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A Bicycle Safety Flasher (p. 43)

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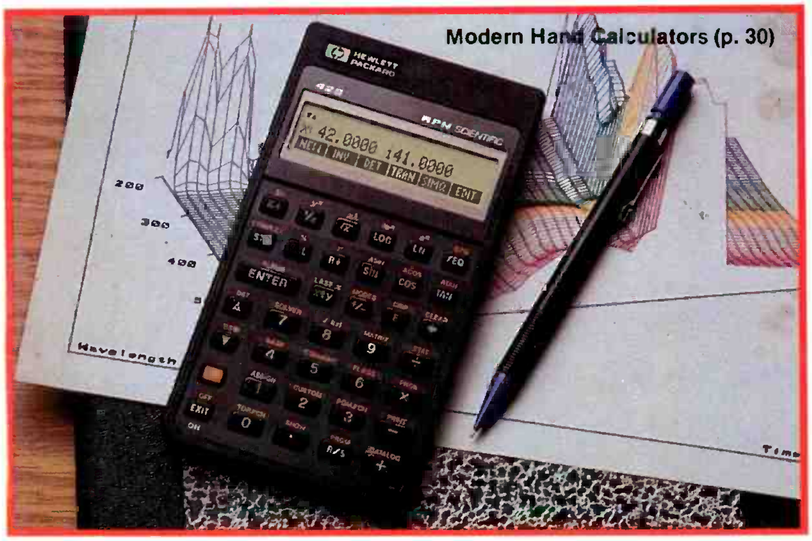

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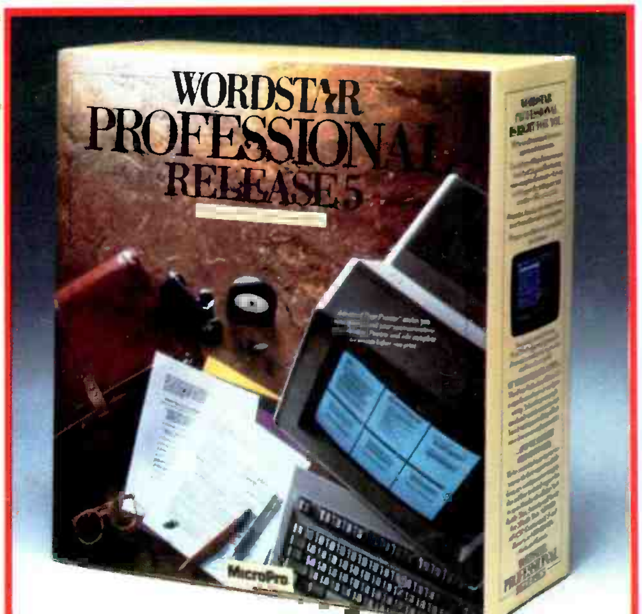

WordStar Professional Release 5 (p. 75)

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Plus: A Programmable Controller For Light Displays (Conclusion) ● Forrest Mims on CMOS Micropower Op Amps & Comparators ● Evaluating WordStar Professional Release 5 ● The Status of Advanced TV in the U.S. ● The Great PC Bus War ● Electronics & Computer News ● Latest Books & Literature . . . more.

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DECEMBER 1988

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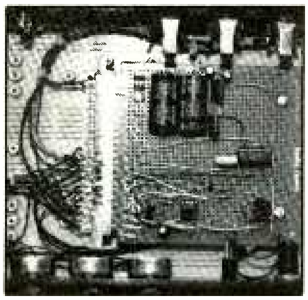

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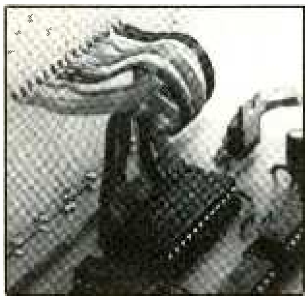

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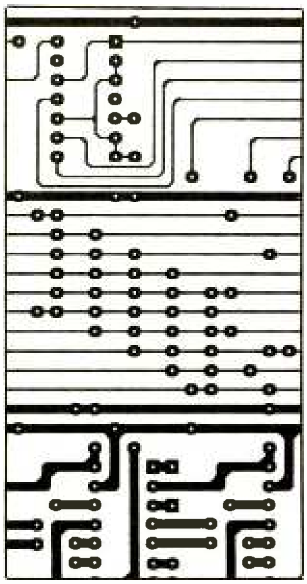

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COLUMNS

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EDITORIAL

A Star for '89

At year's end, one wonders what next year's electronics or computer stars will be. Prognostications in these volatile fields have a way of missing their marks, of course, since a lot of factors have to come together to propel products into the forefront. The present points to the future, however, so there are some starting points.

In the video field, super-VHS videocassette machines, with matching tape and TV sets with I/O's to take advantage of them, are here now. Doubtlessly, 1989 will see increased sales, but the advanced system will likely have limited sales due to high selling prices. Combination video cameras and recorders (camcorders) will continue to make sales inroads, but this costly electronic equipment will not likely enjoy an unusual sales peak.

With existing video products not likely to generate a sales boom next year, what about new product types? Well, there aren't many that can be expected. Enhanced- and high-definition TV are still churning around, so '89 won't be the year when the service and product will take off. I wouldn't expect the new video Walkman to climb quickly toward the sales peak, either. So a video star isn't on the horizon in the coming year, as I see it.

The same holds for audio, unless digital audio tape (DAT) players are shaken loose from the inter-industry battles holding up their production and marketing.

Let's turn, then, to communications. Here, CB Radio has shown some signs of life, but it's been in the slow lane and very unlikely to return to its former heights. In ham radio, although getting a license has been made simpler, there's still a Morse Code requirement. So this area, too, will not ascend to stardom heights. The cellular telephone will continue its growth, but will also have limited sales penetration among our general population. Video phones will remain as up-scale products. Facsimile machines will continue a fast rise, but, again, will not become a product for the masses in '89. Nonetheless, it is indeed possible for enough businesses to conclude that they must have a fax machine, boosting it to star status.

That leaves computers. The coming year could be another fine one for it, but it won't register new-star status either. The OS/2 operating system won't make it into this category in '89; RISC boards are too costly; the brewing battle of the buses won't be settled in time to make one or the other a clear choice. Nor are there any signs that a startling new software program type, equivalent to, say, a Sidekick or Lotus 1-2-3, will take hold.

We've also got CD ROMS, color printers, and so on, that will probably grow in sales, but still not be a 1989 star.

If there's a star about to be born, then, it'll have to make it by having a bevy of factors magically combine. In a way, it'll be a relief not to have a real star among electronic and computer products this coming year. Perhaps more refinements of existing products, additional product penetration among our population, lowered prices and better service/customer relations will be gained.

I'll be able to confirm all this by December 1989, naturally, as you will, too. Hindsight is always terrific. Nevertheless, the pot is boiling over with wonderful electronic and computer products you wish you owned, but don't (yet). So whatever new-technology device you buy for the first time—powerful new computer, wireless security system, CD player, camcorder, laser printer, etc.—it'll certainly be your personal star to enjoy.

BEST HOLIDAY WISHES FROM ALL OF US HERE!

Art Salsberg

LETTERS

Thinking Negative

• "Understanding Negative Logic" by Delton T. Horn in the October 1988 issue was interesting, but his closing sentence was most astute. It is *very easy* to confuse the two types of logic. As a digital designer, I find it better to stick with one approach and then solve the logic problem with Boolean algebra. For example, in the article's truth table, eight combinations of A, B, C and D yield an output of "1." Using the simple rules of Boolean algebra, these eight terms are combined and reduced to the expression AD + BC + BD, which is read A AND D OR B AND C OR B AND D. This expression can be factored further to BC + D(A + B), arriving at the logic shown in Fig. 2(B), which, incidentally, is the positive-logic diagram, not Fig. 2(A).

Bill Holsinger
National Institutes of Health
Bethesda, MD

• Almost 20 years ago, when I was calibrating Tektronix oscilloscopes, I rejoiced at the news that the company had opted for positive logic. Since then, all I've run into has been positive logic. Though I favored positive logic, I would have been satisfied with negative logic if that was all there was in the offing—anything but that abominable one-then-the-other logic. Mr. Horn's "Understanding Negative Logic" in the October 1988 *Modern Electronics* changed my thinking on the matter of negative logic.

Ed Jones
Somerset, NJ

Project Updates

• I read Jim Barbarello's "Computer-Controlled Robotic Arm" (October 1988) with great interest because I have also built an interface between my computer and the Radio Shack Mobile Armatron. (Mine uses the internal battery to power the Armatron but is otherwise very similar.) I discovered an error in Fig. 1. With the base of Q6 connected through R6 to pin 9 of P1, data bit 7 controls the voltage polarity sent to the Armatron. Relays K1 through K5 are shown controlled by data bits 0 through 4, respectively. However, the Table and BASIC program listing indicate that polarity is controlled by data bit 0 and that these re-

(continued on page 62)

JAPANESE MANUFACTURERS HERE & THERE. Matsushita Electric Corp. of America, which manufactures Panasonic TV sets in North America (about one-million units annually), announced its first shipment of Panasonic color TV receivers to its parent company's land, Japan. The initial shipment consists of 3,000 wood-cabinet color TV models. Total exports of all Matsushita-produces American products was $450-million in 1987....Another Japanese-owned company, Toshiba America, announced plans to expand its television tube manufacturing facility in Horseheads, New York, adding capacity to produce new "super-size" 30" and 32" TV picture tubes previously available only in Japan.

WALKMAN BALLOONED BATTERY SALES. The dry-cell battery market will top $3-billion retail by the end of 1988, according to a study by Packaged Facts,a NY-based research company. It started with the "Walkman" revolution that took hold 7 years ago. This had a catalytic effect on the consumer electronics industry, opening up portable equipment in audio, video, etc., says the researcher.

THE IC HITS 30. Texas Instruments' Jack Kilby demonstrated the first working integrated circuit 30 years ago, forever changing the face of electronics....The year 1988 also marks a half-century since a patent for the constant voltage transformer was issued to Joseph Sola, who founded a firm that's now called Sola (a unit of General Signal). His invention established ferroresonant voltage regulation technology.

SEARS EYES BRANDED ELECTRONICS. The giant merchandiser, Sears, is looking to expand its electronics sales by adding brand-name products to its own lines. Its being tried out in some midwest Sears stores, and is expected to spread to other stores. Guess that Sears doesn't like being #3 in <u>electronics</u> retailing dollar volume (Radio Shack is #1; Kmart, #2).

A LEARNING MICROCHIP. Bellcore researchers are reported to have created a microchip that can learn by example. The device is said to be structured like a biological neural network in a human brain. It performs its functions 100,000 times faster than computer simulations of the same functions, according to one of its developers, and captures knowledge by being "taught" rather than programmed. It's the first chip to learn to perform the exclusive-OR (XOR) function.

TANDY ANNOUNCES TECH SCHOLAR PROGRAM. Tandy Corp. announced an education initiative program ,"Tandy Technology Scholars," which will be administered by Texas Christian University. The program is designed to recognize outstanding math or science teachers and students at each participating high school in the U.S. The top 100 teachers among them will each receive $2,500; the top 100 students will each receive a $1,000 cash scholarship. Initial awards will be based on teachers' contributions in the 1988-1989 school year and students' 1988 11th-grade accomplishments.

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New Apple Entry-Level Computer

Apple Computer's new Apple IIc Plus personal computer is said to be less expensive and three times faster than the original IIc, which it replaces. It is designed primarily for

education, productivity and entertainment by first-time computer buyers. Built around a 65C02 microprocessor and 128K bytes of RAM (expandable to more than 1M byte), the IIc Plus features an 800K-byte 3.5-inch floppy disk drive; selectable 1/4-MHz operating speed; internal power supply; improved layout/touch keyboard; slide volume control; security lock option; and connector on motherboard for an optional internal modem.

The Apple IIc Plus supports a number of disk drives and printers from Apple and other vendors. It permits the user to daisy-chain as many as three external disk drives, including Apple Disk 3.5, UniDisk™ 3.5 and Apple Disk 5.25 (two maximum 5.25-inch drives). Support is also built in for Apple's ImageWriter® I and ImageWriter II laser printers. Like the original IIc, the IIc Plus has built-in color graphics with up to 16 colors and supports double high-resolution graphics. Supplied with the computer is a set of interactive tutorials on a 3.5-inch disk that enable the user to learn and use the system quickly, as well as the Applesoft BASIC programming language and a related on-disk tutorial system. $675 computer only; $895 with monochrome monitor and stand; $1,099 with color monitor and stand.

CIRCLE 52 ON FREE INFORMATION CARD

Wireless R-F Headphones

A wireless headphone system for listening to music and TV sound privately without a trailing cord has been announced by Datawave, Inc. (Tarzana, CA). Because it uses r-f transmission/reception, the Model WH-100 "Private Waves" phones are not limited to line-of-sight installations the way the usual infrared systems are. Since its signal travels through walls, users of Private Waves have the mobility to listen both indoors and out-of-doors, with an FM-quality frequency range of 18 to 15,000 Hz.

The unit's compact transmitter plugs into the headphone jack of a

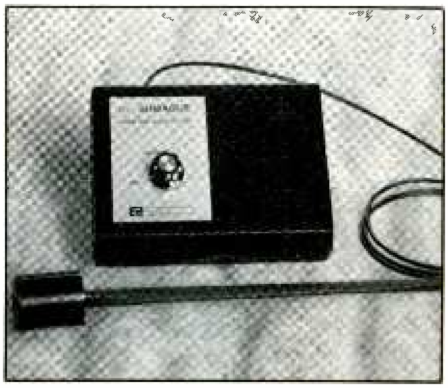
TV receiver, VCR, home stereo or compact-disc player. A miniature lightweight receiver clips onto a belt or other item of clothing, and tiny headphones (with detachable headband) plug into the receiver. Operating range of the system is rated at 75 feet.

The transmitter measures $6\frac{3}{4} \times 4\frac{5}{8} \times 2\frac{1}{8}$ inches, the receiver $4\frac{1}{8} \times 2\frac{5}{8} \times 1\frac{1}{8}$ inches. The latter weighs a mere 3.5 ounces. Included is an ac adapter that plugs into an ac outlet to power the transmitter. A pair of AAA alkaline cells powers the receiver. Both transmitter and receiver have power-switch/volume controls and switch-selectable dual frequencies. More than one receiver can be used with a single transmitter. $99.95.

CIRCLE 53 ON FREE INFORMATION CARD

Inductive Audio Tracer

The "SHMAGUE" from Electron Processing, Inc. (Medford, NY) is an inductive audio signal tracer that picks up the magnetic field developed

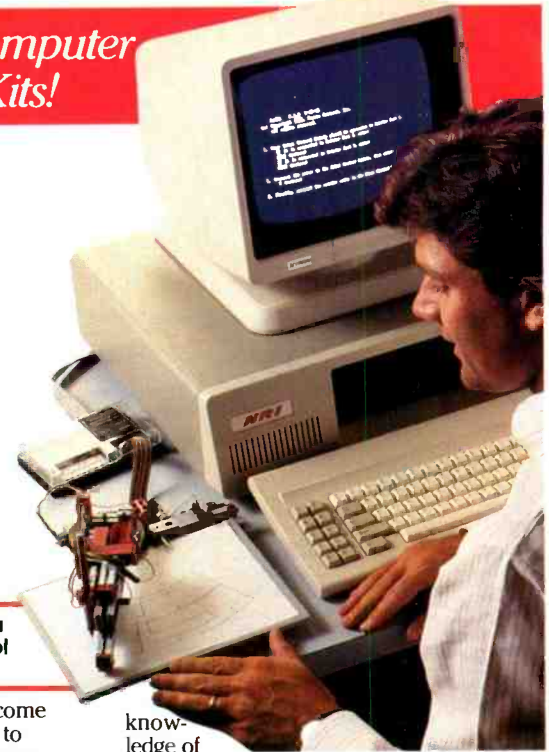


when a current flows through a wire. By holding the instrument's wand near an object, the user can listen to the audio signals passing through the wires without having to make electrical or physical contact. Connected to the SHMAGUE is an inductive wand at the end of a 6-foot cable. Built into the compact enclosure is a speaker through which the picked-up audio signals can be heard. A power-switched volume control permits the level of the signal to be adjusted as needed. A phone jack is provided for connection to an oscilloscope or frequency counter. Power is supplied by a 9-volt battery (not included). $59.95.

CIRCLE 54 ON FREE INFORMATION CARD

(Continued on page 14)

NOW! Training includes XT-compatible computer plus NRI's remarkable Robotic Discovery Kits!

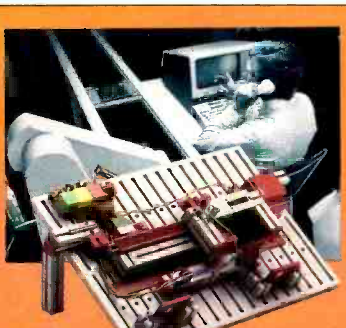


Get training for industry's hottest new jobs as you build and program complete robotic control systems

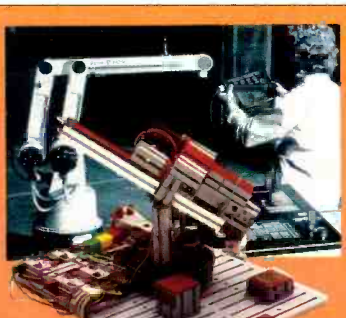
Now you can get the skills in demand for the new jobs in industry today. With NRI's new at-home training in Robotics Technology, you actually build a fully IBM XT-compatible computer, then use it to program and control working robotic systems . . . each one engineered to recreate the exact operations performed by the robotic equipment found in today's industrial workplace.

It's no secret. Industry is being transformed by technology—with everything from precision electronic instruments to giant locomotives now being produced with the help of advanced robotic systems. And with automation have come jobs . . . thousands of jobs building, programming, and servicing the robotic systems in use today.

Now, unlike any other school, NRI offers you training that prepares you to take advantage of these new opportunities . . . training that gives you the practical know-how and the hands-on skills to advance on the job or start a new career as a robotics and industrial control technician.



Two tasks frequently performed by robots are measuring and sorting, be it sorting eggs or eliminating scrap from a production line. You build this sorting system, then program it to accept short and long blocks, measure these blocks, and move them to the correct storage bins.



This "teachable" robotic arm is the most complex robot model you construct. Once you manually put the robot through a sequence of operations, it will "remember" these steps and perform them whenever asked.

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As an integral part of your NRI hands-on training, you build a fully IBM XT-compatible computer from the keyboard up. You assemble the power supply, install the 5¼" floppy disk drive, and attach the high-resolution monitor. Most important of all, by performing meaningful tests and demonstrations at each stage of assembly, you come to a full understanding and appreciation of the microprocessor technology that makes today's robotics applications possible. But that's just the beginning.

You go on to use your computer to program and control a diverse array of robotic systems you create with NRI's remarkable Robotic Discovery Kits.

Robotics comes to life as you see real-world industrial control principles in action

Your NRI Robotic Discovery Kits come complete with everything you need to create working, moving robotic systems. You get structural members, motors, gear drives, sensors, scanners, potentiometers, plus a special Robotics Interface that links the robots you build to your computer.

Together, your computer and the robotic devices you construct become fully integrated automation systems, programmed by you to do the types of operations and tasks performed in today's industrial environments. Tasks such as plotting polar coordinates to create graphic displays of numeric data . . . sorting different size objects and routing these objects to separate containers . . . even performing a preprogrammed sequence of operations again and again just as robots now do on manufacturing lines.

Nothing is left out, nothing is left to chance. You get everything you need—the skills, the confidence, and the equipment—to feel completely at home with today's robotics technology.

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Rapidly, theory becomes understanding as you move on to digital logic, computer fundamentals, right up to writing practical programs to control specific robotic operations using NRI's Robotic Programming Language software included in your course.

Your success is assured by your personal NRI instructor, whose expertise and personal guidance are always available to you whenever you need a helping hand along the way.

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NEW PRODUCTS ••• *(from page 10)*

"Technical" Workbench

A Technical Workstation from Tennsco Corp. (Dickson, TN) combines modular flexibility and user comfort. It features a heavy-duty steel frame with concealed fasteners, slip-resistant adjustable footrest, comfort-rounded work surface edging and adjustable glides. Options available with the workbench include a static-controlled work surface and convenient power-distribution rail that contains up to eight 117-volt outlets with a 15-ampere circuit breaker, power switch and 8-foot-long power cord. Other options include an instrument shelf (with optional power rail and static-controlled shelf surface) and drawer units with epoxy-coated roller slides for quiet, smooth operation. Color and trim options allow the Technical Workstation to complement any work environment.

CIRCLE 55 ON FREE INFORMATION CARD

Pocket Power Inverter

Not much larger than a deck of cards and weighing just 14 ounces, the PC100+ power inverter from Statpower Technologies Corp. (Pt. Roberts, WA) is said to produce 100 watts of ac power from a 12-volt battery source to power portable computers. It works with the Toshiba 3100, 3200 and 5100 and the Compaq Portable II and 386, as well as most

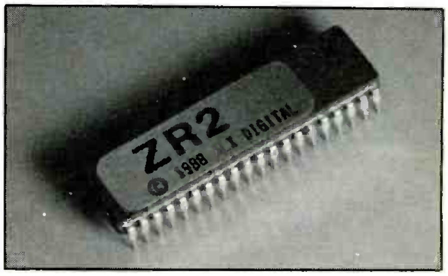
other portable computers. The inverter provides continuous ac power for operating these computers (and printers, modems, radio scanners, FAX machines, etc.) from automotive or marine batteries. It also gives laptop users the ability to recharge their computers and peripherals on the road as easily as they can at home.

Specifications include: 10 to 15 volts dc input; 115 volts ac ±5 percent, 60 Hz ±1 percent output; 200/100 watts peak/continuous output; 90 percent efficiency; 0.06-ampere no-load current drain; and modified sine-wave output. The inverter features a single three-contact ac receptacle, a low-battery alarm, automatic low-battery cutoff to prevent damage to the user's battery, and overload and thermal protection. $179.95.

CIRCLE 56 ON FREE INFORMATION CARD

A Talented Chip

A new TTL-compatible 40-pin HMOS IC from ALX Digital (Miami, FL) contains 12 different functions that can greatly simplify and reduce the cost of the circuitry required to perform various tasks. In most cases, the only requirements to get the chip operating are a 5-volt dc power supply and a 4-MHz crystal. Among the functions offered by the ZR2 chip are: ac and dc light dimmers; transmit/receive serial data manipulation; a 64-channel controller; a 16-channel direct-mode controller; serial-to-direct channel control; counting; and four chasers/zoners with 16 channel outputs.



The chip provides three modes of operation: auto run, sync and manual run. In auto, operation is free-running, while sync requires a series of pulses to trigger operation—which is ideal for music-sync functions like light shows. Variable speeds are available for the light dimmers and zoners, which makes the chip suitable for stage lighting and motor control applications.

One routine allows the chip to be connected to hundreds more of the same chip, dramatically expanding the total number of output lines. Though not RS-232 compatible, the serial data routines can be used to store and retrieve files on tape. The same routine can also be used to create a personal modem system. Both 16-channel controllers output the selected lines in OR or AND mode. One controller requires serial, the other parallel, data entry. This chip is claimed to be fully software compatible and can be interfaced to almost any computer. $35.

CIRCLE 57 ON FREE INFORMATION CARD

Telecommunications Tester

American Reliance's (Rosemead, CA) Model AR-180T tester is de-

signed for telecommunications and data-communications technicians who need to take level and noise measurements as well as to measure ac and dc voltage, dc current and resistance. In addition, the instrument can generate four precision tones (404, 1,004, 2,713 and 2,804 Hz) for frequency-response measurements. For ac voltage and level measurements, a true-rms ac converter is used, while for noise measurements a built-in "C-message" noise weighting filter is employed. Ac/dc can be measured to a maximum of ±200/750 volts with resolution of 0.1/1.0 volt and accuracy of ±0.5/±1.5 percent. Maximum dc current is ±200 mA, with resolution of 0.1 mA and accuracy of ±0.5 percent + 1 digit. Fuse protection is provided in the dc current function.

The instrument is switchable between 600-ohm terminated or bridge measurements at an impedance of 1 megohm. An audible continuity beeper is included, and measurements are displayed in a 3.5-digit LCD window. Separate "transmit-

(Continued on page 84)

Making Printed-Circuit Boards The Old-Fashioned Way

Using photographic techniques without a camera or darkroom can provide repeatable professional results at low cost

By Anthony J. Caristi

Many readers fabricate circuits on printed-circuit boards for their personal construction projects, often using etching-and-drilling guides such as ones printed in *Modern Electronics*. There are a variety of ways to create such circuits, including dry transfer, resist tape, photographic, and so on. Each method has its advantages and disadvantages.

The photographic method, which is the subject of this article, is often desirable to achieve professional-quality results when the circuit is more complex than a very simple one or when more than one identical board has to be produced. The term, "photographic," is really a misnomer here since a photolab with camera equipment and a darkroom is not required. Instead, it simply means that light-sensitive material is used that must not be exposed to bright light, a negative of sorts is produced, and the circuit board is developed in a solution.

Following the techniques to be described, you will soon be making pc boards that can be virtually indistinguishable from professionally-made boards.

The Artwork Materials

In printed-circuit work, the master layout of the desired copper-trace pattern that is to remain on the board after it has been etched is known as the "artwork." The artwork is laid out on translucent or transparent film, usually Mylar in composition. The pattern for the copper traces is laid down on this film using self-adhering tapes, "donuts," IC and transistor pads, and other specialized patterns.

Basic to the artwork materials lineup are donut pads and tapes. These are available in a number of colors and "scales" to suit different layout needs. Black is the color most popularly used, though red and blue and sometimes other colors are used on artwork for very complex, multiple-layer boards.

Typical of the scales available are ×1, which is actual finished size; ×2, which is twice actual size; and ×4, which is four times actual size. Larger-than-actual-size and colors other than black artwork materials are usually used where pc patterns are extremely complex and usually call for two or more layers of copper patterns on a single circuit-board assembly.

For our purposes, we'll concentrate on the use of actual-size artwork composed with commonly available black materials since we want to avoid the need for an expensive photography lab or the additional cost of having the artwork generated photographically sized as needed by an outside source.

The materials you'll be using are sold through some electronics supply houses and graphics art supply stores under several brand names. Kits of pc materials and individual items are made by DATAK, Bishop Graphics, Kepro, GC Electronics and Vector Electronic, among others.

The artwork materials with which you'll be working are simple. These include 10-box-per-inch grid paper or film; transparent or translucent Mylar drafting film; an assortment of donut sizes and tape widths; and DIP IC pad patterns. The only "tools" you need are a hobby knife with spare blades or single-edge utility razor blades and a roll of masking tape.

Based on the types of circuits you generally make into projects, choose an assortment of different tape widths and donut diameters. Typically, tape widths of 0.020, 0.040, 0.080, 0.100 and 0.125 inch will be sufficient for any but high-power circuit pc layouts. If your projects are exclusively low-power digital designs, all you may ever need are the first two tape widths and perhaps the 0.100-inch width for heavy power bus and ground runs. For most work, donuts in diameters of 0.080, 0.100 and 0.125 inch will suffice and perhaps 0.050 inch for the feed-through holes required on double-sided board artwork designs.

Though there are available a variety of different DIP IC pad patterns that have anywhere from 14 to 48 pads in two rows that are 0.30 or 0.60 inch apart, you really don't need every one of these. Actually, if you make a large number of IC-intensive pc guides throughout a year, the best and most economical IC-pad artwork configuration to use has long strips of single-row pads that can be cut to length as needed and be individually placed on the Mylar film. These strips are available in a number of pad configurations. If you anticipate a lot of work in which conductors will have to pass between pads, use the configuration that has narrow pads that will permit this.

When laying out the actual master artwork, it's a good idea to set the IC-pads, donuts, edge connectors, etc., in place first. Burnish them solidly down. Then make the tape runs that interconnect the various pads and patterns. Don't stretch the tape as you place it down on the film; if you do, it will lift or "creep" toward other tapes or pads in time, creating unwanted short circuits in the artwork. Also, though the tapes are flexible, avoid making sharp turns.

Layout of the master artwork begins with taping a sheet of the transparent or translucent film onto grid paper. If you're copying directly from a printed etching-and-drilling guide like those provided for many of the projects in *Modern Electronics*, tape the film over the published artwork—*not* a photocopy of it, which may introduce size distortion—and work directly from that. Size the film as needed for the pc layout, leaving an inch or so extra all around.

To generate a pc artwork "master" for an original circuit design, the first step is to make a rough layout of the pc pattern that will be used. The simplest way to go about this is to tape a sheet of tracing paper over the circuit and another over a sheet of grid paper; the latter can have any number of boxes per inch, though 10 boxes per inch will make it more convenient to directly copy the rough.

Draw whatever DIP integrated-circuit pads are needed on the tracing paper laid over the grid paper. Then make each connecting line in turn, drawing in the pads for the discrete components as you go along. Draw each connecting wire run also on the tracing paper laid over the schematic to keep track of what you've already done and what still remains to be done.

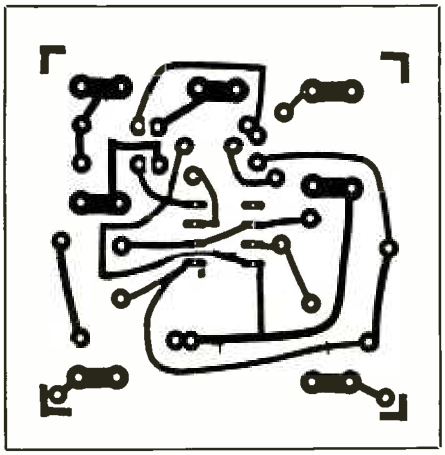


Fig. 1. A typical artwork pattern composed on drafting film using DIP IC pads, donuts and three widths of tape. This view is of the copper side of the board.

As you come to the end of each tape run, place the edge of the hobby knife's blade or the razor blade against the terminal point of the tape and snap the tape sharply to make a clean edge. Do not use a sawing or slicing action that may cut through the donut or pad at the terminating point. Firmly burnish each tape run to solidly fix it in place on the Mylar film as it is being made. A typical example of a printed-circuit master artwork is shown in Fig. 1.

When making the master artwork for a double-sided board, compose the solder side view first. Flip over the composed artwork and tape to it a second sheet of Mylar and compose the component side view, using the first artwork master as a guide to assure perfect registration (see Fig. 2). If you find the tape runs and patterns on the bottom artwork to be confusing, slide a sheet of tracing paper between the two sheets of Mylar. You'll still be able to clearly see the bottom pattern, but it won't be nearly so obtrusive as you work on the top pattern.

When both original master artwork patterns have been composed, label the first "solder side" and the second "component side." Also place labels on each to identify the projects for which they were composed. Figure 3 illustrates the artwork masters for a simple double-sided pc board.

Your artwork "masters" aren't meant to be used directly. They're simply the "positives" from which "negative" exposure masks are made. The latter are what are actually used to expose the copper-clad blanks that will become the printed-circuit boards for your projects.

Whenever you finish making an original piece of master artwork, carefully check it against the published artwork or the rough artwork from which it was made. Immediately correct any errors that were made during composition.

Making the Exposure Mask

It's almost a maxim nowadays that you'll be using "B neg" resist for printed-circuit work. With this type of resist, exposure to ultraviolet light hardens the exposed areas. Recall that your master artwork "positive" has black patterns on a clear or translucent background. If this were to be used as is to expose a presensitized pc blank, the UV light would harden the resist over the areas from which you wish copper to be removed. Consequently, you need a *negative* of the master artwork.

We'll discuss use of readily available materials from 3M to generate a negative from the positive master artwork to obtain clear lines and patterns on an orange background that's opaque to UV energy. (Other "reversing" films are available as well from suppliers of professional pc materials. These might have black, dark brown or other base color. The following procedure will work equally well with reversing films other than those from 3M.)

Materials required for the photoreversal operation, are 3M's No.

77-9802-9269 transparent negative color proofing film and No. 77-9800-7992-3 color proofing film developer. These materials are available from many photo graphics supply outlets and from the source given in the box at the end of this article.

In addition to the film and developer, you need some kind of contact print frame or box, such as those used by photographic hobbyists. Best are commercial models, of course, but you can easily use a sheet of glass and a perfectly flat piece of plywood. The "contact box" will be used to expose the photographic film to a source of ultraviolet light, using the original master artwork as the "positive" from which your "negative" exposure mask will be made.

Your source of ultraviolet energy can be the sun itself, assuming you can depend on bright sunny days, with the sun's rays directly striking your exposure setup. If you don't want to have to depend on the whims of nature for exposing your negatives and presensitized pc blanks, consider investing in a commercial UV light.

Preliminary to setting up the exposure arrangement, determine which side of the reversing film has the emulsion (coating) on it. This can be done by any of several methods. One is to visually inspect both sides of the film to identify the dull or emulsion side. This must be done in subdued lighting or under safe lighting conditions. It also may prove to be a bit difficult because there is very little difference in reflectivity between the two sides.

Another way to determine which side is which is to try to write on both sides near the edge of the film with a soft lead pencil. The side to which the lead more readily takes is the emulsion side.

To make absolutely certain that you've properly identified the two sides of the film, there is another, better, test you can make. That is to gently scrape one surface near the edge of the film with a sharp hobby knife or razor blade. If after a couple of strokes the clear plastic of the base doesn't show through, flip over the film and scrape the second side. This time, when the clear film shows through, you know that you're scraping on the emulsion side.

When you're absolutely certain that you've identified the film's two sides, place a small self-stick label on the emulsion side near a corner. Write on this the words "emulsion side" for future reference.

Conduct all tests on the reversing film under subdued or "safe" lighting conditions. To obtain a safe lighting environment, use a common yellow "bug light" in your work area as the source of illumination. This light can be quite bright without having an effect on the film. Do *not* work in sunlight, which is a robust source of ultraviolet radiation. If you work in an incandescent-lighted area, do not expose the film directly to the light and keep the brightness of the illumination as low as possible and work as quickly as you can.

The procedure for producing a negative exposure mask from the positive master artwork is fairly simple:

(1) Cut a piece of the reversing film to about ½ inch larger in both dimensions than the original master artwork. If the artwork is very small—say, less than 1 inch in a given dimension, add a bit to the reversing film to facilitate easy handling.

(2) Referring to Fig. 4, place the cut piece of film emulsion side down on the wood plate of your contact box and follow up with the original master artwork. Position the art-

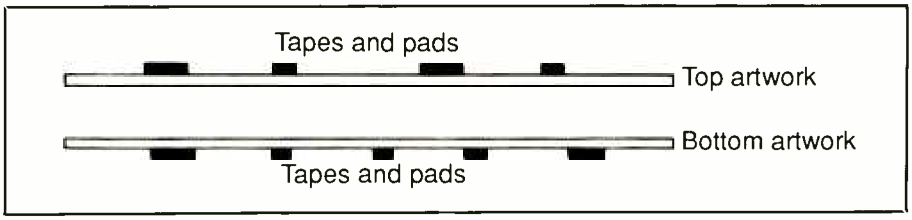


Fig. 2. Drawing illustrates orientations of the solder-side (bottom) and component-side (top) artwork masters during composition.

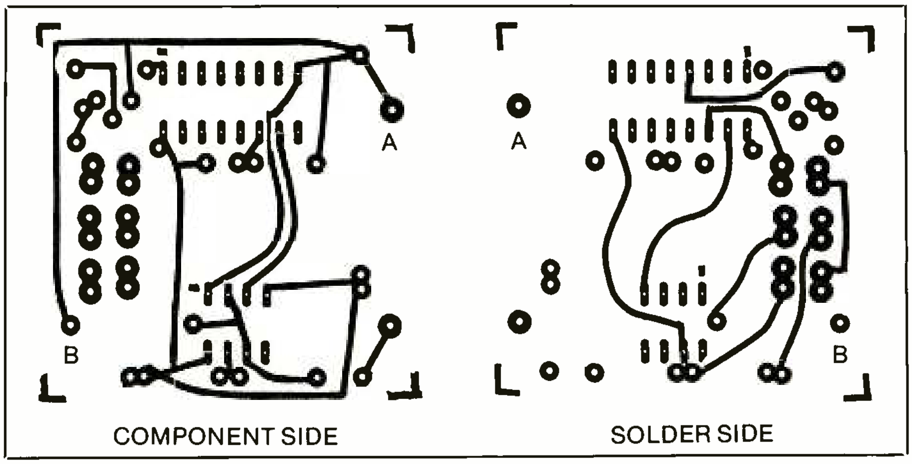


Fig. 3. Solder-side (left) and component-side (right) artwork masters for a double-sided pc board. Arbitrarily selected holes "A" and "B" are predrilled in the pc blank prior to sensitizing to permit exact registration of each negative exposure mask during the exposure operation.

