead's internal capacitance turned the squarewave into a pulse-shaped wave. To avoid capacitive loading, keep cables short, preferably under two feet, and use a low-capacitance oscilloscope test probe.

The capacitive-loading effect will be even more pronounced on short duration pulses. As shown in Fig. 4, a conventional shielded cable turns an essentially rectangular pulse of 20,000 pps into a thin spike.

Finally, keep in mind that the effective load resistance seen by the adapter should not go below 50 ohms. If you are driving a circuit with an input impedance less than 100 ohms, temporarily disconnect resistor R2 so that it does not parallel the input impedance of the circuit being tested, which would result in a total load of less than 50 ohms. Add an SPST switch if you work with low-impedance circuits often.

DESIGNER'S NOTEBOOK

Over-voltage indicator

I GET A GREAT DEAL OF MAIL ASKING for circuits that can add to the well being of batteries. People want to know how to keep them charged, how to prevent memory effects in Ni-Cd's, how to watch out for dying cells, and so on. I thought I had covered just about every possibility until I got a letter asking for a circuit that could be used to indicate an overvoltage condition.

There are many circuits that could do the job, but this is one occasion when simpler is better. You can get LM3914's and LM3915's (bar/dot display drivers) at low prices these days, but if you use one of them, you're still faced with the problem of setting it up for a specific voltage. Not only that, but an LM3914 (or a '15) may be a classic case of overkill.

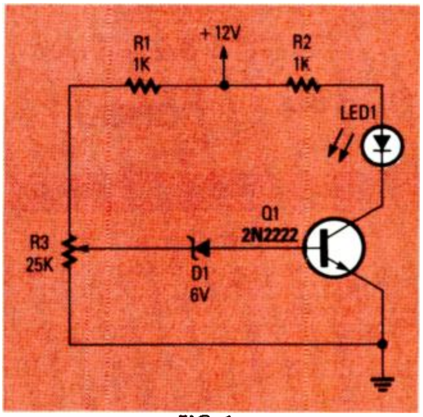


FIG. 1

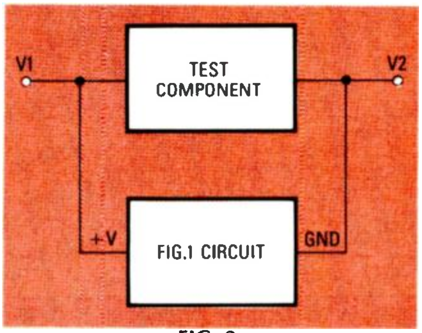


FIG. 2

The minimalist approach

If all you need is a circuit that will light an LED, sound an alarm, etc., when a particular voltage level is reached, the easiest way to get the job done is with the circuit shown in Fig. 1. It has the whole range of good things—it's simple, it's straightforward, it costs next to nothing to put together, and it's totally bulletproof.

It works like this. When the voltage across potentiometer R3 reaches a particular level, Zener diode D1 will start conducting and turn on the transistor. That, in turn, will light the LED. Resistor R2 limits the current through the LED and R1 does the same for the Zener diode. The accuracy of the circuit is mostly a function of how finely you can tune R3. You can use just about any control you want, but a small multi-turn PC-mount device will provide the greatest precision.

By using a variable-voltage power supply, you should be able to set the circuit to trigger within less than a tenth of a volt of the target voltage. The Zener you use isn't critical. For most applications, a ¼-watt unit will do. The transistor can be any small-signal NPN type. The circuit is so small that it can be installed easily in the case of just about anything. If you want to keep an eye on more than one voltage, you can build several circuits on the same board.

Although the output device is

shown as an LED, you can couple just about anything to it by using the transistor to drive a relay.

The values shown in the schematic are set to work with power supplies as high as 12 volts. Exceeding that value will require some component changes, but basic circuit operation remains the same. A ¼-watt Zener will probably suffice, but its breakdown voltage should be about half the maximum voltage you expect to apply to the circuit. And R1 should be chosen using Ohm's Law, to make sure that Zener current is kept within the diode's limits.

The same restrictions apply to the transistor. Make sure that its rated collector-emitter voltage exceeds any voltage you expect to apply to the circuit.

