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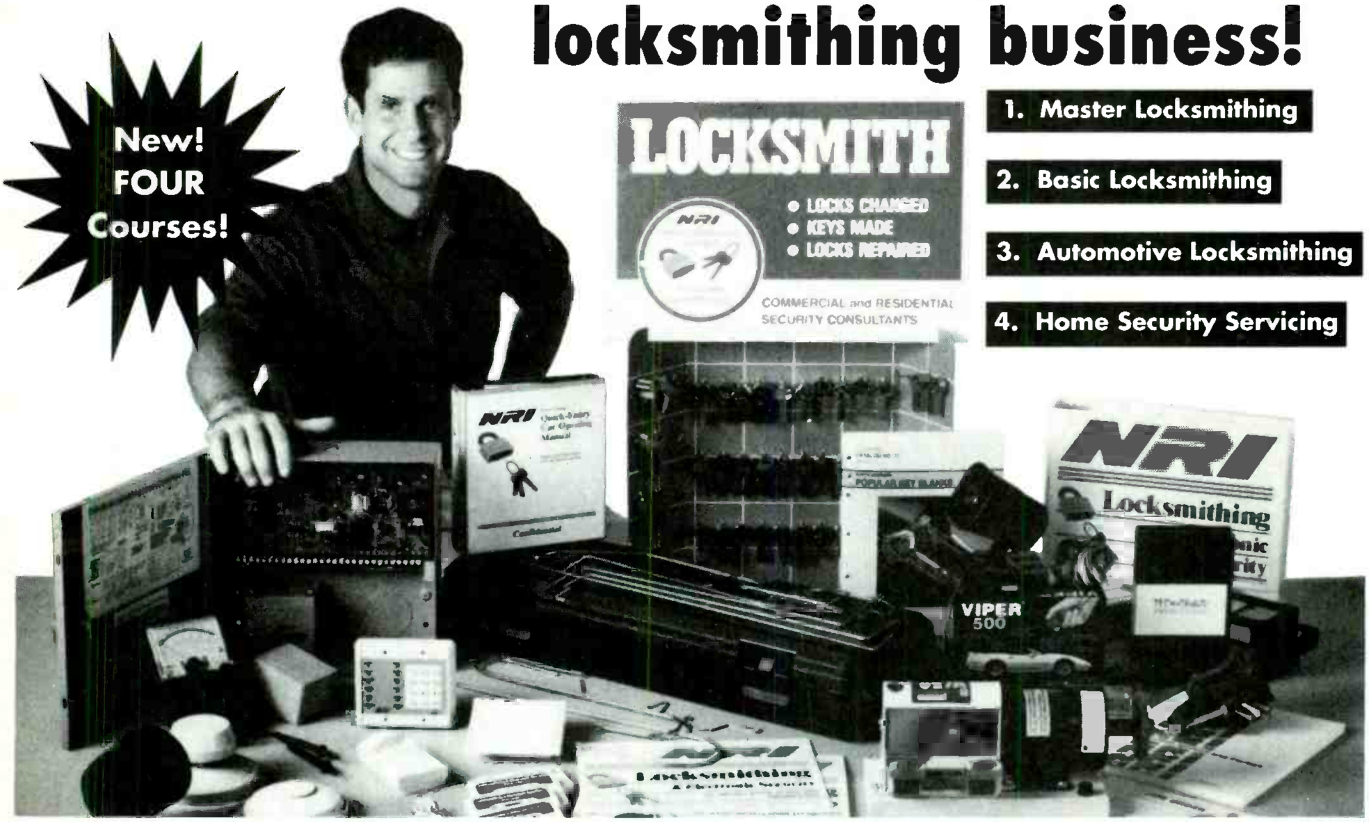


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Electronics NOW

Vol. 65 No. 12

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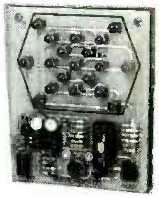







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*A review of the latest happenings in electronics.*

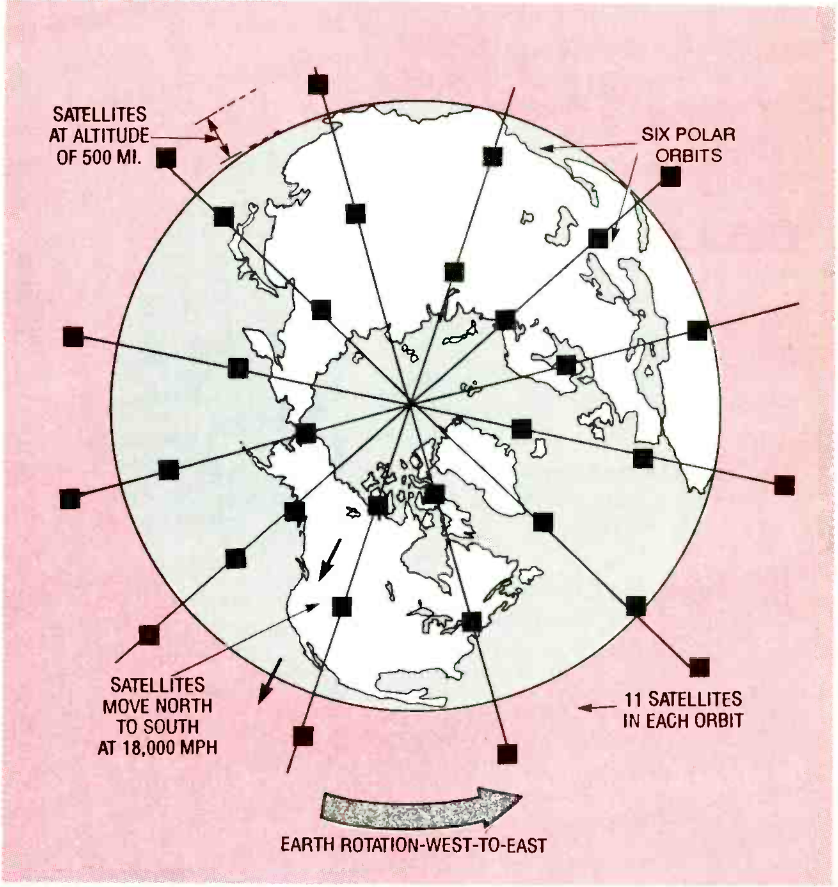
### Iridium System Funds Raised

Motorola has surprised its critics and skeptics by raising the initial $1.57 billion it needs to build a global telephone system based on 66 small satellites. The 66 satellites are 11 fewer than the 77 originally planned for the Iridium system, and the date for the start of service has been pushed back two years to 1998.

Iridium Inc. is the Motorola subsidiary formed four years ago to manage the project named for a white, brittle metal with an atomic number of 77—the same as the number of satellites originally planned. Iridium is used in watch bearings, pen points, and scientific instruments because of its resistance to corrosive chemicals.

The Motorola company will be responsible for launching the satellites and building a $3.4 billion global network that will permit people anywhere in the world to talk to each other over handheld wireless telephones. The satellites are now being built, and Iridium executives say that they can finance the rest of the project through debt offerings. However, Motorola has had to increase its investment in Iridium to more than 25% rather than reduce it as it had hoped to do.

Each satellite includes computer-based switch gear to relay signals to companion satellites around the world in the 1.610- to 1.627 GHz band. The system is intended to permit telephone communication between two persons thousands of miles apart without ever making use of telephone land lines.




**MOTOROLA'S IRIDIUM SYSTEM: Global wireless telephone coverage will be provided by 66 satellites arranged 11 to each of six low polar orbits (LEO).**

### 256-mega DRAM chip developed

South Korea's Samsung Electronics has developed the world's first 256-megabit DRAM (dynamic random access memory). The device has 268 million fully functioning memory cells. According to Samsung, the process technology developed for manufacturing the DRAM is also suitable for mass producing super-fast, large-scale, low-power-consuming memories with sub-micron geometries.

The Samsung DRAMs are made with a 0.25-micron CMOS process which permits each device to store the equivalent of 2000 newspaper pages. The company expects that the DRAMs will find applications in computer main memory and in high-performance workstations. It also sees the devices assuming a major role in HDTV and multimedia products of the future.

Samsung says it was the first company to develop the 64-megabit DRAM, a feat it accomplished two years ago. Samples of the 256-megabit DRAM are expected to be available to key customers between 1997 and 1998, and full-scale production is forecast by the turn of the century.

### Joint-venture DRAM manufacturing facility

Texas Instruments and Hitachi plan to build the semiconductor industry's first joint-venture manufacturing plant in the United States. The half-billion dollar wafer fabrication facility will produce 16- and 64-megabit dynamic random access

*(Continued on page 8)*

# VIDEO NEWS

*What's new in the fast-changing video industry.*

**DAVID LACHENBRUCH**

• **Projection TV takes off.** The growth of home theater, better pictures, more models, and somewhat lower prices have contributed to an unexpectedly strong growth of projection TV. Sales in 1994's first seven months were up almost 37% from 1993. U.S. Precision Lens, which manufactures plastic lenses for about 80% of projection TVs, has raised its forecast of sales this year to as many as 650,000 sets from its prediction early this year that 535,000 would be sold, despite prices starting in the $2,500-and-up area.

The company gives these basic reasons for projection's "explosive growth: "(1) Big-screen sets constitute "the only profitable segment of color TV." (2) "The new sets feature significant improvements, including a smaller footprint than most large-screen direct-view models." (3) "Dramatic growth of home theater" has spurred retailers to give effective demonstrations and add more floor space for projection. (4) "More emphasis on sports and movies in viewing has increased demand for bigger screens, and this will grow with such developments as direct satellite broadcasting and video-on-demand."

**Sales of projection TVs, such as the SharpVision XV-H35U LCD projection system pictured here, have risen dramatically, thanks in part to the growing popularity of big-screen sets and home theater, and an increased emphasis on movie and sports viewing.**

• **HDTV tests successful.** The first field tests involving the Grand Alliance high-definition system were described as "incredibly successful" by Mark Richer, chairman of the Systems Evaluation and Testing Working Party. The Charlotte, North Carolina, tests were the first over-the-air evaluations. However, they involved only transmission subsystems. Earlier tests had been conducted in the lab. For the on-air tests, digital data stream was transmitted using the system's eight-level vestigial sideband transmission modem, and measurements were made at 199 sites on VHF and UHF channels. The tentative schedule calls for the construction of a full HDTV system prototype this winter, to be followed by lab tests this winter and over-the-air field tests of the full system in the U.S. and Canada in 1995.

• **"Magic Wand" for TV?** With the coming of interactive TV comes another problem: How will humans interface with the set? Current infrared remotes are insufficient and computer techniques are inappropriate, according to think tanks addressing the problem. One study by a team at AT&T Bell Laboratories set up these criteria for a remote interface to interactive TV:

(1) It must move the cursor smoothly on the screen. (2) It must be cordless. (3) The user must be able to hold and operate it with one hand. (4) It must be energy efficient and battery powered. (5) It must be simple. (6) It must be usable in the dark. (7) It must have few moving parts. (8) The cursor shouldn't be on screen at all time, but the user should be able to activate it easily. (9) It must be foolproof and resistant to errors if the wrong button is pressed. (10) It should be easy to use for children, the elderly, and both left- and right-handed people. (11) It should easily point to any cell in a 10 × 10 matrix from over 20 feet away. (12) It should be popcorn and coffee resistant. (13) Its use should be intuitive, at least as easy as a trackball or mouse.

The study found that computer interfaces fall short. Touchpads can't be used, nor can a 70-button computer keyboard, and users "do not want to have a screen cluttered with the TV equivalent of the PC tool bar and menu."

After a series of tests, the researchers said that the first generation of interactive TVs might have "a new wand-like pointing technology," which has proven so far to be "the most promising in selecting choices and moving objects on a TV monitor." This control device "will look very much like a cross between

*(Continued on page 8)*

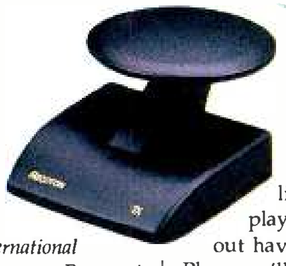
### 900 MHz breakthrough!

# New technology launches wireless speaker revolution...

*Recoton develops breakthrough technology which transmits stereo sound through walls, ceilings and floors up to 150 feet.*

*Breakthrough wireless speaker design blankets your home with music.*

*By Charles Anton*




If you had to name just one new product "the most innovative of the year," what would you choose? Well, at the recent *International Consumer Electronics Show*, critics gave Recoton's new wireless stereo speaker system the *Design and Engineering Award* for being the "most innovative and outstanding new product."

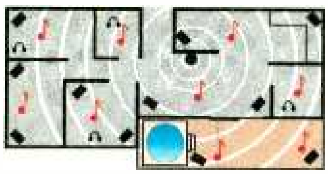
Recoton was able to introduce this whole new generation of powerful wireless speakers due to the advent of 900 MHz technology. This newly approved breakthrough enables Recoton's wireless speakers to rival the sound of expensive wired speakers.

**Recently approved technology.** In June of 1989, the *Federal Communications Commission* allocated a band of radio frequencies stretching from 902 to 928 MHz for wireless, in-home product applications. Recoton, one of the world's leading wireless speaker manufacturers, took advantage of the FCC ruling by creating and introducing a new speaker system that utilizes the recently approved frequency band to transmit clearer, stronger stereo signals throughout your home.

**150 foot range through walls!**

Recoton gives you the freedom to listen to music wherever you want. Your music is no longer limited to the room your stereo is in. With the wireless headphones you can listen to your TV, stereo or CD player while you move freely between rooms, exercise or do other activities. And unlike infrared headphones, you don't have to be in a line-of-sight with the transmitter, giving you a full 150 foot range.

The headphones and speakers have their own built-in receiver, so no wires are needed between you and your stereo. One transmitter operates an unlimited number of speakers and headphones.



*Recoton's transmitter sends music through walls to wireless speakers over a 75,000 square foot area.*

**Crisp sound throughout your home.** Just imagine being able to listen to your stereo, TV, VCR or CD player in any room of your home without having to run miles of speaker wire. Plus, you'll never have to worry about range because the new 900 MHz technology allows stereo signals to travel over distances of 150 feet or more through walls, ceilings and floors without losing sound quality.

**One transmitter, unlimited receivers.** The powerful transmitter plugs into a headphone, audio-out or tape-out jack on your stereo or TV component, transmitting music wirelessly to your speakers or headphones. The speakers plug into an outlet. The one transmitter can broadcast to an unlimited number of stereo speakers and headphones. And since each speaker contains its own built in receiver/amplifier, there are no wires running from the stereo to the speakers.

**Full dynamic range.** The speaker, mounted in a bookshelf-sized acoustically constructed cabinet, provides a two-way bass reflex design for individual bass boost control. Full dynamic range is achieved by the use of a 2" tweeter and 4" woofer. Plus, automatic digital lock-in tuning guarantees optimum reception and eliminates drift. The new technology provides static-free, interference-free sound in virtually any environment. These speakers are also self-amplified; they can't be blown out no matter what your stereo's wattage.

**Stereo or hi-fi, you decide.** These speakers have the option of either stereo or hi-fi sound. You can use two speakers, one set on right channel and the other on left, for full stereo separation. Or, if you just want an extra speaker in another room, set it on mono and listen to both channels on one speaker. Mono combines both left and right channels for hi-fi sound. This option lets you put a pair of speakers in the den and get full stereo separation or put one speaker in the kitchen and get complete hi-fi sound.