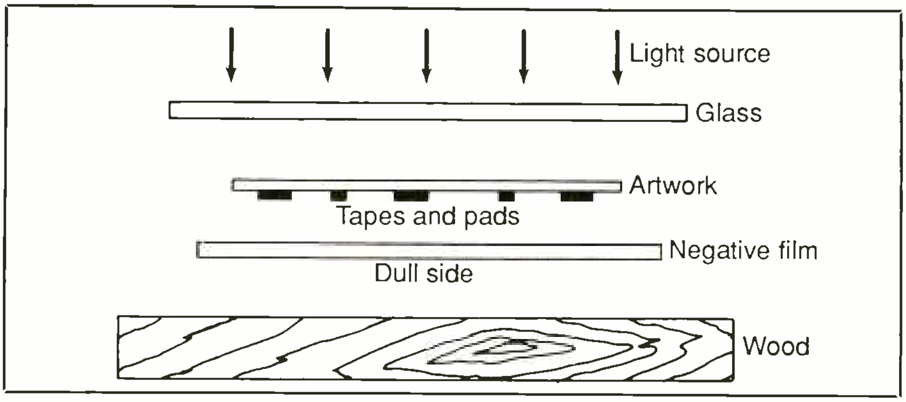


Fig. 4. Shown here are details for making a negative of the original artwork master. A glass sheet holds the artwork master and reversing film in intimate contact with each other during exposure.

work so that it is centered on the film and has its tape-and-pattern side down. Place over this the sheet of glass, the weight of which will force the artwork into intimate contact with the reversing film during the exposure process.

It is *very* important that the artwork and film be maintained in intimate contact during exposure to prevent unwanted light from bleeding under the black pattern of the artwork. If such bleeding should occur, you will end up with a poor quality negative. If you're careful to keep the exposure setup tight, you will end up with a crisp, sharp negative of the original artwork.

(3) Expose the assembly to a source of ultraviolet light or direct sunlight for as long as necessary to "set" the emulsion on the film in the selected areas. Exact exposure time is impossible to give here, since it depends on the strength and purity of the UV energy and other factors. In bright direct sunlight, the exposure time will average about 60 seconds, while for UV lamps it can vary from less than half this time upward.

To determine how long to expose the reversing film for the specific UV energy source you're using, run a series of test exposures on a strip cut from the film. Expose ½-inch-wide sections of the reversing-film strip, emulsion side down, in increments of 10 seconds. Use a permanent marker to write the exposure time of each section of the film and expose through the lettering. (If you're using a UV lamp, maintain the same distance between it and the exposure setup throughout the test exposures.)

After test exposing the film, place it emulsion side up and pour onto it a sufficient amount of developer to soak the emulsion. Work in subdued lighting or under safe lighting conditions. Spread the developer over the entire emulsion-covered surface and allow it to soak in for 15 seconds or so. Use a very soft tissue or cloth dampened with additional developer to gently rub the developer into the film until all softened portions of the emulsion wash away. Then thoroughly rinse the strip of film under running tap water to remove all developer. Examining the result, the proper exposure time for the UV source you're using will be the time marked on the film that appears in sharp contrast against a transparent film background.

(4) After exposing the film through your original master artwork, immediately return to safe lighting conditions. Place the exposed film emulsion side up and "develop" it as you did for the test strip above. Work slowly and carefully and use plenty of developer when rubbing away the unwanted portions of the emulsion. If the exposure was correctly made, the conductor pattern represented by the tape-and-dot layout on the master artwork will begin to appear as clear against the orange of the reversing film. Continue rubbing until the entire pattern is visible.

Bear in mind that with the developer on the film, the emulsion may be fairly soft at the end of the rubbing operation and can easily be damaged by mishandling. Therefore, handle the developed film with care. You can now work under normal lighting conditions. Thoroughly rinse off every trace of developer under cold running tap water. Then allow the film to thoroughly air dry. Do *not* pat or rub it dry with a cloth or paper towel or tissue.

(5) When it has dried, examine the negative under fairly bright light, comparing it against the original master artwork. If the negative does not have clear, sharp lines in accordance with the artwork, your exposure was too long. If some of the orange background has washed away, the exposure time was too short. If your negative is almost perfect, you can gently scrape away unwanted parts of the orange background, using a sharp razor blade or hobby knife, and touch up with photographic opaquing ink any spots that should be opaque.

(6) If you wish to make more than one printed-circuit board at a time, make as many negatives of the original master artwork as needed. When you're done and all negatives are completely dry, trim them for minimal pc blank wastage and arrange them together with magic or clear tape to make a single multiple-pattern exposure mask. Figure 5 shows the result of taping together of the same pieces of negative artwork for making four identical pc boards at the same time.

(7) Make certain that you identify the side of the negative that repre-

sents the copper-side view of the pc board for which it will be used. Since this will invariably be the shiny side of the film, use a permanent marker to label the film accordingly. While you're about labeling, write on the film the name of the circuit or project for which the artwork was prepared and indicate whether it is for a single- or a double-sided board.

Preparing the PC Blank

Before you can expose the printed-circuit blank for exposure through the negative, the blank must be coated with a light-sensitive photoresist. Of course, presensitized blanks can be purchased from pc materials suppliers at a premium cost. However, if you're planning to fabricate a number of boards, either of the same type or of different patterns for different projects, it makes better economic sense to purchase copper-clad pc blanks and spray-on or paint-on photoresist. You can prepare blanks as they're needed at less cost for each and less risk of the deterioration a presensitized blank is subject to as it sits on a shelf for a long period of time.

To sensitize a pc blank, you need a can of photoresist and compatible photoresist developer, such as KTI Chemicals' No. 175-2074 resist and No. 175-3572 developer. These items are available from most graphics supply outlets or the source given in the box at the end of this article. Of course, the KTI Chemicals items specified are just an example of similar materials available from a number of other suppliers. Some brands of photoresist are paint-on, others are spray-on. Which you use will be dictated as much by availability as by your personal preferences. Either will work effectively.

Sensitize a copper-clad pc blank as follows:

(1) Cut to a piece of pc blank to a size approximately ½ inch longer and wider than needed for the size of the pc artwork negative to allow for final trimming and drilling of mounting holes for the board.

(2) Thoroughly clean the pc blank, removing all traces of dirt, oil, oxidation and other contaminants from the copper surfaces. Use scouring powder and an abrasive pad or fine steel wool during this operation. If you're preparing a double-sided pc blank, scour *both* copper surfaces. Holding the cleaned blank by its edges only, thoroughly rinse away all traces of the scouring powder under warm running water. Examine the scrubbed copper. It should be bright and shiny; if not, repeat scrubbing until it is. The blank must be squeaky clean when you're finished. This will be indicated by a smooth coat of water flowing over the copper surface. If it isn't thoroughly clean, there will be defective areas in the exposed blank.

(3) Be sure to handle the board only by its edges from here on. Thoroughly dry the cleaned blank. Do *not* use a towel or other material that might contaminate the copper surface. Instead, allow the blank to air dry, dry it in a warm oven or force dry it with a blow dryer. If the copper cladding discolors slightly, it won't affect the process, as long as the blank is clean.

(4) When the blank is completely dry, take it to an area where the lighting is subdued or you're using a yellow bug lamp. Place the blank on a meticulously clean surface, copper-clad surface up. If you're using a liquid photoresist, pour a small amount of it on the copper-clad surface and use a clean Q-Tip or similar spreader to paint the entire copper surface with an even layer of resist. If necessary, add more resist to assure complete and uniform coverage. Alternatively, pour the resist into a glass—*not* plastic—tray that is large enough to accommodate the pc blank and submerge the blank in the resist.

If you're using a spray-on photoresist, place the blank inside a box to contain over-spray and spray the copper surface with a uniform layer of resist. Make the coating quite wet and free of visible imperfections.

Whichever type of photoresist is used, prop the coated blank on edge to allow excess photoresist to to drain off. Leaving the coated blank propped almost vertically, allow the resist to thoroughly air dry under light-tight conditions. The drying process will take two or more hours.

It's absolutely essential that no light be allowed to strike the pc blank

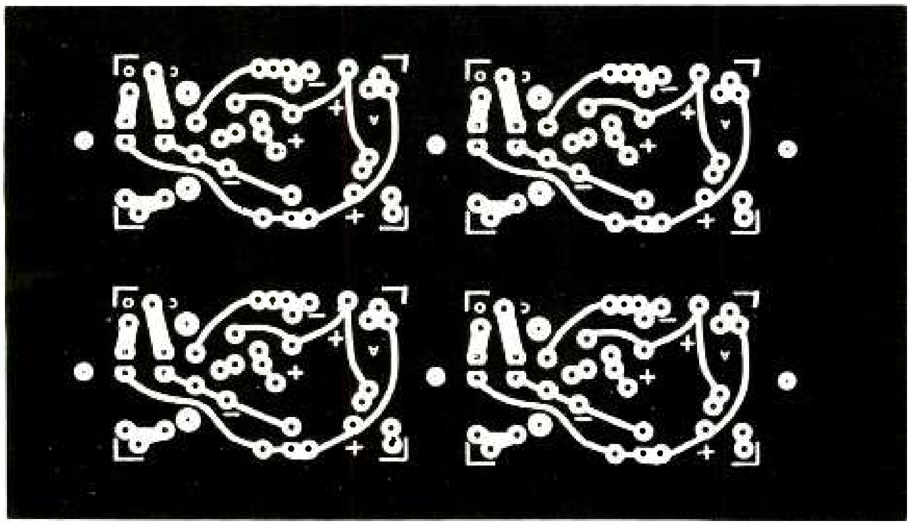


Fig. 5. The original artwork converted into a negative that will then be used to expose a presensitized pc blank. This step-and-repeat pattern permits four identical pc boards to be made simultaneously.

from the moment it's coated with resist. Otherwise, the blank will have to be stripped of resist and thoroughly scrubbed and be resensitized. Since the resist-coated blank is highly light-sensitive, sensitizing more blanks than will be used in a single day isn't recommended.

(5) When coating with resist a double-sided blank, the procedure is the same, except coat the second side after the first has thoroughly dried. Of course, if you use the alternate immersion method, the whole operation can be performed in one pass.

(6) Keep the sensitized pc blank inside its light-tight enclosure until you're ready to use it. When you are ready to use it, place the sensitized blank inside a light-tight box or envelope—such as the plastic envelopes computer boards are usually supplied in—while transporting it to your working location.

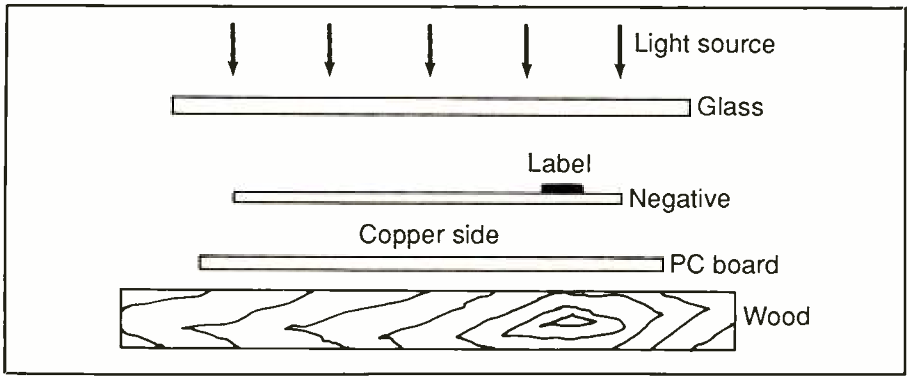


Fig. 6. Illustration of placement of the negative exposure mask and sensitized pc blank for exposure. The glass sheet holds the exposure mask in intimate contact with the pc blank.

Exposing the PC Blank

Expose the presensitized pc blank to ultraviolet light in exactly the same procedure as the reversing film was exposed through the master artwork. In this case, though, the negative is used as the "master." Use the same contact print box or frame or separate plywood board and sheet of glass, as illustrated in Fig. 6. The procedure is as follows:

(1) In subdued light, place the sensitized pc blank copper side up and lay over it your exposure mask, the marked "copper side" up. Make certain you orient the exposure mask properly; if you place it upside-down on the pc blank and proceed to expose, develop and etch the blank, you'll end up with a useless board. Center the mask on the blank and place the sheet of glass over the two. Figure 6 illustrates this arrangement.

(2) Place the exposure mask and blank inside your contact print box so that the two are held firmly in intimate contact with each other. Any space between the exposure mask and pc blank will result in a blurry printed-circuit pattern.

(3) Expose the pc blank through the mask to a source of ultraviolet light or the sun itself. Again, as was the case in preparing the negative from your artwork positive, exposure time will have to be determined experimentally in much the same manner as before. Typically, it will be twice as long as was required to properly expose the reversing film. Therefore, a good starting point would be 2 minutes with test exposures at 20-second intervals.

(4) Once you've determined how long an exposure is required, expose the pc blank. Meanwhile, pour the board-developing solution into a glass—*not* plastic!—tray that is large enough to handle the pc blank to a depth of about ¼ inch.

(5) When the pc blank's exposure period has lapsed, turn off the UV source (or shield the setup from the sun) and arrange safe lighting conditions. Remove and set aside the sheet of glass and exposure mask. Then, handling the exposed pc blank only by its edges, transfer it to the tray containing the developer solution. If the blank is single sided, place it copper side up in the solution. Allow the blank to sit in the developer for 2 minutes, at which time, the blank will no longer be sensitive to light and you can finish working under brighter ambient lighting conditions.

(6) Handling the pc blank only by its edges, thoroughly rinse it under cold running water to wash away all traces of the developer. As you're doing this, avoid touching the copper surface because the remaining resist pattern is likely to be quite soft and relatively easy to damage. To "set" the resist pattern and dry it at the same time, it's a good idea to force dry the pc blank with a blow dryer. Otherwise, allow the blank to dry naturally by evaporation.

(7) Careful examination of the pc blank should reveal the pc pattern formed by the remaining resist. If you note any area or areas in which the pattern has washed away to excess or entirely, your exposure time was too short or you improperly presensitized the blank with photoresist. If the resist hasn't been removed sufficiently from certain areas, your exposure time was too long or the presensitized blank was exposed to light before it was placed in the contact box. In either event, you'll have to strip all resist from the blank and start over again from scratch.

During your examination, if you note any minor defects in the resist pattern, you can correct them by scraping away the resist in areas where it didn't wash off or add resist

A Dry-Transfer Alternative

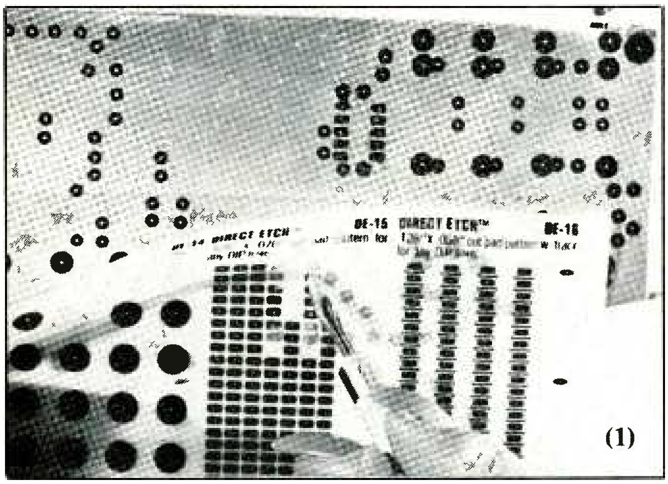
There are a number of alternative ways to make printed-circuit boards. A popular method is the dry-transfer one where etch-resist is applied to a printed-circuit board, which can be done in various ways. For example, DATAK's systems are popularly used to make one-time artwork and single boards.

The company's ER-4 Photo-Etch Kit ($37) contains all the material needed to reproduce artwork published, say, in *Modern Electronics*. It also includes the company's Direct-Etch system to make single pc circuits without artwork, which simplifies trying out different circuit layouts.

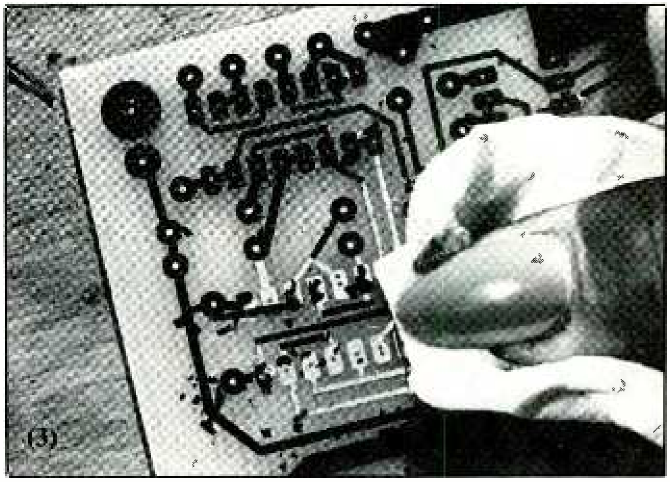
The latter system uses plastic etch-resist patterns that are transferred by pressure onto a copper-clad circuit board. A set of 69 different sheets of patterns—DIP's, TO's, surface-mount, edge card contacts, straight-line connections, polarity symbols, etc.—is available as DE-973 for $34.95, while refill sets of two sheets cost $2.

To create a circuit on a copper blank, one simply lays down a selected pattern on the sheet and rubs it with a ball point or spoon burnisher. Then connecting traces from the sheet are cut to the desired length with a razor or knife and similarly transferred to the board. The completed circuit is then sprayed or tank etched, followed by removing the resist by soaking the board in mineral spirits and rubbing clean with a soft cloth.

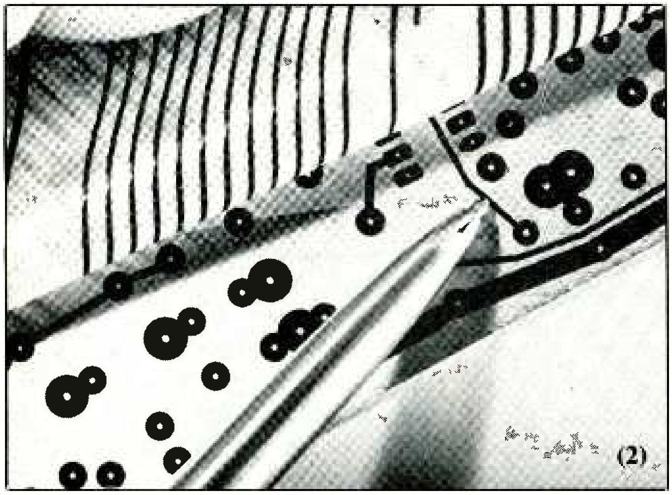
As you can see, there are many ways to skin the cat.



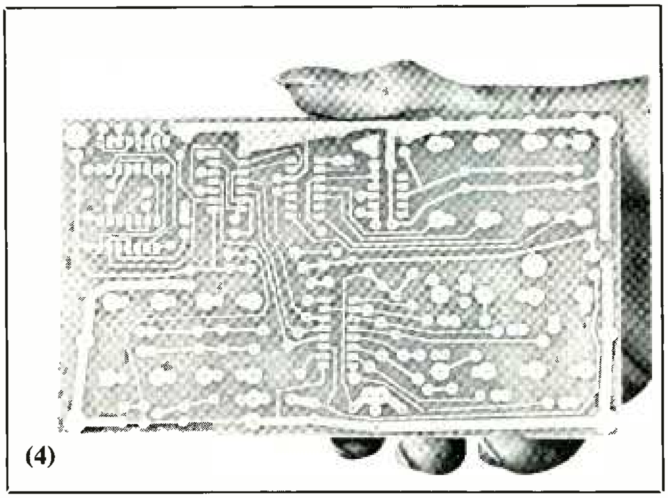
A Direct-Etch Dual-Inline-Pin (DIP) pattern is transferred to a copper-clad pc board by laying the pattern down where it's to be positioned and rubbing it with a burnishing tool.



After etching, the dry transfer etch resist is easily removed by rubbing it with a cloth that's impregnated with mineral spirits or rubber-cement thinner.



Printed-circuit connecting traces are first cut to length and then transferred between pattern points, as shown.



The finished printed-circuit board, displaying clean edge definition, is pictured here.

with an artist's paintbrush where it washed off but should not have. If you add resist, you must expose it to UV light to set it prior to etching the pc blank.

(8) Whatever developer remains in the tray can be reused. Pour it back into its container and seal tightly.

If you're making a double-sided printed-circuit board, your exposure task will require a few extra steps. To begin with, of course, you must expose the pc blank twice, once for each side.

Alignment of the two exposure masks—technically known as "registration"—is critical. The simplest way to assure this is to align the two exposure masks with the sides labeled "solder side" and "component side" facing out and punch pinholes in two or more strategically selected component-hole locations through both masks (see points "A" and "B" in Fig. 3). Place "solder side" mask copper side up on a double-sided pc blank that has been previously cut to size and gently center-punch the hole locations onto the copper surface of the blank. Remove the mask and drill No. 60 holes at each marked location.

After drilling the holes, double-check alignment between the blank and two masks. Then clean and sensitize the blank as described above. When you're ready to expose the blank, place it on a corrugated cardboard box. Orient one mask on it with its punched holes aligned with the holes in the blank and push straight pins through from the mask side in each hole location and completely into the cardboard.

Place the glass over the assembly and check for intimate contact between the mask and pc blank. If you note any lifting of the mask, due to the heads of the pins, place thin pieces of cardboard on top of the mask and weight the assembly down with the sheet of glass. (Don't forget to do all this under subdued or safe lighting conditions!) Expose the blank through the mask to UV light. Then repeat the entire procedure for the other side of the blank and remaining exposure mask.

Etching the Blank

Etching is a chemical process by which the portions of the pc blank not protected by the resist pattern are attacked and eaten away by a chemical solution. In effect, the unwanted copper is washed away, leaving behind only enough copper to make up the desired copper-trace pattern for the printed-circuit board.

Two etching agents are popularly used by both industry and home experimenters and hobbyists. These are ferric chloride and ammonium persulfate. Of the two, ferric chloride is much the faster etchant, requiring about 10 to 30 minutes, depending on solution temperature and agitation activity, to eat away the unwanted copper from a typical size pc blank. Ammonium persulfate may take up to 2 hours to do the same job.

Ammonium persulfate is a graceful etchant compared to ferric chloride. Both chemicals are poisonous and, therefore, must be kept out of the reach of children. They must never come in contact with eating utensils. This being the case, you should purchase a glass baking dish and use it exclusively for pc work. In fact, buy two or three dishes, saving each for exclusive use of only one chemical (etchant, developer, etc.).

A word of caution about ferric chloride is highly in order here. This is a particularly nasty chemical in that it will attack almost any metal and will stain anything else it comes into contact with. Be very careful not to spill or splash this chemical. Wash it immediately off anything that may accidentally come in contact with it. Also, if you pour ferric chloride into a sink, it will stain the surface.

Ferric chloride comes premixed and ready to use. Ammonium persulfate, on the other hand, is supplied in a crystal form and must be mixed with water at the time it is to be used. Both chemicals work faster at elevated temperatures and are at their optimum at about 100 degrees Fahrenheit. You can warm ferric chloride to 110 or even 120 degrees by placing it in its unopened container in a pail of very hot hot water until it becomes hot to the touch before actually using it. With ammonium persulfate, simply use hot water in which to dissolve the crystals.

Pour the etchant into a glass baking dish to a depth of ⅜ to ½ inch. Then place the pc blank in the etchant. As the etchant begins to work, gently rock the dish back and forth to agitate the etchant and wash away the released copper. Continue etching the blank, rocking the dish every couple of minutes or so, until all copper has been etched away from the areas not protected by resist. Take care to avoid splashing or spilling the etchant.

During the etching process, periodically lift the board out of the etching solution to inspect the progress. Use only plastic tongs to lift the board from the solution. *Never* use metal tongs; the etchant will immediately begin attacking them if you do.

Don't over-etch the pc blank. If you do, you may find that the etchant will begin to attack the desired copper pattern. When etching is done, remove the board from the glass baking dish and thoroughly rinse it under running tap water. Then carefully examine the board to verify that it has been properly etched. If there are still traces of unwanted copper, return the board to the etching solution until they've been dissolved and once again thoroughly clean the board.

Once the etching process is truly complete and all traces of the etchant have been rinsed from the board, remove the resist that remains on the copper pattern to make it possible to solder to the copper pads. Use fine steel wool or very fine emery cloth to remove the resist.

If you use ammonium persulfate etchant, be advised that it is not reusable. Upon completion of etching a board, this chemical should be disposed of according to the rules for such disposal in your community.

You'll know when ferric-chloride etchant has become saturated with dissolved copper by the fact that its copper-removing action will be noticeably slower or cease altogether. When this occurs, it's time to discard the etchant. The best way to do this is to pour the etchant into a container of dry sand, which will soak it up like a sponge, and then dispose of it with your normal trash pick-up. Before doing the latter, however, check with your local environment protection agency if this method of disposal is legal; if not, ask what must be done to get rid of the etchant.

At this point, you're ready to finalize your new pc board. If the board is to take an odd shape—such as an "L" or a triangle—or must have cutouts or notches, do whatever cutting is required *before* drilling any holes. Then drill all holes, starting with the largest and working down to the smallest. If the centers of any donut or IC pads have no copper removed from them, carefully dimple them using a sharply pointed center punch and a gentle tap from a hammer.

Your printed-circuit board is now ready to be populated with components. If you followed the routines outlined here, the board—and, by extension, the wired circuit-board assembly—should look every bit as professional as any you can get from commercial sources.

Once you master the "art" of fabricating pc boards, you'll discover a whole new dimension of the electronics hobby. Given professional-looking pc assemblies, you'll undoubtedly want to show off your projects. **ME**

Materials Availability

The printed-circuit artwork and board materials mentioned in this article, as well as others that are not mentioned, are available from a number of sources. However, to make it more convenient for you to obtain small quantities of the supplies needed to make professional-quality pc boards, the following items are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463:

- An artwork kit consisting of an 8½ × 11-inch sheet of drafting film, roll of 0.030-inch-wide tape; 192 0.100-inch-diameter donut pads; and 10 DIP IC pad patterns, $16.95.
- 3M negative film (5 × inches),$7.95, and 3M film developer (2 ounces), $3.95.
- Paint-on-type photoresist (1 ounce), $6.95, and developer (4 ounces), $4.95.
- Ammonium persulfate crystals to make 1 quart, $4.95.

Add $5 per order to cover P&H. New Jersey residents, add state sales tax.

Passive Wave-Shaping Circuits

Using resistors, capacitors, inductors and diodes to do a job that has traditionally been the task of op amps and other active elements

By Joseph J. Carr

Much has been written about active wave-shaping and wave-generating circuits in which operational amplifiers and other linear IC devices are used to create special waveforms. Did you know, though, that it is also possible to use *passive* circuits to shape waveforms? Resistors, capacitors, inductors and diodes can be used to shape waves at less cost than with active devices.

The use of passive devices in shaping waveforms is due to the nature of pulse signals and the nature of diodes. Since a pulse is made up of a fundamental sine wave and an assortment of harmonics, the mix of which harmonics and how strong each is depends upon the particular waveform generated. Traditionally, wave-shaping circuits have been made up of frequency-sensitive RC, LC and RLC networks that shape and form pulses by altering their frequency content.

We will investigate passive wave-shaping networks and how they can be incorporated into practical circuit designs. You may find here ways of simplifying your own wave-shaping designs or means of designing circuits that can save on the cost of your next project.

Action On Square Waves

Shown in Fig. 1 is the 10-volt peak-to-peak (p-p) square wave of an elderly Heath Model IG-18 sine/square-wave audio signal generator. For these experiments, the frequency of these square waves was set to approximately 400 Hz. Although age has deteriorated the rise time of the leading edges of the square waves generated by this instrument, the signal is adequate for purposes of experimenting.

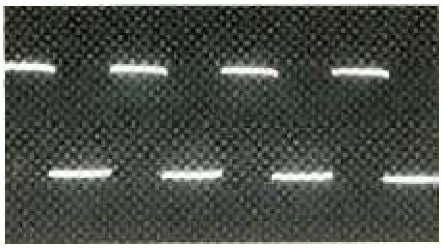


Fig. 1. Screen photo of a 10-volt peak-to-peak square wave from an old Heath Model IG-18 sine/square-wave audio generator.

Recall that a square wave consists of a fundamental sine wave plus a collection of odd harmonics. This waveform can be shaped by enhancing or rolling off those harmonics. Of course, if these harmonics are rolled off to too great a degree, the only thing remaining will be a sine wave whose frequency is the fundamental.

When the Fig. 1 square wave is applied to the input of an RC low-pass filter, or "integrator," network like that shown in Fig. 2(A), the output signal appears as shown in Fig. 2(B). Note here that the amplitude of the output signal is somewhat reduced compared to that of the original input signal, the result of losses (attenuation) in the RC network. Also note that the fast rise- and fall-time edges of the input signal have become curved in the output waveform so that it appears much like a capacitor charge/discharge waveform. This wave shape results from rolling off the high frequencies present in the square wave.

The degree to which the edges of the output waveform are rounded depends on the values of *R* and *C* in the network. A high RC product is a lower-frequency low-pass filter and, thus, will have a larger effect on the waveform.

A low-pass filter also serves to mathematically "integrate" an output waveform. As a result, the output of this network represents the time-average of the input waveform. This fact is used to good effect by instrumentation designers.

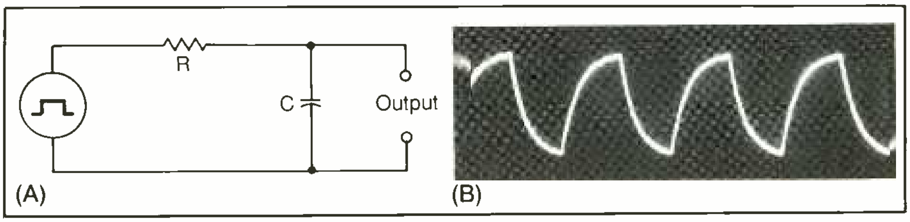


Fig. 2. An RC low-pass filter or integrator (A) and the output signal that occurs when a square wave is applied to its input (B).

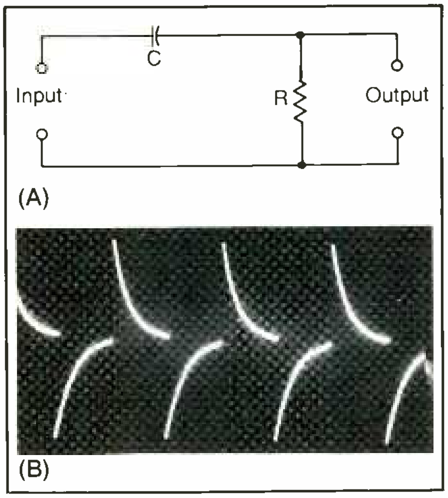


Fig. 3. An RC high-pass filter or differentiator (A) and the output that occurs when a square wave is applied to its input (B).

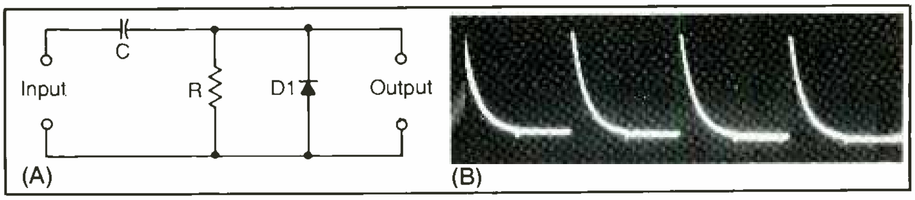


Fig. 5. A diode connected across output of a differentiator circuit to clip negative peaks (A) and output signal that results from its inclusion in circuit (B).

Figure 3(A) illustrates an RC high-pass filter, also referred to as a "differentiator." In this circuit, the elements are the same as those used in the low-pass filter arrangement shown in Fig. 2(A). However, their respective roles are reversed. In this case, the high frequencies are not attenuated as much as are the low frequencies. Therefore, the square wave becomes tilted in favor of the high frequencies. Put another way, the output waveform is "peaked up," as shown in Fig. 3(B), which shows the output waveform with a characteristically fast rise time and an exponentially decaying fall time. This waveform, called a "differentiating square wave," is used for applications such as counting or triggering other circuits.

A problem with using the straight differentiated square wave for either triggering or counting purposes is that it has two separate peaks, one in the positive and the other in the negative directions. To be used effectively, this waveform must be modified to eliminate one polarity's peaks. For this wave-shaping task, we turn to the ordinary diode.

Figure 4 shows the current-versus-voltage (I-vs.-V) characteristic for a diode. When the applied voltage is such that the anode (A) is negative with respect to the cathode (K), the diode is cut off and no current flows through it, which is the reverse-biased condition. In theory, current flow through the diode is zero. (In real diodes, however, there is always a tiny leakage current (I_{leak}) in the reverse direction. As a general rule, the smaller the leakage current, the better the diode, and the higher the "reverse resistance" as measured on an ohmmeter.

When the diode is forward biased such that its anode is positive with respect to its cathode, the diode conducts current freely. Below a certain junction potential, referred to as V_g, conduction is nonlinear. Above V_g, the diode's action begins to obey Ohm's Law. The value of the junction potential is 0.2 to 0.3 volt for germanium diodes like the 1N43, 1N60, etc., and 0.6 to 0.7 volt for silicon diodes like the 1N914, 1N4148, and others like them.

As a result of the diode's characteristics, we know that a diode: conducts in only one direction; is linear above the junction potential; and does not conduct current when reverse biased. Knowing these things, let us connect the diode into a circuit and observe what occurs.

Figures 5(A) and 6(A) show a "clamping diode" connected across the output of the differentiating RC network shown in Fig. 3(A). In the case of Fig. 5(A), the diode is connected such that it is reverse biased by positive output voltage excursions

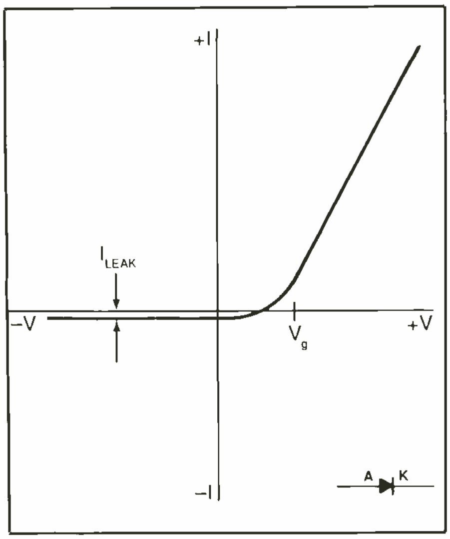


Fig. 4. The current-versus-voltage transfer characteristic of a diode.

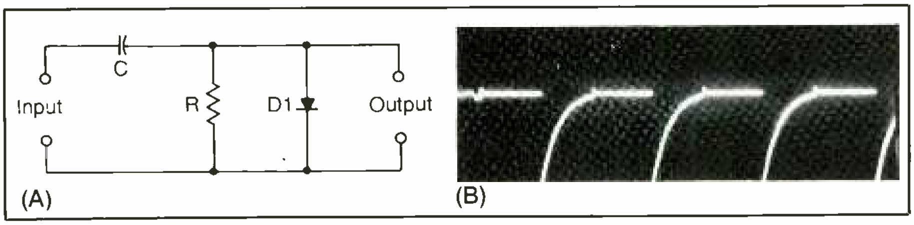


Fig. 6. A diode connected across output of a differentiator circuit to clip positive peaks (A) and output signal that results from its inclusion in circuit (B).

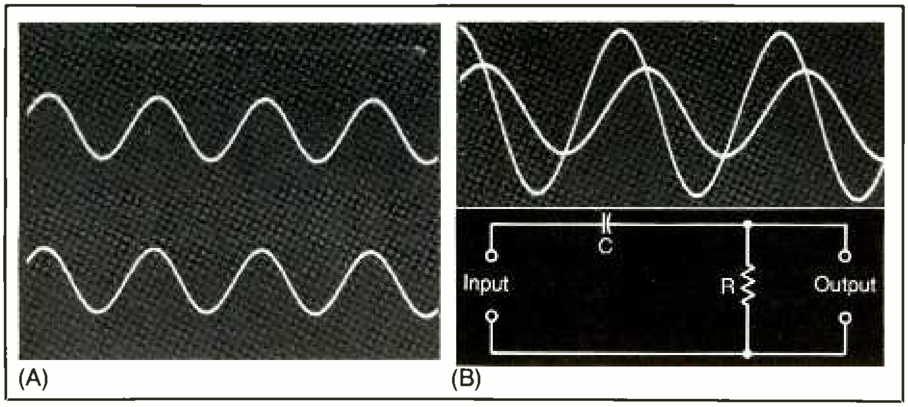


Fig. 7. A sine-wave signal applied to both inputs of a two-channel oscilloscope with the waveforms in-phase with each other (A) and input and output waveforms from an attenuator superimposed on each other (B).

and is forward biased by negative output excursions. The result is the waveform shown in Fig. 5(B). Here we see the same type of differentiation as before on positive peaks, but now the negative peak of the output waveform has been clipped.

If you are eagle-eyed, you can see a small "pip" on the Fig. 5(B) trace at the point where each negative excursion would have begun if the signal had not been clipped. This pip is the result of the junction potential of the diode. The experiment to make these photos used a network containing a 1N60 germanium diode, which had a 0.2- to 0.3-volt junction potential, which is the approximate amplitude of the pips shown in both Fig. 5(B) and Fig. 6(B).