Advanced uses

One consequence of keeping the circuit so simple is that it's very fast, so you can use it for other things. For example, you can have the transistor switch in some sort of circuitry to drop the voltage in your circuit to a safe level. And a bit of thought should let you add to the circuit and make an electronic fuse.

That's possible because the overvoltage indicator draws very little current. Ordinarily you would connect it across the battery or power supply. But, because it uses so little power, you can use it to monitor the voltage just about anywhere in a circuit.

Figure 2 illustrates the basic idea. Even though the monitor is designed to sense excess voltage, it can sense excess current flow by monitoring the voltage across a component. Make sure that V1 exceeds V2 by at least six volts; otherwise you may have to use a different Zener. **R-E**

COMMUNICATIONS CORNER

continued from page 33

MUX sends the digital signals down the fiber-optic path to the receiving MUX, which routes each data block to its specific restorer. The receiving MUX knows which data block goes where because of the header.

Because it's the header that determines the routing, the data or bit groups need not be sent in any particular order. As shown in Fig. 1, the transmit MUX might organize the signal blocks in their most efficient progression. In the example shown, although inputs 1, 3, 7 and 8 are being MUXed, the data group order at a particular time period is 1, 7, 3, 6.

A restorer in the receive MUX puts together however much data it's designed to handle and passes it through to the proper outgoing line in digital form. That's an important point to keep in mind: The receiving MUX simply recreates the original digital signals that were input to the sending MUX; but after the receiving MUX, the devices must know what to do with the data.

Assume for the moment that the sending MUX is at the telephone company's switching center and the receiving MUX is in your home. At any given moment the following could be taking place: The signal on Line 1 might be the communications circuit between your personal computer and the bank's mainframe (you're untangling your credit-card bill). Line 3 is a digitized-TV download of pay-per-view sports (junior is watching the hockey game he used to see for free before all forms of entertainment were sold out to pay-per-view). Line 6 is a pay-per-copy download from the local record store to your daughter's digital tape recorder. Line 7 is Mom talking to her Mom via a long-distance provider, and both are using digitizing telephones; that is, their output is a digital representation of the voice so that the signals can be sent directly through, and to, digital telephone equipment and personal computers.

Now that is a lot taking place at the same time on the same circuit, and all at very high speed; yet, it's made possible because fiber optics are inherently a high-speed, wide-bandwidth medium. I, for one, cannot conceive of the same facility using wires, and I'm only talking about 200 megabits/sec. What's more, since 1 gigabit/sec is easily accomplished today, imagine the speeds that will be available next year.

Noise free

In addition to the advantage of speed, fiber optics provides its signals with a noise-free environment, something almost impossible to attain with long metallic lines even when they are shielded. More than that, a fiber-optic cable passing through an area of high electrical disturbance, such as lightning, will not pick up electrical noises; nor will a fiber-optic line radiate interference—a common occurrence when passing digital signals through wires. Not only do fiber optics prevent interference to nearby receiving equipment, because there is no radiation of any kind the filament is secure; external equipment cannot "read" the data in a fiber-optic filament. Short of actually cutting into the filament, there is no known means for unauthorized interception of the signals flowing in a fiber-optic line.

Different wires

One of the surprising things about consumer fiber-optic circuits is that they are not much more difficult to install than conventional metallic wiring. Home-and-office fiber-optic cables look very similar to conventional wire cables, and they can even be stapled to mouldings, door jambs, etc. A four- or six-filament fiber-optic cable terminated on both ends by a connector looks very similar to a four- or six-wire metallic cable that's terminated with standard modular plugs. Even the fiber-optics LED-equipped sender connector, and the diode-equipped receiver connector, is just about the size of a modular plug. So as far as home or office wiring is concerned, one kind of line is about as easy to install as the other. **R-E**

NEW IDEAS

Outdoor light controller

MOST AUTOMATIC YARD LIGHTS ARE controlled using just a simple photocell. However, since the ambient light levels at dawn and dusk change rather slowly, that approach usually results in some flickering just before the light fully locks on or off, which can significantly shorten bulb life. That can be avoided by using the controller shown in Fig. 1. That circuit *snaps* the light on or off, depending on whether ambient light levels are rising or falling.