*These wireless stereo headphones have a built-in receiver.*

**Factory direct savings.** Our commitment to quality and factory direct pricing allows us to sell more wireless speakers than anyone! For this reason, you can get these speakers far below retail with our 30 day *"Dare to Compare"* money-back guarantee and full one year manufacturer's warranty. For a limited time, the Recoton transmitter is only $69. It will operate an unlimited number of wireless speakers priced at $89 and wireless headphones at $59 each. Your order will be processed in 72 hours and shipped UPS.

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*Recoton's Design and Engineering Award*

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**WHAT'S NEWS**

*continued from page 4*

memories (DRAMs).

The demand for DRAMs is expected to outpace Texas Instrument's existing production facilities. The plant will be built in Richardson, Texas. That site was selected because of the presence of a large pool of skilled semiconductor workers in the Dallas-Richardson region. It is expected that more than 500 persons will be employed when the plant is fully operational. Production is expected to begin in the third or fourth quarters of 1996.

Most of the plant will be owned by Texas Instruments and Hitachi, but other minority investors are participating. The joint-venture arrangement allows the two companies to work together and share the financial burden of a leading-edge wafer fab facility in an increasingly multinational industry.

It might not have been feasible for either of the major participants to finance the advanced facility with its own resources. It can be expected that there will be more joint ventures in the industry because of the spiraling costs of constructing facilities capable of manufacturing sub-micron dimension semiconductor devices.

Texas Instruments and Hitachi have been cooperating on memory-device research and development since 1988 when they shared technology for fabricating the 16-megabit DRAM. The two companies worked together to develop 64-megabit DRAMs in 1991 and 256-megabit DRAMs in 1993.

### Quadrillion-watt laser

A new laser beam that is expected to produce ten times the power of Nova, the world's most powerful laser, is under construction at the Lawrence Livermore National Laboratory.

Called the Petawatt Laser, it will make use of only one of Nova's ten beams and yet produce a tenfold increase in power by reducing laser pulse duration by a factor of 1000. (A petawatt is a quadrillion watts.) It will be installed in beam line six of the Nova laser.

When the Petawatt Laser is completed in December 1995, it will generate 1000-trillion watts (one-quadrillion watts) of peak power, in pulses as short as a half-trillionth of a second. For that extraordinarily short interval, this power is about a thousand times the output of the entire electrical generation capability of the United States.

The ten-beam Nova laser now produces 100-trillion watts of power, or one-tenth of the output of the U.S. electrical grid, in less than a billionth of a second.

New short-pulse laser technologies have also permitted the development of a new concept called "Fast Ignition" by Lawrence Livermore researchers. This technique will ignite the tiny deuterium-tritium fuel capsule in a laser fusion implosion.

Fusion occurs when heavy isotopes of hydrogen combine and release energy—a process that powers the sun and other stars. Fusion is being studied at Livermore because similar conditions occur in the detonation of nuclear weapons and because it is a potentially safe, clean, and almost unlimited source of energy.

Two lasers are teamed in Fast Ignition. The first laser would employ conventional fusion techniques to implode the deuterium-tritium fuel capsule, while asecond intense laser (like the Petawatt Laser) would initiate the fusion reaction within a few trillionths of a second.

This concept could substantially reduce the requirements for laser energy and implosion symmetry needed for laser fusion, compared to those required by conventional laser fusion. In the past, conventional laser fusion experiments have uniformly imploded spherical, pinhead-sized fuel capsules, forming a hot spot in the center and hotter temperatures—up to 100 million degrees—as the hydrogen fuel was compressed.

Now, with Fast Ignition, the heating phase is separated from the implosion phase. However, it works in a region of new and untested physics where the laser intensities are one-million times greater than those of the Nova laser. Ω

**VIDEO NEWS**

*continued from page 6*

the common TV remote and a computer light pen." However, the report said, "the next generation will explore new, less computer-like technologies."

The research team pointed to a common misunderstanding—particularly in the computer industry—that in the future a computer will substitute for the home TV. "The primary competition for interactive TV," said the report, "is not CompuServe or Lexus, but rather the L.L. Bean catalog, the corner video store, Newsweek and the friendly clerk at the local travel agency. Customers will not tolerate frustration and service providers will not accept abandoned connections." Any interface must be usable by everyone and "offer a wide variety of choices in an environment known for its comfortable simplicity—namely, TV watching."

**• Flash memory camcorder.** The long-sought goal of a video recording system with no moving parts is in sight, according to Hitachi, which says it expects to market a consumer camcorder which uses flash memory instead of tape as its recording medium within five years. Hitachi even demonstrated an early prototype which played back full-motion color and stereo sound. As Hitachi currently plans it, the camcorder will weigh about 10 ounces and will provide 30 minutes of color recording using as the storage device a 400-megabit multilayered flash memory about the size of a sugar cube. According to Hitachi's preliminary design, the camcorder would use a single-chip MPEG-1 encoder/decoder and have an electronic zoom system, further eliminating moving parts. Hitachi says that since the MPEG-1 encoder might not supply adequate picture quality, it's developing a proprietary compression algorithm. In addition to the solid-state video memory, Hitachi says it's developing a hard disK as a possible camcorder storage medium.

*(Continued on page 16)*

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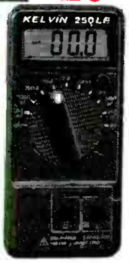


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Meter is designed in accordance with safety requirements specified in IEC-348, UL-1244 VDE-0411.

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# LETTERS

*Write to Letters, Electronics Now, 500-B Bi-County Blvd., Farmingdale, NY 11735*

### SORRY, WRONG NUMBER

*We inadvertently published the wrong part number for the two transistors in the "Light-Controlled Sound-Effect Generator" (*Electronics Now, *Sept. 1994, page 65). The correct part number for both transistors is D44C11. They are bipolar junction transistors, alternate-sourced by Harris Semiconductor, Motorola, and other manufacturers.—Editor*

### SCHOLARSHIP COMPETITION

The National Science Teachers Association (NSTA) and Duracell have announced their 13th annual Duracell/NSTA Scholarship Competition open to *all* students enrolled full-time in a high-school (grades 9 to 12) in the United States or its territories.

The students are asked to design and build working devices or circuits that are powered by Duracell batteries. Each submission must be accompanied by a two-page description stating possible applications, a schematic diagram, and a photograph of the device. The top 100 finalists will be asked to send in their creations for the final judging. The deadline for this year's competition is January 13, 1995.

One first-place, two second-place, ten third-place, 25 fourth-place, and 59 fifth-place awards will be made. They will be U.S. Savings bonds in denominations from $20,000, to $100. In addition, the top six winners, their parents, and their teacher/sponsors will be flown to the site of the NSTA National Convention to attend an awards banquet held in the winners' honor.

Teacher/sponsors of the top six winners will receive personal computers; lesser awards will go to teacher/sponsors of the other 94 top finalists. Everyone entering the competition will receive a gift and a certificate.

I would like to emphasize that most students can compete in this contest. Students are asked to think up original ideas for circuits or mechanism and build them by themselves. However, the rules permit contestants to seek technical advice from a teacher, parent, or a science/technology professional.

An Official Entry Form can be obtained by writing to Duracell/NSTA Scholarship Competition, 1840 Wilson Blvd., Arlington, VA 22201-3000, or by calling 703-243-7100.

ERIC CROSSLEY
*Manager, Industry/Education Programs*
*National Science Teachers Association*

### BATTERY-BACKUP CORRECTION

A professor I had in college once told me that errors are propagated in technical magazines, and my experience in the electronics field has shown this to be true. The response to the first question in September's "Q&A" column is incorrect. The fault is in the way the capacitor is connected in the circuit shown as Fig. 1.

"Q&A" states that the capacitor will "swallow any voltage glitches" and provide power when the battery is removed. The 1 microfarad capacitor is in parallel with diode D2 and resistor R, so, based upon fundamental electrical circuit principles, the same voltage is across all three components.

When the circuit is forward biased (system voltage is zero), there will be a voltage drop of approximately 0.6 volts across the capacitor. Thus the capacitor's voltage will be 0.6 volts. Resistor R forms an RC discharge circuit that defeats the objective of providing energy during battery replacement.

Once the battery is removed, no voltage will flow to the backup circuit because the negative terminal is not connected to the circuit common, and the capacitor will discharge through the RC circuit. To provide power during battery removal, the capacitor's negative terminal should connected to the system common. Then the battery can be removed, and the capacitor will supply energy to the circuit.

PHIL LEYVA
*Hollister, CA*

### MORE DIVERSITY ANTENNA

The "Diversity Antenna" project (*Electronics Now*, Nov. 1993, page 31) offers spectacular improvement in reception for all FM stereo listeners. Unfortunately, the circuit wont't work for FM mono, AM, shortwave, TV, amateur radio, and CB listeners.

I'd like to see the diversity antenna redesigned or adapted to work from the automatic gain control (AGC) voltage of receivers of those other signals. I think most *Electronics Now* readers would have no difficulty finding the place where the circuit would be connected in their receivers.

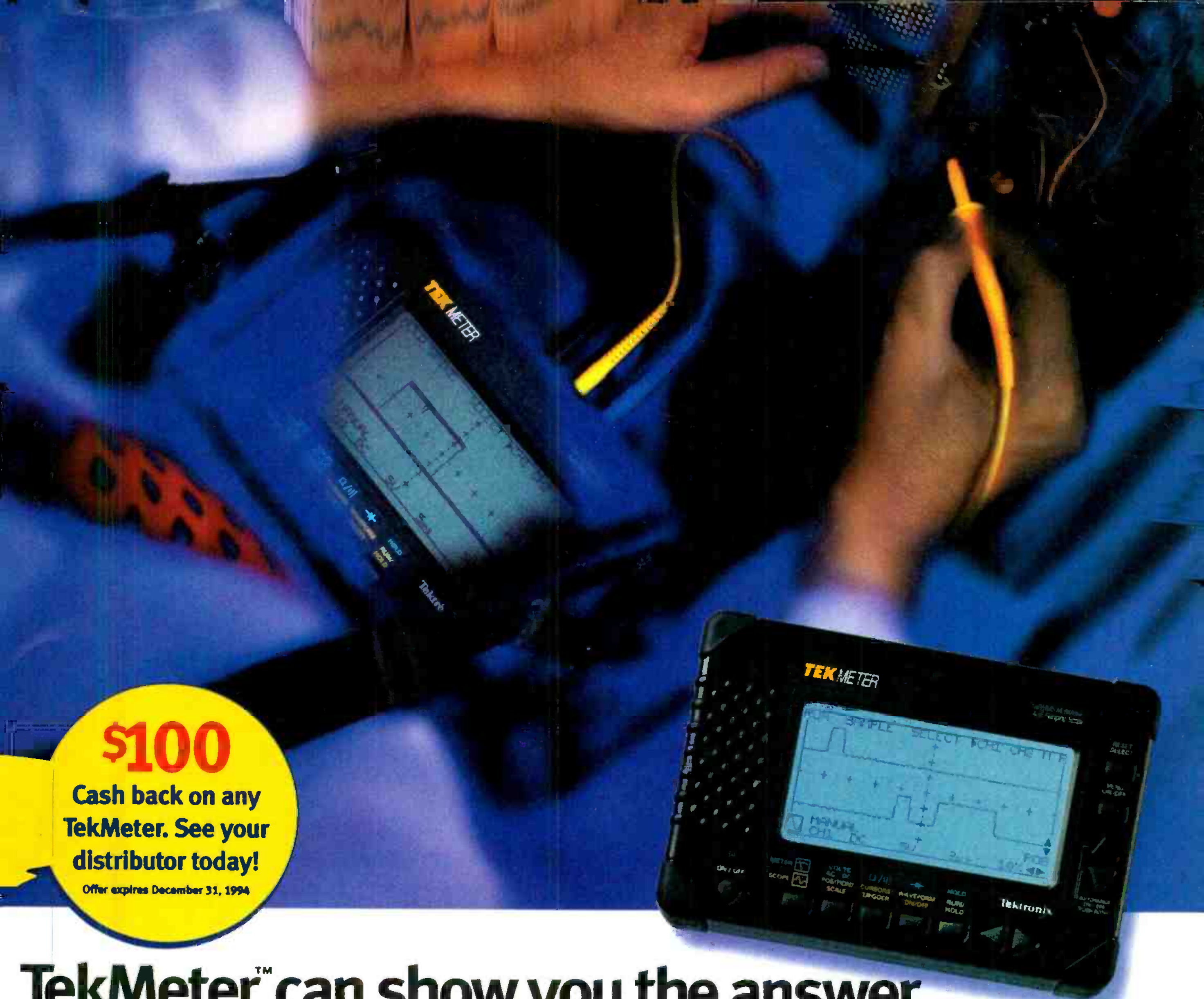
Over the years I have spent more than $1000 for equipment that helps me to receive an FM mono station 120 miles away more clearly. However, I still experience signal fading and total signal loss from time to time. A diversity antenna circuit could have solved my problem—if it worked from the AGC.

I am sure that many other readers would appreciate it if the authors, John Neves and Bill Lewis, could adapt the circuit for receivers that do not have a 19-kHz pilot signal. Then the rest of us could all enjoy hiss-free reception.

EDMUND G. GOOD
*Harrisburg, PA*

### TUBE TALK

I eagerly reached for *Electronics Now*, excited by the "TubeHead." article. However, I was disappointed when I realized that the preamplifier receiving tubes are run at low voltage, in their nonlinear regions. Moreover, John Simonton's intro-

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**Tektronix**

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ductory comments left me with the impression that he wants to distance himself from the ongoing "tube vs. solid-state" debate.

I readily admit that I am writing this letter to defend vacuum-tube sound and to prevent the dissemination of misconceptions about receiving tubes so they don't get a "bad rap." I realize that I might be defending a lost cause because most engineers and "techies" have long since dismissed tubes as obsolete relics.

The best way to gain the full benefit of a tube amplifier is to have one with a transformer-coupled output stage. The operation of preamplifiers tubes at low voltages results in raspy, unmusical sound. I hope that nobody who builds the TubeHead will assume that this operating mode is what makes tubes appealing.

A book entitled *A Desktop Reference of Hip Vintage Guitar Amps* by Gerald Weber (Kendrick Books, P. O. Box 160, Pflugerville, TX 78660-0160; about $27) is principally about guitar amplifier circuitry. However, the discussion in this book will clear up a lot of misinformation about how receiving tubes work.

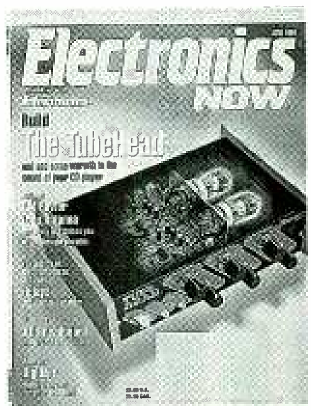
If you want to build a *real* tube amplifier, contact Sonic Frontiers, 760 Pacific Road, Unit 19, Oakville, Ontario, Canada L6L 6M5 (telephone: 905-829-5858). It offers an upgraded "Dynaco" circuit kit, with a upgraded power supply and an improved transformer.

The kit is not recommended for novices without experience in building vacuum-tube circuits, but it is recommended for those with experience in building tube circuitry who want to experiment with vacuum tube amplifiers.