Exactly the opposite situation is illustrated in Fig. 6(B). In this case, the Fig. 6(A) circuit was arranged to clamp the positive-going spike so that only the negative spike remains. Otherwise, operation of the Fig. 5(A) circuit is identical to that of the Fig. 6(A) circuit.

Using a diode to clamp the spike is one way to ensure that only correct triggering signals get to a circuit. Otherwise, operation of such circuits as one-shot multivibrators, voltage-to-frequency (V/F) converters and others would be difficult to predict when two pulses arrive at their inputs.

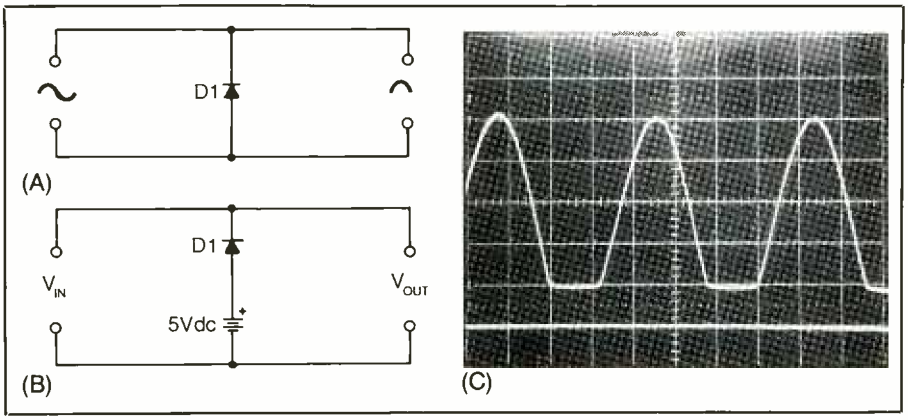


Fig. 8. A circuit with a diode clamp across an ac signal line (A); the same circuit with a battery used to provide a dc offset (B); and the output waveform from the circuit using dc offset (C).

Sine-Wave Response

Figure 7 shows a sine wave applied to both inputs of a two-channel oscilloscope. In Fig. 7(A), the two waveforms are in-phase, rising and falling in step with each other. However, when the sine wave is applied to either high- or low-pass RC filters, two things occur. The first is that the output waveform shown as the bottom trace will be attenuated. The second is that the relative phase between the waveforms shifts. This effect is illustrated in Fig. 7(B). To better show the effect, the two waveforms are shown superimposed on each other in Fig. 7(B). Note that the smaller-amplitude is the output waveform and that it lags the input waveform by almost 90 degrees. Thus, you can conclude that even in sine-wave circuits, passive RC networks are useful as phase shifters. A well-known oscillator circuit, called appropriately enough the "phase-shift oscillator," is based on this principle.

Connecting a diode in shunt—or in series—with the ac sine-wave signal produces a half-wave output. This fact is used to advantage in power-supply circuits. Figure 8(A) shows the circuit of a diode clamp across an ac signal line. This type of circuit is occasionally used in CB and other communications equipment to limit the percentage of modulation to a maximum value. In this application, two diodes are connected in parallel and opposite polarity to clip alternate halves of the modulating signal waveform.

A modified circuit in which a biasing voltage is applied in series with the diode is shown in Fig. 8(B). In this configuration, the diode is forward biased by +5 volts dc. The result is a +5-volt offset to the half-wave output signal, as illustrated in Fig. 8(C). The sine wave has a peak-to-peak value of 25 volts; therefore, the half-

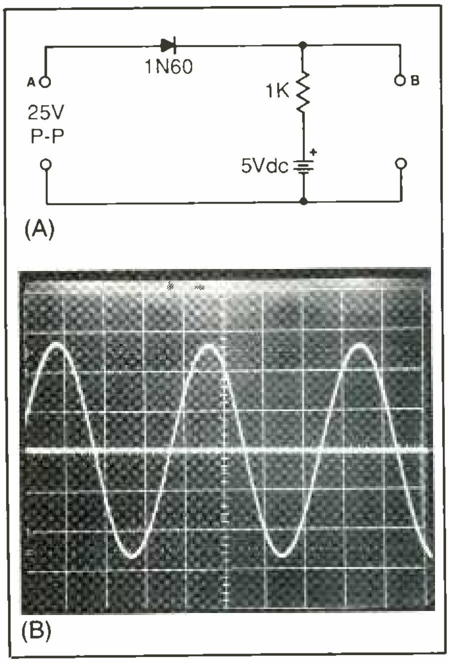
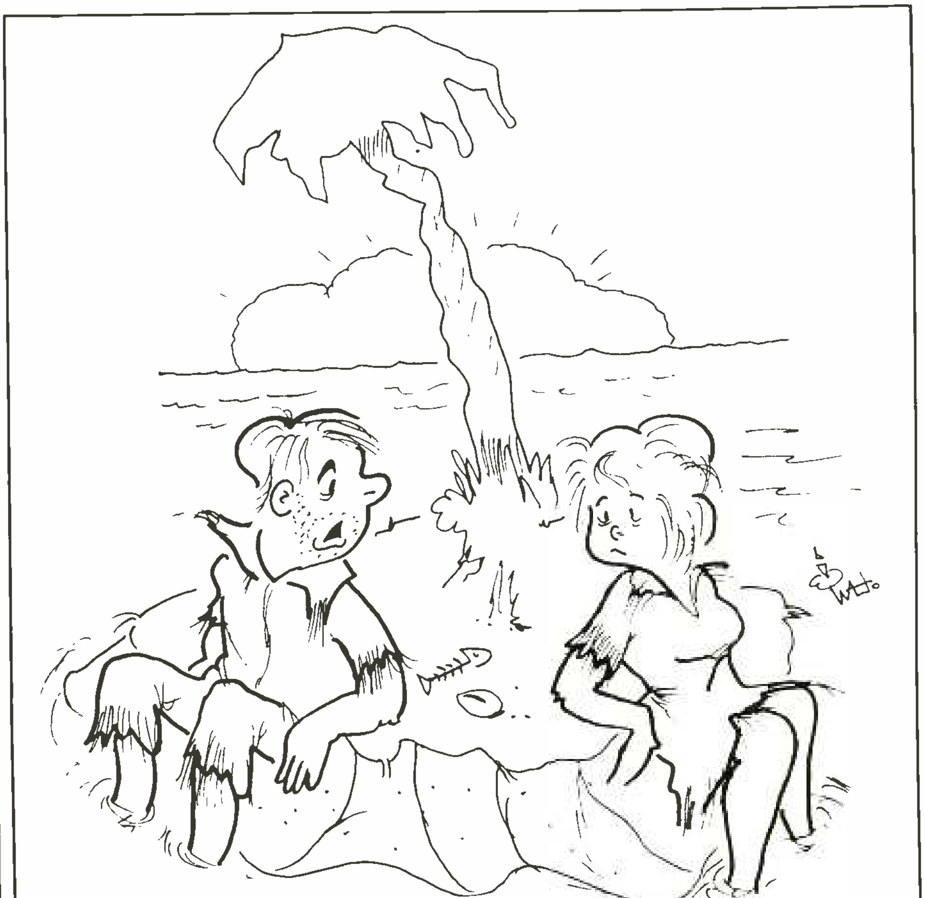


Fig. 9. A circuit in which a germanium diode is connected in series with the signal line with 5-volt dc bias applied in series with a 1,000-ohm resistor (A). With a 25-volt peak-to-peak sine wave (B) applied to circuit's input, what waveforms will appear at points A and B? (See text for answer)

wave amplitude is 25 volts − 5 volts, or 20 volts.

You can set the trip point and exact output characteristic by selecting the amount of the bias voltage, whether to forward- or reverse-bias the diode, and exact circuit configuration.

Here is a little quiz that will test what you have learned about passive wave-shaping circuits. Shown in Fig. 9(A) is a circuit in which a 1N60 germanium diode is connected in series with the signal line. A 25-volt p-p, 400-Hz ac signal like that shown in Fig. 9(B) is applied to the input of the circuit. If the bias voltage is +5 volts *dc* and it is connected in series with a *1*,000-ohm resistor, what waveforms can be expected at points A and B? Assume that the junction potential is negligible compared to the peak amplitudes. The answers to this question appear on page 85.



"YOU'RE RIGHT . . . I MISS THE VCR, TOO."

Modern Hand Calculators

Using computer technology, the latest handhelds pack more power and more functions than ever before, while simplifying their use

By Art Salsberg

Once past the cheap four-function calculators that are essentially throw-away types today, there are moderately priced professional handhelds that might be called advanced calculators. This latest breed of battery-powered handhelds complement personal computers, enabling users to perform a host of calculating functions while on the move. Further, the new calculators' dedicated math functions often provide greater speed and operating simplicity than possible with general purpose personal computers.

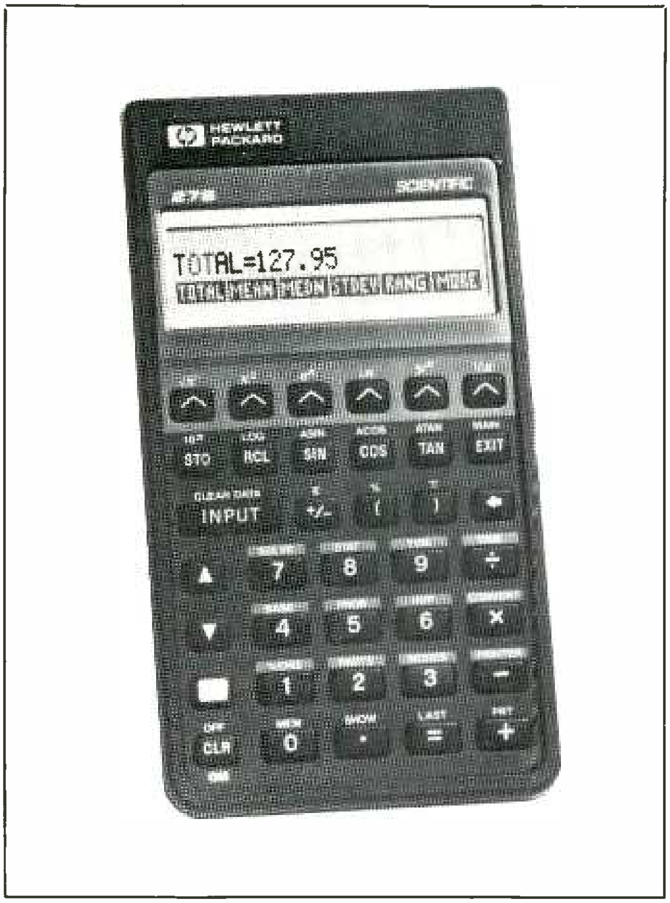
They're broadly directed to two markets: scientific and business. The former are used by engineers and scientists, while the latter are favored by business professionals in fields such as finance, marketing, real estate, and similar areas. Students and educators in each specialty are attracted to modern handheld calculators, too.

The HP-28S is Hewlett-Packard's top-of-the-line scientific calculator. It can solve symbolic algebra and calculus problems and graph multiple equations in its large liquid-crystal display window.

Combining easy use, small size, and high productivity, the latest generation of handheld electronic calculators has only a few manufacturer players in the market: Casio, Hewlett-Packard, Sharp and Texas Instruments. Hewlett-Packard has been especially active in developing new types of scientific and business handheld models during the past year. It now has six models that exemplify the changing nature of these products.

Hewlett-Packard's new handhelds build on the hardware and software concepts introduced last year with its HP-18C Business Consultant and HP-28C scientific professional models. The former has been succeeded by the $175 HP-19 Business Consultant II, while a second business-oriented model, the $110 HP-17B Business Calculator, adds a second-tier handheld. Similarly, the HP-28C scientific has been superseded by the new $235 HP-28S Advanced Scientific Calculator, with a second-tier model, the $110 HP-27S, newly introduced. The lower-priced models use algebraic entry instead of Hewlett-Packard's traditional Reverse Polish Notation (RPN), while the costlier models can be used either way.

In addition to the foregoing models introduced early '88, HP announced two more new calculators just in time for the holiday shopping season: the HP-42S RPN scientific calculator ($120) and the HP-14B business calculator ($79.95), an algebraic-entry calculator. RPN entry eliminates use of parentheses or an equal-sign key. Here, entering "2,



The HP-275S scientific calculator for technical professionals in management comes with HP Solve that permits entering of custom equations without programming.

The HP-14B (left) gives business students and professionals the ability to label values for easy identification, while the HP-42S (right) RPN scientific calculator for engineers displays complex numbers in the same way they are written on paper.

Enter, 2, +" yields the answer, 4. With algebraic entry, the user would enter the more familiar "2, +, 2, =" to get the displayed answer.

Novel Features

HP's top-of-the-line scientific handheld, the 28S, is a problem-solving demon. It does symbolic algebra and calculus, produces graphs on a four-line 23-character LCD display and can plot them on an optional HP infrared-linked printer.

It incorporates 32K of user RAM to store programs, data and graphics displays, as well as 128K of dedicated ROM. Like its predecessor model, it's packaged so that it can open up like a folding case, revealing an alphabetic keyboard on the left half and a numeric keyboard on the right, where the LCD display is also located. When open, it measures 7.5 × 6.3 × 10.5 inches. It's powered by three replaceable alkaline N-cells.

Menu labels on the display, with selection keys on the calculator body just under them, make calculations easy. Just keying in the information enables the handheld to solve mathematical problems using its internally dedicated formulas. The user simply keys in the numbers, presses the appropriate menu label key to register each, and then presses the key that represents the missing value. The answer is then displayed. This might be the monthly loan payment amount if you had entered the number of months per year × number of years, and total loan cost and interest percent.

Moreover, users can create their own equations and menus for variables without doing any programming. Here, the user need only employ words and symbols. The system is called HP Solve, which also gives users an opportunity to do fast "What if?" calculations. The menus can be organized into menu trees, too.

Menus for a variety of operations are chosen by pressing a shift key and then the key that represents what you want. These might be Solve, Stat (for statistics menu), TVM (for time value of money), Base (number base conversions), Prob (probability), Hyp (hyperbolic and inverse functions), Convert, Printer, etc.

The lower-cost algebraic-entry

HP-27S operates in a similar manner, but does not have the separate alpha keyboard. Its display is smaller, being a two-line, 22-character LCD. Memory is more limited, too, with 64K-bytes of ROM and 6.7K-bytes of user RAM, and it does not feature graphics displays. Nevertheless, it is still a powerful scientific handheld that's priced at less than half of the senior scientific calculator.

Special-solutions books are also available, including one titled "Electrical Engineering."

HP's new business-oriented calculators operate in a manner similar to its scientific models, though focusing on solving business problems. The HP Business Consultant II offers statistical and cash-flow graphics, cash-flow graphs, histograms, etc. It also has a Text application for name and number lists, currency conversion, and an appointment menu with alarm clock.

The above handheld has a 128K-byte ROM and 6.5K of user RAM. The smaller business handheld, the HP-17B, is a less-powerful version of the top-of-line Consultant II. It has a 64K ROM and 6.5K RAM, and does not feature graphics.

In addition to the four handhelds described, just-released information relating to two new end-of-year models were announced by Hewlett Packard. The new HP-42S has RPN Scientific emblazoned on its case, in contrast to the HP-27S's plain old Scientific. Seems that HP did not want to ignore its traditional line of RPN machines and the loyal followers who have long favored this programming-efficient system, pricing the economy RPN one $10 higher than the economy algebraic handheld previously introduced to the marketplace.

The latest scientific handheld entry focuses on engineering calculations with complex numbers and vectors, which are displayed just as they're written on paper. As an example, it displays 0.0000 i2.0000 in rectangular mode for the square root of negative four, as contrasted to an error message typically displayed on most calculators. Therefore, one can see both real and imaginary parts of a number. The HP-42S is reported to have a sophisticated matrix editor for simplifying solving of simultaneous equations, and an equation solver that prompts for variables for assignment to softkeys.

And as one might expect, the new machine is said to be program compatible with the highly popular HP-41C/CV calculators, which means thousands of existing programs. HP positions the modestly priced HP-42S as a calculator that complements the more costly HP-41, which is expandable. There's an optional, no-cord-needed infrared printer available for the new calculator, too. This handheld has more than 7.2K bytes of user RAM and a 64K ROM. Dimensions are 3.1 × 5.8 × 0.6 inches and the LCD display has two 22-character lines.

The new low-cost algebraic-entry HP-14B business calculator provides the most often-needed functions for business students and professionals, including forecasting with four curve fits, small-business functions and cash flows. Keys for many items work together automatically, so that keying in two values issues an automatic calculation and display of the third. It only has a one-line, 12-character liquid-crystal display, 16K bytes of ROM in keeping with its diminished capabilities and 0.5K byte of RAM.

In sum, pocket-size calculator design has taken a new turn, using digital technology to enhance their capability and new production methods to maintain small size. Graphics and dedicated problem-solving, for example, represent revolutionary improvements that were formerly limited to computers. Moreover, there's a wide choice of handheld calculators with different capabilities at different price points to match one's needs.

Speaker Overload Indicator

Alerts listener to speaker signal input problems that can damage the transducers

By David Miga

If you've ever blown out a loudspeaker with your audio amplifier or wish to minimize the possibility, you'll be interested in this simple circuit. The Speaker Overload Indicator (SOI) circuit will monitor your amplifier for three problem areas: too much output, too much distortion, and too much positive or negative dc voltage at the amplifier's output. Best of all, the circuit does not require a power supply, and it's small enough to be mounted inside the speaker enclosure or on the amplifier's chassis.

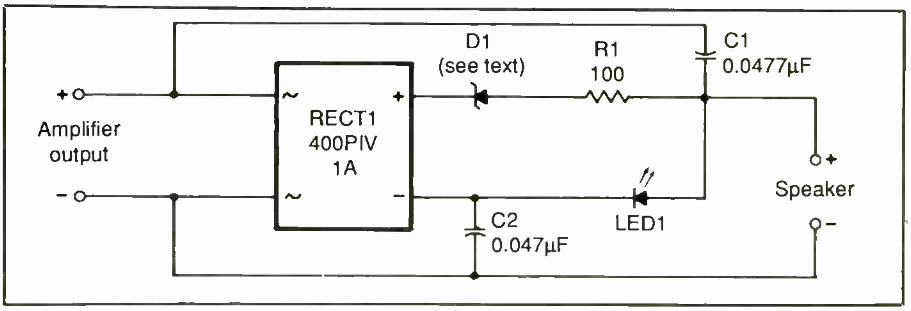


Fig. 1. Schematic diagram of Speaker Overload Indicator circuit. Connections to amplifier's output and speaker's input are shown.

How It Works

Looking at the schematic diagram in Fig. 1, you can see that the circuit is deceptively simple. Full-wave-bridge diode pack *RECT1* rectifies audio signals from the amplifier, enabling the SOI to monitor both positive and negative halves of the audio waveform. The SOI draws no power from the amplifier until the signal becomes too high in level, distortion or dc voltage, at which time it powers itself from the amplifier's output power and flashes bright red or orange light-emitting diode *LED1*.

To trigger the SOI for maximum output power indication, select the zener voltage for *D1* by referring to the table given in Fig. 2 or by using the formula

$$V = \sqrt{RW} - 3.1$$

where V = zener voltage, R = speaker resistance and W = power in watts to cause the indicator to flash. The wattage value should be the speaker's maximum continuous power handling rms input rating.

The formula was arrived at by using the well-known formula $W = V^2/R$ and compensating for the 1.4-volt loss at *RECT1* and the 1.7-volt loss at *LED1*, then rearranging the formula to make it easy to use.

Sharp readers will note that the formula is accurate only if the speaker's resistance is either 4 or 8 ohms. Since speaker resistance is actually an impedance that varies with frequency, the SOI will tend to illuminate a little sooner at low frequencies. Since excess power usually destroys woofers first, this circuit quirk is actually helpful.

Capacitors *C1* and *C2* monitor high-frequency distortion peaks. These may not be audible to some people, but they will fry a tweeter or midrange driver in short order. If an amplifier is driven into clipping, the high-frequency components of the distortion will bypass bridge *RECT1* and zener diode *D1* and illuminate *LED1*.

Finally, if your amplifier has a blown channel that is putting out a high positive or negative dc voltage that may not be audible, the LED will brightly illuminate even when the amplifier's volume control is turned down. If this happens, turn off your amplifier immediately and get it serviced.

PARTS LIST

C1,C2—0.047-µF capacitor
D1—1-watt zener diode (see text for voltage rating)
R1—100-ohm, ½-watt resistor
RECT1—400-PIV, 1-ampere bridge rectifier assembly
Misc.—Terminal strip; Plexiglas rod and clear epoxy cement (optional—see text); small wood screws; hookup wire; solder; etc.

Construction & Installation

Since the SOI is simple and used primarily for low audio frequencies, component layout is not critical. Mount all six components on a terminal strip with the leads of *LED1* kept at maximum length. If you're mounting the device inside a speaker enclosure, remove the woofer to prevent accidental damage to it. With access to the inside of the enclosure, drill a 13/64-inch hole wherever you want *LED1* to mount. Since the front panel of the speaker enclosure is

Indicating Watts	Zener Voltage at 8 Ohms	Zener Voltage at 4 Ohms
25	10.9	6.9
50	16.9	10.9
75	21.4	13.9
100	25.2	16.9
125	28.5	19.3
150	31.5	21.4
175	34.3	23.4
200	36.9	25.2
225	39.3	26.9
250	41.6	28.5

Fig. 2. Determining zener voltage for D1 in circuit. Locate in column 1 desired wattage at which circuit should indicate, read across to 8- or 4- ohm column, whichever is your speaker's impedance, and use a zener diode whose voltage rating is closest to the voltage indicated here.

thicker than the length of the LED, you should countersink the hole *inside* the enclosure with a 1/4-inch or larger drill so that the LED can be exposed past the front surface.

If you wish, you can obtain a length of 3/16-inch Plexiglas rod, file the dome of the LED's case flat, and use clear epoxy to cement the rod to the LED. Now you can drill the 13/64-inch hole clean through the enclosure's front panel past the grille cloth. If you do this, the exposed end of the rod should be filed and polished into a dome shape for maximum light dispersal. Lastly, mount the terminal strip inside the enclosure near the drilled hole with two small wood screws.

You may notice that inexpensive low-power amplifiers may light up the indicator LED more frequently than a high-power amplifier. This is because the cheaper amplifiers do not clip cleanly and, therefore, exhibit high-level distortion peaks.

Only one audio channel SOI is shown in Fig. 1. You'll need another to protect a second channel's speaker, of course. **ME**

A Musical-Instrument Fuzz Box

A special-effects accessory for use with an electric guitar, music synthesizer or other musical instrument

By C.R. Fischer

One of the most popular special-effects devices available to the electronic musician has been the overdrive produced by "fuzz" boxes. Such an accessory is used to create intentional distortion that adds overtones and "punch" to the sound produced by a musical instrument. Used primarily by electric guitarists, it it s mainstay in the bag of musician tricks in virtually all types of modern music.

Presented here is a professional-quality fuzz-box accessory that will work with an electric guitar, bass, synthesizer and electronic keyboard. Its performance is similar to that of a professional device but its cost is only a fraction of such devices. Professional quality is assured by the inclusion in the project of a variable-gain voltage amplifier that allows the fuzz box to be used with virtually any signal source. Additionally, the amount of distortion, high-frequency equalization and output levels can all be continuously varied as desired. Active switching permits the effect of the fuzz box to be controlled by a remote footswitch.

Though this fuzz box delivers true professional performance, it is easy to build because the basic circuitry uses only two easy-to-find integrated circuits. It includes an ac-operated power supply that eliminates the need for a battery. Finally, the circuit design makes use of high-quality components to assure minimum noise with maximized performance.

About the Circuit

Over the years, a number of designs have been used to produce signal distortion effects. Any amplifier will distort if a large enough excursion signal is applied to its input. However, most distortion is undesirable and does not sound sufficiently "musical" for our purposes. Ideally, clipping should be symmetrical to minimize odd harmonics. That is, both positive- and negative-going portions of the waveform should be clamped at the same level. Because the harmonics that are created by doing this can be piercing to the listener, some form of treble control is a necessity. Cheap circuit designs might use a crude treble-cut network, where active equalization with adjustable cut and boost is preferable.

In the design of the fuzz-box circuit shown schematically in Fig. 1, all signal processing is accomplished with two low-noise operational amplifiers contained inside a single IC package. These are identified as *IC1A* and *IC1B* in Fig. 1. Operational-amplifier *IC1A* is configured here as a variable-gain noninverting amplifier whose gain is adjustable from 1 to approximately 50. With gain control provided by GAIN potentiometer *R4*, the fuzz box can accommodate virtually any input signal level.

Once an input signal has been amplified by *IC1A*, it is applied to a simple clipping network made up of *R6*, *D1* and *D2*. DRIVE potentiometer *R5* controls the amplitude of the signal, with proper adjustment allowing the exact amount of distortion to be set. Lower settings provide a subtle effect, while higher settings provide a more dramatic effect that is useful in hard-rock and heavy-metal styles of music.

Once the signal has undergone

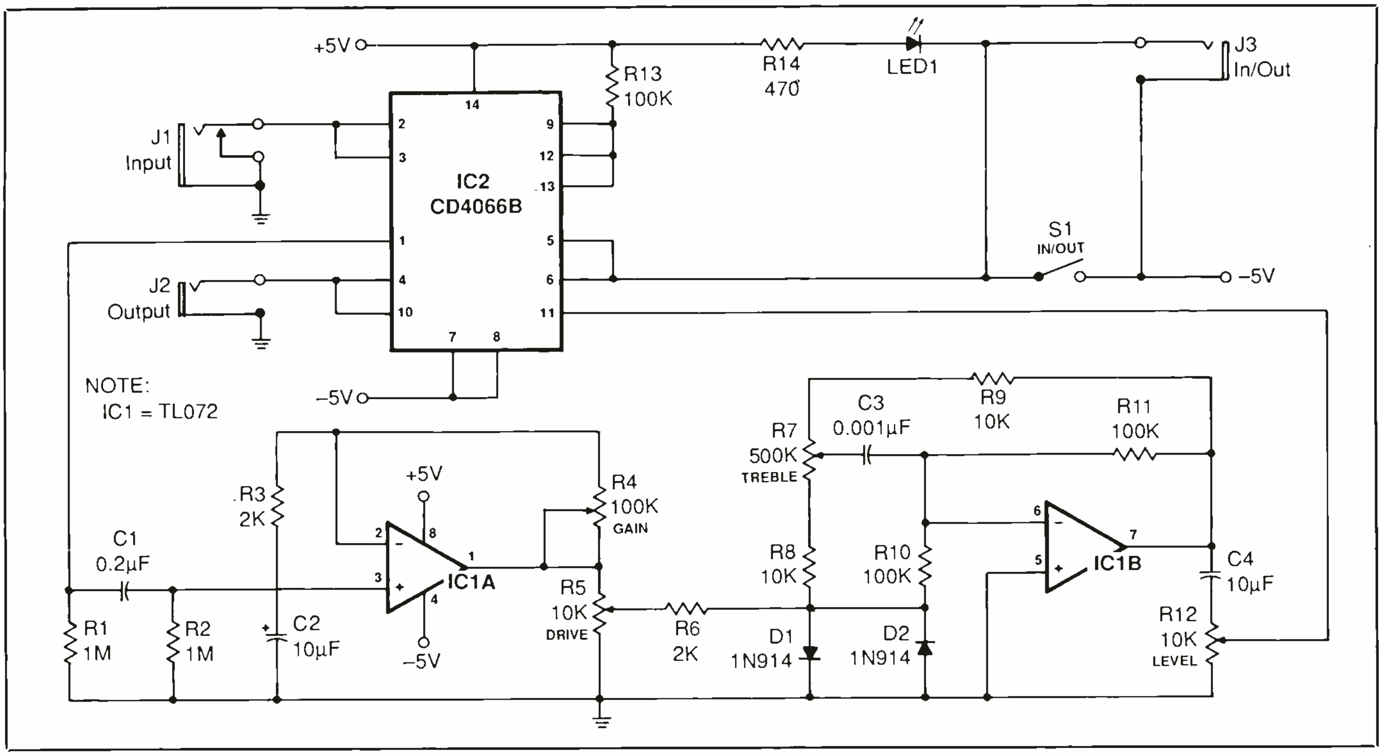


Fig. 1. Schematic diagram of basic signal-processing sections of the fuzz box.

clipping, it is processed by a high-frequency equalization network built around *IC1B*. TREBLE control *R7*, resistors *R8* and *R9* and capacitor *C3* form a cut/boost network whose effect begins at approximately 1.6 kHz and has a range of ±20 dB at 20 kHz. By altering the value of *C3*, the frequency response of the network can be varied for best results with different instruments. In fact, if you plan on using this project with a variety of instruments, you might want to consider incorporating into it a rotary switch that can be used to select the correct capacitor value for each instrument. Capacitor *C4* and LEVEL control *R12* couple the output of *IC1B* to the input of *IC2*.

Most special-effects devices for use in the playing of music require some sort of foot-switching to activate and disable them as desired without requiring hand control. This can be accomplished in either of two ways. One is use of an ordinary footswitch and several shielded cables to directly switch the audio signal. There are a number of disadvantages to this approach, not the least of which is the expense of long runs of shielded cable and the fact that long cable lengths degrade the audio signal more than does the electronics package itself.

A better route to switching the accessory in and out of the signal path is to use a solid-state switch that switches the audio signal at the source and to control the switch with a voltage. In addition, using electronic footswitching makes possible computer control of the effects generated by the accessory, not to mention other options.

All switching in our fuzz-box accessory is accomplished with CMOS analog switch *IC2*. Resistor *R14* and light-emitting diode *LED1* pull pins 5 and 6 of *IC2* up to +5 volts, causing the input signal to be connected to OUTPUT jack *J2*. Closing *S1* or an external footswitch plugged into IN/OUT jack *J3* shorts pins 5 and 6 to −5 volts, lights *LED1* and turns on the fuzz effect. Because the footswitch is switching only a dc control voltage, expensive shielded cable can be replaced by low-cost zip cord or other two-conductor cable.

The fuzz-box accessory requires a dual-polarity power supply that delivers +5 and −5 volts at its output for driving the basic signal-processing circuits. Though batteries could have been used to power the project, an ac-operated power supply is more suitable for extended periods of use. A suitable power-supply circuit for this project is shown schematically in Fig. 2. Power transformer *T1* can be either an external plug-in wall-type device or an on-board unit. It delivers stepped down 12.6 volts ac at its secondary, which is rectified to pulsating dc by bridge rectifier *RECT1*. The pulsating dc is then smoothed to +22 and −22 volts dc by *C5* and *C6*, which are then sent to positive and negative voltage regulators *IC3* and *IC4*. The +5- and −5-volt outputs from the regulators are bypassed by *C7* and *C8*, which eliminate noise and transients on the supply lines, be-

PARTS LIST

Semiconductors

D1,D2—1N914 or 1N4148 silicon signal diode
IC1—TL072 low-noise dual operational amplifier
IC2—CD4066B quad analog switch
IC3—7805 +5-volt regulator
IC4—7905 −5-volt regulator
LED1—Jumbo red light-emitting diode
RECT1—50-PIV, 1-ampere bridge rectifier

Capacitors (25-WV or greater)

C1—0.2-μF polypropylene
C2,C4—10-μF tantalum or electrolytic
C3—0.001-μF polypropylene
C5,C6—1,000-μF electrolytic
C7,C8—10-μF electrolytic

Resistors (¼-watt, 1% tolerance metal-film)

R1,R2—1 megohm
R3,R6—2,000 ohms
R8,R9—10,000 ohms
R10,R11,R13—100,000 ohms
R14—470 ohms
R4—100,000-ohm, pc-type trimmer potentiometer (as many as needed for different musical instruments—see text)
R5,R12—10,000-ohm, panel-mount audio-taper potentiometer
R7—500,000-ohm, panel-mount linear-taper potentiometer

Miscellaneous

F1—¼-ampere slow-blow fuse
J1—¼" transfer phone jack
J2,J3—¼" phone jack
S1—Spst slide or toggle switch
T1—12.6-volt, 200-mA power or plug-in wall transformer (see text)
Circuit board (see text); suitable enclosure; pointer-type control knobs for potentiometers; spst switch for switching on and off power (optional—see text); spst footswitch (see text); rubber grommets; ac line cord (if internal power transformer is used—see text); fuse block; dry-transfer lettering kit and clear spray acrylic; shielded cable and hookup wire; panel clip or clear epoxy cement for LED1; power jack if plug-in wall transformer is used for T1 (see text); small-diameter heat-shrinkable tubing; ½" spacers; machine hardware; etc.

fore delivery to the basic signal-processing circuits.

Note the odd arrangement of the power supply circuit. Instead of the secondary wiring directly across the ac inputs of *RECT1*, only one side of this winding goes to *both* ac inputs. The other side of the secondary winding serves as the ground reference for the power-supply and signal-processing circuits. This odd arrangement eliminates the need for a separate secondary winding and bridge rectifier for each polarity output.

Absent from the Fig. 2 circuit is a power switch in the primary side of *T1*'s circuit. If you normally leave your musical-instrument setup plugged into an ac outlet and turn it on and off with its own power switches, you might consider including an spst switch in the power supply, placing it between the ac line input and input side of fuse *F1*. Otherwise, you can either unplug the project's line cord when you are finished using it or power down your system with a multiple-outlet ac strip.

Construction

There is nothing critical about component layout and conductor routing in this project. Therefore, just about any traditional wiring technique can be used in building the fuzz box. If you wish, you can design and fabricate a printed-circuit board on which to wire the components. Alternatively, you can use perforated board with holes on 0.1-inch centers and suitable Wire Wrap or/and soldering hardware. Whichever method you choose, use sockets for *IC1* and *IC2*.

As shown in the interior view of the finished project in Fig. 3, the prototype was wired on a Radio Shack Cat. No. 276-154 prototyping perforated board. This board has more than enough room on it to accommodate all components except the power transformer and those that mount on the front and rear panels of the selected enclosure. Note that the only potentiometer control that mounts on the circuit-board assembly is GAIN trimmer *R4*; all other pots mount on the project's front panel.

Referring back to Fig.s 1 and 2 install and wire together the components that go on the circuit-board assembly. If you are not using a printed-circuit board, use a pen or pencil to go over each wire run on the schematic diagrams (or photocopies of them) as you make it in the project. Doing this will eliminate wiring errors. Do *not* install the DIP ICs in their sockets until after initial voltage checks have been performed.

You can house your fuzz-box accessory inside any enclosure that will accommodate it. The enclosure can be plastic, metal or a combination of the two, such as the commonly available project boxes. Machining of the front panel of the selected enclosure includes drilling of the mounting holes for the three primary potentiometer controls (DRIVE, TREBLE and LEVEL), the LED and POWER switch (the last if used), as shown in the lead photo. The rear panel requires four holes, three for the INPUT, OUTPUT and IN/OUT jacks and entry of the power cord.

Size all holes to accept the components in which they are to be mounted. The only exception is the hole for the IN/OUT jack (*J3*) if the panel on which it mounts is made of metal. In this case, the hole for this jack must be made large enough to accommodate an insulating shoulder fiber washer or rubber grommet that will assure that the his jack mounts in place without making electrical contact with the metal of the panel. Alternatively, you can make the mounting hole much larger than needed and mount over it a thin plastic or fiber panel on which you mount the jack.

Drill holes in the floor of the enclosure for mounting the circuit-board assembly. Then, if you are using an internal power transformer, drill mounting holes for it through the floor panel. Locate the transformer as far as possible from the audio cir-

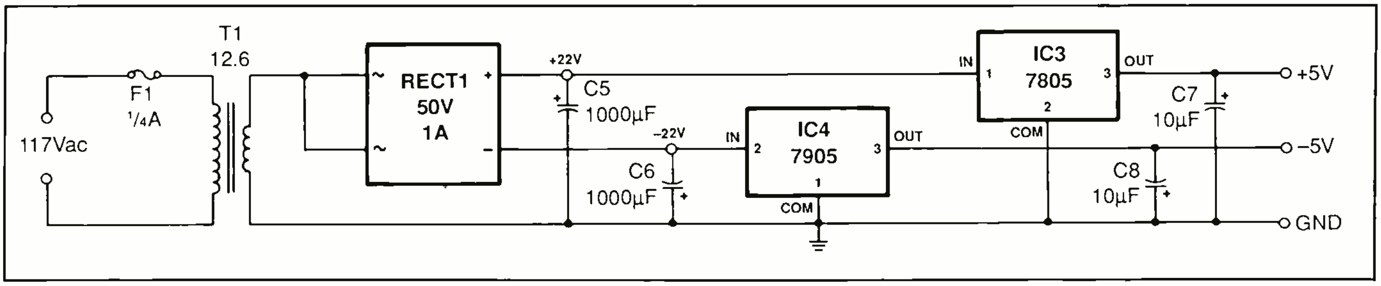


Fig. 2. Dual-polarity regulated dc power supply required by the fuzz box. Power transformer T1 can be either a standard internal type or an external plug-in wall type.

cuitry. If you are using an external plug-in wall transformer, its output cable can be wired directly to the appropriate points on the circuit-board assembly or be routed as needed through a suitable jack mounted on the rear panel. You can mount the fuse block on the circuit-board assembly or the floor or rear panel of the enclosure. If you choose the latter, drill a hole for it in the selected panel location.