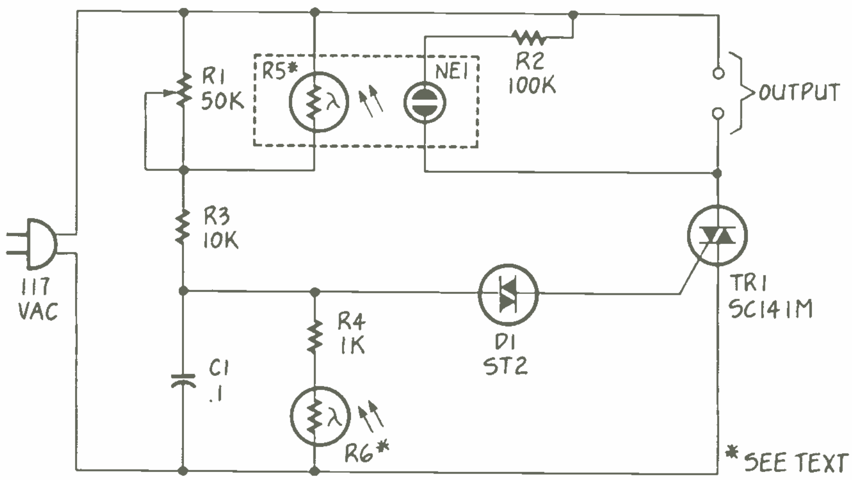


FIG. 1

How it works

The key to the circuit's operation is an optocoupler made up of a neon bulb (NE2 type) and a CdS photocell whose resistance varies inversely with light from 10K to 100K; those components are enclosed in a light-tight housing. A Diac/Triac combination is used to provide the snap-switch effect. A second CdS photocell acts as the main sensor.

As evening approaches the resistance of R6 begins to increase. When it reaches a threshold level, which is set by adjusting R1, the Diac triggers the Triac and causes the neon bulb to light. Even a momentary flicker of the bulb is sufficient to reduce the resistance of R5, causing the Diac to trigger the Triac, which lights the neon bulb, and so on.

As morning approaches, the process is reversed. The resistance of R6 begins to decrease until it drops below the threshold level. That causes the Diac to cease triggering the Triac, which extinguishes the bulb, which causes the resistance of R5 to increase, and so on.

Most of the components can be mounted on a piece of perforated construction board and placed within a small experimenters box. Parts placement is not at all critical. All resistors, except the potentiometer and the photocells are ½-watt units. Once the threshold level for the circuit has been established, the potentiometer can be replaced by a fixed resistor of the appropriate value. Before mounting R5 and NE1, place them in a light-tight enclosure. For my unit, the two were simply wrapped together using some black electrical tape.

Mount R6 so that it can be illuminated by the ambient light. However, take care to shield it from any artificial lighting. In my installation, the unit was mounted inside the lamp post, with the sensor looking out through a conveniently placed plastic lens.

To set up the unit, simply adjust the setting of R1 at dusk until the Triac is triggered. Remember that you are working with line voltages in this circuit, so take the appropriate precautions to protect yourself and others from potentially dangerous shocks.—*E.J. Holtke*

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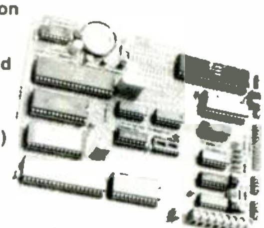