In my view, it's not a fair comparison to run receiving tubes in their nonlinear regions at low voltage and expect them to match the performance of transistor circuitry. What will happen if you run transistors in their nonlinear regions?

WILLIAM ROBINSON
*Gatesville, TX*

*Mr. Robinson is correct in assuming that I wanted avoid a tiresome tube vs. transistor sound debate, principally because they can so quickly degenerate into name calling diatribes. My purpose was to point out that there are real differences between tube and solid-state amplifiers. The TubeHead was designed to illustrate and clearly demonstrate the most obvious differences between the two circuits. It also happens to be a great-sounding audio toy.*




*There was not enough space in the article to say everything I wanted to say about tubes. I would like to have pointed out that, after tubes,*

transformers are the next most favored sources of the unique audio properties of the older amplifiers.

*I would also have mentioned that, in addition to phase shifts caused by frequency response and hysteresis losses, transformers exhibit the same audio "squashing" properties as vinyl disks and analog tapes. I might also have pointed out that TubeHead permits the user to replace as much or as little of those distributed compression nonlinearities as the user wishes with its "lumped constant" design.*

*In my view, Mr. Robinson's concerns about the TubeHead circuit giving receiving tube amplifiers a bad rap would be set to rest if he were to build one and really listen to it. I would ask only that he make no changes in any component values that he thinks might "improve" the circuit.*

*Mr. Robinson will be pleasantly surprised to find none of the raspy, unmusical sound that he fears. (I'd also request that he reread the "Clipping and Squashing" sidebar in my article). If he is serious about testing the TubeHead, he could do blind A/B testing of a signal chain with and without the TubeHead. He will be astounded by how much a signal chain must be "squashed" before a typical listener can detect any difference in its sound.—John Simonton*

## VIDEO NEWS

*continued from page 6*

• **Games on demand.** At our deadline, ten Blockbuster stores in Columbia, South Carolina, were participating in a test of in-store recording and delivery of video games. More than 200 different games for the Sega Genesis system were being delivered on demand for customer rental. At the heart of the system is a data storage server that contains the games and an encoder that burns them into a blank cartridge. The prospective renter chooses his or her game, and it's instantly recorded on the blank cartridge. In some stores, the renter gets a free preview on a touchscreen kiosk before making a selection. The system eliminates the necessity of storing hundreds or thousands of titles. A similar system for video rentals could be tried as soon as copyright problems are worked out. Ω

*Of course I built it myself. I just put the brand name on it to make it look professional.*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# EQUIPMENT REPORTS

## Hewlett-Packard HP973A Digital Multimeter

*When you want to step up to a better handheld digital multimeter, step up to a Hewlett-Packard.*

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If you are a typical Electronics Now reader, you probably own your own handheld digital multimeter (DMM). Chances are you bought it years ago when you transitioned from an analog multimeter, or perhaps you bought it when you got interested in building circuits at home. Even if your handheld meter is more than ten years old, it can probably perform all of the basic AC and DC measurements and is still in good working condition. However, you might have a hankering for those extra features that you have read about.

The declining price of electronic components and the increasing complexity of ICs with ever more on-chip functions have made it possible for manufacturers to cram more user-friendly features into the latest-generation DMMs. And they have done it with little or no increase in price. When you learn about the price-performance relationships, you'll probably want to retire your old model and get a newer, more powerful model.

This introduction leads into a discussion of Hewlett-Packard's new HP 970 series of multimeters (the HP 971A, 972A, 973A, and 974A). All of these handheld instruments measure AC and DC voltage, frequency, current, and resistance. In addition, they offer continuity and diode testing, manual and autoranging modes, and an innovative safety shutter that prevents users from making inadvertent connections to the current terminals.

Three of the multimeters, the HP 971A, 972A, and 973A, have 3½-digit liquid-crystal displays and DC accuracy from 0.3 to 0.1 %. The fourth model, the HP974A, has a 4½-digit LCD display and basic DC accuracy of 0.05 %.

All four meters can make Fahrenheit and Celsius temperature measurements and test diodes. In addition, they have time stamps to record elapsed time with each minimum/maximum value, many different math functions, and selectable automatic power-off circuits. All of them include such safety features as rugged cases, fused inputs, and audible warnings for input overload. The differences in the models permit prospective buyers to select those combinations of features that are most appropriate for their personal needs.

Individual models have other features. For example, the HP 972A and 973A can measure capacitance values, and they have dual digital displays which allow users to view two digital readings simultaneously. The HP 973A and 974A offer true root mean square (RMS) and AC + DC readings that permit accurate measurement of nonsinusoidal waveforms. The HP 973A and 974A can also report voltage measurements in dBm and relative dB units over a wide dynamic range. While the HP974A has a wider LCD and improved accuracy, it does not have the bargraph, capacitance, and dual-display features.

All four HP multimeters include a set of test leads, an extra fuse, a certificate of calibration, a protective rubber boot, an operating manual, and two AA batteries. Curiously, these are the first DMMs we can recall that are powered by only 3 volts; most use a 9-volt battery. Optional thermistor probes (HP E2308A) are also available.

### The 973A examined

Electronics Now borrowed an HP973A for evaluation. It is a rugged, professional-quality instrument that impressed us with its substantial construction. It makes one think of the earlier generation military-specification instruments that were built to survive shocks, vibration and a lot of rough handling. It gives one the impression of being built like a tank.

This multimeter, like others in the family, is cradled in a rubber boot that fits so tightly that it's difficult to remove. It turned out that the impediment to removal is the wide rubber gasket that is installed between the two halves of the meter's case, intended to make it water-resistant. The gasket protrudes slightly from the sides of the meter, and also seats in a groove molded in the rubber boot.

Rubber against rubber provides a substantial grip. It was obvious that the boot would not fall off if this meter were dropped out of a third-story window! However, the boot installation does not prevent extending the fold-out bail on the back of the case that holds the DMM in an upright position for easy viewing.

The fully autoranging multimeter has one large rotary switch and seven rubber-covered selection pushbuttons on its front panel. If necessary, the autoranging feature can be turned off. Most of the rotary switch positions select more than one function, and a select pushbutton scrolls through the possibilities. The readout displays icons for every selected function, including that of range setting.

An unusual damage-prevention

feature on this meter is its red plastic shutter that covers its two current terminals (10 amperes and milliamperes/microamperes). The shutter prevents inadvertent insertion of the test leads. A slide switch on the side of the meter flips the shutter open and closed. The shutter will not open unless the meter is set to measure current, and the rotary switch cannot be moved from the current-measuring positions if the shutter is not closed. The safety shutter is a simple, yet effective solution to a potentially dangerous situation.

**DMM operations**

The rotary switch on the front panel has nine positions. Starting from the top position, by turning the switch counter-clockwise, three current ranges are encountered: one has a maximum of 10 amperes, another spans 10 microamperes to 4 milliamperes, and a third spans 0.1 microamperes to 4 milliamperes. The meter will autorange within those limits unless that feature is turned off.

The next position is for measuring capacitance from 10 picofarads to 1000 microfarads. In the third rotary switch position, diodes can be tested from 0 to 2 volts. In this setting, the select button switches the meter between manual and automatic diode testing. In the automatic mode, the meter will reverse the diode test polarity every few seconds, and the bargraph indicates those polarity reversals.

The next switch position initially measures resistance from 0.1 ohm to 40 megohms. Push the select button once and the meter tests continuity and an audible alarm sounds for readings less than 20 ohms. A second push of the select button organizes the meter to measure temperature in degrees Fahrenheit from −112 to 302 ° F. A third keying sets it on the Celsius scale for measuring −80 to 150° C. To make temperature measurements within this range of the rotary switch, the optional 5-kilohm thermistor probe must be connected.

The next switch position organizes the multimeter to measure DC volts from 10 microvolts to 400 millivolts. The first push of the select button resets the meter to AC volts with the same range as the DC volts. A second push of the button puts the meter in its dBm measurement mode permitting it to make measurements from −59.9 to −5.7 dBm.

The third push on the button organizes the meter to measure the wider temperature range of −58 to +1292° F. A fourth push on the key switches the meter to the −50 to +700° C scale. An optional K-type thermocouple probe must be connected to make temperature measurements in this range.

The next switch position is DC volts from 1 millivolt to 1000 volts. The select button switches the meter to DC+AC volts to 1000 volts. The last position starts as AC volts and permits measurements up to 1000 volts AC. The select button first sets the meter to measure frequency from 2 hertz to 200 kilohertz, with the AC input value displayed in a secondary display. A second push of the button sets the meter to measure in dBm units from −19.9 to 62.2 dBm.

All other math functions such as percentages, relative differences, and averages can be selected when appropriate. Despite the many measurement functions that can be selected, the display is organized to show enough information to prevent the user from becoming confused about the last setting that was chosen.

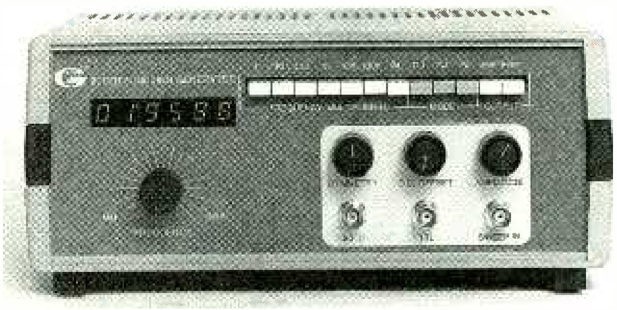
It is obvious that the HP 973A was designed and built for professional use, although it's price puts it within reach of serious electronics hobbyists. All of the other instruments in the HP 970 family are made with the same attention to detail and quality, and their prices reflect their features.

So if it's time to put your present DMM out to pasture, you can be pretty certain that one of the new Hewlett-Packard DMMs will satisfy your needs for many years to come. The HP 971A is priced at $195, the HP 972A is priced at $245, the HP 973A is priced at $290, and the HP 974A is priced at $370. (Hewlett-Packard Company, Direct Marketing Organization, P.O. Box 58059, MS51L-SJ, Santa Clara, CA 95051-8059, 800-452-4844.) Ω

# NEW PRODUCTS

*Use the Free Information Card for more details on these products.*

**MULTIPURPOSE FUNCTION GENERATOR/FREQUENCY COUNTER.** The Model 2002D function generator/ frequency counter from Global Specialties has a frequency range from 0.2 Hz to 2 MHz, and it displays frequency counter output with a six-digit display from 10 Hz to 2 MHz. The instrument provides sine, triangle, and square wave outputs as well as ramps and pulses with variable amplitude, symmetry, and offset control possible over the complete frequency range.



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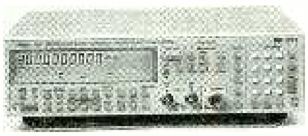
With a weight of only 3.78 pounds, the function generator offers VCO control of frequency with sweep input, separate TTL-compatible output, and symmetry control for duty-cycle adjustment. Sine-wave distortion is specified as less than 1% from 10 Hz to 200 kHz.

The Model 2002D multipurpose sweep/function generator has a price of $269.

**Global Specialties**
70 Fulton Terrace
New Haven, CT 06512
Phone: 203-466-6103
Fax: 203-468-0060

**TIMER/COUNTER/ANALYZER.** The PM 6681 timer couter from Fluke is the latest addition to the company's family of timer/ counter/ analyzers. It offers time interval resolution of 50 picoseconds single-shot and 1 picosecond averaged, and a speed of up to 8000 measurements per second.



CIRCLE 21 ON FREE INFORMATION CARD

Designed for the system environment, the PM 6680B is optimized for GPIB/IEEE-488 programming and fast transfer of individually triggered measurements to a controller.When linked to a personal computer running the TimeView software package, the timer/counter becomes a highly accurate modulation domain analyzer. TimeView handles time and frequency analysis and advanced statistical and FFT processing.

The PM 6681 is capable of analyzing frequency stability and revealing and qualifying signal anomalies (e.g., jitter or noise). It is also capable of analyzing frequency modulation, locating hidden noise sources, plotting frequency vs. time, analyzing VCO transient response, and viewing frequency locked-loop dynamics.

Once a measurement has been made, a wide range of functions are available to analyze the measurement data. Built-in statistical facilities, such as max., min., mean, and standard deviation (RMS jitter), provide data at the touch of a button. The PM 6681's built-in mathematical processing makes it easy to perform offset, drift, linearization, scaling, or inversion calculations.

The PM6681 can make continuous "back-to-back" period measurements on signals with repetition rates up to 40 kHz. This permits measurements to be made on every input cycle without missing a single event.

The PM 6681's basic 300-MHz frequency range can be expanded up to 4.5 GHz for calibration of microwave links, satellite communications, and radar equipment.

The PM 6681 timer/ counter with a fully SCPI-compatible GPIB/ IEEE-488 interface is priced at $2950.

**Fluke Corporation**
P. O. Box 9090
Everett, WA 98206
Phone: 800-44-FLUKE
Fax: 206-356-5116

**SMT-BOARD REWORK SYSTEM.** The MTR-5000-WSA mixed technology rework system from OK Industries provides all of the tools needed to remove and replace both through-hole and surface-mount components from circuit boards. This seven-function system contains a solder-paste dispenser, a vacuum pencil, a SMT thermal tweezer, a high-power soldering iron, a high-power desoldering tool, a hot-air pencil, and a focused convection SMT rework tool.

Each tool has its own power switch and controller, allowing users to select the function or functions they need at any given time. Each handpiece has a separate controller so the operator can monitor the set temperatures at a glance.


CIRCLE 22 ON FREE INFORMATION CARD

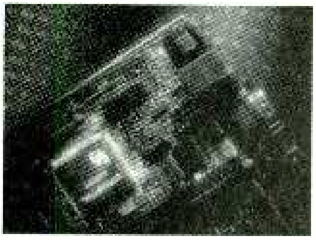
The MTR-5000-WSA has a closed-loop sensor feedback control for the precise regulation of the thermal response of each tool. Power is instantly delivered on demand with no thermal overshoot. The system meets all U.S. military standard requirements for EOS/ESD safety.

The MTR-5000-WSA has a starting price of $3495.

**OK Industries**
4 Executive Plaza
Yonkers, NY 10701
Phone: 914-969-6899
Fax: 914-969-6650

**SINGLE-CHIP I/O–LAN INTERFACE.** National Semiconductor's PC87340VUL SuperI/O+LAN, is a single-chip, PC-compatible peripheral device that combines an Ethernet local area network interface and National's SuperI/O integrated multifunction I/O controller. The single chip reduces board space requirements and cost compared with the motherboard and adapter card previously required.

Personal computers with all standard I/O and IEEE 802.3 Ethernet interface functions on the motherboard are now possible. The PC87340VUL includes all of the basic I/O functions of the industry-standard PC and includes a NE2000 software-compatible, 10Base-T Ethernet controller.


CIRCLE 23 ON FREE INFORMATION CARD

Other embedded functions include a floppy-disk controller with analog data separator, two 16550 buffered UARTs, an IEEE 1284 ECP parallel port, an IDE hard-disk drive interface with DMA logic, on-chip phase-locked loop (PLL), and a 6Kbyte static RAM buffer.