When you are finished machining the enclosure, deburr all holes. Then thoroughly clean it and allow it to dry. When dry, label the front and rear panels with a dry-transfer lettering kit. Protect the lettering with two or more light coats of clear acrylic spray, allowing each coat to dry before spraying on the next.

Mount the potentiometer controls, switch (if used) and jacks in their respective locations. Make absolutely certain that IN/OUT jack *J3* is electrically insulated from any metal! Place pointer-type control knobs on the shafts of the potentiometers. If the power transformer is to be mounted internally, use suitable-length machine hardware to mount it into place and line the ac line cord's entry hole with a small rubber grommet. Otherwise, mount the external transformer's jack in its hole in the rear panel. Mount the fuse block in place if it is not already installed on the circuit-board assembly.

Strip 1 inch of insulation from both ends of an 8-inch shielded cable. Separate the shield conductors back to where the outer insulation begins and strip ¼ inch of insulation from the inner conductor at both ends. Tightly twist together the fine wires in the shield and the inner conductor and sparingly tin all four bundles with solder. Connect and solder one end of this cable to the appropriate points on the circuit-board assembly.

Prepare suitable-length hookup wires for connection between the circuit-board assembly and the panel-mounted jacks, controls, LED, IN/OUT switch and fuse block and POWER switch if used. Connect and solder one end of each of these wires to the appropriate points in the circuit.

If you are using an internal power transformer, route the free end of the ac line cord through its rubber grommet into the enclosure. Tie a strain-relieving knot in the cord inside the enclosure about 6 inches from the free end. Tightly twist together the fine wires at the free end of the ac line cord and sparingly tin with solder.

Assuming you have included a POWER switch, crimp one line-cord conductor to one lug of the switch and solder the connection. Then crimp and solder the free end of one of the wires coming from the fuse block to the free lug on the POWER switch. Slide a 1-inch length of small-diameter heat-shrinkable tubing over the free end of the other wire coming from the fuse block. Strip an additional ¼ inch of insulation from the end of this wire. Then tightly twist the bare conductor with the bare conductors of one of the power-transformer's primary. Solder the connection. Slide the tubing over the connection to completely cover it and shrink into place.

Pretin the other lead of the transformer's primary with solder. Strip an additional ¼ inch of insulation from the other line cord's conductor. Slide a 1-inch length of heat-shrinkable tubing over the transformer's primary lead. Twist together this lead and the other line cord lead and solder the connection. Shrink the tubing over the connection to insulate it.

Trim both power transformer secondary leads to 4 inches. Strip ¼ inch of insulation from each and tightly twist together the fine wires and tin with solder. Connect and solder one lead to the common ac input tie point for *RECT1* and the other lead to a convenient circuit-board assembly ground.

The foregoing assumes that the power transformer is to be installed internally. Of course, if you are using an external transformer, you connect it to the project differently. If you are using a jack, wire this into the circuit just as you would wire the the internal transformer's secondary into place. If the connection is made directly, you must remove the jack on the end of the transformer's cord, separate the conductors, feed them through a grommet-lined hole, tie a strain-relieving knot in the cord and wire it into the circuit as you would the secondary of any other transformer.

Once the transformer is wired into

the circuit, use ½-inch spacers and suitable machine hardware to mount the circuit-board assembly into place. Then connect and solder the free ends of the wires coming from the board to the controls, jacks and IN/OUT switch. The only wires that will not be connected up to this point are those for the LED.

Trim the cathode lead of the LED to ½ inch long and form a small hook in the stub. Mount the LED in its hole in the front panel, using either a panel clip or a small daub of fast-setting clear epoxy cement. Slide a 1-inch length of heat-shrinkable tubing over the two LED1 wires coming from the circuit-board assembly. Identify which of these wires goes to the cathode of the LED and crimp and solder it to the trimmed lead. Slide the tubing up over the connection until it is flush with the bottom of the LED's case. Repeat for the anode lead and wire. Shrink the tubing snug around the connections.

Checkout & Use

With *IC1* and *IC2* still not installed in their sockets, plug the fuzz box's line cord (or external transformer) into a convenient outlet and, if you installed it, set the POWER switch to ON. Now use a digital dc voltmeter or multimeter set to the dc volts function to perform preliminary voltage checks. All voltage measurements must be made with respect to circuit ground, which means that the negative probe of the meter should connect to the negative (−) lead of *C5* or *C7*. Then use the positive lead to probe the specified points in the circuit. (Note: If you use an analog meter to make the following measurements, transpose the meter's common and positive leads to take the negative-voltage readings.)

First check the output of the positive voltage regulator by touching the meter's positive probe to the OUT pin of *IC3* (pin 3) and note that the reading should be +5 volts. Do the same

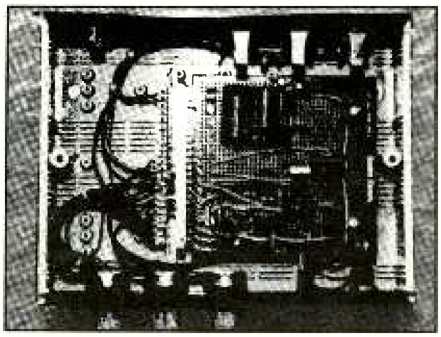


Fig. 3. Interior view of author's prototype wired on perforated project board. Circuit can also be wired on a printed-circuit board of your own design.

for the negative voltage regulator by touching the probe to the OUT pin of *IC4* (pin 3 again) and note that the reading should now be −5 volts.

If all is okay so far, touch the meter's positive probe to pin 14 of the *IC1* and pin 8 of the *IC2* sockets. In both cases, the readings should be +5 volts. Touching the meter's positive probe to pins 5 and 6 of the *IC1* and pin 4 of the *IC2* socket should yield a −5-volt reading.

If you do not obtain the proper reading at any point, power down the circuit and rectify the problem before proceeding. Double check all your wiring and make certain that the electrolytic capacitors and diodes are wired into the circuit in proper polarity and that regulators *IC3* and *IC4* are properly based.

Once you obtain the correct voltages at the specified points, power down the project and install *IC1* and *IC2* in their respective sockets. Make certain that you orient these ICs properly and that no pins overhang the sockets or fold under between ICs and sockets. Exercise the usual safe-handling procedures for MOS devices when handling these ICs.

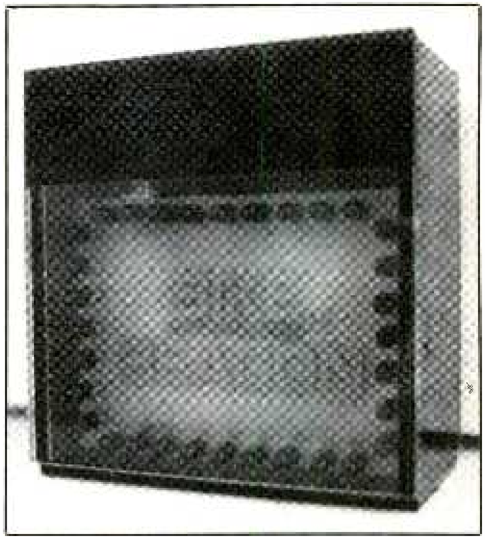
Plug a musical instrument into INPUT jack *J1* and connect a suitable cable between OUTPUT jack *J2* and the input of your amplifier. Turn the amplifier's volume control to a very low setting, just in case you miswired the circuit. Now plug the fuzz box into an ac outlet and power up the system. If pure high-level dc voltage is fed into the fuzz box, it can damage your speakers, your amplifier, your ears or all three!

Set all potentiometer controls in the project to mid-rotation and IN/OUT switch *S1* to OUT (*LED1* extinguished). At this point, you should hear your musical instrument as it is being played. Setting *S1* to IN should produce audible distortion. While the instrument is being played, vary the settings of the three front-panel controls and listen for the effects each produces, as well as verify that they are working as they should.

To properly set GAIN trimmer control *R4*, set the DRIVE control fully clockwise and adjust the setting of *R4* until the distortion stops increasing. If you set *R4* too low, the circuit will not produce maximum distortion, while too high a setting will increase the audible noise level without increasing the distortion effect.

Proper setting of *R4* depends on the particular musical instrument with which it is used. If you are planning to use the fuzz box with only one instrument—say, an electric guitar—a one-time-only setting is needed. However, if you plan on using it with a variety of instruments with different requirements, you can install as many 100,000-ohm trimmer potentiometers as you expect to use the project with different types of instruments and a nonshorting rotary switch to select each as needed. Of course, you must "calibrate" each trimmer for the particular instrument assigned to that setting of the switch.

For best signal-to-noise ratio (S/N) keep the setting of DRIVE control *R5* as high as possible, while keeping LEVEL control *R12* turned down. Aside from this, no special settings are required for the fuzz box. During use, if the fuzz box seems to be generating excessive noise, check your instrument for improper shielding or excessive noise generation. ME



Bicycle Safety Flasher

Aids visibility and increases safety when cycling at night

By Michael Swartzendruber

Now that evening comes much earlier, many bicyclists are pedaling around in the dusky hours near or after sunset. This period is particularly dangerous for bike riders because motor-vehicle drivers are often straining to see obstacles—including cyclists—under less-than-ideal light conditions.

One way to really get the attention of drivers is to use a flashing red light, which is the universal signal of danger to drivers. Though a repetition of equally spaced flashes might do the trick, you are much better off using a sequential running red light that adds a note of urgency to the danger signal. This is exactly what the Bicycle Safety Flasher described here is designed to do. Mounted on the rear of your bicycle (you can mount one on the front, too, if you build two Flashers), it pulses a series of 32 high-brightness red LEDs that pinwheel in one direction and then the other. This easy-to-build project uses readily available components and runs on two 9-volt alkaline batteries for a long time.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the Bicycle Safety Flasher's circuit. This circuit is made up of an interesting combination of a few elementary electronic building blocks. It uses a simple clock source, an up/down counter with a count-recycle/reverse support circuit and a 1-of-16 data distributor.

Power for the circuit is provided by two 9-volt batteries wired in parallel with each other to deliver a long operating time. The 9-volt dc source, shown as *B1* in Fig. 1, is converted to a TTL-compatible 5-volts dc through 7805 regulator *IC6*. The output from the voltage regulator is further stabilized by filter capacitor *C2*. To ease the power burden on the battery supply, all ICs in this circuit are low-power devices, as specified in the Parts List.

The clock source for the Bicycle Safety Beacon is low-power 555 timer *IC1*, shown here wired in an astable pulse mode. The output pulse train at pin 3 of this timer is delivered directly to the input of 74191 up/down counter *IC2*. This counter is very versatile. It can count up in binary from 0 to F (hex) or down from F to 0, depending on the logic level of its up/down count input at pin 5. Up-counting occurs when pin 5 is at a logic low, while down-counting occurs when pin 5 is at a logic high. Up/down control is crucial to operation of the Bicycle Safety Flasher.

Up/down counter *IC2* counts the pulses from the *IC1* timer. Each time *IC1* pulses, the binary state of the

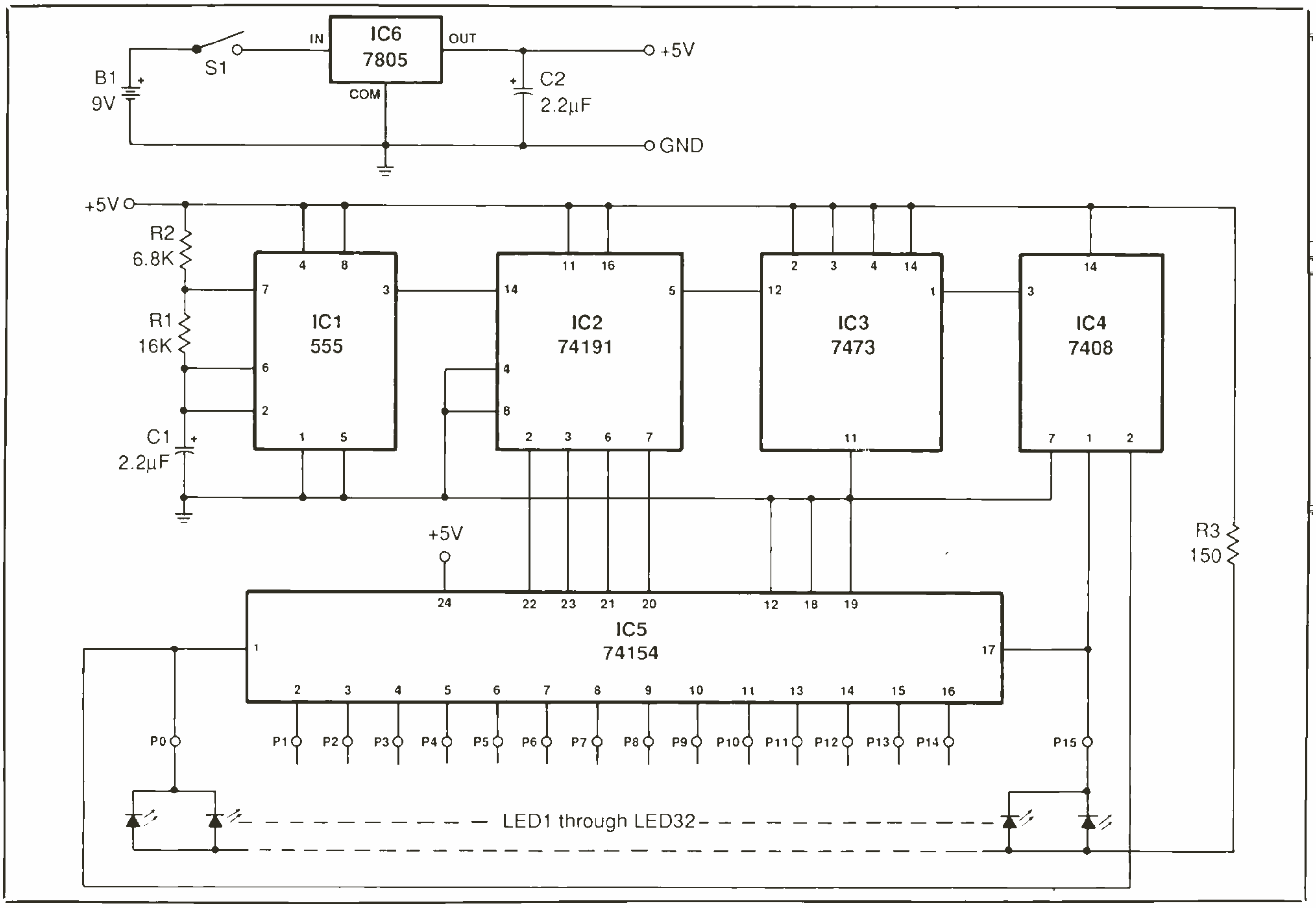


Fig. 1. Complete schematic diagram of the Bicycle Safety Flasher.

74191 counter is incremented or decremented by 1. The four Q outputs of the *IC2* counter at pins 2, 3, 6 and 7 are sent to output-select pins 22, 23, 21 and 20, respectively, of 74154 1-of-16 distributor *IC5*.

Of the 16 output data lines available on the 74154 chip, one and only one can be enabled at any given instant. The particular output line selected at any moment is determined by the binary value applied to the output-select pins of the 74154. Therefore, as the counter is incremented or decremented with every clock pulse, the output lines are selected in an ascending or descending sequential order in *IC5*.

As an output line of the data distributor is enabled, whatever activity present at its input is passed to the output line. In this circuit, the data line is tied low, which causes an output line of the 74154 to pulse low every time it is enabled. Each time the output line is pulled low it sinks current for the LEDs connected between that output pin and the + 5-volt power-supply line through limiting resistor *R3*. This causes the LEDs in that line to momentarily turn on as long as that output remains low.

If just the elements so far described were all that there were to the circuit, the project would merely count from 0 to F and would continuously repeat for as long as power is applied to the circuit. This would cause the outputs of the 74154 to be enabled from 0 to 15 sequentially. However, there is a "pennywhistle" built into this Bicycle Safety Flasher that causes the counter to reverse counting direction whenever a maximum or minimum is reached. This added feature enhances the Flasher's visual display to more quickly get the attention of motorists in its vicinity.

The fact that each line of the 74154 1-of-16 data selector is pulled low every time the counter holds the binary value of that output line becomes useful to the count recycle circuitry.

Output 0 pin 1 and output 15 pin 17 on the 74154 represent the minimum and maximum count of the 74191. Each time one of these values is reached, the count reverses direction. That is, if the counter is counting up and reaches 15, the count recycle/reverse circuit will change the state of the up/down input to the counter to

PARTS LIST

Semiconductors
IC1—NE555 low-power timer
IC2—74LS191 binary up/down counter
IC3—74LS73 dual JK flip-flop
IC4—74LS08 quad 2-input AND gate
IC5—74LS154 1-of-16 data selector
IC6—7805 +5-volt regulator
LED1 thru LED32—T-1¾ jumbo red light-emitting diode
Capacitors (50 WV)
C1—2.2-µF electrolytic
C2—2.4-µF tantalum
Resistors (¼-watt, 5% tolerance)
R1—16,000 ohms
R2—6,800 ohms
R3—150 ohms
Miscellaneous
B1—Two 9-volt batteries
S1—Miniature spst toggle switch
Printed-circuit boards or perforated board with holes on 0.1-inch centers and suitable soldering hardware (see text); suitable enclosure (see text for types and details on custom Plexiglas type); circuit-board mounting hardware; two snap-type connectors for B1; ribbon cable; hookup wire; solder; etc.

make the counter start counting down to 0. When 0 is reached by the counter, the recycle/reverse circuit again changes the state of the up/down count pin of the 74191, causing the count to reverse once again and resume up-counting.

Reverse-count direction is accomplished with simple circuitry. Normally, each line of the 74154 is held high and pulses low only when that output line is selected. If both the 0 and 15 output pins are applied to both inputs of a two-input AND gate (*IC4* in Fig. 1), the output of that gate will normally be high. The output of the gate pulses low whenever a maximum or a minimum value is reached by the counter. The output pulse from pin 3 of AND gate *IC4* is used to clock JK flip-flop *IC3*, which is wired here in toggle mode. The Q output at pin 12 of *IC3* is delivered to the pin 5 control input of *IC2*.

Each time the output 0 or 15 pin of *IC2* is selected, the momentary low on one of these pins causes the output of the AND gate in *IC4* to pulse low momentarily. The low-going pulse toggles the *IC3* flip-flop, whose output changes states and thus reverses the count direction of 1-of-16 data distributor *IC2*.

When power is applied to the circuit by closing *S1*, *IC1* begins to generate a pulsed output whose frequency is approximately 20 kHz with the RC values specified. These pulses are delivered to counter *IC2* that, in turn, outputs a binary value to data selector *IC5*. Whichever line is selected is pulled low, causing the LEDs connected to that pin to glow momentarily.

The counter changes its binary state with each pulse delivered to it from the 555 timer. This changing state causes the next sequential output of the 74154 to be pulled low to cause the LEDs to flash in a sequential or "running-light" manner.

Whenever the maximum or minimum count is reached, count-reverse/recycle flip-flop *IC3* changes the counting direction of *IC2*. This causes the running light to change direction each time the count reaches one of these values.

Construction

This circuit is best built on two printed-circuit boards for three rea-

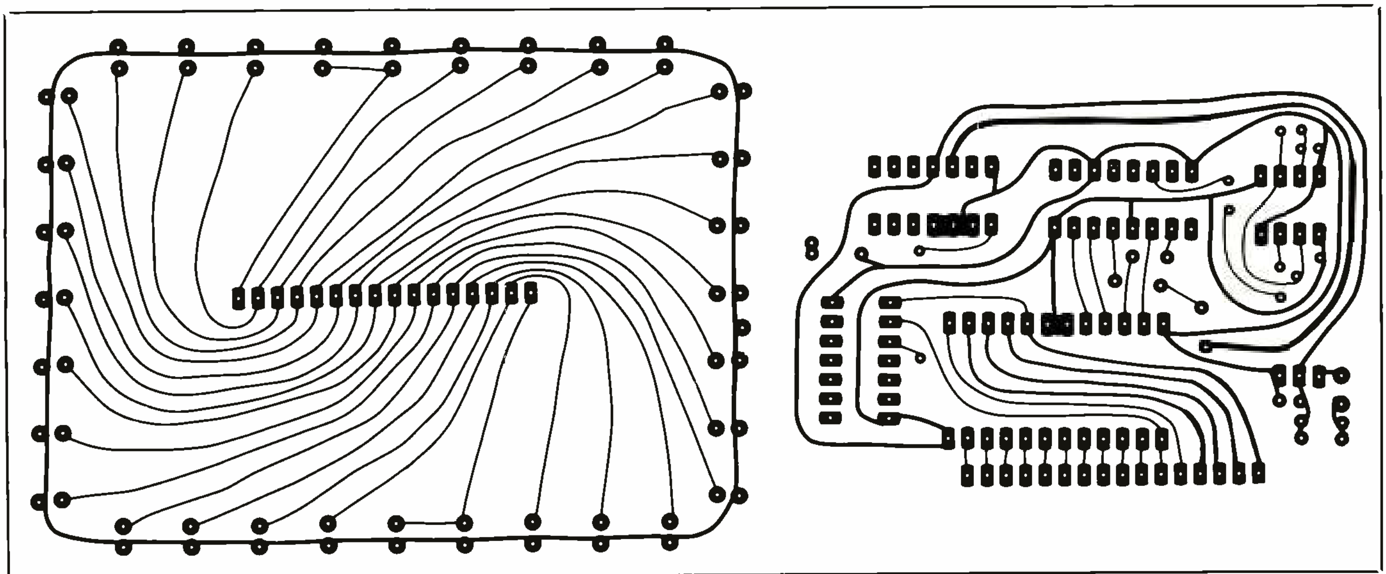


Fig. 2. Actual-size etching-and-drilling guides for LED display (A) and main (B) printed-circuit boards. Trim these boards to exactly the same size.

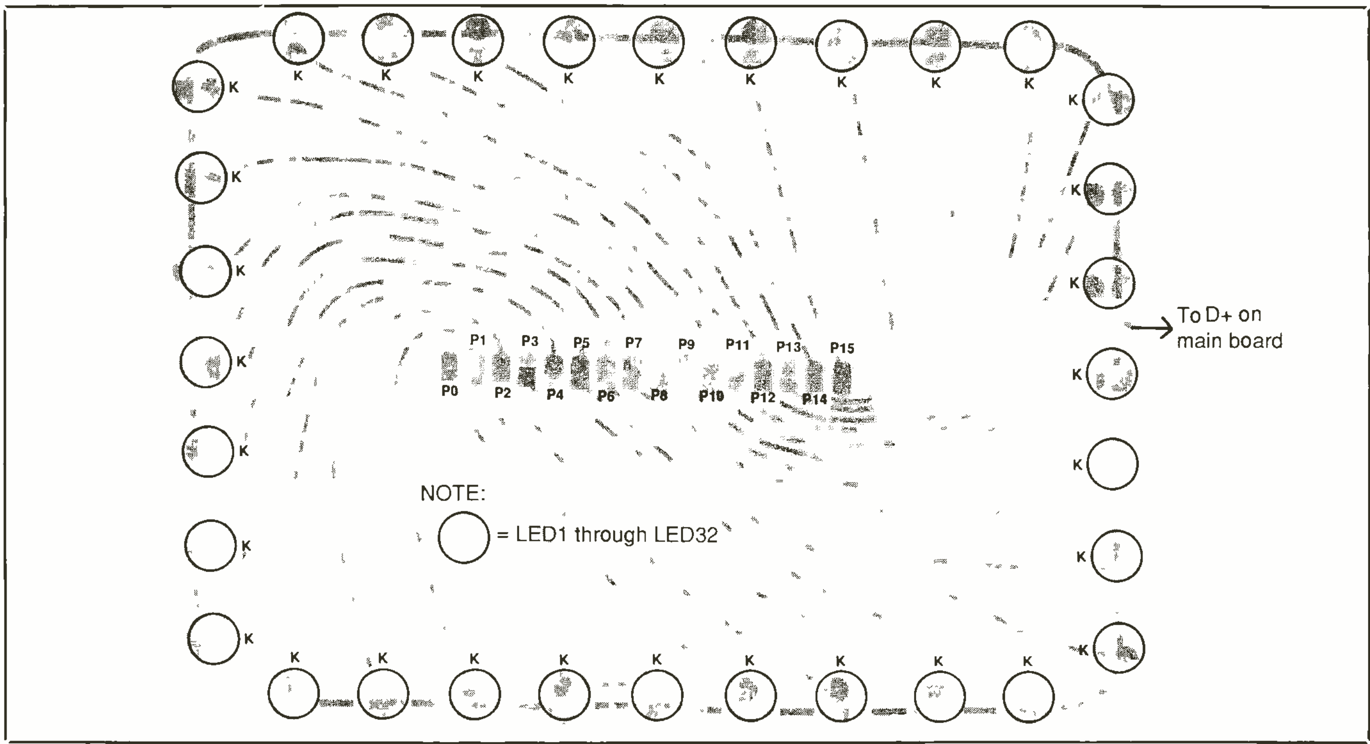


Fig. 3. Wiring guide for LED display board.

sons. One is that the two boards, whose actual-size etching-and-drilling guides are shown in Fig. 2, can easily be fabricated on a single 4 × 6-inch printed-circuit blank. After etching the boards, trim both to exactly 4 × 3⅛ inches and then drill all holes. The second reason is that the display board can be easily redesigned to suit any other purpose. And the third is that this counter circuit has many other possible applications, making it desirable to have it available as a separate module that can be used as needed to fit any of those applications. Of course, if you wish, you can substitute perforated board that has holes on 0.1-inch centers and appropriate Wire Wrap or/and soldering hardware for the pc board.

In this section, we will discuss construction of the project on printed-circuit boards. Once you have etched, drilled and trimmed the boards, begin assembling the project by wiring the LEDs onto the display board, as illustrated in Fig. 3. Make certain that you observe correct polarity for all 32 of these LEDs. You can usually tell which lead of a LED is connected to the cathode. This is the one near the flat on the domed plastic case of the device or the shorter of the two leads. However, if you have any doubt, check the data sheet for the particular LEDs you are using.

Note that all LED anodes, which share a common tie point in the circuit, go into the holes near the edges of the board, and the cathode leads go into the holes nearer the center of the board. Install the LEDs on one edge of the board at a time. Use soldering heat judiciously. If you cannot heat sink each lead as it is being soldered into place, solder only the anode lead of each LED and then return to the first LED and solder the cathode lead of each LED into place. This way, soldering heat is less likely to damage the LEDs. Install all LEDs so that they are the same height above the board's surface, plugging them in as far as the point where their leads get wider.

Prepare five ¾-inch and one 1½-inch solid No. 22 hookup wires by stripping ¼ inch of insulation from both ends of each. Bend the exposed conductors at a right angle to the wires to form U shapes. Plug these wires into the holes labeled J on the main board (see Fig. 4) and solder into place.

Install and solder into place the five DIP sockets in the IC1 through IC5 locations. As you solder each socket pin to the copper pad on the bottom of the board, be careful to avoid creating solder bridges between the closely spaced pads and conductors.

Strip ¼ inch of insulation from both leads of two 9-volt battery snap connectors. Tightly twist together the fine wires of each and sparingly tin with solder. Plug the red-insulated leads into the holes labeled B1+ and the black-insulated leads into the holes labeled B1− and solder all four connections. Loosely twist the leads of the battery connectors together. Do not twist these leads so tightly that any of the connectors are stressed.

Strip ¼ inch of insulation from

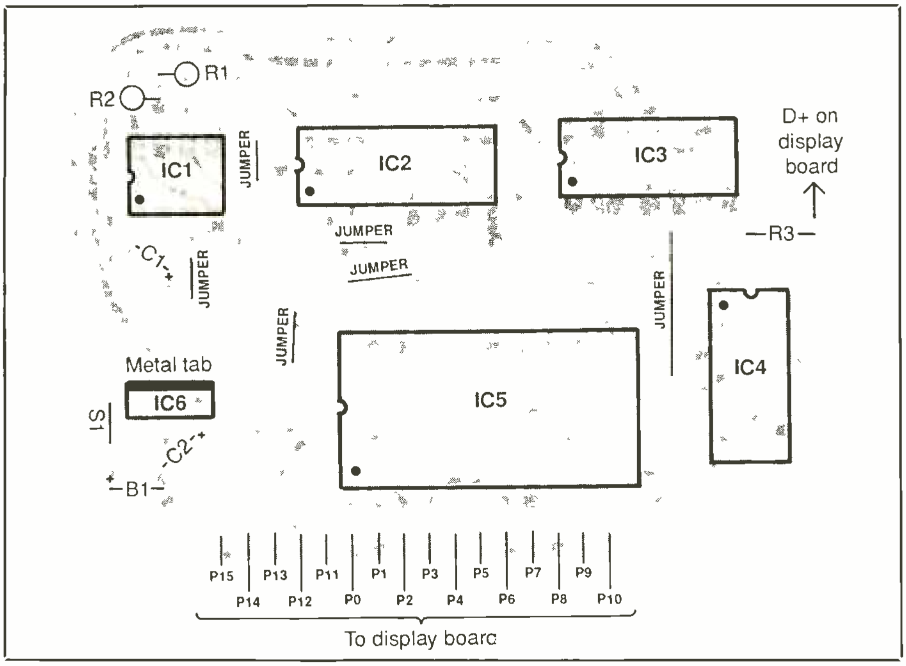


Fig. 4. Wiring guide for main board.

both ends of two 4-inch-long No. 22 solid hookup wires. Solder one end of each into the holes labeled S1. Loosely twist these wires together, leaving ½ inch untwisted at the free ends. Crimp and solder the free ends of these wires to the lugs of spst POWER switch *S1*.

Carefully separate a 6-inch length of 16-conductor ribbon cable into separate 5- and 11-conductor cables. Carefully separate the conductors at both ends of the 11-inch cable a distance of ½ inch and each third conductor an additional ½ inch. Strip ¼ inch of insulation from both ends of each conductor, twist together the fine wires in each conductor and carefully tin with solder. Use solder and soldering heat judiciously to prevent charring the insulation.

Plug the conductors at one end of this cable into the holes in the main board with the first conductor in the hole labeled P0 and solder into place. Plug the second conductor into hole P1, the third into hole P2 and so on up to the eleventh conductor in hole P10, soldering each into place as it is installed. (You may find it easier to solder the conductors into place in groups of three.)

Prepare the other ribbon cable in the same manner as above. Plug one end of this cable into the holes labeled P11 through P15 in the main board and solder into place.

Install *R1* and *R2* into the circuit board on-end and *R3* flat against the board. Before soldering *R3* into place, strip ¼ inch of insulation from both ends of a 7-inch-long hookup wire. Plug one end into the hole labeled D+ and solder the resistor and wire into place.

Next, install *C1* and *C2* in their respective locations, making sure they are properly polarized before soldering their leads to the pads on the board. During installation, press the electrolytic capacitor as close as possible to the board before soldering. When mounting the tantalum capacitor near *IC6*, leave approximately ¼ inch between its body and the surface of the circuit board.

Now install 7805 voltage regulator *IC6* as shown. Position the main board so that *R3* is to the right and the battery connectors are to the left. The ribbon cables should be on the side of the board closest to you. Now insert the regulator so that the metal mounting tab is facing away from you. With it properly oriented, solder the regulator's pins to the bottom of the board.

Carefully inspect the main board

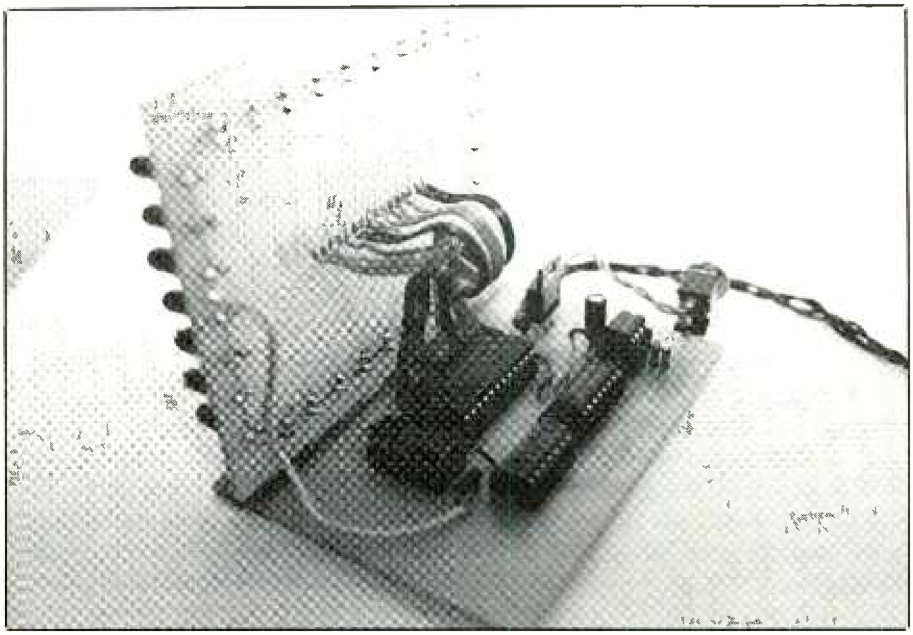
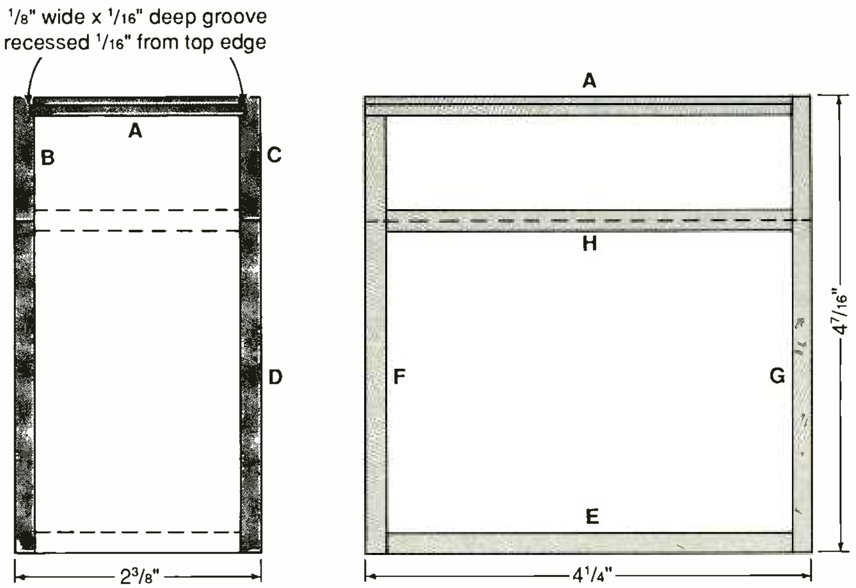


Fig. 5. Photo shows how ribbon cables wire both boards to each other.

for cold or/and bad soldered connections, solder bridges and short circuits. Solder any connections you have missed and reflow the solder on any suspicious connections. If you locate a solder bridge, use solder wick or a vacuum-type solder sucker to remove it.

With the POWER switch set to OFF and no ICs installed in the *IC1* through *IC5* sockets, plug a 9-volt battery into each of the snap connectors. Connect the common lead of a dc voltmeter or a multimeter set to the dc volts function to a convenient circuit ground point, such as one of the negative battery clips. Then use the meter's "hot" probe to touch pins 4, 6, 7 and 8 of the *IC1* socket; pins 11 and 16 of the *IC2* socket; pins 2, 3, 4 and 14 of the *IC3* socket; pin 14 of the *IC4* socket; pin 24 of the *IC5* socket; and the D+ pad on the bottom of the board. In all cases, the readings obtained should be approximately +5 volts. Readings taken at all other socket pins should be 0 volt.

If you do not obtain the proper reading at any point in the circuit, power down the project and remove the batteries. Rectify whatever is causing the problem before proceeding.



A Top: 4 1/16" x 2 1/8" x 1/8" smoked
B Rear: 4 7/16" x 4 1/4" x 3/16" smoked
C Upper front: 4 1/14" x 1 1/4" x 3/16" smoked
D Lower front: 4 1/4" x 3 3/16" x 3/16" smoked
E Bottom: 3 7/8" x 2" x 3/16" smoked
F Left side: 4 1/4" x 2" x 3/16" smoked
G Right side: 4 7/16" x 2" x 3/16" smoked
H Center divider: 3 7/8" x 2" x 3/16" smoked

Note: Route 0.080-inch-deep by 1/16-inch-deep grooves down the length of both side panels, spacing the first 5/8 inch and the second 1 5/8 inch from the rear edge of each panel. When assembling the enclosure, make sure these grooves are on the inside of the box.

Fig. 6. Fabrication and assembly details for optional custom Plexiglas enclosure described in text.

Once you have obtained the proper voltage readings, position the main board in front of you so that the battery snap connectors are to the left and the wire coming from hole D+ is to the right. The two ribbon cables should be on the side of the board nearest to you. Now place the display board LED side down and the D5 hole to your right between you and the main board.