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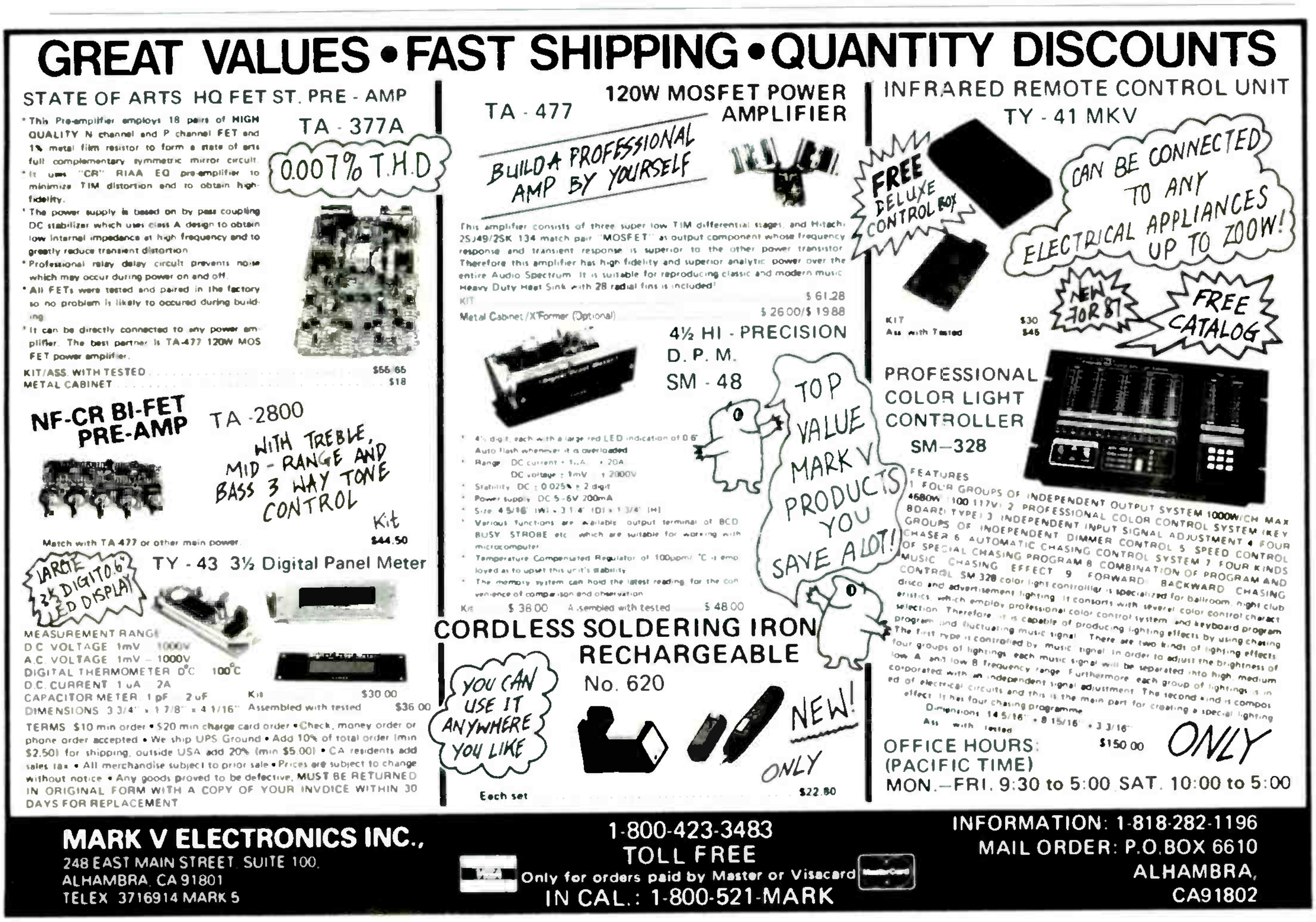

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128	.29	.26	.23	197	.38	.34	.30	376	.48	.44	.40
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74S08	.35	74S124	2.20	[illegible]	[illegible]
74S09	.40	74S133	.45	74S189	1.60
74S10	.29	74S135	.85	74S194	[illegible]
74S11	.35	74S138	.75	[illegible]	[illegible]
74S15	.35	74S139	.75	74S240	1.40
74S20	.29	74S140	.50	74S241	1.40
74S30	.29	74S151	.75	74S244	1.25
74S32	.35	74S153	.75	[illegible]	[illegible]
74S40	.29	74S157	.75	[illegible]	[illegible]
74S42	.85	74S158	.90	[illegible]	[illegible]
74S51	.35	74S161	[illegible]	[illegible]	[illegible]
74S74	.45	74S163	[illegible]	[illegible]	[illegible]