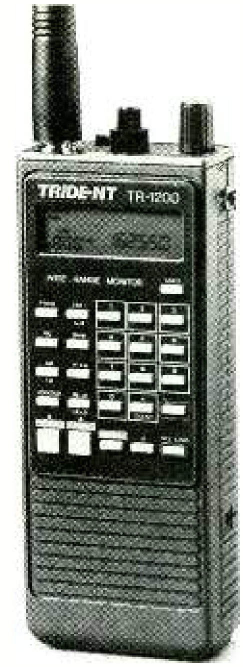
The monolithic five-volt PC87340VUL SuperI/O+LAN integrates five components: the Super I/O chip, the AT/LANTIC LAN interface chip, two separate SRAMs, and a 20-MHz crystal oscillator. With the new chip, motherboard space is reduced by 40% or more. The device includes all components needed for implementing the popular 10Base-T (twisted pair) Ethernet interface. For implementing The coaxial-cable interface (10Base-5/10Base-2), an external transceiver is also required.

The PC87340VUL is available in a 160-pin PQFP (plastic quad flat pack). The user can design a motherboard that overlays the PC87340 pinout over the PC87332 pinout.

The PC87340VUL SuperI/O+LAN is priced at $23.50 in quantities of 10,000 units.

**National Semiconductor Corporation**
2900 Semiconductor Drive
Santa Clara, CA 95052-8090
Phone: 1-800-272-9959

**SHORTWAVE AND PUBLIC-SERVICE BAND RECEIVER.** The handheld Trident TR1200 radio receiver from




CIRCLE 24 ON FREE INFORMATION CARD

Ace Communications can receive most voice broadcasts from around the world. Frequency coverage starts at 500 kHz and extends to 1.3 Gz. This range includes the AM radio band, shortwave and public-service band broadcast frequencies, including Personal Communications services in the microwave range.

Users can tune to the AM band for worldwide broadcasts and the narrow FM band for police, fire, and emergency treansmissions. The wide FM setting will receive radio and TV-audio broadcasts.

The unit is tuned by pressing in the desired frequencies on a kepad. All entries are displayed on a backlighted liquid-crystal display.

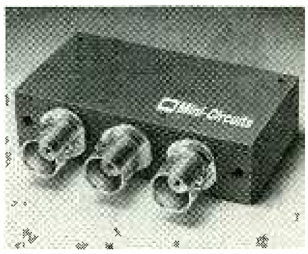
The receiver will search for active channels automatically and allow the user to store those broadcasts in any of 1000 permanent memory locations. As many as ten different search ranges can be set.

Tuning increments are user-selectable in steps as low as 5000 kHz, allowing accurate signal detection. The radio will scan through memorized frequencies at up to 25 channels per second, and will lock on active calls to receive the broadcast. Audio can be heard through the built-in speaker or the earphone supplied with the unit.

The Trident TR1200 receiver, including a 12-volt DC automotive cigarette-lighter plug, an AC battery charger, four AA power cells, an earphone, a belt clip, a flexible "rubber" antenna, mounting hardware, and operating instructions, is list priced at $629.

**Ace Communications Inc.**
Phone: 800-445-7717 or 317-849-2570
Fax: 800-448-1084 or 317-849-8794

**MINIATURE MIXER.** The ZP-11A microwave mixer from Mini-Circuits has a frequency range of 1.4 to 1.9 GHz RF local oscillator and a 40 to 500 MHz inter-

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mediate frequency. Conversion loss specifications are statistically controlled to better than 4.5 sigma from the mean. Conversion loss is flat (0.6 dB typical) over the full range, and 1 dB compression is typically 1 dBm.

The ZP-11A mixer has a price of $47.95.

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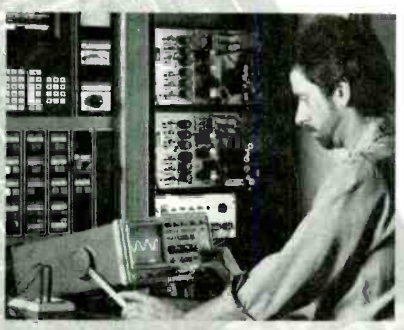

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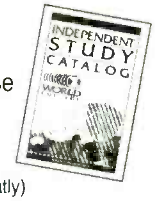


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# NEW LITERATURE

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**Build Your Own Pentium Processor PC; by Aubrey Pilgrim. Windcrest/McGraw-Hill, Blue Ridge Summit, PA 17294-0850; Phone: 1-800-233-1128; Fax: 717-794-2103; $$19.95.**

Intel's Pentium microprocessor is more powerful, faster, and more expensive than any of its earlier generation 386 and 486 processors. However, the good news, according to the author of this book, is that it is no more difficult to build an IBM-compatible personal computer with a Pentium than any of those earlier MPUs. Pilgrim's book explains how to build an IBM-compatible, Pentium-based computer from mail-order components and peripherals for a fraction of the retail price of a Pentium-based PC.


CIRCLE 337 ON FREE INFORMATION CARD

Following an overview of the Pentium processor and its capabilities, the book describes in illustrated, step-by-step detail how to build a Pentium-based PC. Included are instructions for obtaining and putting together motherboards, floppy-disk and hard-drive, CD-ROM drive, printer, input devices, monitor, graphics cards, fax/modems, memory devices, and backup systems.

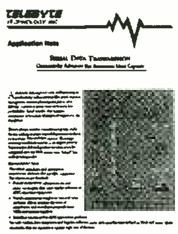
Pilgrim explains where to find the best components and peripherals at the lowest prices, and he also explains which software packages will best suit a variety of personal needs, including multimedia applications. The review of operating systems and a convenient list of troubleshooting techniques in the book make it a valuable reference even for those who do not plan to build a Pentium-based PC.

**Serial Data Transmission Application Note. Telebyte Technology, Inc., 270 Pulaski Road, Greenlawn, NY 11740-1616; Phone: 1-800-TELEBYT or 516-423-3232; Fax: 516-385-8184; free.**

This six-page, full-color application note explains how advances in serial data connectivity have created a powerful and economical alternative to local area networks (LANs) for intelligent data capture and interchange. It explains the benefits of the versatile multi-drop RS-485 communications interface.

The note explains progress in serial data connectivity since the RS-232 standard was developed for mainframe computers to link "dumb" terminals with a 300-baud transmission rates. This background sets the stage for a discussion of RS-485.

The application note explains how modern developments have improved the range of effective communications, data rate, data integrity, versatility, and equipment reliability.



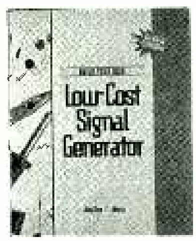
CIRCLE 338 ON FREE INFORMATION CARD

New application-specific ICs (ASICs), data-communications circuits, protocols, and fiber-optic cables with opto isolation have led to increasing acceptance of the RS-485 interface option.

The note also includes a table of sources for free application guidance to help users put the latest serial data connectivity to work.

**Build Your Own Low-Cost Signal Generator; by Delton T. Horn. Tab Books Inc., Blue Ridge Summit, PA 17294-0850; Phone: 1-800-233-1128; $19.95.**

This book describes how to build a signal generator that will generate most of the signals that the hobbyist or experimenter is ever likely to need. Horn's book also contains instructions on building individual circuits that can be combined to form an inexpensive signal generator which can be used for circuit analysis, maintainence and the test of prototype circuits.

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Horn's book supplies the schematics and parts lists needed to build circuits for generating sine waves, square waves, sawtooth waveforms and other waveforms for such special purposes as pink- and white-noise generation and frequency modulation.

**The Photo CD Book; by Heinz von Buelow and Dirk Paulissen. Abacus, 5370 52nd Street SE, Grand Rapids, MI 49512; $29.95 including CD-ROM.**

This book presents a practical introduction to digital image processing with Photo CD techniques developed by Eastman Kodak. The book explains the Photo CD and how to turn a personal computer into a photography studio.

Background information is provided on the latest developments in photo CDs, but the book emphasizes the Photo CD as a means for transforming ordinary images with special effects. The hardware for recording, manipulating, and producing Photo CD images is explained, and the popular software packages that support Photo CDs are described. These include Micrografx PhotoMagic, CorelDRAW!, Aldus Freehand and PhotoStyler, Microsoft Publisher, and Adobe PhotoShop programs.

The companion CD-ROM disk includes application samplers. These will permit experimentation with photographic special effects and catalog Photo

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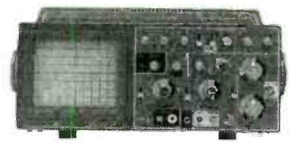

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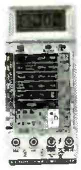

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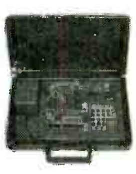

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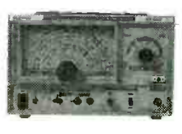

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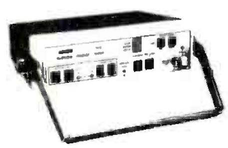

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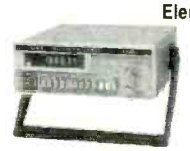

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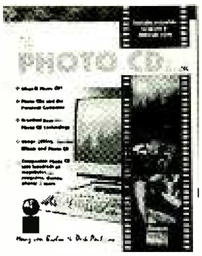


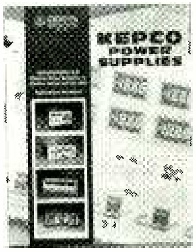
CIRCLE 340 ON FREE INFORMATION CARD

CDs, as well as the viewing of Photo CD images. The programs include shareware, demonstrations, and working versions.

For example, Paint Shop Pro converts images from Photo CD to other formats and allows the images to be flipped, rotated, and mirrored. PhotoStar provides "photo album"-style image storage, and ThumbsUp organizes thumbnail views of clip art and graphics for easy retrieval. The disk also contains photographs from noted photographers.

**Power Supply Catalog/Handbook. Kepco, Inc., 131-38 Sanford Ave., Flushing, NY 11352; Phone: 718-461-7000; Fax: 718-767-1102; free.**

Kepco manufactures both linear and switching power supplies to serve both OEM and laboratory markets. Its latest catalog and handbook lists available power supplies in a wide range of size, cost, and output power. Included are descriptions of Kepco's latest switching supplies with full specifications.




CIRCLE 341 ON FREE INFORMATION CARD

The catalog also includes pictures and specifications data on its modular PC-card-style multi-output models, high-density DC-DC converters, and high-power modules that can be arranged in "power banks." These redundant arrangements permit the "live" removal and replacement of faulty modules without shutting down the system being powered.

**Audio/Video Cable Catalog. Belden Wire & Cable Company, P. O. Box 1980, Richmond, IN 47375; Phone: 317-983-5262; free.**

This 76-page, illustrated catalog discusses Belden's line of Brilliance audio and video cable products for the broadcast industry. It includes detailed information and drawings of wire and cable products for audio and video signal transmission. These include microphone and musical-instrument cables, analog audio and digital audio cables, speaker cables, and analog video coaxial cables.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Also included are fiber-optic cables, precision analog/digital coax, RGB and SVHS cables, A/V composite camera cables, 50-ohm transmission cables, and power cords. Full specifications and descriptions are given.

Belden's catalog also includes application and technical information. A three-page introductory section discusses the special requirements for broadcasters. A nine-page technical information section contains a video-connector cross reference, color-code charts, a glossary, a trade number index, a cable-substitution chart, and a standards reference guide.

**Learn WordPerfect 6.0 in a Day; by Felicia Case. Wordware Publishing, Inc., 1506 Capital Avenue, Plano, TX 75074; Phone: 214-423-0090; $14.95, including diskette.**

WordPerfect is one of the most popular word-processing programs. This book-and-diskette package is intended to teach the "ins and outs" of WordPerfect 6.0 to beginners, but it also contains information of value even for experienced WordPerfect users.

CIRCLE 343 ON FREE INFORMATION CARD

Specific information is offered on such features as pull-down menus, text editing, spell checking, the use of the thesaurus, and grammar guide, Grammatik. The reader will also learn about saving text, printing, setup options, File Manager, footnotes, fonts, reveal codes, and document viewing. Illustrations of what will be seen on the computer screen supplement the text. The companion diskette includes sample exercises that will reinforce the lessons taught in the book. Ω

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Bugs of a very small size are easy to build and they can be placed quickly in a matter of seconds, in any object or room. Today you may have used a telephone handset that was bugged. It probably contained three bugs. One was a phony bug to fool you into believing you found a bug and secured the telephone. The second bug placates the investigator when he finds the real thing! And the third bug is found only by the professional, who continued to search just in case there were more bugs.

The professional is not without his tools. Special equipment has been designed so that the professional can sweep a room so that he can detect voice-activated (VOX) and remote-activated bugs. Some of this equipment can be operated by novices, others require a trained countersurveillance professional.

The professionals viewed on your television screen reveal information on the latest technological advances like laser-beam snoopers that are installed hundreds of feet away from the room they snoop on. The professionals disclose that computers yield information too easily.

This advertisement was not written by a countersurveillance professional, but by a beginner whose only experience came from viewing the video tape in the privacy of his home. After you review the video carefully and understand its contents, you have taken the first important step in either acquiring professional help with your surveillance problems, or you may very well consider a career as a countersurveillance professional.

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To obtain the information contained in the video VHS cassette, you would attend a professional seminar costing $350-750 and possibly pay hundreds of dollars more if you had to travel to a distant city to attend. Now, for only $49.95 (plus $4.00 P&H) you can view ***Countersurveillance Techniques*** at home and take refresher views often. To obtain your copy, complete the coupon or call.

# COMPUTER CONNECTIONS

## That dirty dog—the "D" word.

JEFF HOLTZMAN

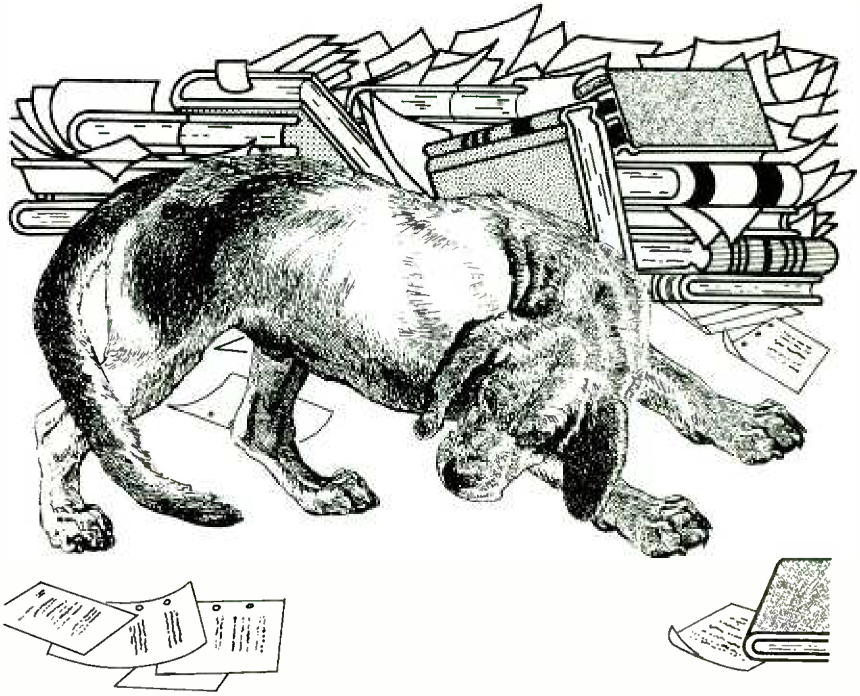
You might have heard comedian George Carlin's comedy skit about the seven unmentionable words of the English language. In the computer industry, there is a different list. The first item on it is (shhh!) the "D" word, *Documentation.*

Almost everyone hates documentation. First and foremost, users hate it because it is usually so woefully inadequate. Vendors hate it because it's expensive to produce and adds little value to their products, except as a way of meeting packaging needs and gratifying users' desires for what they *think* they are entitled to. Engineers hate documentation because it takes them away from what they love best. Those who produce the stuff are sometimes called technical writers. Ironically, the typical member of this species is seldom very technical nor much of a writer. Technical writers don't love the stuff they produce either. Production seems to be accompanied by a fatalistic nobody's-going-to-read-it-anyway attitude. I know of no technical writer whose ambition it was, when they were young, to grow up and be a technical writer. On the other hand, I know of many engineers whose ambition it was to grow up and be an engineer.