All cable and wire connections to the display assembly are to be made to the *solder* side of the board. Therefore, be sure to leave about 1/8 inch of bare wires visible above the surface of the solder pads as you solder them into place to avoid charring the insulation.

Starting with the 11-conductor ribbon cable coming from the main board, insert the left-most conductor into hole P0 on the display board and solder into place. The remaining conductors in this cable plug into the holes in the display board in sequential order from left to right. As you solder these conductors into place, be very careful to avoid creating solder bridges between the closely spaced copper pads on the board. After soldering all 11 conductors into place, clip excess wires from the other side of the board.

There should be five unoccupied pads in the center of the display board. These will be occupied by the conductors in the 5-conductor ribbon cable coming from the main board. Note that hole P11 on the display board is on the far right and that hole P15 is on the left of the five-hole group. To insert the 5-conductor cable correctly into the holes in the display board, you must put a half-twist in the cable. Feed the cable under the 11-conductor cable previously installed, as shown in Fig. 5, to ease the wiring task. Bear in mind that if this cable is not installed in proper sequential order, the running lights will not flash sequentially.

Plug the DIP ICs into their respective sockets, as shown in Fig. 4. Make sure each is properly oriented and that no pins overhang the sockets or fold under between ICs and sockets.

You can house the project inside any enclosure that will accommodate the circuit-board assemblies, batteries and switch. A small plastic enclosure with removable top panel is almost ideal for this purpose. If you use this type of enclosure, replace the removable panel with a red transparent panel.

If you use a standard project box for the enclosure, mount the POWER switch in a convenient location where it will not interfere with either the circuit-board assemblies or batteries. Also, mount some mechanical arrangement that will allow you to anchor the project to the rear of your bicycle. Mount the circuit-board assemblies to the rear wall of the enclosure with 4-40 × 1¼-inch machine screws, nuts and lockwashers, placing ½-inch spacers between the two boards and ¼-inch spacers between the main board and rear wall of the enclosure.

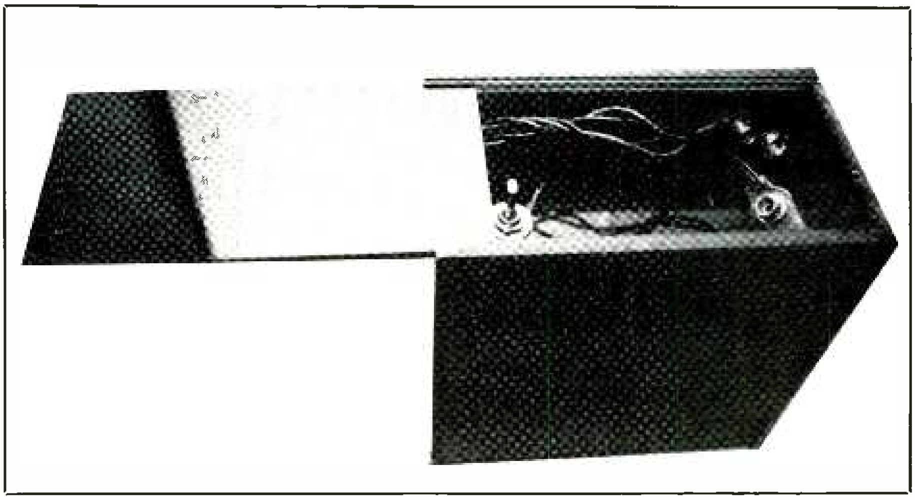


Fig. 7. Top panel slides back to provide access to switch and battery compartment.

An attractive alternative to the common project-box enclosure is shown in the lead photo. This is a custom enclosure you make yourself from sheet Plexiglas, details for which are given in Fig. 6. Note that all panels are fabricated from 3/16-inch-thick smoked Plexiglas except the lower-front, which is made from the same thickness clear or transparent red Plexiglas, and the slide-on/off lid, which is made from ⅛-inch-thick smoked Plexiglas.

When making the custom enclosure, use a fine saw to cut all panels to size and finish all edges with fine emery cloth and polish them with No. 0000 steel wool. Clip one corner off the center-divider panel to permit the leads from the battery connectors to go from the lower to the upper compartments. Also, drill a mounting hole in this panel for *S1*, locating it near the left end of the panel and positioning it so that, when the switch is mounted, it will not interfere with the circuitry in the lower compartment.

Route a ⅛-inch-wide by 1/16-inch-deep channel along the inside top edges of the rear and upper-front panels into which the top panel will slide. Space this channel 1/16 inch from the top edges of both panels. Similarly, route 0.080-inch-wide by 1/16-inch deep grooves down the length of both side panels, spacing the first ⅝ inch and the second 1⅝ inch from the rear edge of each panel.

If you do not have access to the proper tools or do not have enough experience cutting and finishing Plexiglas panels, you can usually have this done by the dealer from which you purchase the Plexiglas. Just give exact dimensions for all panels and instructions for cutting the top-panel grooves. Of course, be prepared to pay for this service, about $15 more or less, depending on where you buy.

Assemble the enclosure using the appropriate cement for bonding the panels together or cyanoacrylate cement (super glue). Make sure that the grooved sides of the side panels are facing inward and that the grooves that are spaced ⅝ inch from the edges are butted against the rear panel. If you work with the latter, be very careful to get it on only the panels where they join and not on your fingers or other items that may be nearby.

Regardless if you are using Plexiglas solvent or cyanoacrylate, the gluing process works best if you have the joints vertical as you apply the cement and allow it to set. The only panel that does not get bonded into place is the top, which must be allowed to slide on and off to give you access to the switch and batteries.

When both side, both front, the bottom and the rear panels have been bonded together and the cement has set, slide the circuit-board assemblies into the open top, using the grooves as guides, and push it down snug against the bottom panel. Make sure the battery snap-connector leads and the wires attached to the switch are at the top-left (viewing the enclosure upright from the front). Also, make sure the side on which the LEDs are mounted faces outward through the clear or red-tinted panel.

Mount the switch in the hole drilled for it in the divider panel. Then fit the panel into place, with the battery snap-connector leads out of the way in the notched-out area at the left-rear corner. Push the divider panel as far down as it will go. Then snap a battery into each connector. Flip the switch to "on" and observe that the LEDs light up in the manner described earlier. If all is okay, set the switch to "off" and slide the top panel into place.

To use the Bicycle Safety Flasher, you simply slide back the top panel (see Fig. 7) and flip the switch to "on." Replace the batteries when the light output from the LEDs diminishes noticeably. ME

Programmable Light Controller
(Conclusion)
Construction, installation, checkout and use details

By David Miga, CET

This concluding installment of a two-part article on building a sophisticated Programmable Light Controller for holiday, commercial and theatrical displays, finishes with how to build the Light Controller, installation details and checkout and use instructions.

Construction

Due to the sheer complexity of this project, use of printed-circuit boards (there are two, one main one and a separate smaller one for the display subassembly) on which to mount almost all of the components is highly recommended. Of course, you can go the route of perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware, but the assembly task will be very time-consuming and very prone to wiring errors if you are not extremely careful.

You can fabricate your own pc boards using the actual-size etching-and-drilling guide shown in Fig. 7. Alternatively, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. The following assembly details assume you are using a pc board.

Begin wiring the large main board by identifying where they go and install and solder into place the 77 jumper wires, referring to Fig. 8. Use solid bare wire for the shorter jumpers and insulated solid hookup wire for the longer ones.

Proceed to installing the large diodes, capacitors, resistors and transistors in that order. Next, mount all DIP ICs in their respective locations, making certain that they are properly oriented before soldering their pins to the pads on the bottom of the board. Lead identification for the 2SB544 transistors used for *Q1* through *Q5* is emitter (E), collector (C) and base (B) left to right when viewing the transistors with their leads pointing toward you and the rounded portion of their cases facing down.

Capacitors *C6* through *C11* do not appear on either the schematic diagrams or the Fig. 8 wiring guide. These noise-suppression capacitors mount between the +5-volt and ground pins of *IC1* through *IC6* on the bottom of the board. Wire the capacitors between pins 8 and 16 of *IC1* and *IC2*, pins 5 and 10 of *IC3* and *IC4*, and pins 1 and 8 of *IC5* and *IC6*.

Special attention must be paid to mounting *D18* through *D221*. Plug the *cathode* leads of all of these 1N914 small-signal diodes into the holes identified by solid black dots along the 10-line step bus in Fig. 8 and solder each into place. After mounting all diodes and clipping away excess lead lengths close to the soldered pad connections, bend all anode leads at a right angle to the diode bodies and facing toward the center of the board.

Tie together the leads in each vertical column (with the board viewed as shown). When you are finished, you should have 50 columns of anode-lead bundles. Sets of five bundles go to five different holes strategically situated around each of the data-selector chips. Layout of the holes around *IC7* through *IC16* has been arranged to provide fairly close alignment with the bundled-diode columns to simplify the wiring process.

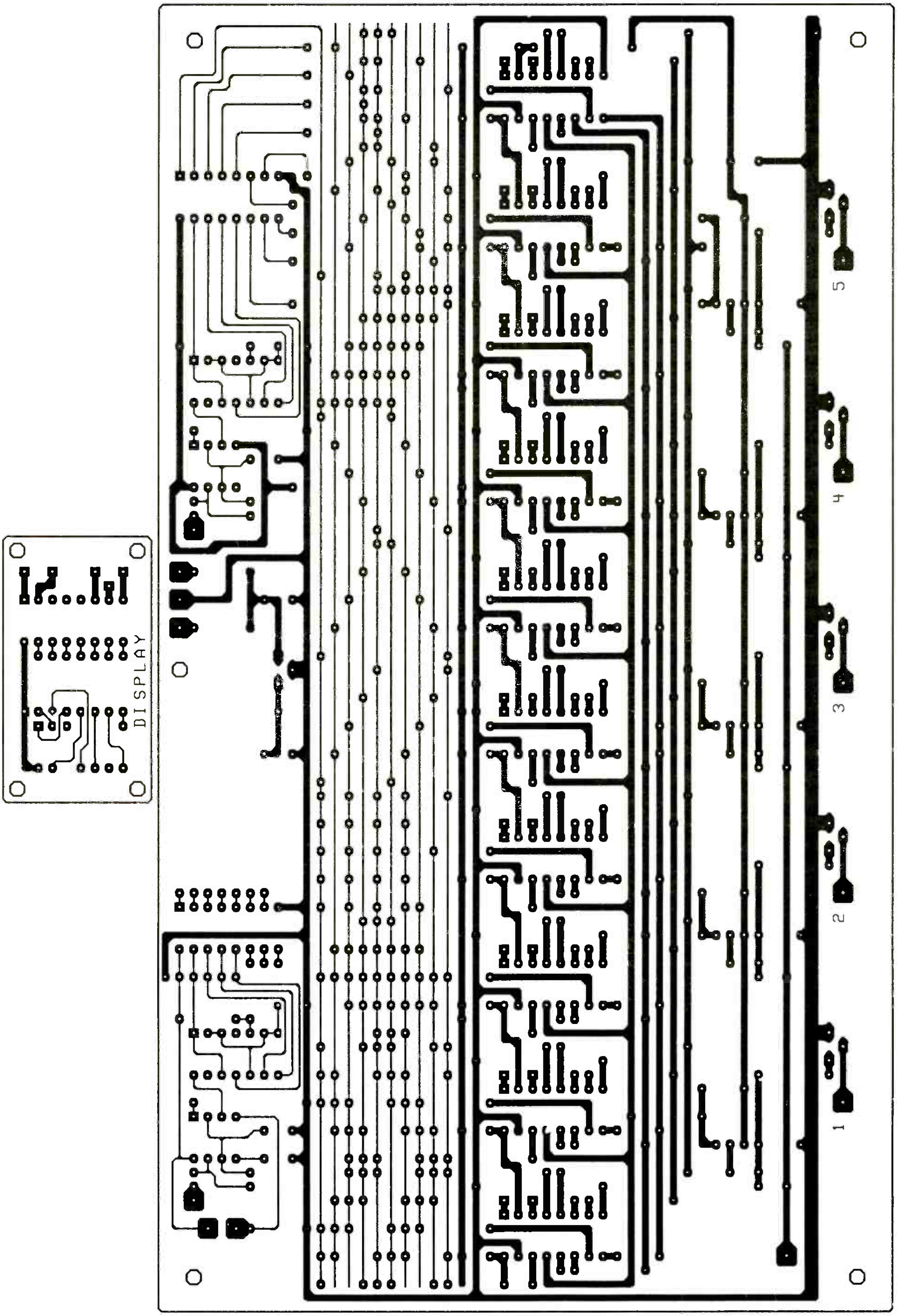
The left-most bundle of diode anodes plugs into the hole for pin 4 of *IC7*, the second bundle to the right plugs into the hole for pin 6, the third into the hole for pin 10, the fourth bundle into the hole for pin 12 and the fifth bundle into the hole for pin 14 of *IC7*.

This process repeats sequentially in the same manner for *IC8* through *IC16*. Use short insulated hookup wires to bridge from the anode bundles to the holes in the circuit board. Also, use heat judiciously when soldering to the anode leads.

When you are finished wiring the diode array, you should carefully check it against both Fig. 8 and Fig. 5 to make sure the wiring is correct.

Regulator *IC17* mounts on the *bottom* of the main board. To do this, bend its pins *forward*, which is exactly the opposite of how you would normally bend them for top-of-board mounting. When you plug the pins into the indicated holes in the board, the plastic face of its case must lie flat on the board's surface. Holding the regulator in place with its tab mounting hole centered behind the ¼-inch hole in the board between *C1* and *C2* and ⅜ inch separating the bottom of the board and the rear of the metal mounting tab, sol-

Fig. 7. Actual-size etching-and-drilling guides for the two printed-circuit boards used in the project.


DISPLAY
5
4
3
2
1

der its pins to the pads on the bottom of the board.

During installation of the circuit-board assembly, *IC17* can be mounted to the floor of whatever metal enclosure is used because it gives off little heat. It need not be insulated from the enclosure with a mica washer because the metal of the enclosure will be at neutral ground potential.

Triacs *TC1* through *TC5* also mount on the *bottom* of the board, but their mounting tabs protrude past the board to provide room for mounting to an external heat sink. They mount with the same ⅜-inch board-to-case spacing as the voltage regulator. The pc board is designed to accommodate the SCI-46M triacs specified in the Parts List. To determine pinouts for this device, view it with its leads pointing toward you and its metal base facing downward. Pinout sequence is then B, MT2 and MT1 left to right.

The SCI-46M triac is becoming difficult to find. So if you decide to use ECG 56006 devices instead, be sure to swap the end leads because Sylvania uses an MT1, MT2 and B pinout arrangement. Also use insulated tubing on all leads to guard against short circuits.

Though no insulation is required for the regulator chip, the triacs *must* be insulated from the enclosure in which the project is housed. Use an insulated mica washer, silicone grease, a plastic shoulder washer and machine hardware for mounting these devices to the metal floor of the enclosure.

If you use TO-220-style triacs, no external mounting hardware is needed for the circuit-board assembly because the mounting hardware for the triacs and regulator chip will hold the assembly very securely in place.

As mentioned in the beginning of this article, you can optionally equip the Light Controller to handle a total load of 12,000 watts. To be able to do this, you must replace the SCI-46M or ECG 56006 triacs with ECG

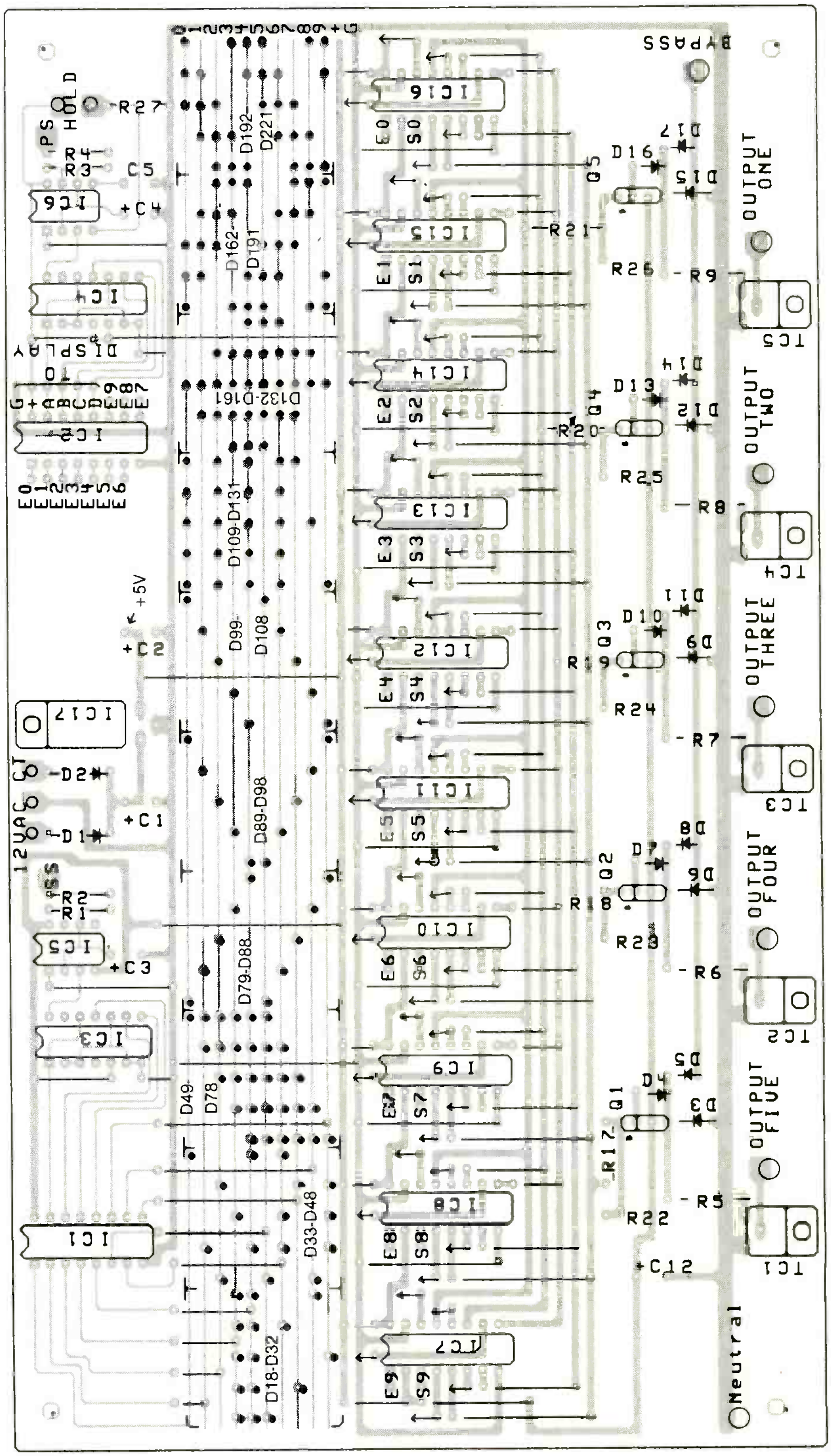


Fig. 8. Wiring guide for the main pc board. Only the cathode leads of the programming diodes plug into the board; the anode leads tie together and connect into the circuit with short lengths of hookup wire. The voltage regulator and triacs mount on the bottom of the board.

56024 40-ampere insulated-stud triacs. These triacs do not mount on the circuit-board assembly. They mount on the heat sink/chassis and 12-gauge or heavier wire must be used to connect them to the appropriate pads on the board.

Referring to Fig. 9, mount *DISP1*, *IC18* and *R10* through *R16* in their respective locations on the display board. Make certain you properly orient the IC before soldering any of its pins into place.

Separate the conductors at both ends of 12-inch-long six-conductor ribbon cable a distance of about 1 inch and strip ¼ inch of insulation from all of them. Tightly twist together the fine wires of all conductors and sparingly tin with solder. Use heat judiciously to prevent charring the insulation.

Plug the conductors at one end of the ribbon cable into the holes labeled +, G, A, B, C and D and solder into place. Plug the conductors at the other end of the cable into the holes with the same legends in the main board and solder them into place.

An enclosure with a substantial amount of metal is required for this project to assure adequate heat sinking for the triacs and voltage regulator. The prototype shown in the lead photo was built into a Compulab No. SC-131 enclosure because it has bottom and side panels composed of a 0.125-inch-thick aluminum plate that is ideal for heat sinking. Besides, this enclosure looks great. However, it is also very expensive. You can build your Light Controller into any metal enclosure that suits your fancy as long as you adequately heat sink the triacs and voltage regulator.

The metal used for heat sinking the triacs must be aluminum and weigh at least 3 pounds. Though the triacs are very efficient switches, even a 99-percent efficiency will cause 50 watts of heat to be generated when a full load of 5,000 watts is switched on. If you decide to build the 12,000-watt version, you need about 7 pounds of aluminum heat sink (or you might get away with 3 pounds if you use forced-air cooling with a fan). Be sure to use insulator kits for the triacs in the 12,000-watt version of the project if you are not using isolated-terminal triacs.

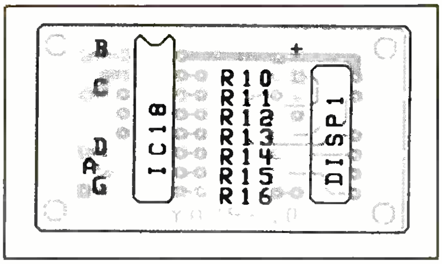


Fig. 9. Wiring guide for display board. This board interconnects with the main board via a ribbon cable.

Plan your layout to minimize interference with the various elements that make up the project. Group the SPEED potentiometers in one area, the CHANNEL lamps in a second area and the switches in a third area.

Mount the power transformer in a convenient location where it will be away from the areas in which the triacs are heat-sinked to keep it from becoming overheated. You can use chassis-mounted or in-line holders for all fuses.

Deburr all holes and thoroughly clean the enclosure. If desired, paint the entire exterior. When the paint has completely dried, loosely mount the potentiometers in their holes and place on the shaft of each a control knob. Mark on the panel where to place their legends. Then use a dry-transfer lettering kit to label the panels, and protect the legends against scratching with several coats of clear acrylic spray. Wait for each coat to dry before spraying on the next.

Cement a 1 × 1-inch piece of red plastic filter material behind the window cutout for the display where it will not interfere with the mounting holes for the display board. Mount the potentiometers, neon lamps, switches, and fuse holders in their respective locations. Line the five exit holes for the OUTPUT cords with rubber grommets.

For the 5,000-watt version of the project, use at least 16-gauge zip cord between the circuit-board assembly the OUTPUT receptacles, which must be rated to handle at least 15 amperes. Tie a knot in each zip cord inside the enclosure to make strain reliefs, leaving enough cord to easily reach the fuse holders. Strip ⅜ inch of insulation from the conductors at both ends of the cables, tightly twist together the fine wires in each and sparingly tin with solder.

Form a small hook in one conductor of each cable end inside the enclosure and crimp but do not solder these conductors individually to one lug of the fuse holders. Plug the other conductor at this end of the left-most cable (viewing the enclosure from the rear) into the hole labeled OUTPUT FIVE, leaving about 3/16 inch of tinned wire visible at the top of the board, and solder into place. Do the same for the free conductors at this end of the remaining four cables and the OUTPUT holes in the board.

Terminate the other ends of the OUTPUT cables in ac receptacles. For this application, it is important that you use the type of ac receptacles that are enclosed in a two-part plastic housing to assure full safety against electrical shock.

If you are building the 12,000-watt version of the project, you *must* use 10-gauge cables and appropriately rated ac receptacles for the OUTPUT devices. These heavy cables are difficult to conveniently knot. Therefore, plan to secure them to the rear wall with cable clamps and machine hardware inside the enclosure.

Strip ¼ inch of insulation from both ends of ten 10-inch hookup wires. Crimp one end of each of five of these wires to the fuse lug to which you crimped the receptacle-cord conductors. Solder both wires to each lug as you make the connections. Route the other ends of these wires to where the neon-lamp assemblies are located. Slip a 1-inch length of small-diameter heat-shrinkable tubing over the free end of each. Crimp together one lead of the lamp labeled CHANNEL 1 and the wire coming from the *F1* fuse holder and solder the connection. Slide the tubing up over the connection to completely insulate it and shrink into place. Repeat for the four remaining wires and neon lamps.

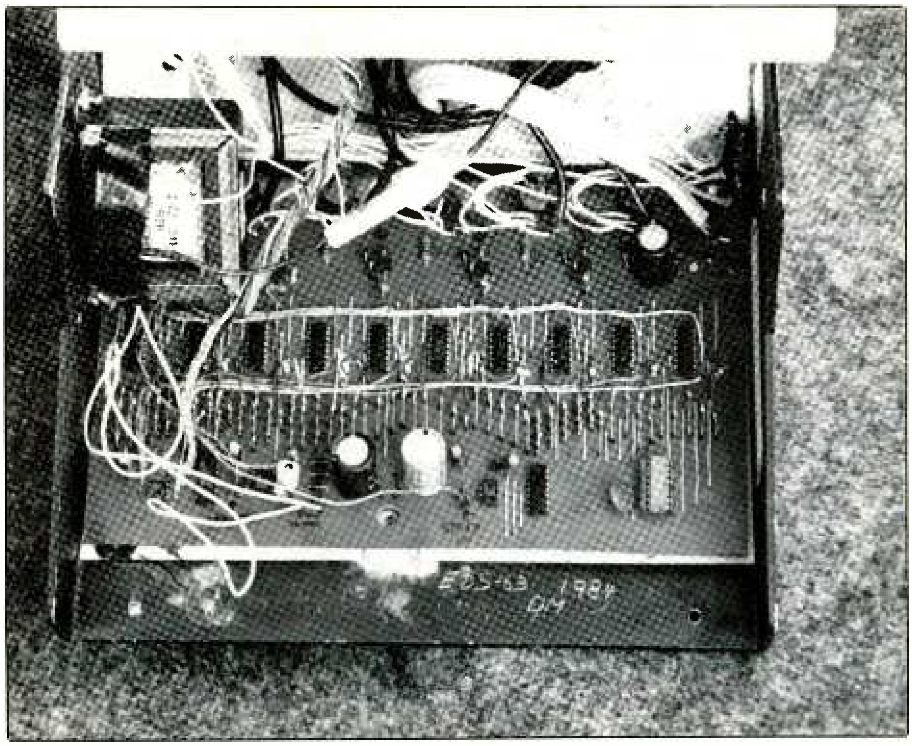
Connect and solder one end of the remaining five wires to the exposed portions of the conductors plugged into the OUTPUT 1 through OUTPUT 4 holes in the main board and solder into place. Hold each wire steady as the solder sets. In the same manner as you did for the first five wires, connect and solder them to the remaining leads of the lamps and insulate them with heat-shrinkable tubing.

Prepare suitable-length wires and connect and solder them to the lugs of BYPASS switch *S3*. Plug the free end of one wire into the hole labeled BYPASS on the main board and solder into place. Then plug the free end of the other wire into the hole labeled +5V in the upper-center of the main board near *C2* (see Fig. 8).

Similarly, connect and solder wires between the lugs of the HOLD switch and the two holes in the upper-right of the board. Then wire the POWER switch into one side of the power transformer's primary circuit through *F6*.

Plug the secondary leads of the transformer into the 12 VAC and CT holes at the top of the main board and solder them into place.

It must be emphasized at this point that this is definitely *not* a "plug into any outlet" project. Your source *must* be direct from your main ac-line circuit breaker or fuse box. That is, the ac line's "hot" conductor (the black wires in the fuse box) must go to the "ac hot" lugs of the fuse holders, as illustrated in Fig. 1. The large grounded neutral center bus to which are connected white-insulated conductors must be connected to the NEUTRAL bus trace on the main circuit-board assebly.



Interior view of wired prototype.

Caution: Because of how this project wires to the ac line, you will be dealing with potentially *lethal* voltages. Therefore, once the project is built, if you have any doubt whatsoever about working directly with the ac line, have a qualified electrician make the connections from the project to your fuse box!

To make the neutral connection, run a 10-gauge stranded wire from the neutral bus in the fuse box to the project. (Use 6-gauge wire if you built the 12,000-watt version of the project.) Note carefully that this conductor does not simply plug into a hole in the main board. The reason for this is that the 0.1-inch-wide NEUTRAL trace can handle only about 1,000 watts maximum. Therefore, after entering the enclosure, the conductor must be stripped of its insulation for a distance of 9 inches. Remove 1 inch of insulation at a time and be careful to avoid nicking any conductors. When the insulation has been removed, twist together the conductors and use a high-wattage soldering iron or a soldering gun to "wet" the entire exposed wire with solder. Also, "wet" with solder the entire length of the NEUTRAL trace on the bottom of the main board.

Place the neutral conductor on top of the NEUTRAL trace and tack solder it into place at three or four points along its length. Check positioning to make sure the conductor touches no trace other than the NEUTRAL one. Then solidly solder it to the trace along its entire length. Work a 1-inch section at a time to avoid scorching the circuit board and/or lifting the trace from the board.

If you plan to use the Light Controller to drive loads of only 200 watts or less per channel, you can use 14-gauge wire from your fuse box to the project. In this case, you can simply strip ½ inch or so from the end of the neutral conductor and solder this flat against the board's NEUTRAL trace. With the maximum load limited to 1,000 watts, you can use a 14-

gauge, three-conductor cord that plugs into an ac outlet and, thus, do not have to make direct connections to the fuse box. If you do this, use 2-ampere fuses for *F1* through *F5*.

Referring to Fig. 8, use suitable-length hookup wires from both ends of which ¼ inch of insulation has been removed to bridge from the E0 through E9 holes near *IC7* through *IC16* to the holes with the same legends to the left of *IC2*.

Wire the PROGRAM LENGTH pot to the main circuit-board assembly via the hole labeled PS in the upper-right corner of the board near *R4* and the +5-volt bus on the board. Tie the wiper and the right lugs of each SPEED pot together and to each other. Then connect a wire from this common connection to the hole labeled SS in the upper-center of the board near *R1*. Run wires from the remaining lugs of the SPEED pots to the respective S0 through S9 holes near *IC7* through *IC16*.

Mount the two circuit boards in their respective locations. Use ¼-inch spacers and suitable No. 4 machine hardware for the small display board. If you built the 5,000-watt version of the project, the large main board requires no spacers to mount it. The No. 4 hardware that secures the voltage regulator and triacs holds it very securely in place. On the other hand, if you built the 12,000-watt version, you must mount the the main board with ⅜-inch spacers and machine hardware—in addition to bolting the voltage regulator to the metal floor of the enclosure.

Make sure you use silicone grease and mica washers between the triacs and chassis floor (or external heat sink for the high-power version) and insulating shoulder washers during mounting. Use only silicone grease between the voltage regulator and floor of the enclosure.

Checkout & Use

Bear in mind that to obtain the full effect of any given program, lights plugged must be plugged into all five OUTPUT ac receptacles. You can run an operational check of the project by plugging into each receptacle a turned-on lamp and set *S1* to RUN. As each program runs, observe the effect produced.

If any one or more lamps do not light, check to make sure that their switches are in the "on" position and that the bulbs are good. If you find nothing amiss here, setting *S3* to BYPASS should cause all lamps to light simultaneously and remain on, regardless of the program being run. If one or more lamps are still off, set the BYPASS switch to "off" and disconnect all lamps from the OUTPUT receptacles and disconnect the Controller from the ac line at the fuse box end.

Carefully check all components for installation (and proper orientation, where applicable) in the appropriate locations, wiring and soldering. Do *not* use the project until you have rectified the problem.

Keep in mind when using this project at or near full load that the BYPASS switch should be used with care. If it is left in the closed "bypass" position for an extended period of time, the wires from the fuse box and to the lamps will overheat and possibly cause a fire! Use this switch only for the purpose for which it was included: to provide a ready means of testing operational status for purposes of isolating which lights, if any, are not working. An operational check should take no longer than 30 seconds or so under the worst of circumstances. If you locate the project where it can be tampered with, replace the common type of switch used for the BYPASS function with a key-operated switch to safeguard the system.

Under normal operating conditions with maximum or near-maximum loads plugged into the OUTPUT receptacles, the wires coming from the fuse box and going to the loads should become no more than slightly warm to the touch. This is because the average duty cycle of the Controller is about 50 percent. Switching to BYPASS raises the duty cycle to 100 percent and effectively doubles the power drawn from the ac line fuse box and delivered to the loads.

Unless you are making a centralized light display, you will probably be controlling lights that are located a considerable distance away from the Controller. If so, be sure that you use extension cords that can easily handle the loads. Also, if any lights are to be outside, make sure you use outdoor-rated extension cords.

The effects you obtain from the Programmable Light Controller depend on how you arrange the lights plugged into the OUTPUT receptacles. With a bit of practice, you should soon be making exciting light arrangements that are certain to attract attention, whether for the holidays or any other time of the year **ME**

Kit Availability

A complete Parts List for this project was given in Part I of this article. For those readers who wish to purchase a kit of parts or individual components, the following items are available from Electronic Design Specialists, 951 SW 82 Ave., N. Lauderdale, FL 33068 (305-726-2427): Main pc board with layout, $35 plus $3 P&H; display pc board with layout, $4 plus $1 P&H; kit of components to build 5,000-watt version pc-board assembly only (does *not* include enclosure, fuse holders, indicator lamps, switches, knobs, ac receptacles, and miscellaneous hardware), $189 plus $8 P&H; complete kit of all components with drilled and silk-screened Compulab enclosure with full instructions, $389 plus $10 P&H. Florida residents, please add state sales tax.

Also available from Kepro Circuit Systems, 630 Axminister Dr., Fenton, MO 63026-2992 (800-325-3878): An actual-size plotted negative for shooting Kepro sensitized pc board. Call or write for price and ordering information.

ELECTRONICS NOTEBOOK

CMOS Micropower Op Amps and Comparators

By Forrest M. Mims III

The relatively high current consumption of bipolar integrated-circuit amplifiers, comparators and timers has long been a drawback to their use in battery-powered circuits. Thanks to CMOS technology, a new generation of micropower linear ICs has overcome the current-consumption problem. Now it is possible to design linear circuits that consume as little power as CMOS digital watches and pocket calculators.

Another important benefit of applying CMOS technology to linear circuits is that a lower power-supply voltage is required. Most CMOS micropower linear ICs can be powered by a single-polarity (single-rail) 2- or 3-volt supply. Some devices can be powered by a 1-volt supply.

The low-power advantage of CMOS linear circuits does not reduce their performance in comparison with their bipolar counterparts. For example, CMOS operational amplifiers have an extremely high input impedance (typically 10^{12} ohms), a unity-gain bandwidth that exceeds 1 MHz, high gain and the ability to operate from a single-polarity supply.

As you can see, this new generation of micropower devices has lots of potential. Circuits that use several op amps, comparators or timers can be powered by lithium button cells and small solar-cell arrays. They will perform at least as well as older bipolar ICs that consume many times more power.

In an upcoming column, I'll cover micropower timers. In this column, I'll review op-amp and comparator basics and describe the specifications and features of some typical CMOS micropower operational amplifiers and comparators. Some demonstration and application circuits that exploit the very-low-power consumption of these devices are also included here. Before getting to these, however, let's examine a sometimes overlooked caveat.

Linear CMOS Caveat

Even though linear CMOS ICs consume very little power, it's important that you realize that some circuits designed with linear CMOS chips can consume nearly as much power as the same circuits that use linear bipolar chips. This situation occurs when the circuit either drives or includes power-hungry components, such as light-emitting diodes, loudspeakers and relays.

If you require lowest possible power consumption, you should think of linear CMOS chips as devices that are on standby when power is applied. Only when a preset condition occurs should the circuit drive a component or circuit that draws additional power.

A typical example of this operating mode is a linear CMOS comparator that is operated as a temperature detector. The comparator's input is connected to a temperature-sensitive thermistor. Its output is connected to a relay through a driver transistor. Normally, both the driver transistor and relay are off. Therefore, only the comparator draws current. Only when the temperature changes to a point where the comparator is switched does the circuit draw appreciable current.

Operating Precautions

Linear CMOS integrated circuits have come of the same vulnerabilities as digital CMOS chips. The best-known problem is electrostatic discharge (ESD). Linear CMOS may include protection circuits or diodes that reduce the possibility of ESD damage. Nevertheless, *all* linear CMOS chips should be handled in accordance with standard CMOS handling procedures. While improper handling may not cause device destruction, the protection circuits may be degraded to a point at which the performance of the device is affected.

As is the case with digital CMOS ICs, all unused input pins of linear CMOS devices *must* be terminated at ground or one of the supply voltages. Unused pins that are left "floating" may pick up stray signals and cause unwanted oscillation that greatly increases the chip's power consumption.