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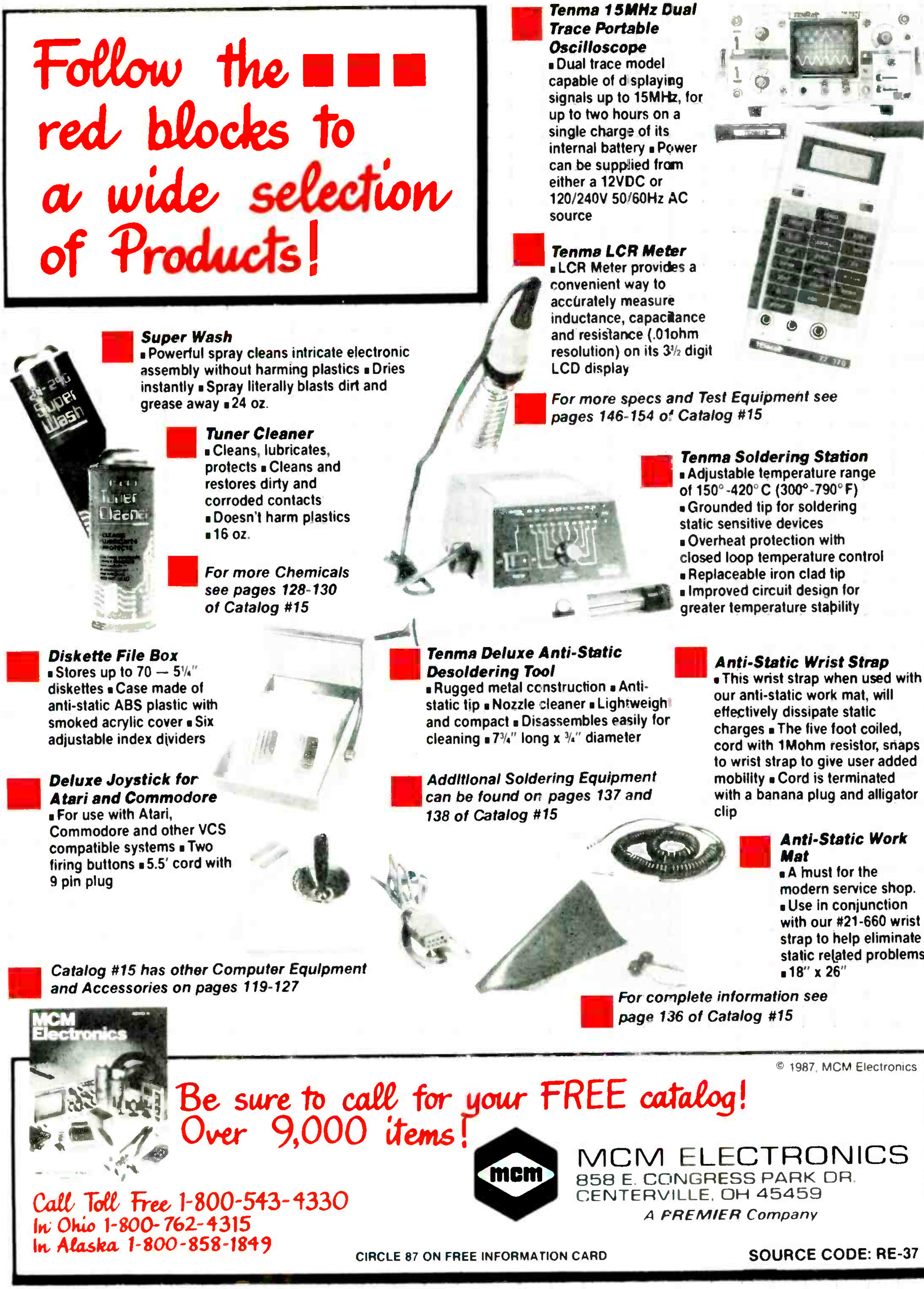
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74LS03	.18	74LS173	.49
74LS04	.16	74LS174	.39
74LS05	.18	74LS175	.39
74LS08	.18	74LS191	.49
74LS09	.18	74LS192	.69
74LS10	.16	74LS193	.69
74LS11	.22	74LS194	.69
74LS12	.22	74LS195	.69
74LS13	.26	74LS196	.59
74LS14	.39	74LS197	.59
74LS15	.26	74LS221	.59
74LS20	.17	74LS240	.69
74LS21	.22	74LS241	.69
74LS22	.22	74LS242	.69
74LS27	.23	74LS243	.69
74LS28	.26	74LS244	.69
74LS30	.17	74LS245	.79
74LS32	.18	74LS251	.49
74LS33	.28	74LS253	.49
74LS37	.26	74LS256	1.79
74LS38	.26	74LS257	.39
74LS42	.39	74LS258	.49
74LS47	.75	74LS259	1.29
74LS48	.85	74LS260	.49
74LS51	.17	74LS266	.39
74LS73	.29	74LS273	.79
74LS74	.24	74LS279	.39
74LS75	.29	74LS280	1.98
74LS76	.29	74LS283	.59
74LS83	.49	74LS290	.89
74LS85	.49	74LS293	.89
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74LS107	.34	74LS367	.39
74LS109	.36	74LS368	.39
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74LS123	.49	74LS375	.95
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74LS125	.39	74LS378	1.18
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74LS132	.39	74LS393	.79
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74LS158	.29	81LS97	1.49
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74F00	.69	74F74	.79	74F251	1.69
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74F04	.79	74F138	1.69	74F257	1.69
74F08	.69	74F139	1.69	74F280	1.79
74F10	.69	74F157	1.69	74F283	3.95
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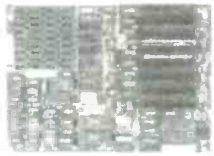