Don't get me wrong; some of my very best friends are technical writers. In addition, among other things, I am a technical writer (although in a broader sense than just a documentor of computer products).

These remarks might lead you to think that I believe that technical writers are the root cause of the sorry state of computer documentation—but that is not the case. Even when conscientious people do their best and still produce inadequate results, one should look elsewhere for the cause. The first place one might look is the "profession" itself.

- The technical writing "profession" has no standards, no qualifications, and no way of demonstrating proficiency, so anybody who want's to can call him or herself a technical writer and get away with it. It's kind of like being a "financial advisor" or a palm reader.
- The "profession" lacks methodology. If I were to ask you to reduce a fraction, divide two numbers, or sort a list, you can select one of several methods (algorithms) for doing so. If I ask a technical writer to write a computer manual, he or she won't know where to begin. Yes, there will be some comments about task-orientated writing, breaking text into easily digestible chunks, and designing pages that are easy to scan—but these are a far cry from a *method.*
- The technical writing "profession" lacks proper tools. Today's ultra super whiz-bang WYSIWYG word processors—with changeable fonts, multiple colors, and desktop publishing capabilities—are all garbage. They're fancy typewriters designed for typists.



**THE DOCUMENTATION DOG continues to chase its tail as users clamor for more and vendors seek ways to cut costs.**

### It's not the writer

Let's ignore the writing profession for a moment and concentrate on the individuals who participate in it. Suppose, for the sake of argument, that a true technical writer existed, someone who could both understand the technology he or she was writing about, and could communicate those ideas clearly, concisely, economically, and perhaps even elegantly. Could this person produce acceptable technical documentation?

The answer is no. Why? Because the intended user wouldn't know how to read it.

What? The problem with documentation is not the writer but the reader? Wasn't I just implying that the technical writer is the problem?

I've thought about the trouble with technical writers a lot. I've read quite a bit on the subject. I've practiced it off and on for more than fifteen years. I've talked to other practitioners and researchers. And I've had some research in this area published myself.

Over and over I kept asking, "What's the best way to present information?" Nobody knew. Nobody had a simple, unequivocal answer. Meanwhile, the answer had been staring me in the face all along. It's that people are intellectually lazy—and perhaps afraid. They don't want to know how things work; they only want to know how to use them. The concept is best explained by example.

### The toaster model

Once upon a time there was a person with a broken toaster. It toasted only the lower half of the bread, and the owner required evenly toasted bread. To meet that requirement, the owner had several choices.

- Throw the toaster away and buy a new one.
- Fix the toaster himself.
- Pay to have it fixed by a knowledgeable technician.
- Find a way to work around the problem.

The owner did not know anything about resistance heating, alternating current, or Philips-head screws, hence he chose the last alternative. In attempting to remedy the problem, the owner first tried extending the length of time the bread remained in the toaster. This worked to some extent, but had the unfortunate side effect of burning the lower half of the slice. Then the owner hit on a mildly ingenious solution: After toasting one half of the slice, pop it out, turn it over, then stick it back in and toast the other side. However, this operation was too arduous and took too much time. So he simply threw the toaster out and bought another.

Obviously, this person was not a toaster engineer or technician who understood how toasters work. Rather, he treated the toaster as a black box that merely provided desired results.

Like toaster users, most computer users don't want to know what's inside the black box; they're only interested in results. Even people who are experts in some aspect of computer technology exhibit this response. There are so many tools, and they're all so complex, that no one can master them all.

Further compounding the problem is that product developers cannot anticipate all the intended uses of their black boxes. That is why most complex products go through beta testing. In essence, the end user becomes part of the development organization; his or her job is to try out program features and functions in various combinations and permutations. The producer hopes to find bugs before a product is released to the market. Some companies (the honest ones) go through formal beta programs; others depend on the first or second general (i.e., revenue-producing) release of a product.

### The challenge for readers

So the challenge for the technical writer becomes one of writing down all possible applications for a given product, when by definition, doing so is impossible.

As an example of the phenomenon, consider the rash of computer books on the market with titles like "1001 Tips for Using X." Everywhere you turn there are volumes of what is essentially trivia. The appeal of this kind of "documentation" is that it's painless (intellectually easy) to scan through that kind of minutiae. However, there are many drawbacks with the approach.

- What if you want to perform a specific task that's not covered by the documentation?
- What if you know a product can do something, but you don't know how to do it, and don't know what it's called? Then you're dependent on the imagination of the creators of the documentation's index. Failing that, you're reduced to a random or linear search through the mountains of documentation.
- Most people tend to perpetuate existing ways of doing things rather than finding new, more efficient ways. It is only in the search for more efficient methods that computer science shows its worth. How do you transition users from the

tried-and-true but stale to the unproved but challenging?

**A solution: CD**

I have a proposed solution that I'm tentatively calling Conceptual Documentation. It is not marketing fluff. It is not detailed "how-to." It is not an intimate design-level view of underlying data structures and algorithms. It is certainly not programming code documentation. It is not a list of features and functions. And it is not a rehash of the obvious features of the user interface ("To open a file, choose Open from the File menu...").

It's more like a high-level design document. It provides a conceptual model of the tool and the objects upon which it operates. It is short—about 40 pages for a fairly meaty application such as learning how to use a contemporary word processor or spreadsheet. Perhaps it can be read in an hour or two; it contains lots of block diagrams.

The purpose of Conceptual Documentation is not to tell you how to operate the toaster. The purpose is to give you a conceptual understanding of how something works so that you can figure out how to operate it yourself. If you can figure it out, it is a good product, and it is well-documented. If you can't, either the document is poor, the product design—not implementation—is poor, or both.

As an example, the conceptual documentation for a hypothetical word processor might read as follows: "The basic unit is the page, which may (or may not) correspond to an actual printed page. A page can contain one or more objects. An object can be a bit-map graphic, a vector graphic, or a unit of text.

Text is treated as a stream that can flow from page to page in contiguous or noncontiguous blocks. Multiple streams of text can appear on one page. The same stream can appear on multiple pages. The stream of text consists of textual objects in size ranging from one character to an upper limit determined by system resources. A text object can have the following attributes: font, point size, style, line spacing, absolute text placement, prior object, next object..."

That might sound abstract; indeed, it is. The irony is that, whether you know it or not, a similar conceptual model is built of every tool we use. With simple tools, it's easy to predict behavior; intelligent humans do so instinctively. For example, under normal circumstances one would not use a surgical scalpel to chop wood, nor a pipe wrench to adjust a wrist watch. But when it comes to computer tools, both equally preposterous scenarios are commonplace.

Every user of every computer program ever written creates some sort of model in his own mind, usually subconsciously, in an effort to understand how to use the program. The difficulty with a subconsciously developed model is that it is probably inaccurate, perhaps wildly so. That makes it difficult to predict the behavior of the program accurately. It also makes it difficult to determine how to do something original, especially something that isn't already documented. This situation is further complicated if the documentation for it cannot be located. Thus, experience and memory become substitutes for reasoning. As a result, software developers spend as much time, if not more, on live, interactive help than on written and on-line documentation.

**Conclusion**

I believe that Conceptual Documentation could help some computer users. That user typically accepts responsibility for the tools he or she uses. That user doesn't just want a black box that turns white bread into golden brown toast. The difficulty, obviously, is that most users do not behave that way. They're not interested in how things work. "Don't bore me with a lot of high-falutin' concepts; just tell me how to solve my problem, quickly!"

Therefore, the difficulty with documentation is a social response. If emphasis continues to be placed on short-term results rather than real understanding, the documentation dog is doomed to continue chasing its tail and it will wonder why it's not getting anywhere. The irony here is that users complain about poor documentation. But if they were given what they really need, they wouldn't use it because it would require study and thought.

My plea to vendors of high-technology products: Conceptual Documentation would be a relatively inexpensive add-on. It would be useful for tech-support staffs (including both your own and those of your large corporate accounts), integrators, and consultants. Moreover, some end users might appreciate it as well. I know I would.

I think that we would all be much better off if documentation simply explained the function of each tool in general. Then it would be up to the user of the software to figure out for himself how those tools could best be used to suit his needs. In the same way that a skilled carpenter rarely misses the head of a nail with his hammer—and never smashes his thumb—the software user would become more and more skilled at using his tools to get jobs done more efficiently.

If you know of a magic solution to the shortcomings of technical documentation I've overlooked, or have a strong feelings either way, E-mail me at jkh@acm.org. Ω

TOD T. TEMPLIN

# BUILD THE RETRO-REMOTE

**_Add remote-control capability to anything that doesn't have it already with the Retro-Remote._**

ONE MAJOR FEATURE THAT SEPArates most consumer electronics from home-built gear is remote-control capability. Even some of the most inexpensive commercially manufactured electronics is equipped with a wireless remote control. Hobbyists have been unable to include remote controls in their projects simply because there is no "off the shelf" circuitry available to do the job. That's not true any longer!

The Retro-Remote Control presented in this article is designed for maximum interfacing flexibility. The versatile circuit can be configured to remotely control the operation of home and automotive entertainment systems, home and auto security alarms, robotics, and almost any other project that might benefit from the addition of wireless remote control. So, whether you want to add remote-control capability to an older device that lacks it, or have shelved an idea for a great stereo project because it wouldn't be as convenient to operate as a store-bought unit, then the Retro-Remote is the perfect solution.

## Description

The remote-control system consists of two separate circuit boards. One board contains an infrared receiver/decoder. It is added to the device that you want to operate remotely. The second board is an infrared "training transmitter." Its purpose is to train a commercially available universal "learning" remote control transmitter. The universal remote can then operate your equipment.

The universal remote control that you purchase will undoubtedly be smaller and more attractive than anything you could build easily. Learning remote controls have the added advantage of being able to learn the commands of multiple devices, thereby consolidating the functions of many separate remotes into one. You might already own a learning remote, as they are included with many brands of TVs, VCRs, and stereo receivers. If you don't own a learning remote, one can be purchased from a consumer-electronics store for as little as $20. The author used a Radio Shack Model 150 learning remote that can store codes for controlling up to four devices (TV, VCR, AUX 1, and AUX 2).

The training transmitter ensures that you can select unique codes for controlling "retro" devices that never had remote-control capability. You must be sure that the newly assigned codes will not interfere with those in use by your existing remote-controlled devices.

The training transmitter circuit is battery operated for portability and convenience. It is built on a small PC board that contains a pair of DIP switches to select the address (1 of 256) and command codes (0 through 15). It also contains the encoder IC, a modulator circuit, and the infrared transmitter diode. In practice, the training transmitter is placed next to the learning remote in an "eye to eye" fashion. An address and data command code are selected with the DIP switches, and then the learning remote is "taught" up to 16 commands. If more than 16 commands are required, a second receiver board set to a different address can be built for those commands.

The receiver/decoder board contains a pre-built and aligned infrared receiver module. It also has address and data decoding circuits that match those of the training transmitter, and interfacing circuits to connect it to the device that you want to control. The module can be self-powered or power can be provided by the device it serves.

The board can decode 16 command codes at any one of 256 possible addresses, for a total of 4096 available codes. Commands 0 through 11 are user-definable. That is, they decode to simple TTL-level signals which are selected by the user to

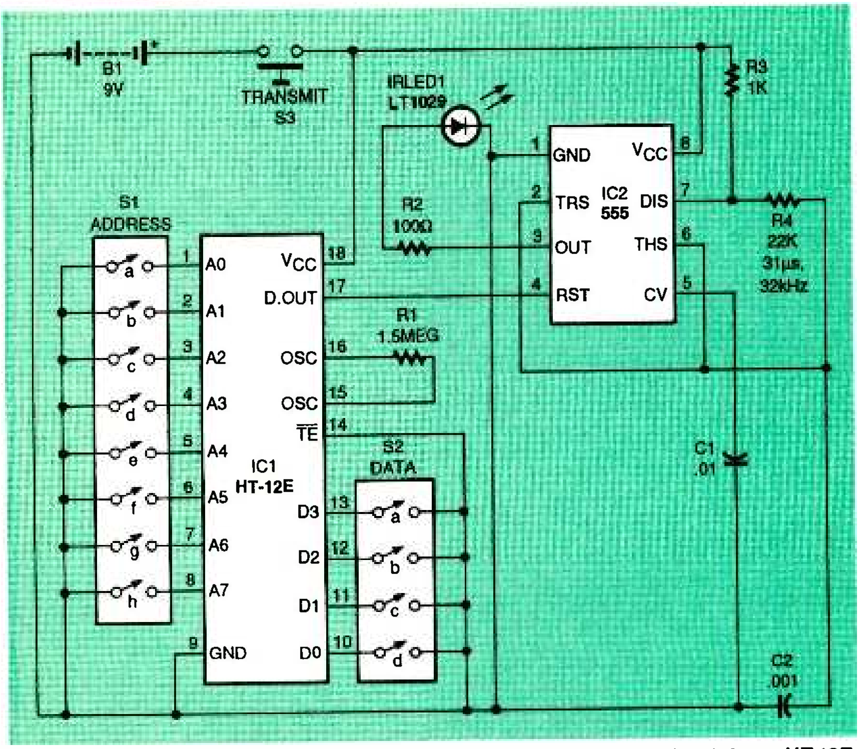



FIG. 1—TRAINING TRANSMITTER SCHEMATIC. The heart of the circuit is an HT-12E remote control encoder manufactured by Holtek Microelectronics.

be either latched or momentary, and high or low, as needed. The 12 decoded commands are brought out to a header for connection to external circuits. The four remaining commands (12, 13, 14, and 15) are hard wired on the decoder board to relays that operate a motorized potentiometer for volume-up and volume-down controls and for power on/off and mute on/off controls.

## Transmitter circuitry

Figure 1 is the schematic for the training transmitter. The heart of the circuit is an HT-12E remote control encoder (IC1) manufactured by Holtek Microelectronics. The HT-12E encodes 12 bits of information into a serial stream of data. Eight bits select the system address while the remaining four bits select the data code. Both the address and data are binary-coded decimal (BCD). The encoded serialized data stream appears at pin 17 of IC1 whenever pin 14 (TE, or TRANSMIT ENABLE) is held low. Note that TE is grounded at all times, and transmit switch S13 enables the entire circuit. Resistor R1 sets IC1's internal oscillator frequency to about 3 kilohertz.

A 555 timer (IC2) modulates the encoded data onto a carrier wave and also drives the infrared LED transmitter diode (IRLED1). An infrared modulation frequency of 32 kilohertz was chosen to be compatible with the receiver module. Data from pin 17 of IC1 is routed directly to pin 4 (RESET) of IC2, which is configured as an astable multivibrator with a free-running frequency of about 32 kilohertz. This is determined by R3, R4, and C2. Data going into pin 4 of IC2 effectively turns it on and off in-step with its high or low value, thereby presenting a series of 32-kilohertz pulses that match the data stream to the infrared LED. Resistor R2 limits the current provided by IC2 to a safe value for the LED.