Where are the unused input pins on a two-input op amp? There are none if the circuit is properly designed. What you

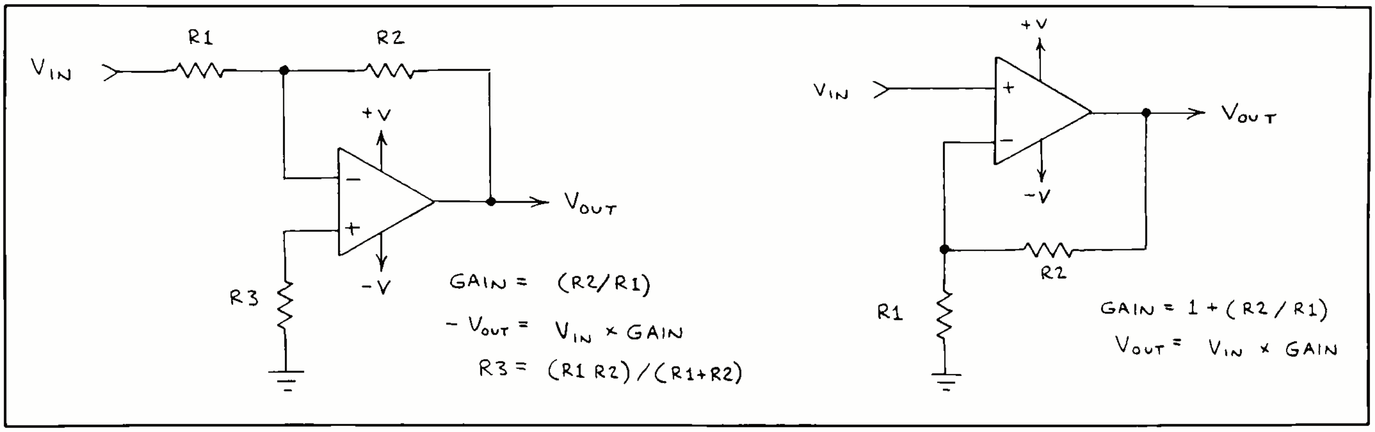


Fig. 1. Basic inverting (A) and noninverting (B) amplifiers.

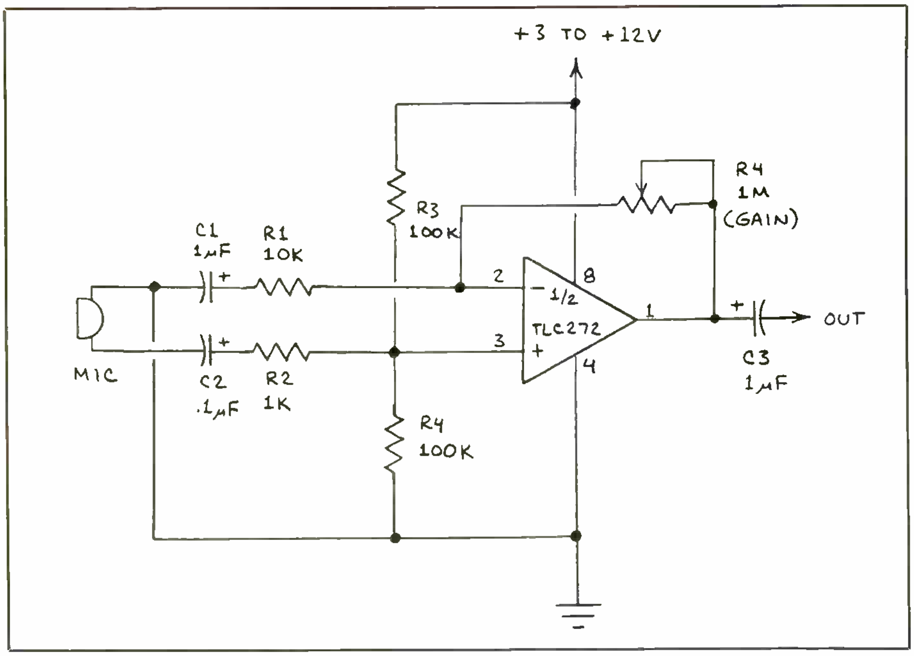


Fig. 2. Single-polarity power-supply microphone preamplifier.

must watch out for are the inputs of *unused* op amps on a chip that contains two or four amplifiers.

Latch-up is another potential CMOS problem. Latch-up is caused by the thyristor-like structure inherent to the CMOS process. This structure is often known as a "parasitic thyristor." Current flows from the power supply to ground through the parasitic thyristor when it is inadvertently switched on. The result is rapid destruction of the chip.

Several safeguards can be followed to prevent latch-up. Use a stable, well-regulated power supply. Always make sure the input voltage does not exceed the power-supply voltage by more than 300 millivolts. Never apply an input signal to a CMOS IC when the device is not powered. Finally, protect CMOS ICs from power-supply transients by placing a 0.1-microfarad capacitor across the device's power-supply pins. The capacitor should be located as close as possible to the chip.

Application Circuits

For this report, I assembled test circuits using linear CMOS devices made by two major manufacturers of linear CMOS ICs—Advanced Linear Devices, Inc. (1030 W. Maude Ave., Suite 501, Sunnyvale, CA 94086) and Texas Instruments, Inc. (P.O. Box 655012, Dallas, TX 75265). Linear CMOS ICs, especially timers, are also made by several other companies.

Prices for linear CMOS ICs aren't significantly higher than those for bipolar devices. Most devices are available in standard plastic DIPs, ceramic DIPs (CERDIP packages) and both small-outline and plastic leaded chip carrier (PLCC) surface-mount packages.

CMOS op amps will work well in many standard op-amp application circuits. Texas Instruments has published a number of excellent application circuits designed specifically for CMOS op amps. Some of these circuits can be found in specifications sheets for specific chips. Many others have been compiled in *Linear Circuits Applications*, an applications manual for CMOS op amps, comparators and timers.

In the space that remains, I'll describe several application circuits for CMOS op amps and comparators. For the sake of those readers whose background is primarily digital in nature, I'll also include a brief review of op-amp and comparator principles. If you have no previous experience with CMOS op amps and comparators, you should breadboard some or all of these circuits. I'm confident that you'll gain, as I have, an appreciation for the significant performance advantages offered by these devices.

Op-Amp Basics

The operational amplifier is a linear device that amplifies by the same proportion the low and high levels of an incoming signal. Stated differently, the op amp's output is directly proportional to its input.

Both inverting (−) and noninverting (+) inputs are provided in an op amp. The polarity of a signal applied to the inverting input is reversed at the output of the op amp. The polarity of a signal applied to the noninverting input is unchanged at the op amp's output. The op amp is sometimes referred to as a "difference amplifier" because the difference between two voltages applied to its two inputs is amplified by the device.

Amplification factor or gain of an op amp is controlled by a feedback resistor connected between the amplifier's output and inverting input. Figure 1 shows an op amp connected as an inverting amplifier (A) and noninverting amplifier (B).

Representative CMOS Operational Amplifiers

The ALD1701 is a high-slew-rate operational amplifier made by Advanced Linear Devices. It can be operated from a single-polarity power supply whose output can be anywhere from +2 to +12 volts, or a dual-polarity supply whose output ranges from ±1 to ±6 volts. When the supply's output is +5 volts, maximum current consumption of this device is 250 microamperes. Open-loop voltage gain is 100 volts per millivolt, and bandwidth is 700 kHz.

The ALD1702 is similar to the ALD1701, except that is has a higher minimum operating voltage of +2 volts. In turn, it provides a higher bandwidth of 1.5 MHz.

Texas Instruments makes a broad family of CMOS single, dual and quadruple operational amplifiers. The TLC251 and TLC271 series are single low-power op amps designed to operate from either single- or dual-polarity power supplies. These devices are identical to each other with the exception that the TLC251 is guaranteed to function at a supply potential of as little as 1 volt.

Offset inputs are provided with the TLC251 and TLC271. Also provided is a bias-select input that permits one of three ac performance and power-dissipation levels to be selected. When the supply potential is 10 volts and the device is programmed for medium bias, typical supply current is 150 microamperes. This falls to around 6 microamperes when the supply potential is 1 volt.

The TLC277 series of dual op amps have voltage gains ranging from 40 to 55 volts per millivolt. Minimum supply potential for devices in this series is either 3 or 4 volts. The principal difference between devices in this series is current consumption. At a supply potential of 10 volts, the TLC277 consumes 1,000 microamperes; the TLC27M7 consumes 150 microamperes, while the TLC27L7 consumes only 10 microamperes.

In addition to the above devices, Texas Instruments makes a variety of other dual and quadruple CMOS operational amplifiers. Included in these categories is the TLC252 dual op amp that offers guaranteed operation at a power-supply potential of only 1 volt. The TLC254 is a quad op amp that also operates from a supply potential of 1 volt.

Microphone Preamplifier

An important advantage of some CMOS op amps is their ability to operate when powered by a single-polarity supply. Figure 2 is the schematic diagram for a microphone preamplifier that capitalizes on this feature. This circuit has been adapted from the specifications brochure for Texas Instruments' TLC27M2 series of CMOS precision dual op amps.

I assembled and tested a breadboard version of the Fig. 2 circuit. Half a TLC272 was used for the op amp. The microphone was an electret cartridge element, although any low-to-medium-impedance microphone should work with the circuit. This circuit functions remarkable well with no noticeable distortion.

For the applications I have in mind, the most important feature of this circuit is its single-polarity supply capability. Equally important is that the circuit functioned when the supply potential was decreased below 1.5 volts. After discovering this, I disconnected the power supply and connected a single 1.5-volt AA penlight cell to the circuit. The circuit operated just as well as before. Keep in mind that this very-low power-supply voltage may not apply to all TLC272 op amps since this chip is specified for a minimum power-supply potential of 3 volts.

Figure 3 is the schematic diagram for a simple function generator that uses both halves of a TLC272 CMOS dual op amp. The circuit has been adapted from one given in the specifications brochure for the TLC272.

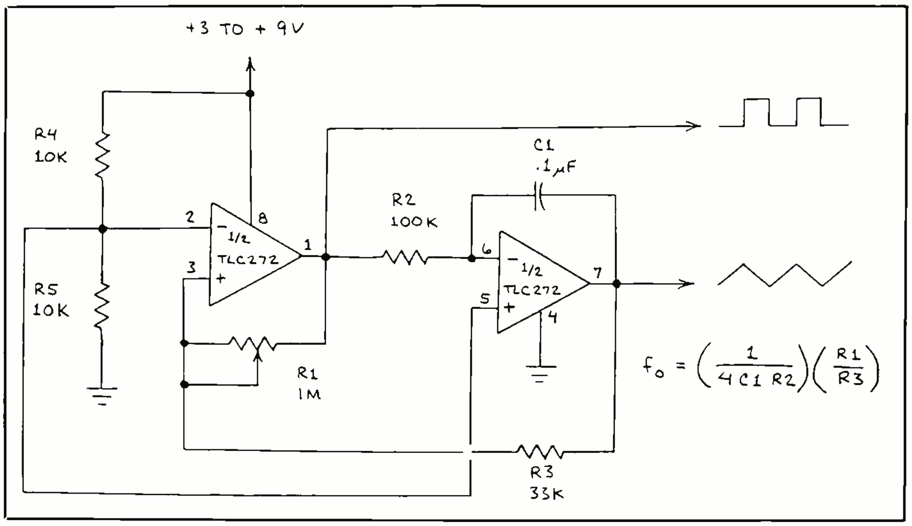


Fig. 3. Single-polarity power-supply function generator.

Like the Fig. 2 circuit, the Fig. 3 circuit uses a single-polarity power supply. It gives the transfer function for the generator. With the component values shown in Fig. 3, potentiometer *R1* can be adjusted to tune the circuit's frequency of oscillation over a range of from about 50 Hz to 950 Hz. When powered by a 5-volt supply, the square wave at the output has an amplitude of 4 volts, and the triangle wave has an amplitude of 2 volts. Rise time of the square wave is about 2 microseconds between the 10- and 90-percent points.

The square wave's amplitude remains a constant 4 volts as frequency is increased, though the amplitude of the triangle wave falls. At 500 Hz, the triangle wave's amplitude is 0.25 volt. At 940 Hz, its amplitude is only 0.15 volt.

I used the same TLC272 in this circuit as in the microphone preamplifier. As was the case with the latter, the function

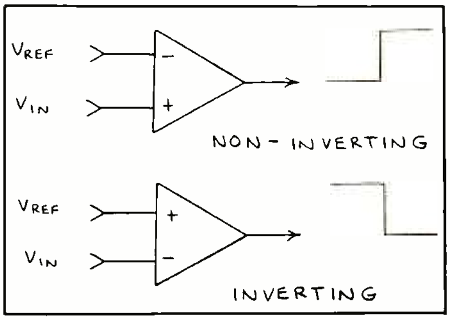


Fig. 4. Basic comparator operating modes.

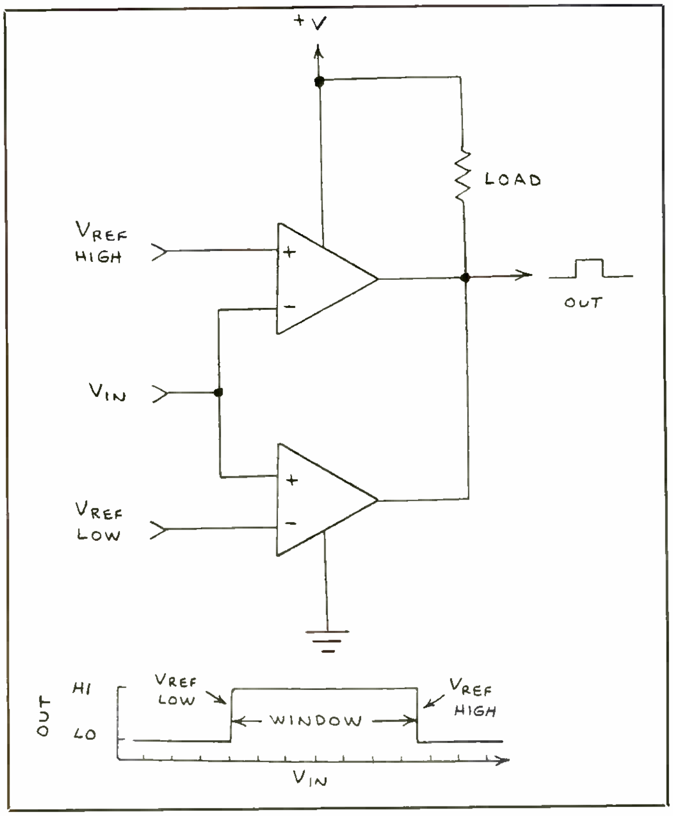
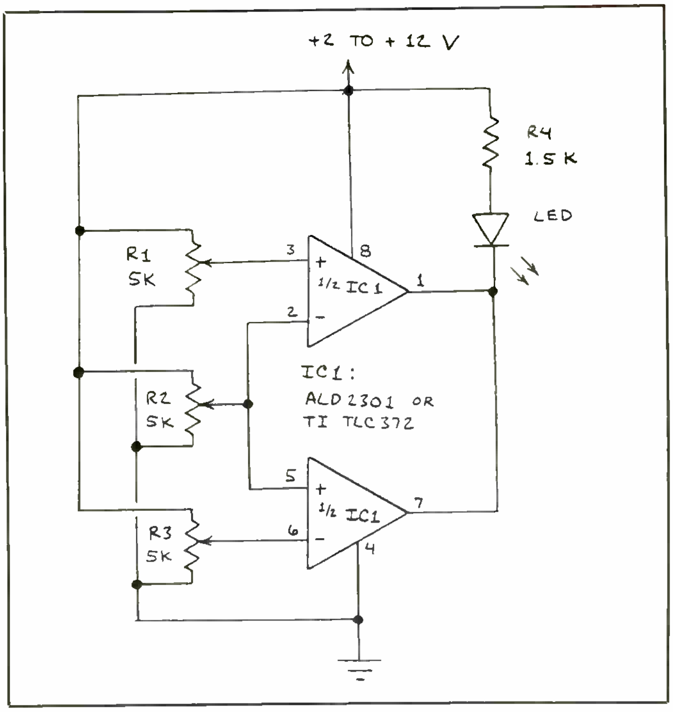


Fig. 5. Basic window comparator.

Fig. 6. Demonstration window comparator.



generator operated when the supply potential was lowered to 1.5 volts.

Comparator Basics

The comparator is a linear circuit that has a digital output. It closely resembles an operational amplifier that is designed to give an output that is either high or low but never linear with respect to the input. Often, in fact, an op amp without a feedback resistor can function as an acceptable comparator.

The most basic comparator application is voltage comparison. There are two basic voltage-comparison modes, both of which are illustrated in Fig. 4.

In the first mode, the comparator's inverting input is biased at a desired voltage level known as the reference voltage. When the voltage at the comparator's noninverting input exceeds the level at the reference voltage, the comparator's output swings from low to high. A comparator operated in this mode is called a noninverting comparator.

The comparator can also be operated in an inverting mode. Here the reference voltage is applied to the comparator's noninverting input. When the voltage at the inverting input exceeds the reference voltage, the comparator's output swings from high to low.

These operating modes permit the comparator to constantly monitor the voltage from a sensor or other source and activate an alarm when the voltage falls below or exceeds a preset reference. The CMOS comparator is much better suited for this kind of task than the bipolar comparator because it consumes so little current in its standby mode.

Representative CMOS Comparators

CMOS op amps can be used as comparators if the feedback is omitted. Many circuits require multiple comparators. For these applications, dual and quadruple CMOS comparators are available.

The ALD2301 is an Advanced Linear Devices dual CMOS comparator that has an output impedance of 10^{12} ohms and a response time of 300 nanoseconds. It can be powered by a single 3- to 12-volt supply or a dual supply that delivers up to ± 6 volts. It has a typical current consumption of only 110 microamperes, and its output can sink up to 60 milliamperes of current (the low-level output current).

Texas Instruments' TLC372 is a dual CMOS comparator that has an output impedance of 10^{12} ohms and a response time of 200 nanoseconds. It can be powered by a single 2- to 18-volt supply or a dual supply that delivers up to ± 9 volts. Typical current consumption is less than 100 microamperes, and its output can sink up to 16 milliamperes of current.

A family of quadruple CMOS comparators is also made by Texas Instru-

LETTERS...

(from page 7)

lays are controlled by data bits 1 through 5. Thus, the correct P1 pin numbering should be 3, 4, 5, 6, 7, 2 and 18, from top to bottom. Also, Radio Shack no longer carries the relay specified for K6. If necessary, two 5-volt dc spdt relays can be substituted.

Eric B. Schuyler
Snyder, NY

You're correct. Pin connections for P1 shown in Fig. 1 were for an earlier version of the project. By extension, the "To P1" numbering sequence at the bottom of Fig. 4 should read 18, 7, 6, 5, 4, 3, and 2 left to right. Digi-Key's Part No. Z105-ND is a suitable replacement for the relay specified for K6. If two Radio Shack Cat. No. 275-243 spdt relays are used for K6, connect both coils between +5 volts and the collector of Q6. Then wire the common line of K1 through K5 (was pin 4 of K6) to the toggle lug of one relay, the black-insulated conductor of the ribbon cable to the toggle lug of the other relay (was pin 13 of K6), the normally open contacts of both relays to circuit ground (was pin 8 of K6) and the normally closed contacts of both relays to +5 volts. Finally, do not leave the Armatron powered when you start up or reboot your computer. The printer-port initialization routine that is automatically executed upon start-up or reboot will "command" the Armatron to move in unpredictable ways. Apply power only after the ARM program has begun.—J.J. Barbarello

• In Fig. 4 of my "Musical Instrument Phase Shifter" (October 1988) the symbol for D3 was omitted, though the correct designation and component type are shown in the appropriate location in the line below D2. This diode connects into the circuit with its cathode going to the ac adapter input jack and its anode going to the input pin of IC5 and negative plate of C12. Failure to include D3 in the circuit can destroy C12, IC5 and possibly other components. Note also that IC5 is a 7915 voltage regulator.

C.R. Fischer

• There is an error in my "Emergency Electronic Ignition" article (October 1988). The value of R3 is 1,000 ohms—not the 100 ohms shown. Readers should

(continued on page 70)

ELECTRONICS NOTEBOOK...

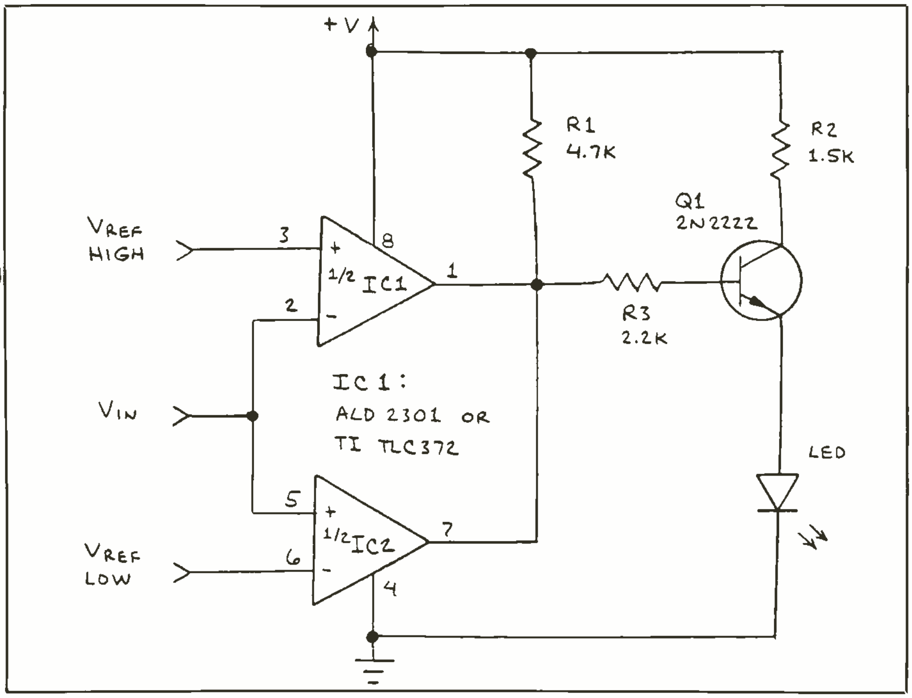


Fig. 7. Window comparator with transistor LED driver.

ments. The TL339 is a CMOS version of the popular bipolar LM339. It consumes only 5 percent of the power of the LM339 for similar response times. The TL3704 is a similar quad comparator that has push-pull output stages that are suitable for driving capacitive loads without need of a pull-up resistor. This saves on power consumption and eliminates the need for a component.

Another TI quad comparator is the TLC3702, which is functionally similar to the bipolar LM393 but uses only 5 percent of the power consumed by the LM393 for similar response times. Like the TLC374, it has push-pull output stages that eliminate the need for pull-up resistors. The TLC374 is a quad comparator that has a wider operating-voltage range than any of the previous devices. It is specified to operate over a range from 2 to 18 volts.

CMOS Window Comparator

Shown in Fig. 5 is a circuit known as a "window comparator." This circuit is ideally suited for use with CMOS comparators. Note that the circuit is a parallel arrangement of two comparators.

When the input voltage falls between the reference voltage applied to the two comparators, the circuit's output is high; otherwise, its output is low. This operating mode is illustrated by the diagram at the bottom of Fig. 5.

Window comparators have important applications in monitoring and control situations. For example, a window comparator can be used to indicate when the temperature of a freezer is either within or out of a desired range. The output signal can be used to actuate the freezer's compressor or an alarm mechanism such as a bell or light.

Figure 6 is a schematic diagram for a demonstration window comparator circuit designed specifically for use with CMOS dual comparators like the ALD2301 or TLC372. In this circuit, *R1* controls the high reference voltage and *R3* controls the low reference voltage. Potentiometer *R2* controls the input voltage. In operation, *R1* should be set to give a higher voltage at pin 3 than the voltage delivered to pin 6 by *R3*.

If the input voltage applied to pins 2 and 5 by *R2* exceeds the high reference voltage or falls below the low reference voltage, the circuit's output goes low and the LED turns on. If the input voltage falls within the window between the high and low reference voltages, the circuit's output goes high and the LED switches off.

Shown in Fig. 7 is how a transistor driver is added to the Fig. 6 circuit to invert the status of the LED. With this circuit, the LED switches on only when the input voltage falls within the window. Potentiometer *R1* serves as a pull-up resistor that permits *Q1* to be controlled by the comparator's outputs.

Use of CMOS comparators gives this circuit several important operating advantages. Firstly, its very high input impedance means that the circuit is essentially transparent to whatever sensor or circuit it monitors. Secondly, its ultra-low power consumption means that the circuit can be operated for long periods of time on battery as long as it's in the standby mode. Finally, the circuit can be powered by a supply that delivers as little as 2 volts.

Test versions of the circuits shown in Fig.s 6 and 7 performed about the same with both the ALD2301 and TLC372 when the input was a slowly varying voltage. The only exception was that the ALD2301, which is specified for a minimum operating potential of 3 volts, functioned at a supply potential of less than 1.5 volts. In fact, the ALD2301 window comparator I tested would be powered by a single AA penlight cell. The TLC372, specified for a minimum operating potential of 2 volts, required nearly 2 volts from the power supply for operation. These minimum operating voltages apply only to the two chips I tested. They may vary with other chips.

At very-low supply voltages, some LEDs may not receive sufficient forward bias to switch on. Or they may not receive sufficient forward current to produce a usable light output. You can overcome the latter problem by using high-brightness or "super" LEDs. These AlGaAs LEDs will emit visible red light when their forward current is only a milliampere or less.

Going Further

CMOS op amps and comparators provide low power consumption, low-voltage operation, ultra-high input impedance and simple interfacing to CMOS digital logic. Many also provide single-polarity power-supply operation. These advantages will bring new life to many traditional op-amp and comparator application circuits.

The working circuits shown here will teach you the basics about CMOS op amps and comparators. After you try them out, be sure to adapt your favorite linear circuits for CMOS op amps and comparators. ME

A New Analog-to-Digital Converter and Switching Power Supply Control Devices

By Harry L. Helms

Computers are being increasingly asked to process input from analog sources in "real-time," and increasing the speed and accuracy of analog-to-digital conversion is the key to future breakthroughs in areas such as robot vision, voice recognition, video digitizing and signal analysis. To meet this challenge, several new "flash" analog-to-digital converter ICs have been introduced recently. The term "flash" denotes a device that has been optimized for high conversion speed and accuracy through the use of parallel conversion techniques. A representative example of "flash converters" is the CA3306 CMOS 6-bit analog-to-digital converter from GE Solid State.

The CA3306 is described as a "video speed" ADC, and its 15-MHz sampling rate is certainly adequate for such tasks. If greater speed is needed, two CA3306 devices can be paralleled for a 30-MHz sample rate. Since the CA3306 is a CMOS device, it can operate from as little as +1 volt (although a supply potential range of +3 to +8 volts is recommended), and power consumption can be as low as 12 milliwatts maximum at a 1-MHz clock frequency.

Figure 1 shows pin connections for the CA3306. Internally, 64 voltage comparators operate in parallel to measure the input signal at pin 11 with respect to a known reference voltage. Three reference-voltage pins are supplied: pin 9 for a positive voltage, pin 10 for a negative voltage and pin 16 for a center (*midpoint*) voltage between the positive and negative voltages. Sixty-three of the comparators are used to digitize (or, more precisely *quantize*) the input voltage, while the remaining comparator produces an "overflow" bit at pin 2.

Accuracy of the CA3306 is within ±0.5 of the least-significant bit (LSB) of the output. The outputs of the CA3306 are labeled B1 (LSB) through B6 (most-significant bit, or MSB). In Fig. 1, conversion speed is controlled by a clock input signal at pin 7, which should be equal to the sampling/conversion rate desired.

A phase control input at pin 8 provides additional control of the clock input; normally, this pin should be tied to ground or to the positive reference voltage.

Figure 2 shows a typical application of the CA3306 as it operates from a +5-volt supply. The positive reference voltage is obtained through a 741 op amp configured as a voltage reference. The 5K potentiometer is used to set the reference voltage precisely. The first clock enable (CE1) input of the CA3306 should be connected to ground and the second clock enable (CE2) should be tied to the +5-volt supply line. This circuit will operate with sufficient accuracy for most applications without any further adjustments other than that for the reference voltage.

The phase and clock-enable inputs also allow two CA3306 devices to be paralleled for a sampling rate up to 30 MHz, as shown in Fig. 3. One converter samples the positive phase of the input clock signal, while the other samples on the negative phase. The resulting outputs are alternately enabled. Note the differing phase and clock-enable input signal levels on the two devices.

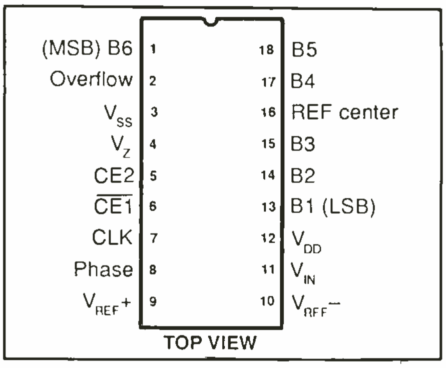


Fig. 1. Pinouts for the CA3306 "video-speed" analog-to-digital converter.

Further information and additional applications circuits can be found in data sheet No. 2115, "High Reliability Slash (/) Series CMOS Video Speed 6-Bit Flash Analog-to-Digital Converter," available from GE Solid State, Box 3200, Somerville, NJ 08876.

Switching Power Supply Control Devices

Switching power supplies operate with greater efficiency, are lighter and small-

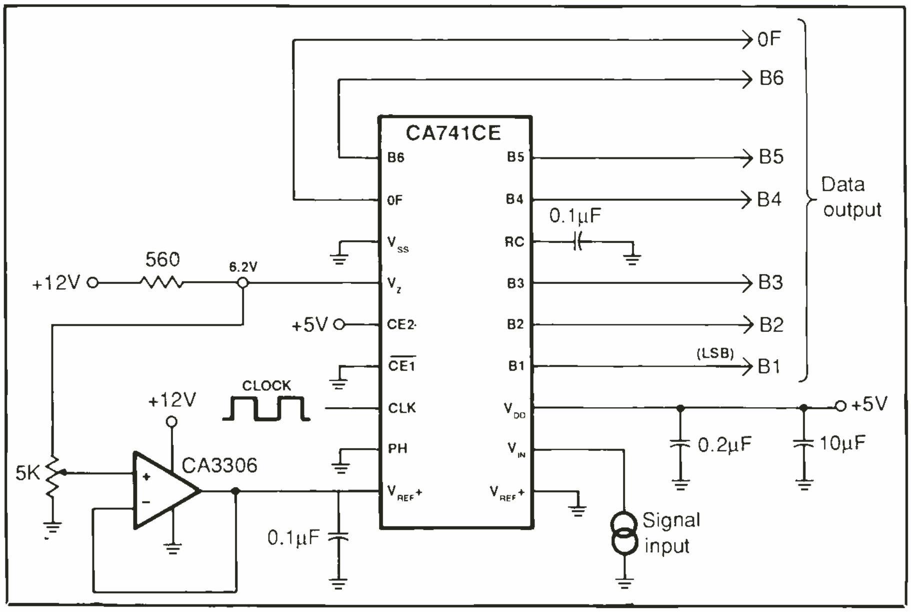


Fig. 2. A typical application circuit for the CA3306 ADC.

CA3306 Specifications	
Supply Voltage Range	+1 to +8 volts dc
Input Voltage Range	-0.5 volts to supply voltage
Resolution	±0.5 of LSB
Quantization Error	±0.5 of LSB
Maximum Conversion Speed	15 MHz
Sample Time	66 ns

er, and at high power levels are actually less expensive than power supplies using conventional linear regulation. The main barrier to wider adoption of switching regulation has been the complexity of switching-regulator circuits.

Recently, several companies have introduced switching voltage-regulator ICs that can be used in place of linear regulator devices. Typical of these is the SG1524C family of switched-mode power-supply control devices from Signetics. These can operate from a supply potential of +7 to +40 volts and supply a 60-volt output at 200 mA of current, with more output current available as output voltage is decreased. Figure 4 shows the pin connections for this family.

The SG1524C family has an internal "bandgap" voltage regulator that produces regulated +5 volts, with an accuracy of better than 1 percent, for all internal circuitry. The positive and negative sensing inputs are connected to an internal comparator, which in turn drives a pulse-width modulator (PWM) stage consisting of a ramp oscillator, high-speed comparator and error amplifier.

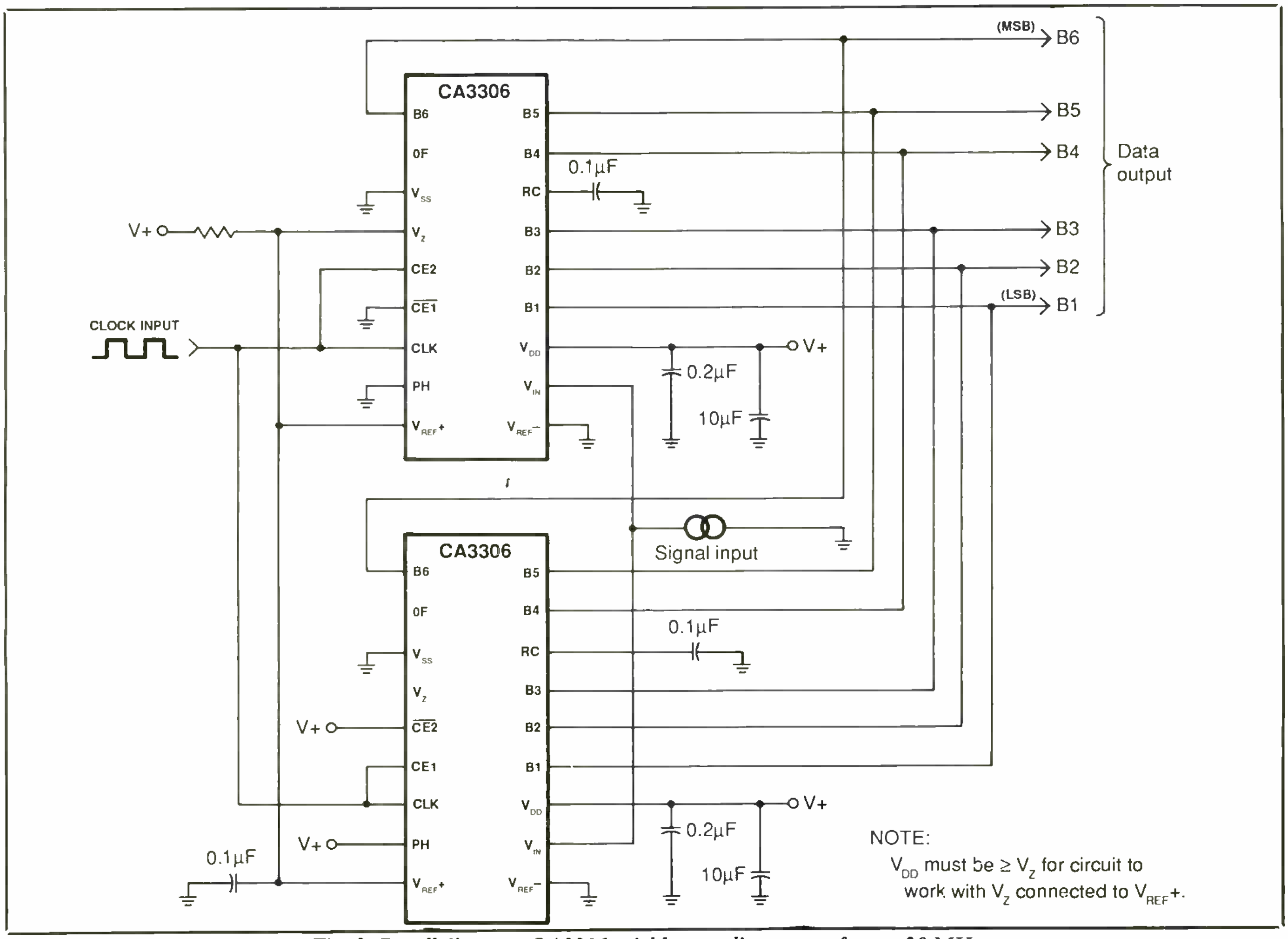


Fig. 3. Paralleling two CA3306s yields sampling rates of up to 30 MHz.

The PWM stage performs the necessary switching functions for voltage regulation. There is also an internal shutdown circuit (note the shutdown input at pin 10) that prevents problems caused by low supply voltages as well as current-limiting circuitry.

Figure 5 shows a typical application for the SG1524C in which a +26-volt input is used to produce a +5-volt output at 5 amperes. Several other switching-regulator circuits can be built around the SG1524C family, and it can also be used in motor-control circuits. More information is available in the "SG1524C/2524C/3524C Switched-Mode Power Supply Control Circuits" data sheet and in applications note No. AN1262, "Theory of Operation and Applications for SG1524C/2524C/3524C," both from Signetics Corp., 811 E. Areques Ave., P.O. Box 3409, Sunnyvale, CA 94088-3409. (All requests should be made on company or professional letterhead.)