- 4.77 OR 8 MHz OPERATION WITH 8088-2 & OPTIONAL 8087-2 CO-PROCESSOR
- DYNAMICALLY ADJUSTS SPEED DURING DISKETTE OPERATION FOR MAXIMUM THROUGHPUT AND RELIABILITY
- CHOICE OF NORMAL / TURBO MODE OR SOFTWARE SELECT PROCESSOR SPEED

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JDR PART #: MCT-XTMB

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- RESET SWITCH, FRONT PANEL LED INDICATOR AND KEYLOCK SUPPORTED
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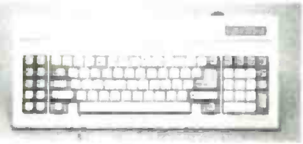

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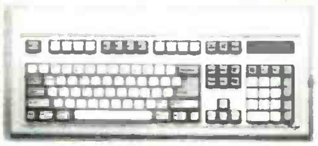
- EXTRA LARGE SHIFT & RETURN KEYS
- LED INDICATORS FOR SCROLL, CAPS & NUMBER LOCK
- AUTO REPEAT FEATURE



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- EXTRA LARGE SHIFT & RETURN KEYS
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- AUTO REPEAT FEATURE
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100% IBM COMPATIBLE, PASSES IBM EGA DIAGNOSTICS

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- LIGHT PEN INTERFACE

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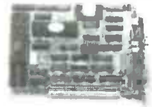

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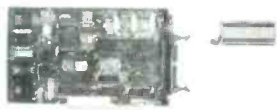

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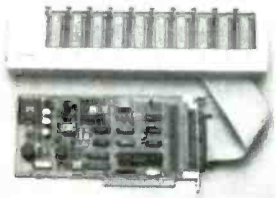

- SUPPORTS VARIOUS MANUFACTURERS FORMATS WITH 12.5, 21 AND 25 VOLT PROGRAMMIMG
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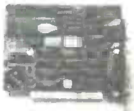
- CLOCK/CALENDAR WITH A BATTERY BACK-UP

SHORT SLOT



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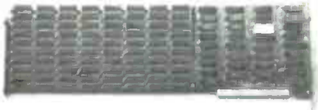
- USE AS EXPANDED OR CONVENTIONAL MEMORY, RAMDISK OR SPOOLER
- SOFTWARE INCLUDES EMS DEVICE DRIVERS, PRINT SPOOLER AND RAMDISK



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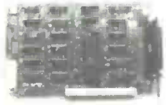

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- IBM XT COMPATIBLE CONTROLLER SUPPORTS 16 DRIVE SIZES INCLUDING 5, 10, 20, 30 & 40MB
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- INCLUDES CABLING FOR 1 INTERNAL DRIVE