## Receiver circuitry

Figure 2 is the schematic of the receiver circuit. The circuit consists of the IR receiver module (MOD1), the HT-12D decoder (IC1), a BCD-to-decimal decoder (IC2), and various driver ICs and relay circuits that interface the Retro-Remote to the outside world. With its clean and stable output, the IR receiver module, whose block diagram is shown in Fig. 3, greatly simplifies the construction and reliability of this part of the circuit. The IR module contains an infrared-sensitive photodiode, followed by a high-gain preamplifier, a limiter circuit, a 32-kilohertz bandpass filter, a demodulator, an integrator, and a Schmitt trigger.

The 12-bit serial signal that is sent from MOD1 when it receives transmitted pulses is buffered and inverted by Q1 and applied to the input of the HT-12D decoder IC, which interprets the first eight bits of the word as address and the last four bits as data. The HT-12D checks three consecutive samples of the received 16-bit word against the address selected by DIP-switch S1. If all three samples match, the VALID TRANSMISSION (VT) output goes high and the four-bit data word is latched onto its output pins. Resistor R8 sets the internal clock frequency of the HT-12D to about 150 kilohertz. Note that the oscillator in the decoder IC must run approximately 50 times faster than the oscillator in the encoder IC.

Although the data on the output pins of IC1 remains valid until a new word is decoded, the VT signal stays high only as long as the actual decoding is being performed. Thus, VT acts like a momentary-contact signal because it is active only as long as a button is pressed on the remote transmitter. The VT output is applied to Q2 which drives relay RY1. The relay provides a connection to ground to light the VT RECEIVED indicator (LED1), and also provides the ground return for the motorized volume-control circuit through RY2 and RY3 (volume up and volume down, respectively). The momentary ground closure is also brought out to the output header pins (HEADER1) for custom user applications that might require it. Note that VT is also routed to IC6, a 7473 dual JK flip-flop, and used as a clock signal.

The latched four-bit BCD data from decoder IC1 is presented to the four-bit input of IC2, a 74154 BCD-to-decimal decoder

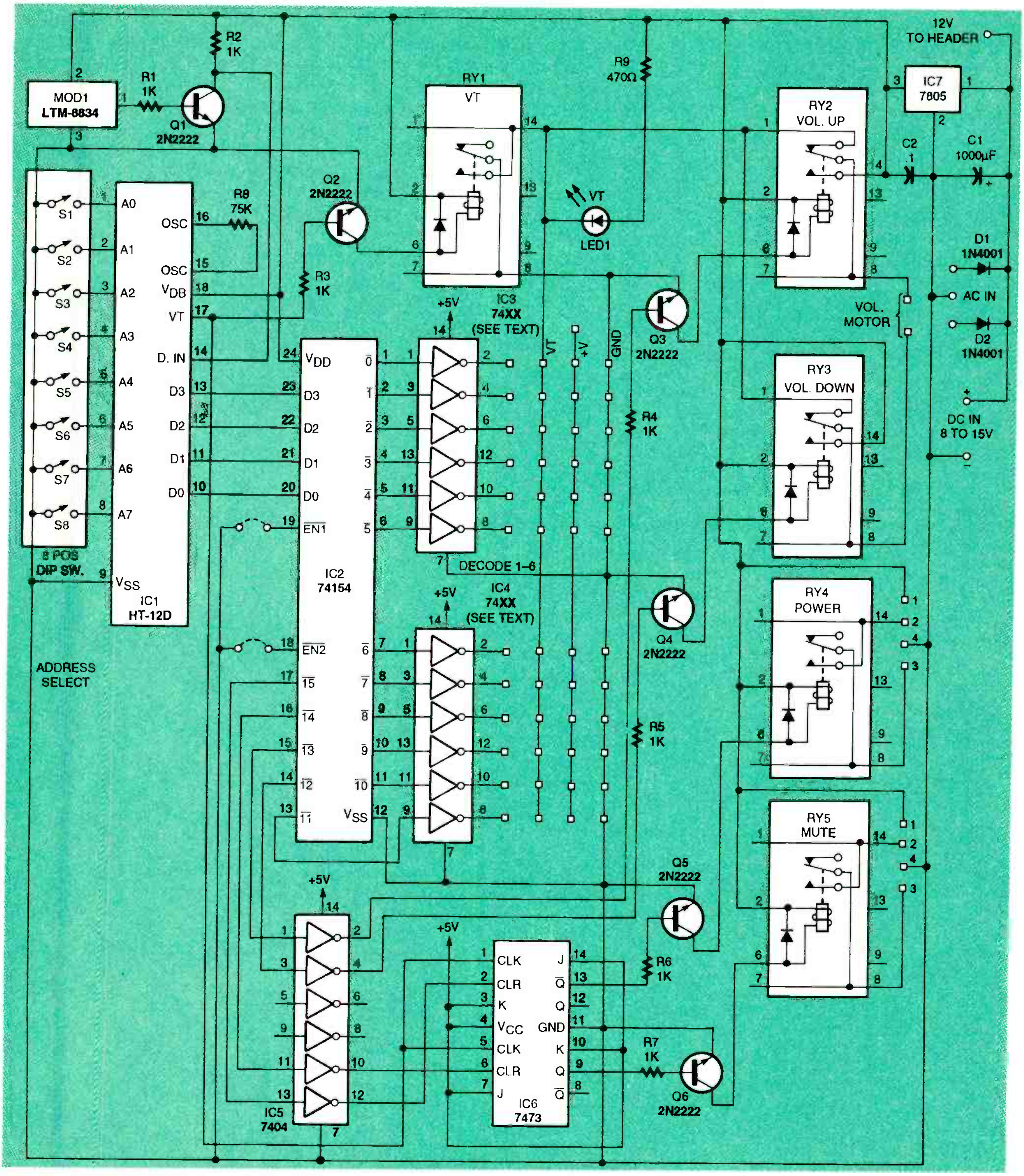



**FIG. 2—RECEIVER/DECODER SCHEMATIC. The circuit consists of the IR receiver module (MOD1), an HT-12D decoder, a BCD-to-decimal decoder (IC2), and various driver ICs and relay circuits.**

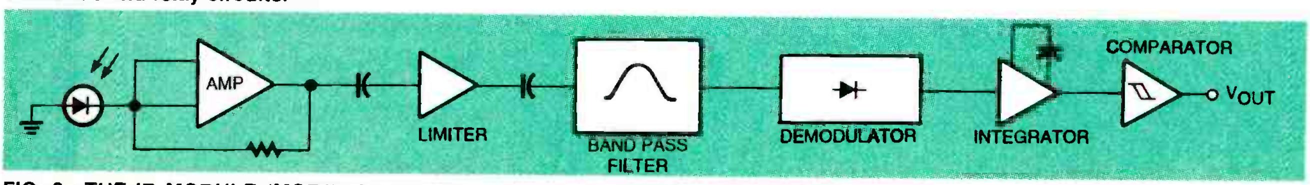



**FIG. 3—THE IR MODULE (MOD1) simplifies the construction and improves the reliability of the circuit.**

which has active-low outputs. The first 12 outputs of IC2 (0 through 11) are connected to inverters IC3 and IC4. The particular inverters selected for IC3 and IC4 should depend on your requirements, but they must be either hex inverters or hex buffer drivers. It is possible to drive LEDs or small relays directly by selecting either the 7406 hex inverting buffer driver or the 7407 hex non-inverting buffer driver. Both of those ICs have open-collector outputs which are rated for about 40 milliamperes and up to 30 volts. The inverter you select should depend on whether you want active-high (7406) or active-low (7407) outputs. If you want to interface with additional TTL or CMOS circuits, obtain a 7404 hex inverter. That IC will provide active-high TTL output signals. Depending on your needs, you might want IC3 and IC4 to be different ICs—one inverting and one non-inverting. The outputs of IC3 and IC4 are brought out to HEADER1 along with VT, ground, and a power-supply bus which can be jumpered to either 5 or 12 volts, as required.

Outputs 12 through 15 of IC2 are reserved for four circuits on the receiver board. These are power on/off, mute on/off, and volume up/down. The volume up/down feature requires a motor-driven potentiometer. Outputs 12 and 13 of IC2 are inverted by IC5 before they turn on Q3 and Q4, which are the drivers for RY2 and RY3, respectively. Those relays are cross connected in a DPDT arrangement so that the output taken at their wipers changes polarity

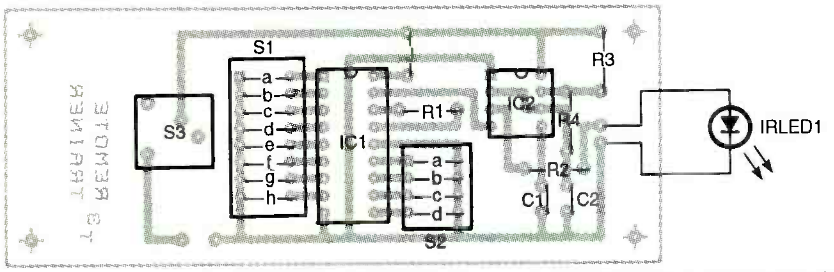



**FIG. 4—TRANSMITTER PARTS-PLACEMENT.** The small board makes a nice handheld unit.

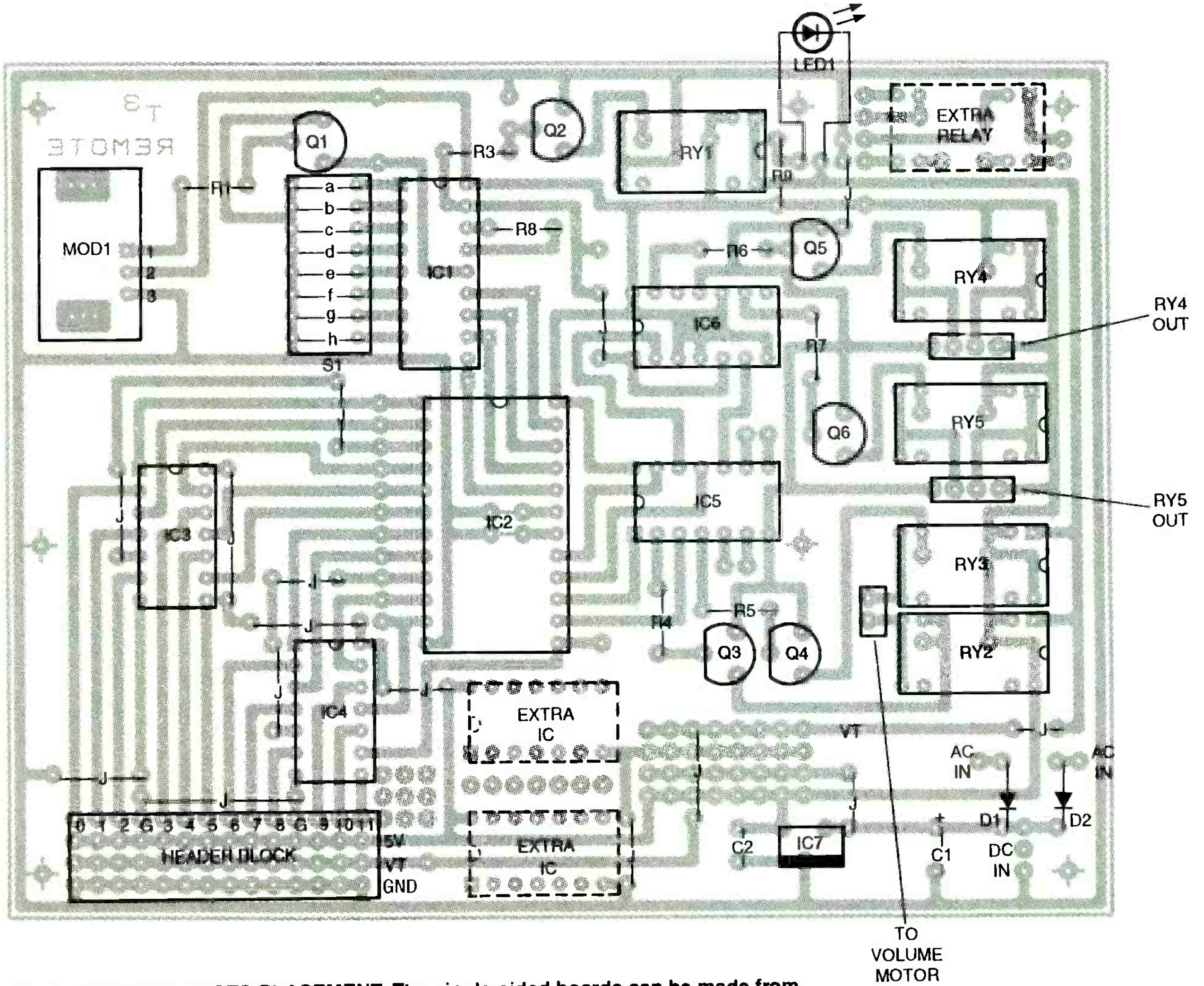



**FIG. 5—RECEIVER PARTS-PLACEMENT.** The single-sided boards can be made from the foil patterns provided here.

## PARTS LIST—TRANSMITTER

**All resistors are ¼-watt, 5%**

R1—1.5 megohms
R2—100 ohms
R3—1000 ohms
R4—22,000 ohms

**Capacitors**

C1—0.01 µF, polyester
C2—0.001 µF, polyester

**Semiconductors**

IRLED1—LT1029 infrared LED or equivalent
IC1—HT-12E remote control encoder (Digi-Key part No. HT-12E-ND)
IC2—555 timer

**Other components**

S1—8-position DIP switch
S2—4-position DIP switch
S3—normally-open push button

**Miscellaneous:** 18-pin IC socket, 8 pin IC socket, 9-volt battery and connector, PC board

## PARTS LIST—RECEIVER

**All resistors are ½-watt, 5%**

R1–R7—1000 ohms
R8—75,000 ohms
R9—470 ohms

**Capacitors**

C1—1000 µF, 25 volts, radial electrolytic
C2—0.1 µF, Mylar

**Semiconductors**

D1, D2—1N4001 diode
LED1—red generic light-emitting diode
IC1—HT-12D remote control decoder (Digi-Key part No. HT-12D-ND)
IC2—74154 4- to 16-line decoder
IC3, IC4—7404 or similar hex inverter (see text)
IC5—7404 hex inverter
IC6—7473 dual J-K flip-flop
IC7—7805 5-volt regulator
Q1—Q6—PN2222 NPN transistor

**Other components**

RY1, RY4, RY5—HE721A0510 SPST DIP relay, N.O. (Hamlin 5-volt 700 series, see text)
RY2, RY3—HE721C0510 SPDT DIP relay, N.O. (Hamlin 5-volt 700 series, see text)
S1—8-position DIP switch
MOD1—32-kHz infrared remote-control receiver module (Digi-Key part No. LT1033-ND or equivalent)