Random Notes

Intel and Siemens have joined as partners in a new company known as the BiiN (pronounced "bine") to produce a modified version of Intel's 432 microprocessor. Reports are that BiiN's products will be intended for the "fault-tolerant" computer market . . . . The first 1-Meg static RAM (SRAM) devices have hit the market. Inova Microelectronics of Santa Clara, CA has introduced a 128K × 8 SRAM, and others are expected to soon follow. SRAMs are used in applications where speed is paramount, such as in supercomputers . . . . The latest buzzword in ICs is "rad hard," which denotes a device that's been *rad*iation *hard*ened. Such devices were developed for weapons systems to withstand the effects (radiation, electromagnetic pulse, etc.) of nuclear explosions. These devices also have

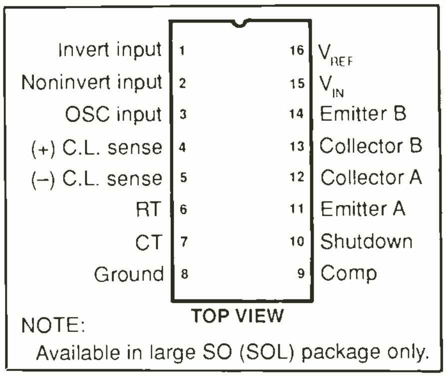


Fig. 4. Pinouts for the SG1542C family of switching power-supply control devices.

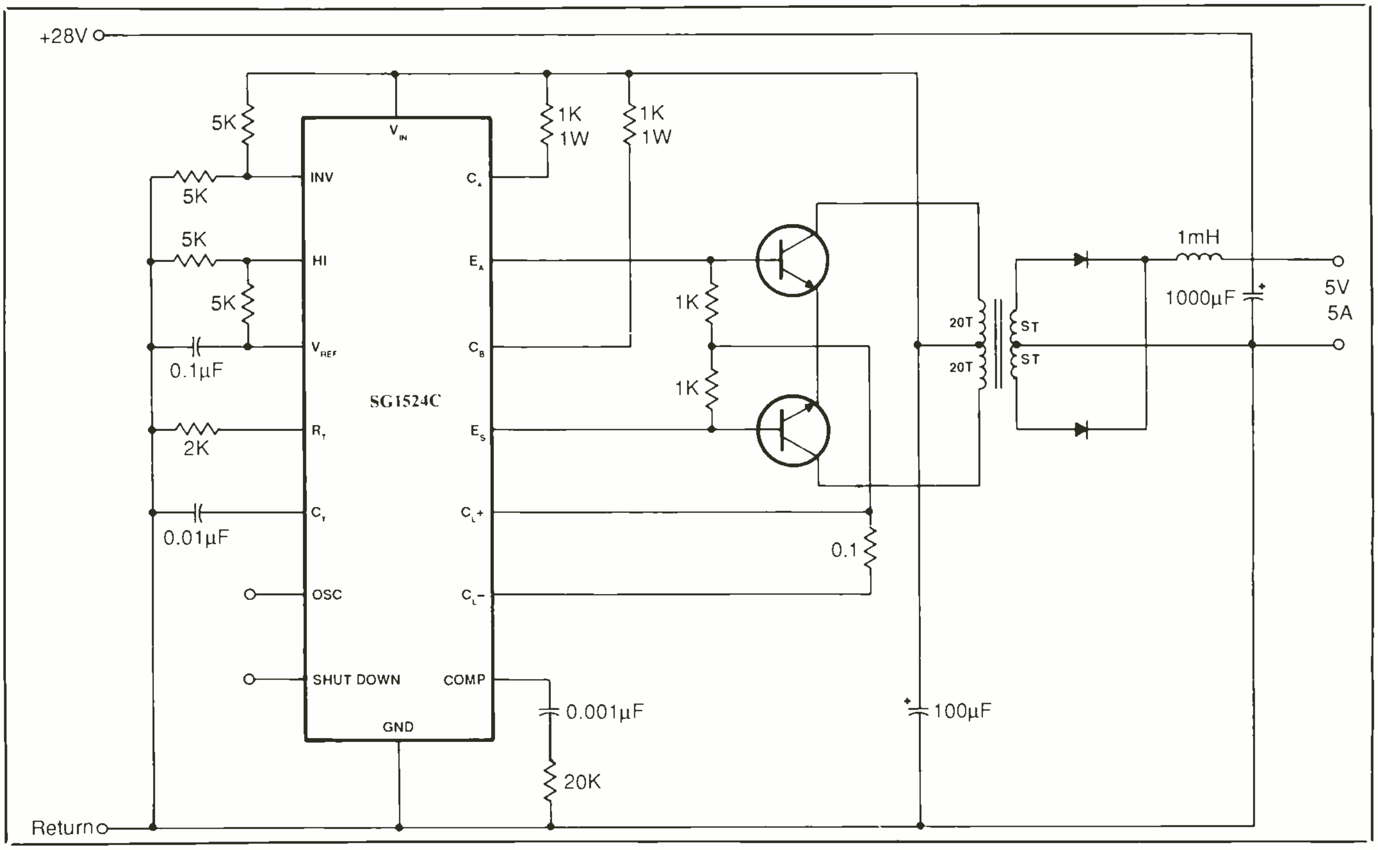


Fig. 5. Using the SG1524C to produce a +5-volt output at 5 amperes.

SG1524C Specifications	
Maximum Supply Voltage	40 volts
Maximum Output Voltage	60 volts
Recommended Output Current, each output	250 mA
Maximum Power Dissipation	1090 mW (may be greater in different IC packages)

peaceful applications, such as in space missions . . . . As of this writing, the DRAM shortage continues unabated, with several companies having to curtail production and orders of supporting components due to a shortage of 256K dynamic RAMs. As mentioned previously in this column, the United States is more dependent upon Japan for semiconductor memories than it is upon foreign oil sources. Since electronics is becoming an ever more "memory-intensive" science, a lack of domestic DRAM manufacturing capacity is leaving us (as well as Europe) dangerously at Japan's mercy in keeping adequate supplies available. During the current shortage, Japanese microcomputer makers have had no problems securing enough 256K chips to keep production lines rolling while PC manufacturers in the U.S., Taiwan and Korea have been forced to stretch out production times and even curtail output due to the DRAM shortage. ME

Advanced Television

By Curt Phillips

Fig. 1. This wide-screen TV receiver from RCA is an example of the new look in home video entertainment displays.

The future of television in the United States is in the process of being decided. Advanced television technologies are being proclaimed widely as the most significant technological breakthrough since the advent of television itself. But politics, not technology, may play the most important part in deciding what we'll get to see.

Stated briefly, advanced television technologies will provide wide-screen pictures with improved color, greater detail and sharper resolution than present television receivers provide.

Increased horizontal and vertical detail and resolution are the most prominent advancements proposed. Most of the proposed TV systems approximately double conventional television's 525 scan lines. The improved detail and truer color rendition will be most noticeable on large-screen television sets, where sales have been hurt by color clarity and sharpness limitations become evident. High-Definition Television (HDTV) will provide sufficient resolution to produce a high-quality picture on screens significantly larger than those available today.

The advanced television screens won't just be larger; they'll be wider, too. Today's television screens are almost square, with an aspect ratio (picture width to picture height) of 4:3. This shape is a carry-over from television's early development when movie theaters showed films with that frame shape. HDTV can produce an aspect ratio of approximately 16:9, which will allow modern wide-screen movies to be displayed in their original composition. Other programming, such as sports events, will also benefit from the more compelling view presented on the wider screen. High-Definition Television sets of all sizes will be immediately recognizable by the wider screens, as the photograph of RCA's prototype shown in Fig. 1 illustrates.

Most advanced television systems include digital multi-channel sound to complement the enhanced picture quality. Although stereo television has not exactly taken the public by storm, programming sources that improve their picture-transmitting equipment for HDTV will likely improve their audio quality as well.

Congress Gets Involved

This past September, the Subcommittee on Telecommunications and Finance of the U.S. House of Representatives held hearings on High-Definition Television (HDTV) and sponsored a demonstration of advanced television technology.

The committee heard testimony from Charles Schott of the Department of Commerce's National Telecommunications and Information Administration and from Richard Wiley of the FCC's Advanced Television Advisory Committee. Industry and trade groups were represented by Sidney Topol of the Electronic Industry Association (EIA) and Scientific Atlanta, Richard Elkus of the American Electronics Association and Jerry Pearlman of Zenith.

The one issue that was already largely decided was that of compatibility. Prior to this hearing, the FCC issued a set of technical guidelines for HDTV development, and one of its directives was that any HDTV system be compatible with the millions of television receivers currently in place that use the National Television System Committee (NTSC) format.

The major remaining "political" issues are U.S. participation and terrestrial

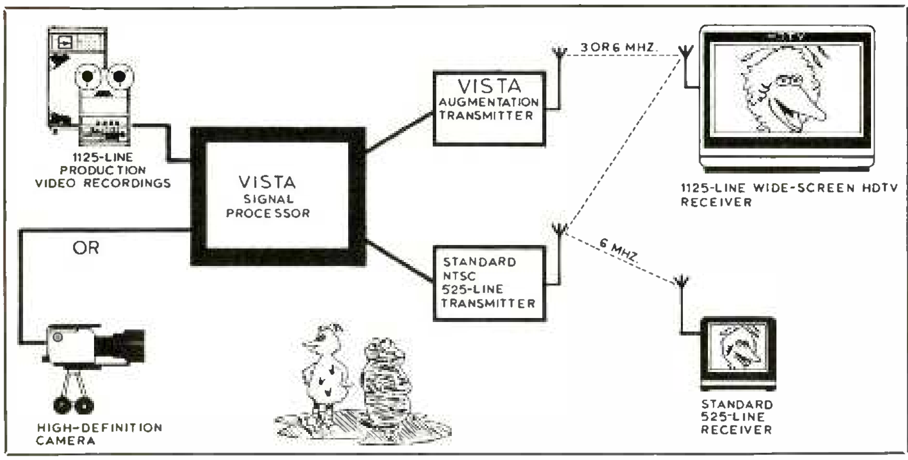


Fig. 2. Details of the Visual System Transmission Algorithm (VISTA) for generating compatible HDTV transmissions.

broadcasters. Subcommittee Chairman Edward Markey of Massachusetts and other members of the committee repeatedly stressed HDTV as a possible source of American jobs. Another concern of both committee members and witnesses was the possible ripple effect of HDTV development on other high-tech industries. It was stated that development of HDTV technology will likely generate technological advancements in photonics, fiber optics and microprocessing, and that the United States cannot afford to fall behind in these areas.

Concern for terrestrial broadcasters seems to be a uniquely American phenomenon. Advanced television advocates in Japan and Europe are aiming toward satellites and cable as HDTV delivery systems. With video disks and VCRs also available to distribute HDTV, terrestrial broadcasters could easily be left out, but the FCC's emphasis on NTSC compatibility and comments of members of the subcommittee indicate that the local content and widespread availability of terrestrial broadcast signals make their inclusion in the HDTV equation an important priority.

The specter of several past developments in consumer electronics shaded comments of participants. Sidney Topol of the EIA recounted the battle between RCA/NBC and CBS over color television, where RCA won.

Richard Elkus told of his experience with the Ampex Corporation. Ampex introduced the first home video recorder 20 years ago, only to transfer the technology to Toshiba later because of cash-flow problems. As recently as 1970, Ampex alone controlled about 75 percent of the worldwide market for video tape recorders in terms of dollars. Today, all U.S. producers combined hold less than 2 percent of the $15-billion VCR market.

There was a fear that without proper governmental guidance, HDTV would turn out to be, as one committee member colorfully phrased it, ". . . an AM stereo scenario *cubed*."

A Glimpse Into the Future

The demonstration of HDTV technology was to give members of Congress, officials of the Executive branch and members of the press an opportunity to view HDTV. Because the technology is in development, some companies didn't have actual HDTV pictures available for viewing, but they gave out information packets and had representatives available to answer questions.

The following companies were represented at the demonstration and are likely to be major factors in the ultimate decision on HDTV:

• *Del Rey Group/Compatible Video Consortium.* Under its single-channel system, referred to as High Definition NTSC (HD-NTSC), picture sharpness is improved markedly by using a technique called "TriScan" that employs digital techniques similar to those used by personal computers. This system is intended for use by all home video transmission media, including terrestrial broadcast, cable, optical fiber, VCR, video disc and Direct Broadcast Satellite.

The Del Rey system starts with a picture that has at least 1,125 lines per frame and compresses that picture for transmission over a single 6-MHz channel. HD-NTSC receivers display a picture with a 5:3 aspect ratio and digital sound. According to the system's designers, it is compatible with existing television sets.

The Compatible Video Consortium is a limited partnership to provide funding for HDTV development. Despite its official presence as this "demonstration," they didn't demonstrate their system.

• *Faroudja Laboratories.* Yves Faroudja, founder of Faroudja Labs, did demonstrate his single-channel "Enhanced NTSC" or SuperNTSC system. The Faroudja system combines preprocessing at the transmitter and post processing at the receiver, which leads to HDTV quality while maintaining compatibility with conventional NTSC receivers on a single 6-MHz channel.

The broadcast SuperNTSC signal retains the old 4:3 aspect ratio of standard NTSC, but the VCR SuperNTSC allows for a wider aspect ratio.

• *Advanced Compatible Television (ACTV).* The David Sarnoff Research Center, NBC and GE/RCA Consumer Electronics are developing Advanced Compatible Television (ACTV), a two-stage evolutionary system designed to encourage the transition into advanced television. The first stage is ACTV-I, a wide-screen enhanced-definition system that requires only a single existing broadcast or cable channel. ACTV-I is fully compatible with current television receivers and offers greatly increased vertical and horizontal resolution.

ACTV-II is a two-channel HDTV system that uses an augmentation channel. This system is designed to meet the technical requirements of even larger screen sizes in the future.

ELECTRONICS OMNIBUS . . .

Implementing ACTV-I would not require extensive regulatory procedures, nor great implementation expense for consumers or broadcasters. ACTV-II would require that spectrum allocation issues be resolved before it could be implemented.

Both ACTV-I and ACTV-II offer 1,050 lines per frame and a 16:9 aspect ratio, but ACTV-II offers better luminance and chrominance resolution.

• *VISTA*. Dr. William Glenn of the New York Institute of Technology Research Center in Florida is developing a system intended for use by all video media, especially terrestrial broadcasting. The Glenn System, also known as VISTA (VIsual System Transmission Algorithm), uses two channels. The final product will use 9 MHz of bandwidth, one 6-MHz NTSC-compatible channel containing the standard 525-line signal and an auxiliary noncontiguous 3-MHz channel that will increase resolution to full 1,125-line HDTV resolution.

The VISTA system of splitting and recombining NTSC and augmentation signals (Fig. 2) is typical of the dual-channel systems. It's designed to be compatible with conventional NTSC receivers.

• *North American Philips.* North American Philips (no relation to me; they don't know how to spell their name) Corporation's High Definition System for North America (HDS-NA) is a dual-channel system geared to be NTSC compatible.

For terrestrial broadcasters, HDS-NA requires a standard 6-MHz channel for the NTSC-compatible signals and a second 3-MHz channel that carries the additional 16:9 aspect-ratio information, as well as high spatial and temporal resolution and digital stereo sound.

• *NHK System.* This is the system that had everyone running scared—not because it is technically better than the others but because it is scheduled for implementation is Japan beginning in 1991.

Since the Japanese system is based upon a Direct Broadcast Satellite as a transmission medium, NHK has developed two systems for the U.S. market. MUSE-6 reportedly offers NTSC-compatible enhancements over the standard 6-MHz channels, while MUSE-9 provides better picture quality through a second 3-MHz augmentation channel. The MUSE system provides 1,125 scan lines and a 16:9 aspect ratio.

• *Zenith.* The Zenith Spectrum Compatible HDTV System provides a transmission and encoding system for HDTV that, according to its designers, enables transmission of a 30-MHz signal through today's unusable portions of the vhf and uhf spectrums. The result is that existing NTSC broadcast stations can obtain a second 6-MHz channel over which a true HDTV program can be broadcast. Zenith did not demonstrate an HDTV picture.

The Next Step

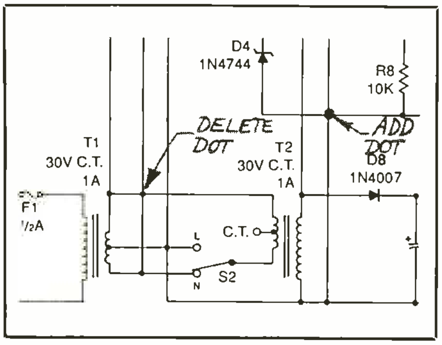
Subcommittee Chairman Markey asked the relevant federal agencies and the American electronics industry, through its trade associations, to submit reports outlining how best to involve U.S. industry in the development and manufacture of advanced television technologies. He asked that the reports be submitted no later than January 4, 1989, in order for Congress to have them before initiating legislative action in the new year.

The old NTSC color standards have been with us for over 30 years. So any new standards that are legislated may be with for some time to come. We need to be sure that any decisions are made carefully. If you want to correspond with the committee directly, write to them at Room H2-316, Washington, DC 20515.

Your comments and suggestions are welcome. You can contact me through The Source (BDK887), Delphi (CURTPHIL), CompuServe (73167,2050), or at P.O. Box 678, Garner, NC 27529. ME

LETTERS . . . *(from page 62)*

can send a check to us at 76 N. Broadway, Hicksville, NY 11801 or by calling 516-681-2922 (9:00 A.M. to 5:00 P.M. Eastern time) for credit-card purchases. Current rates are $17.97, $33 and $48 for one, two and three years, respectively. Back issues are available for $2.50 per copy from the same address. The pages that appear to be missing were assigned to bound-in cards, which is required by postal regulations.



The "Telephone Tester" schematic is in error. Schematic corrections are shown here.—Ed.

make note of this both on the schematic and in the Parts List.

Michael DiJulio

• I recently discovered *Modern Electronics* at a hamfest and in the one issue saw three projects that I'd like to build, two of which I want to get to immediately: the "Telephone Tester" and "Emergency Ignition System." There weren't any subscription forms in the October 1988 issue I picked up. How do I go about starting a subscription and obtaining back issues? Incidentally, while searching for a subscription form, I noticed that there were pairs of missing pages, though there doesn't seem to be anything missing from any of the articles.

The schematic diagram of the "Telephone Tester" shows a direct short circuit across the secondary of T1. How do I correct the schematic?

Thomas Cott
Hicksville, NY

Subscription forms are bound into every issue, but if it is missing from yours, you

The Great PC Bus War

By Ted Needleman

The interesting thing about being involved with PCs is that there's always one controversy or another brewing. If it isn't which computer is "best," it's what type of video board or mouse (or something else) you should be using. The next great conflict shaping up is what type of internal bus your next IBM compatible will have. IBM set a *de facto* standard when it introduced the original PC, extending this standard when the 16-bit wide AT was introduced.

Most makers of compatibles followed the specifications IBM established to take advantage of the large third-party aftermarket in peripheral and memory boards. After all, why go through the time and expense of designing and manufacturing your own memory board, or serial port, or video board when there are a variety of low-cost sources available. In fact, few clone suppliers today actually manufacture anything more than the nameplates they put on their machines.

This was the way things stood until last April, when IBM introduced its new line of PS/2 systems. On the models containing 80286 and 80386 microprocessors, IBM based the bus on an entirely new physical structure called MicroChannel. The MCA (MicroChannel Architecture) bus offers two big advantages over older bus designs—it provides a 32-bit-wide data bus, and has a better scheme for the PC to recognize what peripheral cards are installed.

The 32-bit-wide bus is important because it allows information to be transferred more rapidly inside the system. An analogy is to imagine 20 cars all trying to travel down the same 2-lane road. Chances are, they would be able to reach their destination much faster (ignoring speed limits for the moment) if they were traveling on a four- or six-lane highway.

By providing a bus that's twice as wide as the AT's as well as a faster system clock speed, the MCA lets the computer make good use of the the powerful CPUs that are now available.

The second major advantage of the MicroChannel is that it eliminates most of the DIP switch addressing on peripheral cards. The earlier PC and AT bus designs provided a range of addresses for certain peripherals to occupy. With this type of scheme, when you have a serial I/O card, there has to be some method of letting the PC know what I/O ports the card supplies. This is accomplished with the dreaded DIP switch.

By correctly setting the switches, the PC is notified that the board is providing COMM 1, COMM 2, or some other port recognized by the software. The MCA bus specifications provide a method of automatically identifying a peripheral card installed on the bus.

These features are significant. Unfortunately, there are also three major problems. The first is that the MCA bus machines have been spectacularly unsuccessful. IBM decided that it would license the rights for clone makers to use the MCA architecture, but to date no one has been injured in a stampede to take IBM up on its offer.

Tandy and Dell Computer both announced MicroChannel machines soon after IBM's PS/2 introduction. To date, Dell keeps postponing the ship date for theirs, saying they have the systems ready, but don't see any great demand. Tandy's experience seems to back this up. Their MCA computer has been shipping since the summer, but has not enjoyed great sales as yet.

Added to this, third party providers of add-in cards had great initial difficulty getting the "card-recognition" scheme to actually work. This has been straightened out, but there is still a dearth of add-in cards for the PS/2.

More important is the lack of compatibility between the MCA bus and earlier PC and AT buses. When IBM introduced the AT, they designed it so that there were both 8- and 16-bit slots. While many users upgraded some of their peripheral cards to take advantage of the increased performance the 16-bit bus provided, many others just unplugged cards from their PCs, and stuffed them into their new ATs.

The MCA bus has both a different structure, and different connectors from the previous buses. There is no way to take a PC or AT peripheral, such as an internal modem card, and use it in an MCA bus system.

Though IBM-bashing is great fun, there is a definite need for some standard 32-bit bus. Prices on 80386-based machines are continuously falling, and many vendors are now offering them at reasonable prices. But each vendor seems to have come up with its own 32-bit bus, incompatible with every other vendor's. And until a standard acceptable to most is established, we won't see the wide range of superior graphics and memory boards the the PC and AT bus standard made possible for the less-powerful systems. This, in turn, will impede acceptance of 386 machines (and additionally slow the drop in system prices).

Strangely enough, it may be IBM's major rival that produces a solution. Compaq Computer has garnered support of over 40 other manufacturers and vendors of compatibles for the establishment of a new 32-bit bus standard. While at the time this is being written the standard has yet to be defined, it will most likely be an expansion of the now ubiquitous AT bus, just as this bus is an extension of the original PC bus.

Although this may mean that 386 users will lose the self-addressing peripherals the MCA bus provides, this is a small price to pay if wide-spread adaptation of an industry-standard bus hastens affordability and acceptance of a more powerful processor. There is even an indication that IBM realizes its mistake.

Just as Coca-Cola had to bring back "Coke-Classic," rumors are rampant about the imminent introduction of a new IBM system with the "classic" AT bus. Unfortunately for IBM, the 16-bit AT bus is last-year's news. What the industry needs now is for IBM to join Compaq's consortium and help define the standard for the next generation of machines.

[Update: At a meeting concerning the new 32-bit bus championed by Compaq

PC CAPERS...

Computer Corp., Zenith Data Systems and others, more than 60 companies supported the Extended Industry Standard Architecture (EISA) bus against IBM's MicroChannel Architecture (MCA) bus.

The 32-bit challenger is an extension of the existing IBM PC-AT 16-bit bus. It will use the higher-performance Intel 80386 microprocessor and an MS-DOS operating system to extend capabilities to new, more demanding applications. Moreover, as a superset of the existing standard, it is said to be compatible with hundreds of presently used 8- and 16-bit expansion boards, peripherals and software, thereby preserving users' investments. In contrast, IBM's MCA is not compatible with the AT bus. EISA is a "free" bus, too, as compared to royalty fees of up to 5 percent charged to licensees by IBM for using its MCA bus.

IBM isn't about to give up its MicroChannel bus, but it has introduced a brand new PS/2 Model 35 that's a 16-bit machine with an AT-type of bus. Guess that Big Blue wants in on the terrific AT market that it left to the clones. Furthermore, IBM's MCA-bus machines are here now and more hardware and software are expected in support of it, whereas the competing system will likely not see the light of day for delivery until mid-1989—Ed.]

New Life For An Oldie

Over the past year, this column has tended to concentrate on IBM (and compatible) PCs, with a little Macintosh thrown in. While some might perceive this as a slight against other popular computers, including the Amiga, Atari and Commodore, it really isn't. I don't own any of those others, and won't write about something that I haven't used. One system that I do own, but haven't covered, is an Apple IIe. The IIe is the third in a series of Apple IIs I've owned, and over the years has generated thousands of pages of client general ledgers, tax returns, and word processing documents. Today, though, it is most often used by my three-year old.

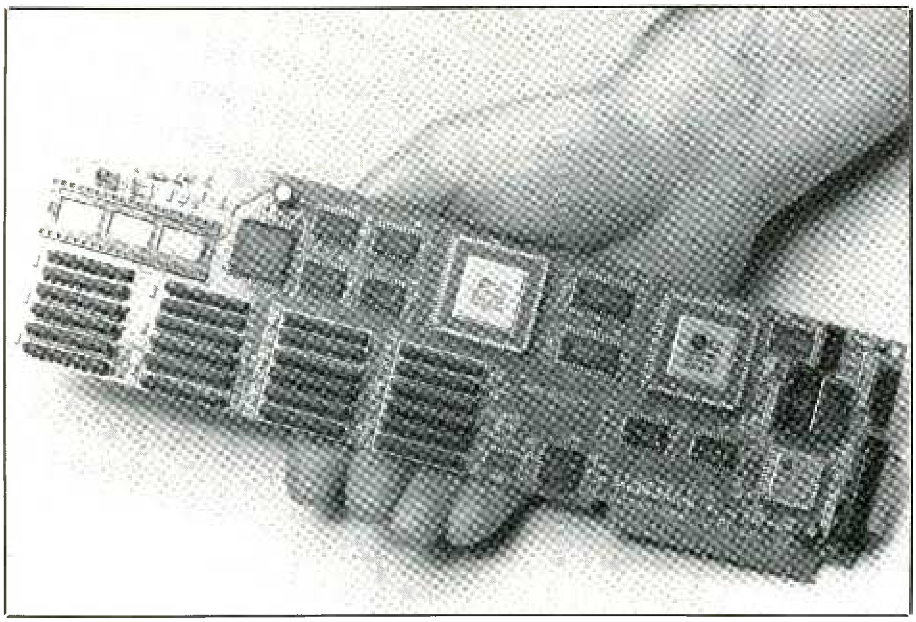
There are, however, over a million Apple IIs out there. When the CP/M operating system was at its zenith, the Apple II was the best-selling CP/M system in existence, thanks to Microsoft's SoftCard and Advanced Logic System's Z-Card. The Apple's open architecture easily allowed addition of the Z-80 CPU to the 6502 native mode.

That was then, this is now. And now is MS-DOS and 8088, 80286, and 80386-based systems. If you have an IBM-PC or compatible computer at work, and an Apple II at home, and have despaired of ever being able to shuttle work back and forth, the Apple's open architecture (and a company by the name of Applied Engineering) has come to the rescue. Just as an optional add-in coprocessor card provided compatibility with the CP/M operating system, Applied Engineering's PC Transporter gives your Apple II, II+, IIe, and IIGS MS-DOS compatibility.

Just like the Microsoft SoftCard, the PC Transporter is a coprocessor card that installs in an open slot in any II, II+, IIe or IIGS. It contains a NEC V30 CPU chip that runs at 7.16 MHz, and between 384KB and 768KB of RAM. The V30 is equivalent to the Intel 8086. This chip is similar to the ubiquitous 8088, but is a true 16-bit chip, having a 16-bit-wide data bus, whereas the 8088 uses only eight bits. The V30 uses the same instruction set as the 8088 and 8086, and is a popular alternate processor on many clones. Intel has, in fact, been suing NEC, claiming patent infringement with NEC's design of the V20 and V30 CPUs.

The RAM memory installed on the PC Transporter is usable by both the Apple in its native PRODOS mode and by MS-DOS. When the Transporter is in MS-DOS mode, 128KB of memory is used by the system software, so that a card equipped with 768KB of memory yields the MS-DOS maximum usable memory of 640KB. As with most PC compatibles, there's even a slot for a math coprocessor chip, in this case the 8087-2.

The PC Transporter also contains built-in disk and video controllers. You can use an Apple 3.5-inch drive (*not* the



Applied Engineering's PC Transporter board gives the Apple II, II+, IIe and IIGS MS-DOS compatibility.

Uni-Drive), or optional 5.25-inch PC compatible drives, supplied by Applied Engineering, which are MS-DOS compatible. A single 360K drive, in its own cabinet, costs $269, while a dual-drive system runs $399. You can also use the 5.25-inch PRODOS drives, already on your system, though they are incapable of reading MS-DOS diskettes.

PC transporter can use the standard Apple composite video, giving you a very readable text display on the black-and-white monitor you probably already have connected. If you are using an inexpensive composite color display, you may want to upgrade your monitor, since the readability of text on one of these leaves a lot to be desired.

With the addition of an inexpensive cable you can use a standard digital RGB monitor to achieve IBM CGA (Color Graphic Adapter) graphics resolution (320 × 200 pixels). If you have a IIGS, there is a ColorSwitch, for $44, which permits use of the GS analog color monitor.

PC Transporter re-maps the keyboard on a IIe or IIGS. All of the standard PC keys, including the function, Control, and ALT keys can be generated, and a map of the equivalent keys is included in the documentation. If you wish, $34 buys an IBM keyboard cable. You can plug a standard PC-type keyboard into this. These are available from various mail-order sources for as little as $40. Or, for $139, you can purchase both the keyboard and cable from Applied Engineering. If you have a II or II+, you will have to use the cable and an IBM-style keyboard. These keyboards did not have the native upper/lower case capability of the IIe and IIGS.

One item that Applied Engineering neither includes or provides is MS-DOS and GW-BASIC. I suppose they feel that if you are buying the PC Transporter, you already have at least one system, somewhere, that came with these items. If you don't, or if you are either going to run both systems simultaneously (your license for MS-DOS is for use on a single CPU at a time) or have the IBM version of BASIC, you can also purchase MS-DOS/GW-BASIC mail-order for $50 or $60.

Incidentally, IBM's BASIC won't run

on this or any other compatible, as a good portion of the language is resident (in an IBM) on ROM. PC-DOS (IBM's version of MS-DOS), however, runs just fine on the Transporter, except for version 3.31, which doesn't seem to run on anything other than a genuine IBM machine.

Installing the PC Transporter took me a little less than an hour. There is a VHS videotape available for $10 that takes you through the installation process, but I decided to just follow the detailed instructions included in the documentation. There are effectively two sets of instructions, one for IIGS owners and another for the II, II+, and IIe owners.

Installation is not much more complex than plugging the card into an empty slot. You can use any slot except 3. Next, you plug in cables which intercept and reroute the keyboard and speaker. Plug in the disk cable, and attach the DB connector to the Apple's back panel.

If you are using an IBM-style keyboard, the cable for this must also be plugged into the PC Transporter card, and the DIN connector mounted on the back panel. Plug the optional IBM compatible 5.25 drive(s) into the connector, and you're finished with the installation.

If you place the included PRODOS utility disk in one of the Apple drives, and an MS-DOS system disk in one of the PC-compatible drives, then turn on the power, in a few seconds you will see a self-test message, a BIOS message, then the familiar A>MS-DOS prompt. Running MS-DOS' CHKDSK utility showed me 640K of system memory.

The PC Transporter really does turn your Apple into a PC-compatible. While I haven't run all that many PC programs on it, it does run Lotus 1-2-3 and WordStar Version 4. It also ran the Norton Utilities, and the SI (System Information) utility included with Norton returned a value of 3.1 (or 3.1 times the power of a standard IBM-PC). It even ran PowerMeter from the Database Group. This benchmarking utility showed the PC Transporter-equipped Apple IIe to be slightly more powerful than a standard 6-MHz IBM-AT.

This power doesn't come for free. The PC transporter card with 768KB of RAM costs $699. Add another $399 for the dual drive PC compatible disks, and you've spent almost enough to buy a mail-order PC compatible.

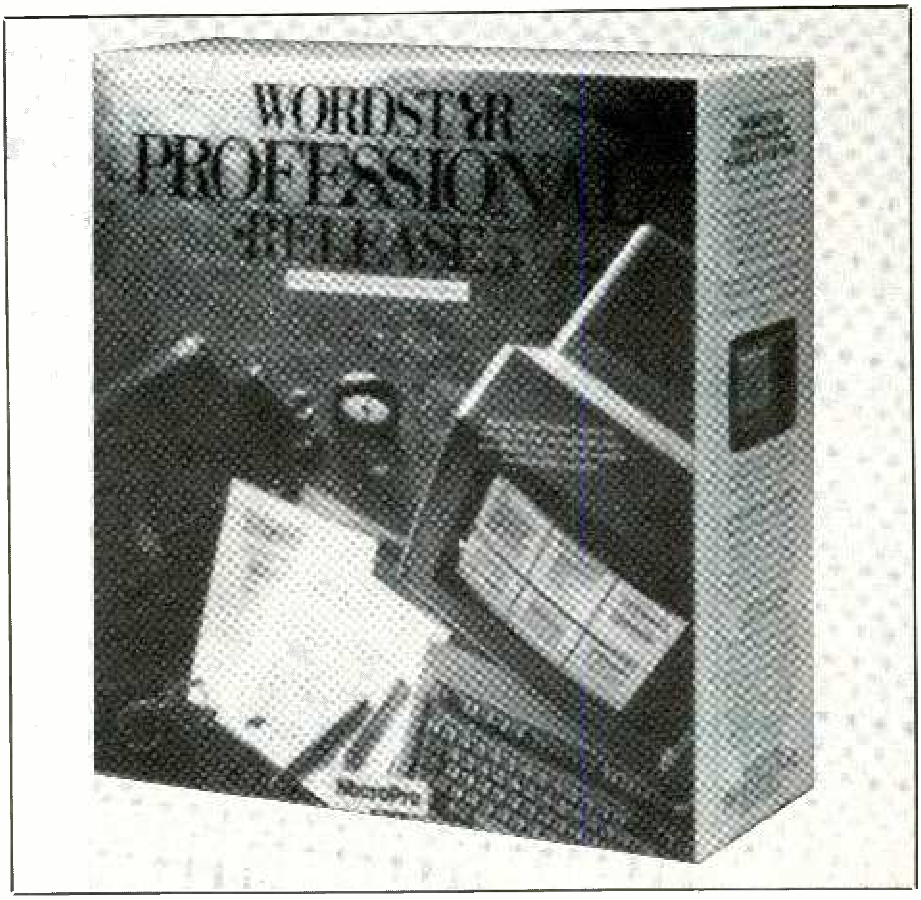
A PC Transporter-equipped Apple, however, is considerably more powerful than an 8088-based clone. Applied Engineering also includes PRODOS drivers so that your Transporter can recognize most PRODOS-compatible peripherals, such as serial and printer cards, Apple's mouse, and a PRODOS clock, and the PC Transporter treats these as their MS-DOS equivalents.

There is even a utility included which lets you transfer files back and forth between PRODOS and MS-DOS. This feature alone saved my bacon when I recently had to move some important AppleWorks files into an MS-DOS application. PC Transporter made this task a snap. In addition, the RAM on the PC Transporter can be used with Apple PRODOS applications, such as AppleWorks, that can take advantage of additional memory. If you use such applications, this alone can almost entirely justify the purchase cost of the board.

Now, in an emergency, I know I can walk over to the old Apple workhorse and, in a few seconds, see the famous Lotus 1-2-3 opening screen on its monitor. It's a warm feeling—both to know there's an extra backup now, and to see that an old friend didn't just fade away, but got a bionic transplant and become better than ever. For more information on PC Transporter, contact Applied Engineering, P.O. Box 798, Carrollton, TX 75006 (Tel.: 214-241-6060). ME

WordStar Professional Release 5: Adds Split Windows, Page Preview, etc.

By Art Salsberg



In our June 1987 issue, 1½ years ago, I reviewed WordStar's long-overdue, impressively upgraded word-processing program, WordStar Professional Release 4.0, observing it still had a few omissions that had to be addressed in order to compete in the front rank of today's software. Let's see what the new version, Release 5, contains and how it fares in comparison to what I wished for 18 months ago and in the current marketplace.

Firstly, hardware and software requirements are much the same. You still need DOS 2.0 or higher and an IBM or compatible computer (any model type, including Personal System/2). RAM memory minimum has been raised from 320K to 384K, however, though 512K is really the bare minimum you need to make sensible use and justify purchase of such a powerful package. To use it to its fullest, 640K is required.

Although it can be employed with dual floppy disk drives, I'd heartily recommend a hard disk drive since the complete program(s) are in the 3-megabyte range.

"List" price is still $495, while registered owners of earlier versions can update for $119. A LAN edition is also available for $595 and $150 per node. The program is not copy protected, as usual.

What's New

There are a great many changes of one sort or another in the WordStar Release 5 upgrade package. Most of the ones on my earlier review's wish list have been included: windows to edit two different documents on the same screen, an outliner, footnoting, paragraph numbering, automatic paragraph reformatting and pull-down menus. On the latter, the classic WordStar menu can also be chosen and one can quickly switch between menu types while in a program by a simple ^JJ keyboard input and choosing the help-level number desired.