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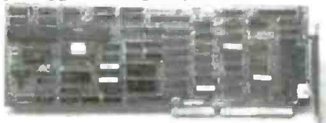

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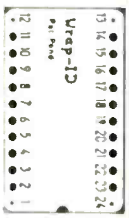

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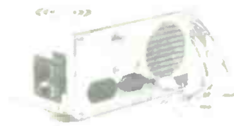

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- 150 WATTS
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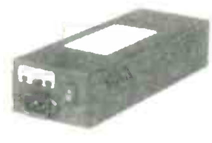

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22	50V	.05	.001µf	50V	.05
27	50V	.05	.0022	50V	.05
33	50V	.05	.005	50V	.05
47	50V	.05	.01	50V	.07
68	50V	.05	.02	50V	.07
100	50V	.05	.05	50V	.07
220	50V	.05	.1	12V	.10
560	50V	.05	.1	50V	.12

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.01µf	50V	.14	.1µf	50V	.18
.047µf	50V	.15	.47µf	50V	.25

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RADIAL			AXIAL		
1µf	25V	.14	1µf	50V	.14
2.2	35V	.15	10	50V	.16
4.7	50V	.15	22	16V	.14
10	50V	.15	47	50V	.20
47	35V	.18	100	35V	.25
100	16V	.18	220	25V	.30
220	35V	.20	470	50V	.50
470	25V	.30	1000	16V	.60
2200	16V	.70	2200	16V	.70
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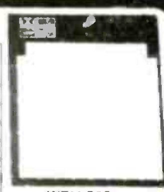
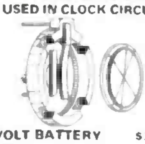


WBU-208

LITHIUM BATTERY

AS USED IN CLOCK CIRCUITS



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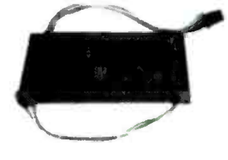

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Mfr — General Instrument

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Mfr — Motorola — Alpha Series

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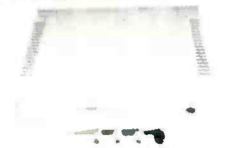

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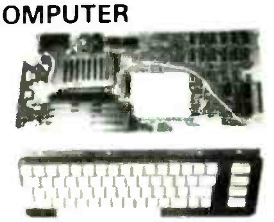

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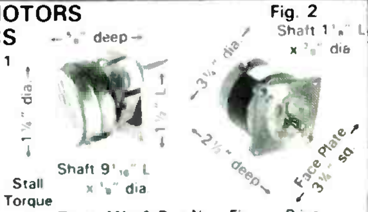

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				2.0	MO61-FF-6201B	2	$37.50
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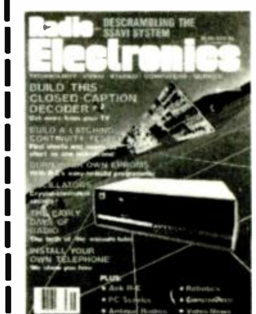

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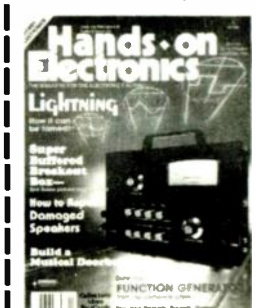

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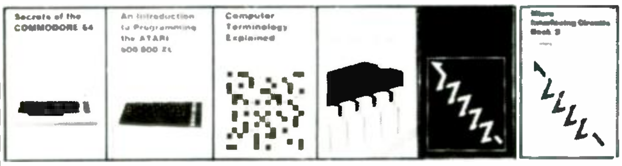

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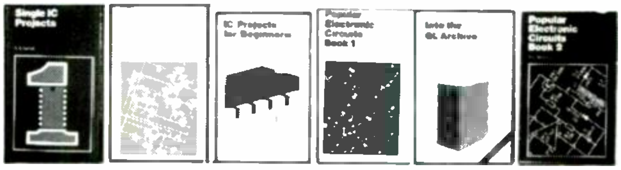

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