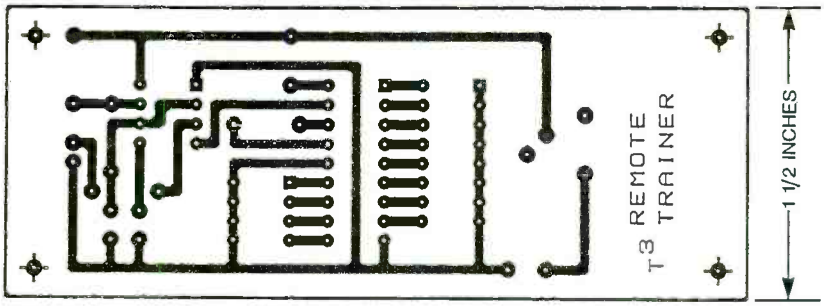
**Miscellaneous:** 11 × 4 header-pin block; 2-, 3-, 4-, and 6-pin headers; 24-pin IC socket; 18-pin IC socket; 16-pin IC socket; three 14-pin IC sockets; PC board; solder

## ORDERING INFORMATION

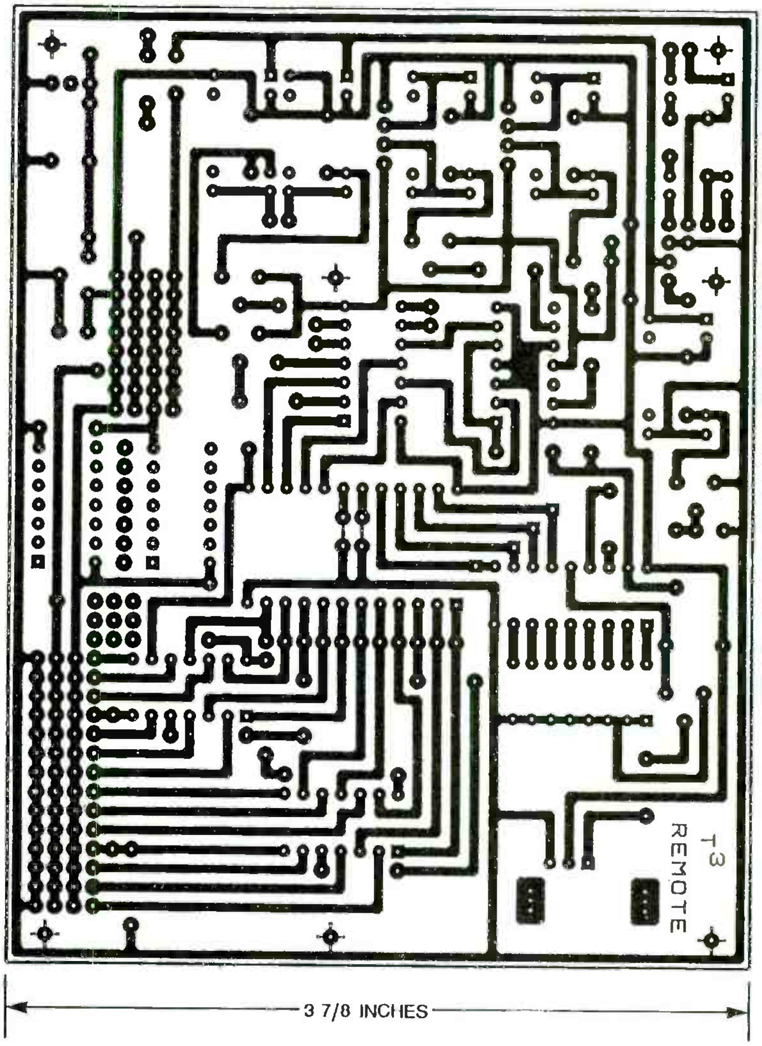
**Note: The following items are available from T3 Research, Inc., 5329 N. Navajo Ave., Glendale, WI. 53217-5036:**

- **Training Transmitter PC board—$6.00**
- **Receiver/decoder PC board—$12.00**

**Add $2.00 S&H to any order. Wisconsin residents must add 5½% sales tax. Other "hard to find" parts including motor-driven potentiometers are available. Send SASE for current list and prices.**




RETRO TRANSMITTER FOIL PATTERN.




RETRO RECEIVER FOIL PATTERN.

depending on which relay closes. The potentiometer motor will rotate clockwise with one polarity and counterclockwise with the opposite polarity. The ground return of the volume-control circuit must be routed through the VT relay so that the motor will run only during the reception of a valid command. Otherwise, the latched data of IC1 would cause the motor to run continuously until it decoded a new command.

Output 14 (pin 16) of IC2—the speaker mute function—is inverted by IC5 and connected to one half of IC6, a dual J-K flip-flop. The flip-flop is wired as an alternating latch that is clocked by the VT signal. The first time IC2 decodes decimal 14 (when the mute button is pressed on the remote control), pin 16 goes to a logic low, presenting a logic high at the clear input (CLR) of

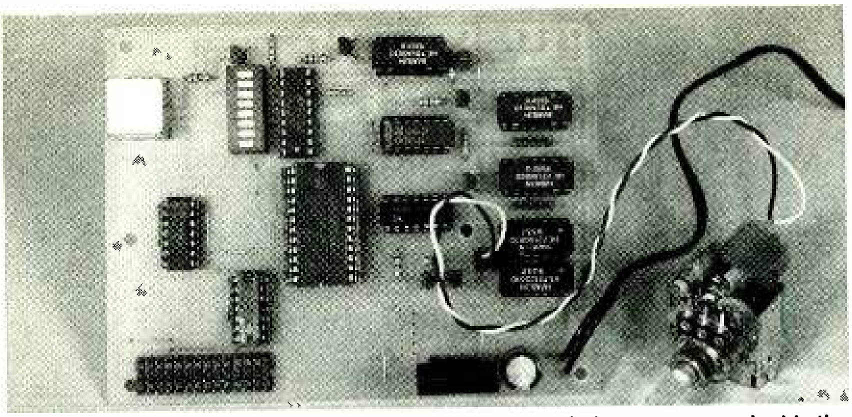


FIG. 6—COMPLETED RECEIVER board can be mounted in its own case or inside the device you want to control remotely.

the flip-flop via IC5. Simultaneously, VT presents a logic high to the clock input. Because the J and K inputs are always set high, the Q output goes high. That, in turn, switches on Q6 and closes relay RY5. If the mute button is pressed a second time, pin 16 of IC2 remains low, but a new VT is received by the flip-flop. That clocks IC6, causing the Q output to go low and open the relay. Note, however, that once latched, pressing any valid key on the remote control will cause a VT signal to clock IC6 into the opposite state. The circuit is wired that way so that an "unmute" occurs whenever a function such as volume up/down or a channel change is requested.

The power on/off function is almost identical to the mute function except that the relay drive signal is taken from the $\overline{Q}$ output (pin 13) of latch IC6-b. In the absence of valid decoded data, pin 13 of IC6 is high, which causes the power on/off relay to close. The power circuit operates the same as the mute circuit except that the first received and decoded power-on command turns the power off. That might seem backwards only until you have cycled the power circuit once. After that it will appear to function normally. The advantage of doing it this way is that pressing any valid key on the remote will switch the power on, but pressing the power key is the only way to switch the circuit off. Builders can wire the flip-flop differently, select a different style flip flop IC latch, or do away with IC6 entirely by using self-latching relays. Select components which suit your particular needs.

A 7805 5-volt regulator, IC7, provides the necessary 5 volts to power the standard TTL devices, the IR receiver module, and the HT-12D decoder IC.

## Construction

Building the Retro-Remote is easy. The parts are installed in the training transmitter and receiver boards as shown in the parts-placement diagrams of Figs. 4 and 5. The single-sided boards are easy to make yourself from the foil patterns provided here, or you can purchase finished boards from the source given in the Parts List. Work carefully with a fine-tipped soldering iron and watch out for inadvertent solder bridges.

To allow for customizing, the receiver board has space for an extra relay, two extra ICs, and many extra pads in the interface area. The DIP relays specified in the Parts List have built-in protection diodes. If the relays you use don't have these diodes, there are pads on the PC board at each relay location where you can add them, but they will have to be mounted on the solder side of the board. Not all DIP relays have the same pinouts. Be sure to use relays with pinouts that match those shown.

Any power source with an output between 8 and 15 volts that can supply a least 250 milliamperes is suitable for the receiver. Diodes D1 and D2 are necessary only if your power source is AC. A clip-on heatsink for IC7 is recommended if your power source is 12 volts or more. Figures 6 and 7 show the completed boards.

It is not necessary to mount the IR module on the receiver/decoder PC board. If you prefer, cut an appropriate length of shielded, balanced microphone cable and attach a pair of three-pin female header sockets to make a jumper cable. Then mount the IR module in a suitable location, and mount the decoder board wherever it's convenient or out of the way. The IR module need not be in the same room as the decoder PC board—the author installed a Retro-Remote receiver board in the trunk of his car to operate stereo equipment. The IR module is discretely hidden behind an air conditioning vent grill on the dashboard. To be sure that the Retro-Remote is receiving properly, mount the valid transmission-received LED away from the circuit board in a visible location.

## Interfacing

The small DIP relays specified for this project are not intended to switch either high voltage or high currents. If you want to switch 120-volts AC power for a TV set or any other AC load, use the DIP relay on the Retro-Remote to actuate a relay with a higher power rating capable of handling the load.

If you are working with TTL or CMOS circuits, as might be found in robotic and security systems, then it is only necessary to select appropriate buffer/driver ICs for IC3 and IC4 to get the proper logic. If you need to use relays in your project, as will most often be the case, then use a pair of 7404 hex inverter ICs for IC3 and IC4 followed by a 1K resistor and a general-purpose NPN transistor to drive a relay. Wire the relay as RY2 is wired in Fig. 2.

## Programming notes

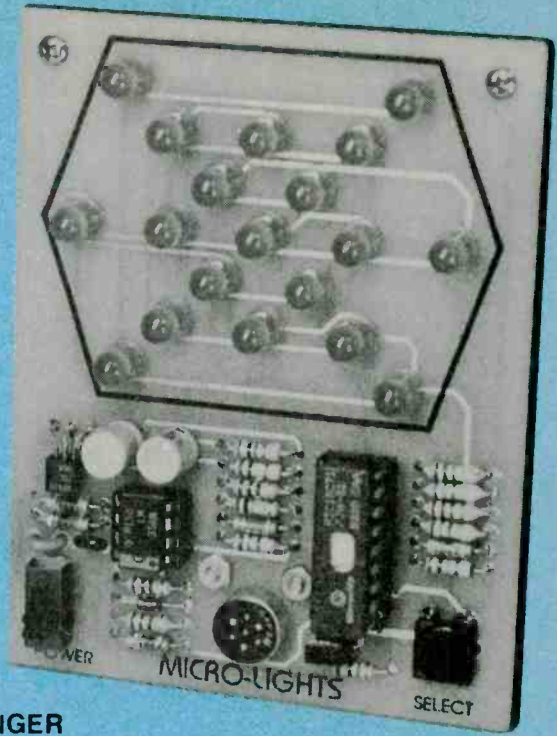
Begin programming by selecting an address on the training transmitter. If you have only one Retro-Remote system, select address 256 by leaving all eight ad-

(Continued on page 68)

BUILD

# MICRO LIGHTS

***Learn how the PIC16C71 microcontroller works and produce your own mini light show with Micro-Lights.***




DAN RETZINGER

FLASHING LIGHTS ATTRACT THE ATtention of people and can lure or warn them. Police cars and ambulances are equipped with flashing lights. Retail stores use strobe lights to attract attention to opening day and special sales, and aircraft strobe lights call attention to them day or night. This article describes how to build a pocket-sized miniature light show called Micro-Lights. It's a neat little project that's sure to get the attention of anyone passing by your desk or coffee table. The cigarette-pack-sized device is controlled by a versatile PIC microcontroller.

The display is composed of 19 LED lamps arranged in a geometric pattern. A microphone built into Micro-Lights makes it responsive to sound. A pushbutton selects one of eight preprogrammed sound-display routines. The circuit is powered from a 9-volt battery, so it's completely portable.

### The circuit

Figure 1 is the schematic diagram of the Micro-Lights circuit. At the heart of the circuit is a Microchip Technology PIC16C71 eight-bit, CMOS microcontroller with built-in EPROM. The PIC16C71 is packaged in an 18-pin DIP package that contains a central processor, clock, EPROM, RAM, eight-bit analog to digital converter, 13 TTL/CMOS-compatible input/output (I/O) lines, and a timer.

An electret microphone (MIC1) is connected to the noninverting input of dual, low-power operational amplifier IC2-a, a National Semiconductor LM358, which amplifies the microphone signal by a factor of about 1000. The-op amp's output feeds two inputs to the PIC16C71. Both inputs can be internally routed to the A/D converter inside the microcontroller. The signal on one input (RA0) is partially filtered by D1, C5, and R7, making the sound amplitude easier to distinguish. The other input (RA1) is fed directly from the op-amp. Software determines which input will be selected at any given time.

An LED array—19 LEDs arranged in a snowflake-like pattern—is connected to nine of the PIC's I/O lines. Resistors R10 through R13 limit the LED current, and help to reduce power drain. The LEDs are multiplexed under software control, with each column of three or four LEDs turned on (if dictated by the display routine) for 20% of the total display time, or about 1 millisecond. A complete display refresh occurs every 5 milliseconds, or 200 times a second. This rate is fast enough so that the human eye will see no visible flicker.

The select pushbutton is connected to I/O RA3 (pin 2). The pin is routinely sampled under software control. By repeatedly pressing the select pushbutton, the circuit cycles through all eight of Micro-Light's display routines.

The PIC16C71's clock circuit can be controlled by a standard quartz crystal, a resonator, or a simple RC combination. For power considerations and simplicity, an RC clock was selected. Resistor R8 and capacitor C7 form the PIC's clock which runs at approximately 100 kilohertz.

Switch S2 turns power on and off. A 78L05 regulator (IC3) supplies power to the circuit. Capacitors C1 and C2 stabilize the regulator output.

### The PIC16C71

Figure 2 is a block diagram of the PIC16C71. Only 35 single-word instructions make up the microcontroller'sRISC-like instruction set.