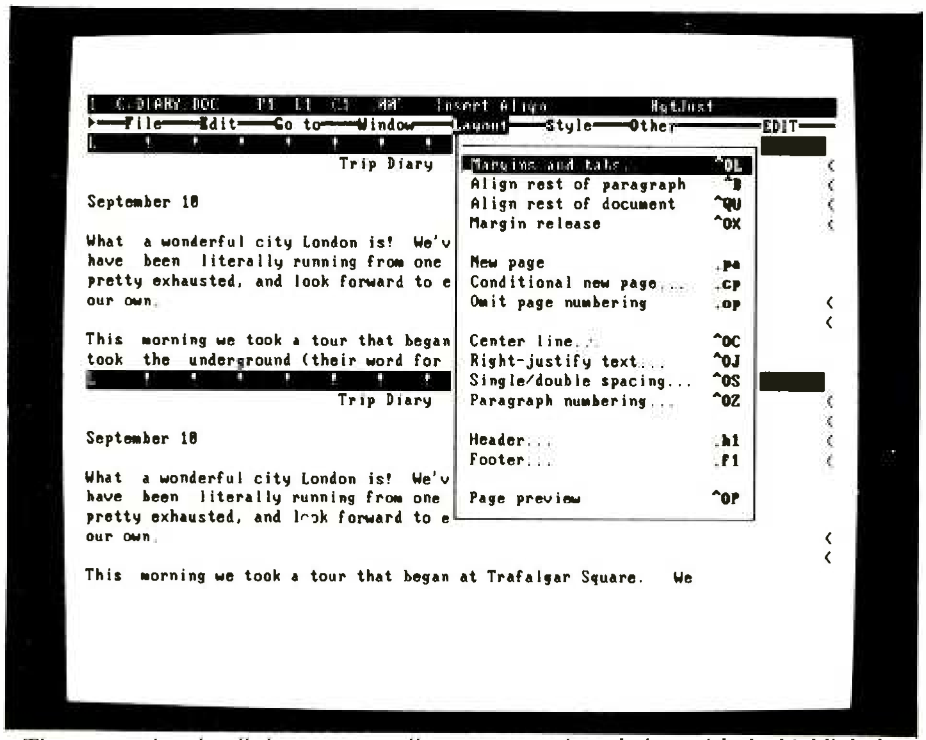
In addition to the foregoing, Release 5 has added a sophisticated Page Preview function; a file and directory manager; a record and cataloging program with fill-in forms for mail list management; a telecommunications program; direct import of Lotus, Quattro and Symphony spreadsheet files and dBase database files without conversion; comment notes; up to 8 newspaper-style columns; and PostScript laser printer support, to name some major enhancements.

A slew of lesser, but welcome changes include a shortcut to opening a new file by typing "S" at the opening menu and giving the document a name *after* you're through typing. The familiar "D" that requires naming a document before the blank editing screen appears is also available. Increased printer and font support, enhanced page layout provisions; context-sensitive help information; timed automatic file saving (on AT-type computers manufactured after November 1985); and an expanded speller and thesaurus with definitions added are just a few of the other changes made. Now let's look more closely at some of these key modifications to see what they do and how well they do it.

User Comments

For anyone not familiar with WordStar and its challenging control code key commands, the option of using pull-down menus and highlight bar command selections demystifies working with the powerful program. It makes preparing documents as easy as when done with low level word processing programs. Micropro wisely included keystroke command information on the menus, too, for those

SOFTWARE FOCUS . . .



The new optional pull-down menus allow users to select choices with the highlight bar. Two windows can be open at the same time to view and edit different documents and move information from one to the other.

who wish to learn the codes (which, for seasoned users, is the fastest way to go) and the option of using the "classic" menu of the previous version. A third alternative is using function keys, of course, which the "classic" menu choice shows at the bottom of the screen in reverse type blocks.

Among the most useful upgrades in Release 5 is the split-window editing function that was sorely missed in previous WordStar editions. At last you can edit text in two windows without using a separate utility, switching from one to the other quickly, and copying and moving blocks of text between them. It works delightfully well, and includes the ability to adjust window size.

Micropro is trumpeting attributes of Release 5's Advanced Page Preview feature. And it's not empty boasting. This is a true WYSIWYG (what you see is what you get) feature that can be quickly brought into play to see what a document you've prepared will look like *before* printing it, right down to actual font styles and sizes, subscripts, italics, etc. You can look at a single page, facing pages, multiple page layouts, and up to 144 pages in "thumbnail" form on a high-resolution monitor.

There are other choices, too, such as 2× or 4× zoom views that magnify sections of fonts and lines for examination and a grid to check layout alignment of pages. You can enter the program with a ^OM or through a highlight bar on the drop-down menu. The page(s) are displayed with amazingly fast speed, so toggling back and forth for editing purposes is not burdensome. There is a long pause the first time you use the Preview as the program builds a font library based on type you've selected that your printer handles. After this one-time delay, preview pages are called up in a flash. It's the best all-around page preview we've seen to date!

The updated version's automatic reformatting and text alignment finally counters the sneers of critics. Sometimes, though, typed characters that will change alignment do not instantly appear on screen. The occasional display delay while the automatic alignment program does its background work can be disconcerting at times, but worth it. The user can also turn off the auto align function.

Release 5 also contains four additional programs: an outliner (PC-Outline by Brown Bag Software) to organize ideas; MailList, which makes creating and using mailing lists a snap, and provides Rolodex-style "cards" for quick and easy viewing and printing; ProFinder, which is a speedy file finder, organizer and DOS shell that simplifies moving around the entire disk, performing tasks such as cut and paste, word search, etc. I appreciated being able to sort files and add comments alongside any to explain what the file contains. Lastly, there's TelMerge, a telecommunications program for modem users that gives easy pre-installed access to computer information services like CompuServe and electronic mail. Among its features are automatic log-on, strip and re-format during transmission, Hayes 1200 and 2400 modem support, as well as Xmodem protocol, and creating scripts.

The 100,000-word Speller and 220,000-word Thesaurus are now integrated into WordStar Professional instead of being separate programs. Using overlays, less memory is used up even though both have been expanded. Double words (a word repeated accidentally) are now caught by the Speller, which previous WordStar spellers ignored. The size of the personal dictionary is unlimited now, so no one has to use it sparingly any longer. Additionally, "definitions" has been added. (This feature won't be loaded for the Speller if you don't have a full 640K of memory.)

In addition to drop-down menus and being able to start a document without providing a file name, there are other operating simplifications advanced in the new WordStar Professional package. Columns of files displayed are now separated by heavy vertical highlight rules, and files can be chosen for loading, deleting, etc., by moving a highlight bar with an arrow cursor key to the file you want and simply pressing Enter, as well as also being able to type in the file name.

Among other improvements is the ruler line at the top of the screen, which displays a moving cursor. It's now an absolute measurement, with each column division representing one-tenth of an inch. The status line also indicates how many inches your cursor has moved on a page, and it automatically reflects how many characters will fit on a line regardless of what fonts or proportional spacing are used. Another new attribute that should be well received is the ability to copy data to a disk without overwriting information it contains. Paragraph and line numbering facilities will be useful for lawyers, among others. Also, paragraph style guides make it easier to set up template formats for margins and tabs.

Rounding out major changes, Release 5 provides extensive footnoting, end notes and annotations. Here the user can control formatting, font style, boldfacing, etc., as well as enjoying automatic renumbering when changes are made. More than 100 printers are now supported. For desktop publishing, there's expanded laser printer support in the new version. This includes HP LaserJet and other popular laser printers, as well as PostScript support for using Apple's LaserWriter. Fonts can be downloaded quickly from a convenient menu of type styles, too.

With a few exceptions, keystroke commands of previous WordStar Professional versions are retained. Among the changes here, Escape is no longer used for purposes other than to back out of an action. Whereas Release 4 used it to commence printing without choosing any options, Release 5 requires using the F10 function key. Also, to see menus while writing, Alt/spacebar brings it up instead of ^J. Thus, except for a few such changes, seasoned WordStar Professional users will be completely at home with Release 5, other than new commands that make operations more convenient or useful and working with the new programs added to the update. To convert Release 4 files for Release 5 use, they first have to be copied to disk, which is a simple and fast process.

Conclusions

WordStar Professional Release 5 has gone a long way in moving the venerable program into the competitive class of other popular high-level word-processing software. There are still a few features we'd like to see integrated, though they're easily added with low-cost, third-party utility programs.

For example, a high-level program such as WordStar Professional should incorporate a print queue. In the same vein, handling of graphics would seem to be an imperative built-in feature today. To enable WordStar Professional to work in a graphics oriented environment, therefore, a low-cost utility such as Inset has to be purchased. The same holds for converting other word-processing programs to WordStar format, which requires adding another low-cost utility such as Star Exchange. Furthermore, cursor movement is still rather sluggish, though many people prefer it so. For those who like a cursor to move with blazing speed, however, it's necessary to add yet another low-cost utility program such as Cruise Control.

This latest version of WordStar Professional, which took a year longer to debut than anticipated, does indeed make it formidable as a text-oriented package that can hold its own against other leading ones. Its new programs and features, both added and refined ones, make it exceptionally powerful and flexible. Moreover, WordStar Professional still can be customized to a remarkable extent.

At the same time, new-to-WordStar users will find that the pull-down menus, which use SAA (Systems Application Architecture) standards, and context-oriented Help messages remove the last obstacle to using the high-level word-processing program. A nice tutorial disk program that comes with the package makes learning how to use WordStar even easier, and everyone will appreciate the fine documentation accompanying Release 5, which includes a chapter on practical applications.

I was certainly happy to see that Release 5 retained the user option of using the old menu and function-key style, however, since this format makes operations faster for experienced WordStar users. Like Coca Cola, I prefer the Classic. Users unfamiliar with the command keystrokes can learn them easily enough since they're noted on pull-down menus, too.

So just where does the newest WordStar Professional sit in the modern world of sophisticated word processors? I believe it is now up there with the best of them for new users. There are indeed tradeoffs with any of the popular ones, just as the latter have tradeoffs against the newest WordStar Professional.

Familiarity with a particular program aside, if the fastest operating speed is uppermost, XyWrite has it, as well as great print control, typeset interfacing, and many windows. For well-roundness, WordPerfect has it all built in, including fine graphics handling and a print queue. And if you want to see the typeface that'll be printed without switching to a page preview, Word is there for you.

Alternatively, WordStar Professional Release 5 offers a Page Preview *par excellence*, as well as a heavy-duty Outliner, superb file organizer and manager, good telecommunications program and a very handy mail-list program. And anyone with WordStar keystroke command know-how who is unfamiliar with the conventions of other top-level WPs, will certainly choose the new upgraded program. In a word, WordStar Professional is now fully in the marketplace race, with enough special features to make it the buying choice of many newcomers who have not yet committed themselves to another powerful and flexible word processing package. **ME**

CIRCLE 51 ON FREE INFORMATION CARD

BOOKS

The Digital IC Handbook by Michael S. Morley. (Tab Books. Hard cover. 586 pages. $49.50.)

This massive volume provides system designers with a ready reference for selecting the most appropriate digital devices for their circuit designs. Organization is very logical, beginning with a chapter that compares the various logic families currently in use. Each succeeding chapter introduces progressively more complex logic elements. Chapter 2 deals with basic gate elements, while Chapter 3 deals with flip-flops, latches and multivibrators. More sophisticated elements are the subjects of Chapters 4, 5 and 6, which are devoted to buffers and transceivers; decoders, encoders and data selectors; and counters and shift registers. The final three chapters in the book deal with arithmetic circuits, memories and microprocessors, the last covering everything from the 8-bit 6502 to the 32-bit 80386 and beyond to custom-designed bit-slice microprocessors.

Being a "reference" book, this volume contains very little formal text. It is almost entirely a series of extensive tabular listings for virtually every device available in each category. The tables are of two types: general device description by number and device name and technical details. Technical information given in these tables include device family identification, type of output, access time, supply current, number of pins and typical retail price. Where applicable, the tables also list maximum operating frequencies, delay times, and other details. More than a third of the total page count is given over to 10 extensive appendices that are actually quick look-up indexes for 54/74, 4000, memories, 6500, 8000/80000, Z80/Z8000, 32000 and 2900 family devices. These tables list device number, name, pin count, amount of power drawn, retail price and supplier codes, the last defined in a final appendix.

Even though no package-configuration drawings or pinouts are given, this volume meets all criteria for the type of reference work it is intended to be.

Shortwave Directory by Robert B. Grove. (Grove Enterprises, P.O. Box 98, Brasstown, NC 28902. Soft cover. 524 pages. $17.95 + $2 UPS.)

In its fourth edition, this massive directory remains a comprehensive frequency guide for the 1.6-to-30-MHz vhf spectrum, but it is now expanded to include international broadcasting and vlf data. As a result, it is a single-source reference for U.S. listeners who want complete shortwave listings. The large-format book (about 8½" × 11") contains 15 major sections: Air Force, Navy, Army, Coast Guard, Federal Government, Aircraft, Space, Maritime, Public Safety, Business/Scientific/Private, Common Carrier, Broadcasting, FAX, RTTY and Longwave. This arrangement greatly simplifies the task of looking up a given service and frequency. All frequency listings throughout the directory are in ascending numerical order. Each frequency listed is accompanied by such data as callsign or ID, location of transmitter, operating time and, in the case of RTTY listings, baud rate/frequency shift.

There is very little "story" text in this book, though there are short caption-size pieces that serve as explanations or to provide interesting information. The book does contains a number of maps and photos, but it contains no advertising of any sort. Whatever "reading" matter it does contain consists basically of an extensive glossary of terms, acronyms and abbreviations commonly used on the shortwave bands.

The book is broken up into white, yellow and blue pages, that appear to give only a general significance. The blue pages contain only a Frequency Cross Reference section and Listener's Logsheets. The yellow pages contain the full RTTY listing section and virtually all of the FAX listing section, though the FAX section, for some unknown reason, also occupies a number of white pages at the beginning as well.

All in all, this is a valuable book for the SWL who needs quick, no-nonsense frequency/service lookup tables. It is, indeed, a one-stop reference on vhf listening.

Bob Middleton's Handbook of Electronic Time-Savers and Shortcuts by Robert G. Middleton. (Prentice Hall. Soft cover. 378 pages. $16.95.)

This book is a treasure trove of practical time-saving information for anyone who professionally tests, services and repairs electronic equipment, whether analog or digital. It details a variety of quick tests, shortcuts, test tips and new servicing techniques the author has learned over many years of practical troubleshooting experience, though a number of them were developed especially for this new book. Procedures are described and illustrated for troubleshooting audio, radio, TV, CB, tape-recorder, intercom, CCTV, telephone and digitally-controlled equipment, touching on virtually every area in consumer and many in commercial electronics.

In addition to traditional techniques like using a triggered-sweep oscilloscope and meters, the author presents a number of unorthodox but innovative test techniques. Among these are a way of using two digital voltmeters to measure dc voltages in a very-high-impedance circuit without drawing current from the circuit; building a simple voltage-controlled audio oscillator to use a tape recorder as a dc voltage monitor; using a dc voltmeter as a high-performance dynamic ohmmeter that measures the internal resistance of powered circuits. These are just a few of the things that make this book fascinating to read and apply, and why everyone who repairs electronics equipment for a living should have it.

As one reads through this book, he quickly discovers that its main thrust is to show ways of doing things that save time and improve troubleshooting efficiency. The material is geared to all levels of experience from beginner on up. The book is divided into two sections—analog and digital—each containing six chapters. In the analog section, separate chapters deal with dc tests, resistance tests, ac tests, impedance measurements, signal tracers and analyzers, and signal injectors and analyzers. Similarly, individual chapters in the digital section deal with general details about basic logic elements; progressive troubleshooting procedures, comparison tests; voltage-, current- and resistance-based troubleshooting procedures; troubleshooting procedures for counters; and encoder/decoder identification and troubleshooting.

For content, this book takes second place to no other of its kind. It is written in an easy-to-read style and is excellently illustrated. All in all, it represents an excellent investment for professional service personnel.

NEW LITERATURE

Short-Form Power-Supply Catalog. A four-page brochure on their Power Supplies and DC-DC Converters is available from Total Power International. It lists power supplies that range in output from 1 watt to 600 watts and have up to six outputs. Modular ac/dc power supplies and dc-dc converters that feature surface-mount technology are also listed. Each listing contains model number and salient technical specifications, including output in voltage, current and power. Power supply listings are arranged according to series in ascending amounts of output power. Converter module listings contain input voltage, output voltage, output current and case style entries. For a free copy, write to: Total Power International, Inc., 418 Bridge St., Lowell, MA 01850.

Ni-Cd Battery Book. A 52-page book that provides technical data on the Cadnica® family of sealed rechargeable nickel-cadmium batteries is available from Sanyo Energy Corp. Made up of nine chapters, the book tells a detailed story of batteries in general and the care,

(continued on page 84)

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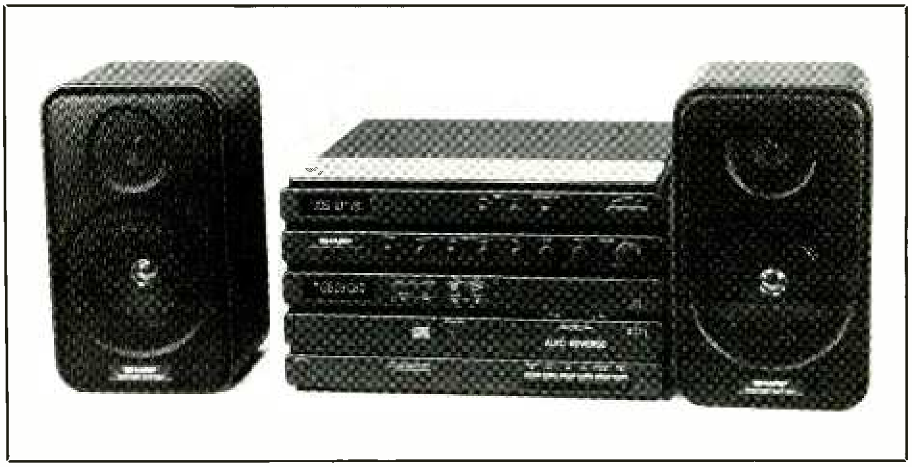
NEW PRODUCTS • • • (from page 15)

ter" and "receiver" inputs are via hooded banana jacks. There are three controls: a large bar-type function/range selector, 0dBm/ – 13dBm output-level switch, BRDG/TERM measurement selector switch and side-mounted "on/off" switch. The user can monitor receiver line signals with an earphone. $249.95.

CIRCLE 62 ON FREE INFORMATION CARD

Full-Featured Sound System



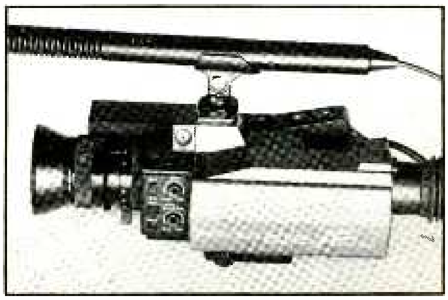
Sharp Electronics' Model CMS-N50CD bookshelf music system features a programmable CD player, auto-reverse cassette deck, belt-driven turntable, AM/FM-stereo tuner, integrated amplifier and detachable two-way speaker systems. The system has been ergonomically designed with frequently used controls like volume, tone, etc, being larger than less-frequently-used controls.

The AM/FM-stereo synthesized tuner has a digital numeric display and 14 station presets that are accessible by pressing only two preset buttons. The CD section features 20-track random-access programming, repeat function and horizontal slide-out CD compartment with built-in 3-inch CD-compatible adapter. A CD output terminal is also provided for use with another system. The cassette deck and CD compartment are side by side to provide easy disk-to-tape dubbing. Offering auto-reverse in both record and playback modes, the tape section also features automatic level control during recording. The cassette compartment is oil damped for soft eject. The belt-drive LP-record turntable on top of the unit features automatic return at end of play. The system is rounded out with a pair of speaker systems that contain 6.5-inch woofers. $499.95.

CIRCLE 58 ON FREE INFORMATION CARD

Video "Tele" Microphone

Audio-Technica's new Model ATR55 Telemike™ shotgun condenser microphone for home video recordists is the audio equivalent of a zoom lens. It has a three-position switch labeled off/normal/tele that can be set to match the distance of a video scene being shot. This avoids record-



ing audio that has a faint or far-away sound when using a camera's telescope function for closeup video recording. Setting the switch to normal causes the microphone to act as a conventional cardioid pickup. Switching to tele causes the microphone to function as a super-cardioid pickup that zooms in to match the sound

NEW LITERATURE (from page 79)

maintenance and use of Sanyo's Cadnica series. Each chapter is broken down into key sections complete with charts, tables, technical and schematic drawings. The nine chapters outline what a battery is, charge characteristics, discharge characteristics, storage characteristics, battery service life, the assembled battery and general remarks. The book concludes with specification tables on the batteries and a glossary. For a copy, write to: Dept. SF-6235, Sanyo Energy Corp., 1201 Sanyo Ave., San Diego, CA 92073.

TV Interference Traps Bulletin. Microwave Filter's Bulletin 08 describes negative traps for five different channel ranges and positive traps for three different channel ranges. It describes mid-band, FM, super/hyper-band, hyper-band, low-band/FM and low-band suppression traps, and filters for low-band/FM and hyper-band isolation, pilot carrier, selected FM channel, selected interference carrier and low-cost channel deletion. Theory of negative and positive trapping and use of pay-TV traps and filters as low-cost interference suppressors. Mention is made of special subscriber multi-channel filter networks for cable systems offering an additional broadcast-only basic package or for institutional hookups. The Positrap pay-TV security system is also described. For a copy of Bulletin 08, write to: Linda DeCoursey, Microwave Filter Co., Inc., 6743 Kinne St., E. Syracuse, NY 13057.

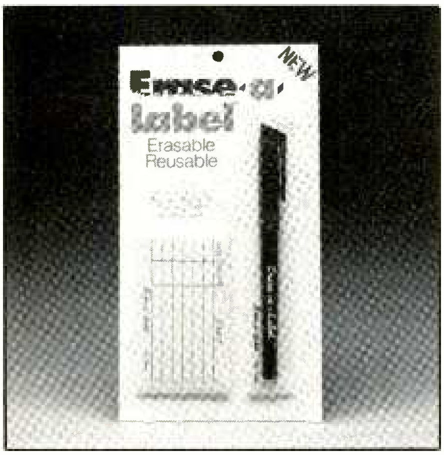
Indicator Light Guide. Dialight's new 184-page indicator light catalog provides detailed product information and guidelines for selecting the proper indicator for specific applications. "The Complete Guide to Dialight Indicator Lights" provides useful information on 1.5-million neon, incandescent and LED indicators, including physical and electrical characteristics. The catalog contains hundreds of dimensioned drawings that show the indicators from several aspects. The front section of the catalog provides applications information. For a copy, write to: Dialight Corp., Catalog Dept., 1913 Atlantic Ave., Manasquan, NJ 08736.

with the picture. Housed in a rugged metal case, the ATR55 comes with pistol grip, camera mount, wind screen and battery. $89.95.

CIRCLE 59 ON FREE INFORMATION CARD

Erasable Labels

Erase-a-Label™ from a company of the same name (Dallas, TX) offers a solution to anyone who has had to cope with constant labeling and relabeling computer disks, videocassette tapes, etc. It is a system that enables



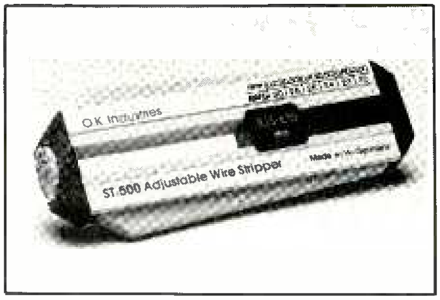
the user to write information onto labels and then later wipe it off. Each system kit consists of a number of self-stick labels and a marker filled with a special fast-drying but erasable ink. The labels have a durable coating that provides the erasable, reusable surface for marking purposes. Once written on, erasure is accomplished with a cloth or tissue dampened with alcohol. No eraser is used to generate particles that can damage delicate VCR and floppy-disk drive heads.

Three color-keyed versions of the Erase-a-Label kit are available. Each contains the special marking pen. One contains 20 labels for 5¼-inch disks (blue), 20 labels for 3½-inch disks (green) and 10 spine and 10 index labels for VHS videocassettes (red).

CIRCLE 60 ON FREE INFORMATION CARD

Precision Wire Stripper

OK Industries Inc.'s new Model ST-500 adjustable precision wire

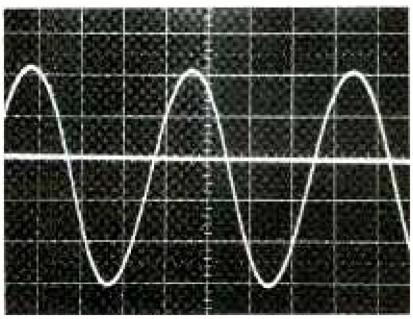


stripper is said to accurately strip insulation from 20-to-30-AWG (0.25-to-0.8-mm) wire. The tool has four hardened blades that strip all types of insulation, including Teflon. Weighing less than 1 ounce, the ST-500 is easy to operate. Its adjustment wheel is first set to the appropriate wire diameter, the wire is then plugged into the end hole, the handle is squeezed and the tool is turned slightly to withdraw the wire. An adjustable wire stop can be set for the amount of insulation to be removed. $29.95.

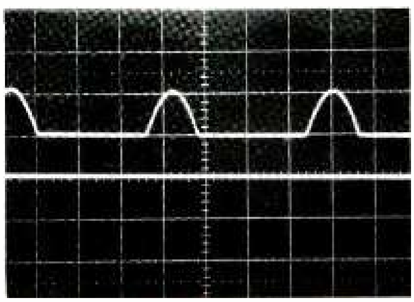
CIRCLE 61 ON FREE INFORMATION CARD

The Solution

Here is the solution to quiz question given on page 29. The waveforms that should appear at points A and B in the Fig. 9 circuit would be as shown in the upper and lower photos, respectively.



(A)



(B)

MODERN ELECTRONICS MART

Classified Commercial Rates: $1 per word, 15-word minimum ($15.00) prepaid. (Word count includes name and address; ZIP code and abbreviation each count as one word; P.O. Box number and telephone number count as two words each.) Indicate free category heading (**Computers, Communications, Electronics, Video** or **Miscellaneous**). A special heading is available for a $6 surcharge. First word only is set boldface caps at no charge. Add 20% for additional boldface words.

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VIDEO

TV/VCR REPAIR TIPS VOLUMES I AND II. Each with 1,000 up-to-date problems/cures listed by model and chassis for quick easy lookup. $29.95 per volume. Add $2.50 postage and handling. Computer Assistance, Box 232026, Anchorage, AK 99523.

PROJECTION TV . . . Convert your TV to project 7 foot picture . . . Easy! . . . Results comparable to $2,500 projectors . . . **PLANS AND 8″ LENS** $24.95 . . . Professional Systems available . . . Illustrated Catalog FREE . . . **MACROCOMA** 15MD Main Street, Washington Crossing, Pennsylvania 18977. Creditcard Orders 24 HRS. (215) 736-3979.

COMPUTER TV/VCR REPAIR TIPS DATABASE PROGRAM (IBM Compatible w/hard drive). Scan symptoms and cures by model or chassis. Add, change, delete, print out. $49.95 for program. $69.95 includes database with over 1,000 up-to-date repair tips. Add $2.50 postage and handling. Computer Assistance, Box 232026, Anchorage, AK 99523.

CABLE TV CONVERTER/DESCRAMBLERS - Original Factory Zenith, Tocom, Scientific Atlanta, Oak, Jerrold, Pioneer, Remotes, Video Accessories, Kits. Best Buys/Warranties - **FREE CATALOG. ARIZONA VIDEO,** 3661 N. Campbell, #310-H, Tucson, Arizona 85719. (602) 323-3330.

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74C00 CMOS

74HC00 CMOS

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Interface

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NEC MICROPROCESSOR CHIPS

SILICON TRANSISTORS

Part	Pkg.	1	10	100
PN5133	TO-92	.24	2.13	18.50
PN5134	TO-92	.24	2.13	18.50
PN5135	TO-92	.24	2.13	18.50
PN5136	TO-92	.28	2.48	21.59
PN5138	TO-92	.24	2.13	18.50
PN5139	TO-92	.24	2.13	18.50
PN5142	TO-92	.24	2.13	18.50
TIP29	TO-220	.84	7.44	64.76
TIP29A	TO-220	.88	7.80	67.85
TIP29B	TO-220	.91	8.06	70.16
TIP29C	TO-220	.95	8.42	73.25
TIP30	TO-220	.91	8.06	70.16
TIP30A	TO-220	.95	8.42	73.25
TIP30B	TO-220	.98	8.68	75.56
TIP30C	TO-220	1.02	9.04	78.64
TIP31	TO-220	.72	6.38	55.51
TIP31A	TO-220	.76	6.73	58.60
TIP31B	TO-220	.79	7.00	60.91
TIP31C	TO-220	.83	7.35	63.99
TIP32	TO-220	1.16	10.28	89.44
TIP32A	TO-220	1.19	10.54	91.75
TIP32B	TO-220	1.23	10.90	94.83
TIP32C	TO-220	1.26	11.16	97.15
TIP41	TO-220	1.16	10.28	89.44
TIP41A	TO-220	1.19	10.54	91.75
TIP41B	TO-220	1.23	10.90	94.83
TIP41CP	TO-220	1.26	11.16	97.15
TIP42	TO-220	1.47	13.02	113.34
TIP42A	TO-220	1.51	13.38	116.42
TIP42B	TO-220	1.54	13.64	118.73
TIP42C	TO-220	1.58	14.00	121.82
TIP61C	TO-220	.67	5.94	51.66
TIP62C	TO-220	.67	5.94	51.66
TIP110	TO-220	1.05	9.30	80.96
TIP111	TO-220	1.16	10.28	89.44
TIP112	TO-220	1.19	10.54	91.75
TIP115	TO-220	1.30	11.52	100.23
TIP116	TO-220	1.33	11.78	102.54
TIP117	TO-220	1.37	12.14	105.63
TIP120	TO-220	1.09	9.66	84.04
TIP121	TO-220	1.12	9.92	86.35
TIP122	TO-220	1.16	10.28	89.44
TIP125	TO-220	1.33	11.78	102.54
TIP126	TO-220	1.37	12.14	105.63
TIP127	TO-220	1.40	12.40	107.94
TIP135	TO-220	1.19	10.54	91.75

1 AMP SILICON RECTIFIERS

Part No.	Description	Pkg.	1	10	1000	1,000
1N4001	50 PIV	DO 41	—	.70	5.60	49.00
1N4002	100 PIV	DO 41	—	.75	6.00	52.50
1N4003	200 PIV	DO 41	—	.80	6.40	56.00
1N4004	400 PIV	DO 41	—	.85	6.80	59.50
1N4005	600 PIV	DO 41	—	.88	7.00	61.25
1N4006	800 PIV	DO 41	—	.98	7.80	68.25
1N4007	1000 PIV	DO 41	—	1.08	8.60	75.25

5% CARBON FILM RESISTORS

Available in 1/8, 1/4 & 1/2 Watt

How To Order. Take any standard resistor value (i.e. 3.2) and add an "E" for 1/8 watt or a "Q" for 1/4 watt or an "H" for 1/2 watt (i.e. 3.2Q for 3.2Ω 1/4 watt), this is the Digi-Key part number.

Pricing	5	200	1,000
1/8 Watt	.25	6.40	25.00
1/4 Watt	.25	3.40	13.00
1/2 Watt	.25	3.50	16.00

1/8 Watt Resistor Assortments

RS112	Set of 5 each of the 73 standard 5% 1/8 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces)	$9.90
RS212	Set of 5 each of the 72 standard 5% 1/8 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces)	$9.90

1/4 Watt Resistor Assortments

RS125	Set of 5 each of the 73 standard 5% 1/4 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohm (365 total pieces)	$9.90
RS225	Set of 5 each of the 72 standard 5% 1/4 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces)	$9.90

1/2 Watt Resistor Assortments

RS150	Set of 5 each of the 73 standard 5% 1/2 watt carbon film resistors in the series 1.0, 1.2, 1.5, 1.8, 2.2, etc., through 1.0 megohms (365 total pieces)	$9.90
RS250	Set of 5 each of the 72 standard 5% 1/2 watt carbon film resistors in the series 1.1, 1.3, 1.6, 2.0, 2.4, etc., through 910 kilohm (360 total pieces)	$9.90

1% METAL OXIDE FILM RESISTORS

Available in 1/4 Watt

How To Order. Take any standard resistor value (i.e. 1.69K) and add an "X" (i.e. 1.69KX); this is the Digi-Key part number.

Pricing	5	200	1,000
1/4 Watt	.50	7.80	30.00

1/4 Watt Metal Film Resistor Assortments

RS1X	5 each of values 10Ω to 97.6Ω (480 total pieces)	$29.95
RS2X	5 each of values 100Ω to 976Ω (480 total pieces)	$29.95
RS3X	5 each of values 1.00KΩ to 9.76KΩ (480 total pieces)	$29.95
RS4X	5 each of values 10.0KΩ to 97.6KΩ (480 total pieces)	$29.95
RS5X	5 each of values 100KΩ to 1.00MΩ (480 total pieces)	$29.95

5% WIREWOUND RES. RESISTORS

Available in 5 & 10 Watt

How To Order. Take any standard resistor value (i.e. 7.5) and add "W5" for 5 watt, or add a "W10" for 10 watt (i.e. 7.5W5 for 7.5Ω 5 watt), this is the Digi-Key part number.

Pricing	1	10	100	500	1,000
5 Watt	.36	3.25	28.00	100.80	182.00
10 Watt	.41	3.78	31.90	118.00	212.00

5 Watt Metal Resistor Assortments

RS105	5 each of values 0.30Ω to 0.91Ω (300 total pieces)	$20.10
RS205	4 each of values 1.0Ω to 9.1Ω (384 total pieces)	$31.30
RS305	4 each of values 10Ω to 91Ω (384 total pieces)	$31.30
RS405	4 each of values 100Ω to 2.0KΩ (288 total pieces)	$31.30

10 Watt Resistor Assortments

R110	2 each of all 10 watt standard resistor values listed in the Digi-Key catalog (168 total pieces)	$58.95

5% METAL OXIDE FILM RESISTORS

Available in 1 & 2 Watt

How To Order. Take any standard resistor value (i.e. 1.5K) and add a "W1" for 1 watt or add a "W2" for 2 watt (i.e. 1.5KW1 for 1.5KΩ 1 watt), this is the Digi-Key part number.

Pricing	1	5	100	500	1,000
1 Watt (0.47-0.91Ω)	.21	.98	12.80	56.00	101.50
1 Watt (1.0-1.0MΩ)	.15	.70	9.00	40.00	72.50
2 Watt (0.47-0.91Ω)	.23	1.08	13.16	59.40	109.40
2 Watt (1.0-1.0MΩ)	[illegible]	[illegible]	10.50	47.50	87.50

1 Watt Metal Resistor Assortments

RS101	5 each of values 0.47Ω to 56Ω (256 total pieces)	$26.95
RS201	5 each of values 62Ω to 7.5KΩ (256 total pieces)	$26.95
RS301	5 each of values 8.2KΩ to 1.0M (256 total pieces)	$26.95

2 Watt Resistor Assortments

RS102	5 each of values 0.47Ω to 56Ω (256 total pieces)	$29.95
RS202	5 each of values 62Ω to 7.5KΩ (256 total pieces)	$29.95
RS302	5 each of values 8.2KΩ to 1.0M (256 total pieces)	$29.95

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T102 ND	16 @ 260	8 @ 520	4.4	7.69
T103 ND	20 @ 220	10 @ 440	4.4	7.69
T104 ND	24 @ 180	12 @ 360	4.4	7.69
T105 ND	28 @ 160	14 @ 320	4.4	7.69

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P301*	Red Clear	Φ5.0	—	1.56	26.00
P303*	Green Diffused	Φ5.0	—	2.31	38.50
P302*	Green Clear	Φ5.0	—	2.31	38.50
P306*	Amber Diffused	Φ5.0	—	2.31	38.50
P304*	Amber Clear	Φ5.0	—	2.31	38.50
P307*	Orange Diffused	Φ5.0	—	2.31	38.50
P305*	Orange Clear	Φ5.0	—	2.31	38.50
P374	Red Diffused	Φ5.0	—	1.56	26.00
P375	Green Diffused	Φ5.0	—	2.31	38.50
P372	Amber Diffused	Φ5.0	—	2.31	38.50
P373	Orange Diffused	Φ5.0	—	2.31	38.50

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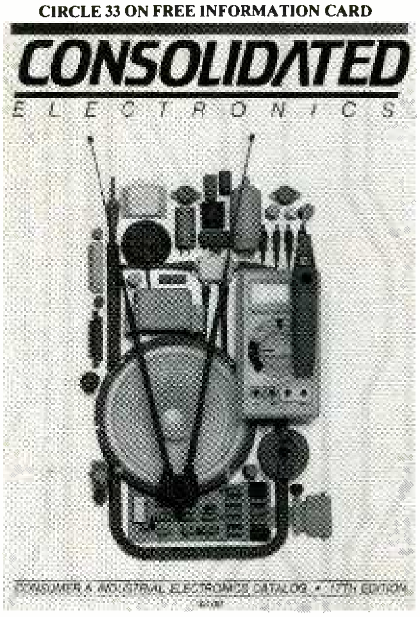

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