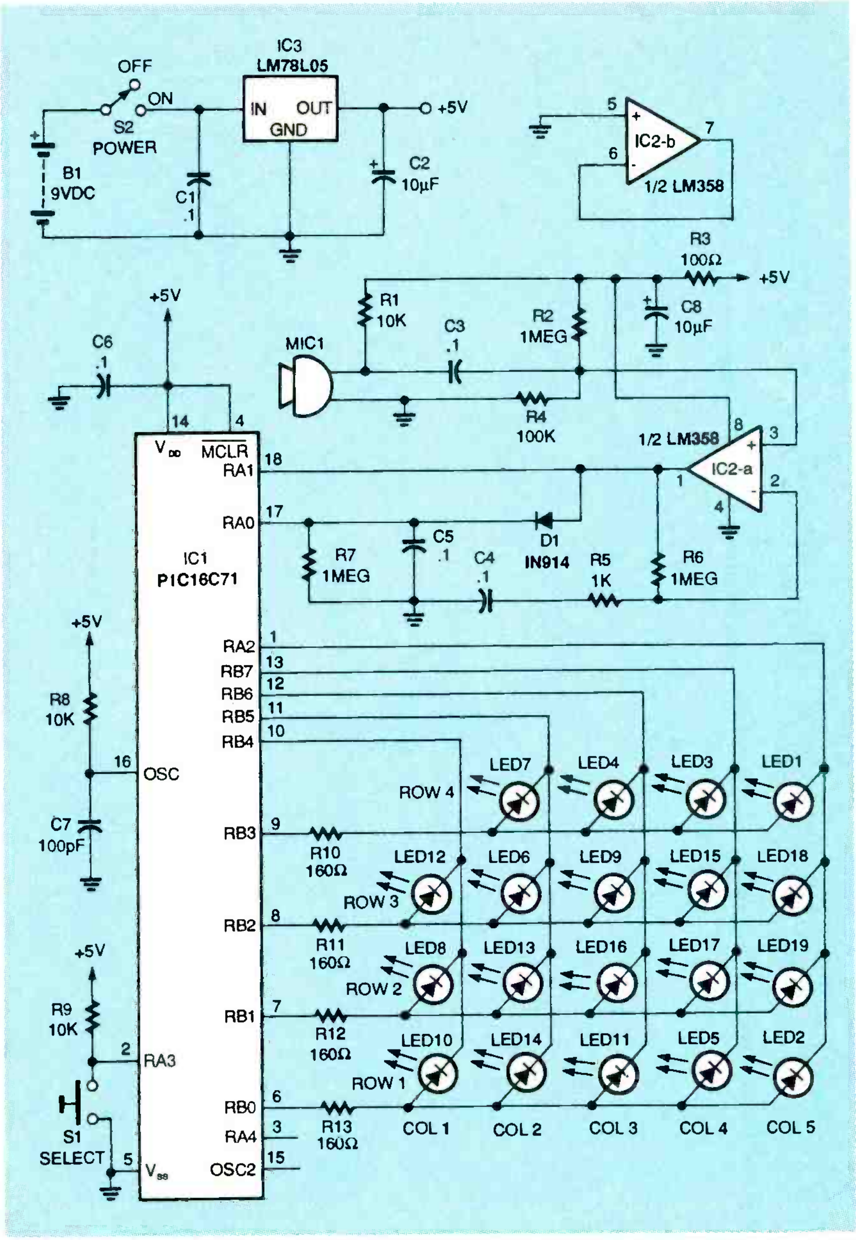



**FIG. 1—MICRO-LIGHTS SCHEMATIC. At the heart of the circuit is Microchip Technology's PIC16C71 8-bit, CMOS microcontroller with built-in EPROM.**

### PARTS LIST

**All resistors are ¼-watt, 5%.**
R1, R8, R9—10,000 ohms
R2, R6, R7—1 megohm
R3—100 ohms
R4—100,000 ohms
R5—1000 ohms
R10-R13—160 ohms

**Capacitors**
C1, C3–C6—0.1 μF, 50 volts, ceramic
C2, C8—10 μF, 16 volts, radial electrolytic
C7—100 pF, 50 volts, ceramic disc

**Semiconductors**
IC1—PIC16C71 microcontroller (Microchip Technology)
IC2—LM358 dual op-amp (National Semiconductor or equivalent)
IC3—78L05 100 milliampere, 5-volt regulator
D1—1N914 diode
LED1–LED19—green light emitting diode, T1¾ package

**Other components**
S1—Pushbutton switch, PC-mount
S2—Slide switch, SPST PC-mount
MIC1—Electret condenser microphone (Panasonic WM54BT or equivalent) B1—9-volt alkaline battery

**Miscellaneous:** PC board, 9-volt battery clip, 9-volt battery holder (Keystone part No. 71), one 18-pin IC socket, one eight-pin IC socket, PC board backing material, four No. 2 screws and nuts, solder.

**Note: The following parts are available from Silicon Sound, P.O. Box 371694, Reseda, CA 91337-1694 (818) 996-5073:**

- **Starter kit (includes PC Board and programmed PIC16C71 microcontroller)—$39.00**
- **Complete kit (includes all parts)—$59.00**
- **Assembled and tested Micro-Lights—$69.00**

**Please add $3.50 for shipping and handling. California residents add 8.25% sales tax.**

The PIC16C71's 13 I/O pins (made up of RA0–RA4 and RB0–RB7) can be programmed individually as inputs or outputs. Configured as outputs, each pin can source 20 milliamperes of current or sink 25 milliamperes. This feature is very convenient for driving LED lamps directly.

The PIC16C71 has four interrupt sources and an eight-level hardware stack. The A/D converter has four channels, eight-bit resolution, built-in sample-and-hold circuitry, and can perform a conversion in under 30 microseconds.

## Software

The Micro-Lights software takes advantage of several PIC features. Figure 3 is a simplified flow chart. The key to controlling the LED display is a timed interrupt routine. Immediately after power-up, an initialization routine presets and enables a timer within the microcontroller. The timer continuously counts up, and upon overflow causes an interrupt routine to be executed. At approximately 1-millisecond intervals, the interrupt software reads internal RAM locations (LED buffers) and outputs on/off states for each LED corresponding to the bit values in the RAM. One column of LEDs is updated per interrupt. Within 5 milliseconds all LEDs are refreshed. The select switch is also sampled during the interrupt.

The main program loop decides which display routine will be entered. The display routines decide which LEDs will be lit by writing to the same internal

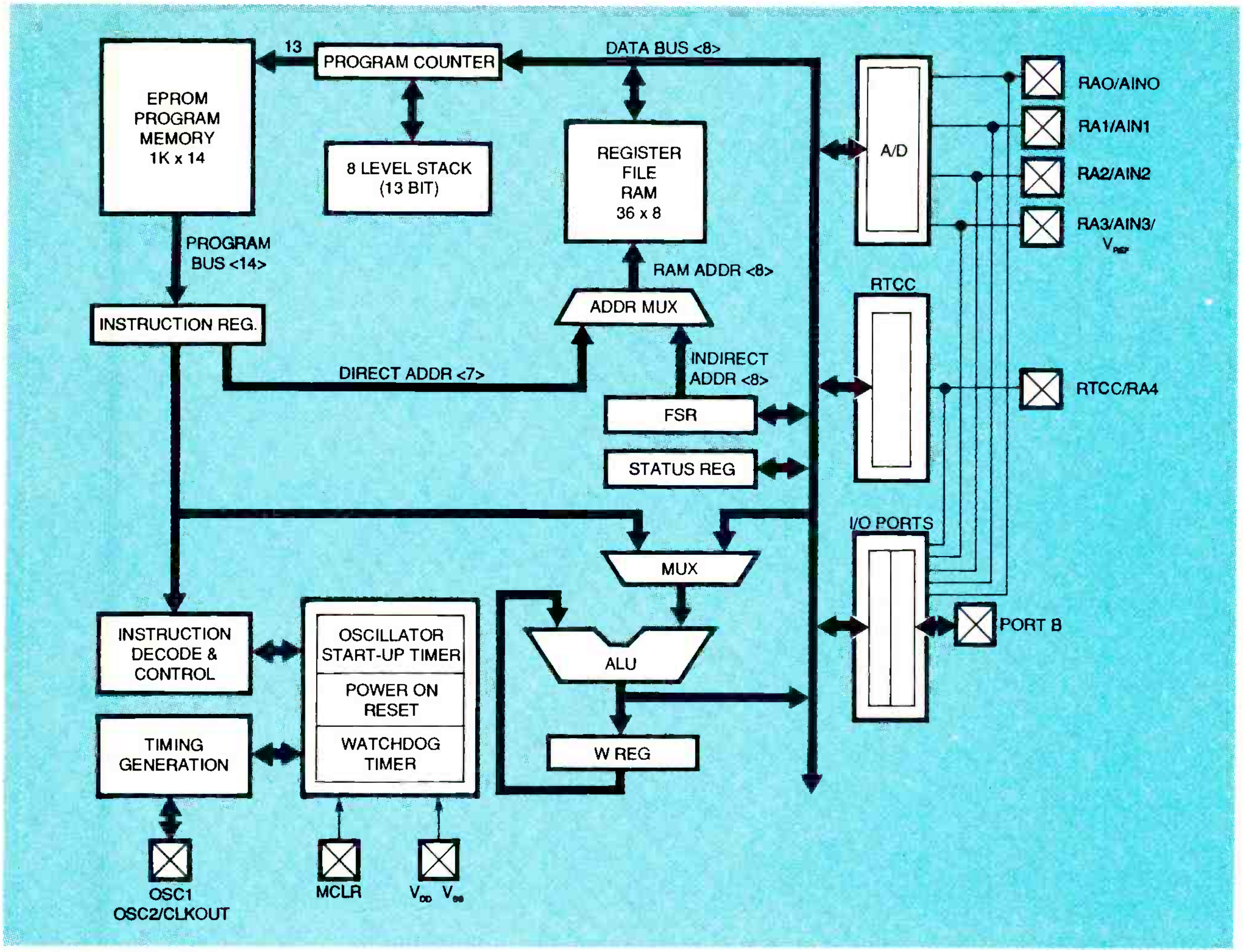
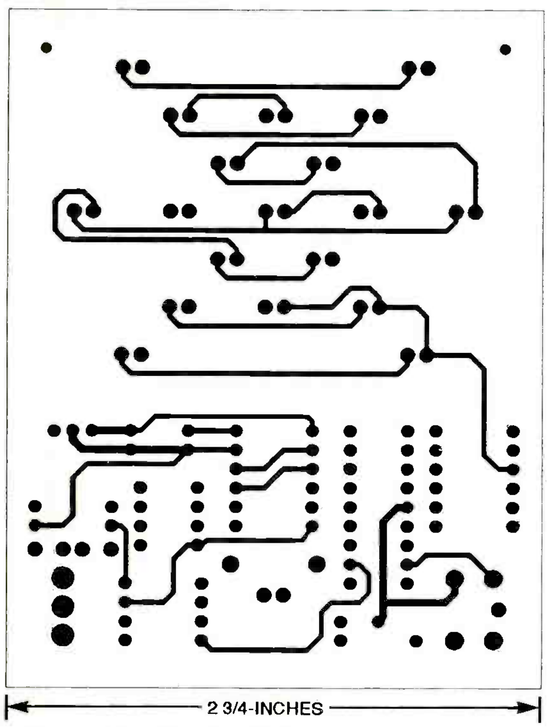
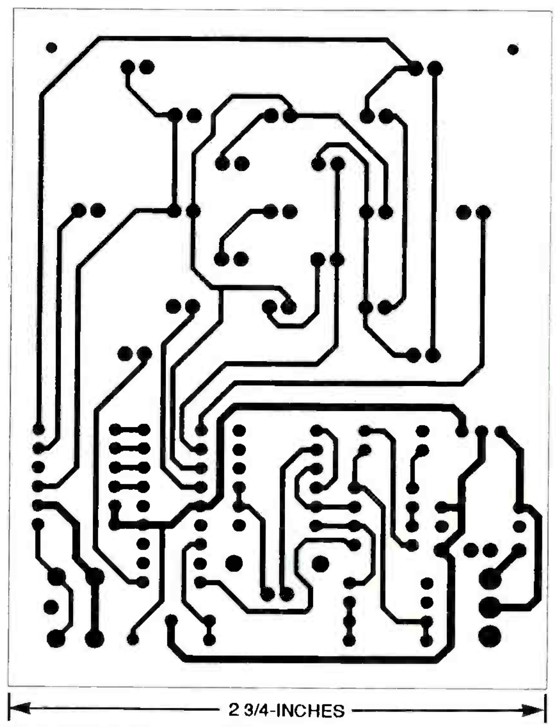



**FIG. 2—PIC16C71 BLOCK DIAGRAM. The chip includes fully static CMOS circuitry, flexible I/O pin programming, timed interrupts, and a built-in eight-bit A/D converter.**




**MICRO-LIGHTS COMPONENT SIDE.**




**MICRO-LIGHTS SOLDER SIDE.**

RAM locations accessed by the interrupt routine. The display routines have access to several subroutines: one reads the A/D converter, and the other generates a random number.

The value produced by the A/D converter corresponds to the sound intensity at the microphone. Some display routines distinguish between different values read from the A/D converter to determine how to turn on the LEDs, and others just look for a minimum amplitude for triggering a pattern. The frequency of sounds can be determined by rapidly reading the A/D amplitudes. A delay subroutine helps control the on and off duration of the LEDs.

Table 1 lists the eight Micro-Lights routines and includes a brief description of each. For example, look at the description for routine 2, "Random Single LEDs." When this routine is selected, the software controls the flashing of single LEDs, one at a time, in random locations on the LED array. When a sound of sufficient amplitude occurs, the rate at which the LEDs are lit is increased correspondingly. The effect is a pleasing twinkling pattern. The other seven routines produce their own unique effects, as mentioned in Table 1.

Listing 1 is a portion of the Micro-Lights source code. The complete source code (a file called MLIGHTS.SRC) can be downloaded from the Electronics Now BBS (516-293-2283, V.32, V.42bis) as part of a ZIP file called MLIGHTS.ZIP. The hex code (MLIGHTS.HEX) is also part of the ZIP file. Listing 1 shows the assembled code for the Star From Center routine 5, and Fig. 4 is the flowchart for that routine.

The status of the select push-

## LISTING 1

```
                    ;Routine 5: Star From Center
                    ;Lights emanate from center, proportional to sound

024C  1C1E  r_5     btfss   bitvar,0    ;check pushbutton
024D  281C          goto    main        ;if pushed, we're done
024E  199E          btfsc   bitvar,3    ;check for auto select
024F  2A52          goto    r_5ok       ;ok to continue
0250  1A1E          btfsc   bitvar,4    ;0 = continue
0251  281C          goto    main        ;if 1, new routine
0252  2284  r_5ok   call    getad       ;get A/D value
0253  1996          btfsc   adata,3     ;skip if bit 3 low
0254  3001          movlw   0x01        ;value for center led
0255  1D96          btfss   adata,3     ;skip of bit 3 high
0256  0100          clrw                ;center led off
0257  008C          movwf   col_1       ;write to led buffer #1
0258  1A16          btfsc   adata,4     ;check bit 4 (A/D)
0259  300F          movlw   0x0f        ;value for 4 leds col_2
025A  1E16          btfss   adata,4     ;check bit 4
025B  0100          clrw                ;turn leds off
025C  008D          movwf   col_2       ;write to led buffer #2
025D  1A96          btfsc   adata,5     ;check bit 5 (A/D)
025E  300F          movlw   0x0f        ;4 leds col_3
025F  1E96          btfss   adata,5     ;check bit 5
0260  0100          clrw                ;turn leds off
0261  008E          movwf   col_3       ;write to led buffer #3
0262  1B16          btfsc   adata,6     ;check bit 6 (A/D)
0263  300F          movlw   0x0f        ;4 leds col_4
0264  1F16          btfss   adata,6     ;check bit 6
0265  0100          clrw                ;turn leds off
0266  008F          movwf   col_4       ;write to led buffer #4
0267  1B96          btfsc   adata,7     ;check bit 7 (A/D)
0268  300F          movlw   0x0f        ;4 leds col_5
0269  1F96          btfss   adata,7     ;check bit 7
026A  0100          clrw                ;turn leds off
026B  0090          movwf   col_5       ;write to led buffer #5
026C  0816          movf    adata,w     ;adata -> w
026D  3C40          sublw   0x40        ;is there sound?
026E  1803          skpnc               ;if sound, skip
026F  2A73          goto    r_5b        ;no sound
0270  3006          movlw   0x06        ;outside leds
0271  048C          iorwf   col_1       ;turn on leds
0272  2A75          goto    r_5c        ;skip turn-off steps
0273  108C  r_5b    bcf     col_1,1     ;turn off led 2
0274  110C          bcf     col_1,2     ;turn off led 3
0275  3007  r_5c    movlw   0x07        ;get hex 07
0276  0093          movwf   delay       ;set delay variable
0277  228A          call    delayl      ;wait, show leds
0278  2A4C          goto    r_5         ;continue with r_5
```

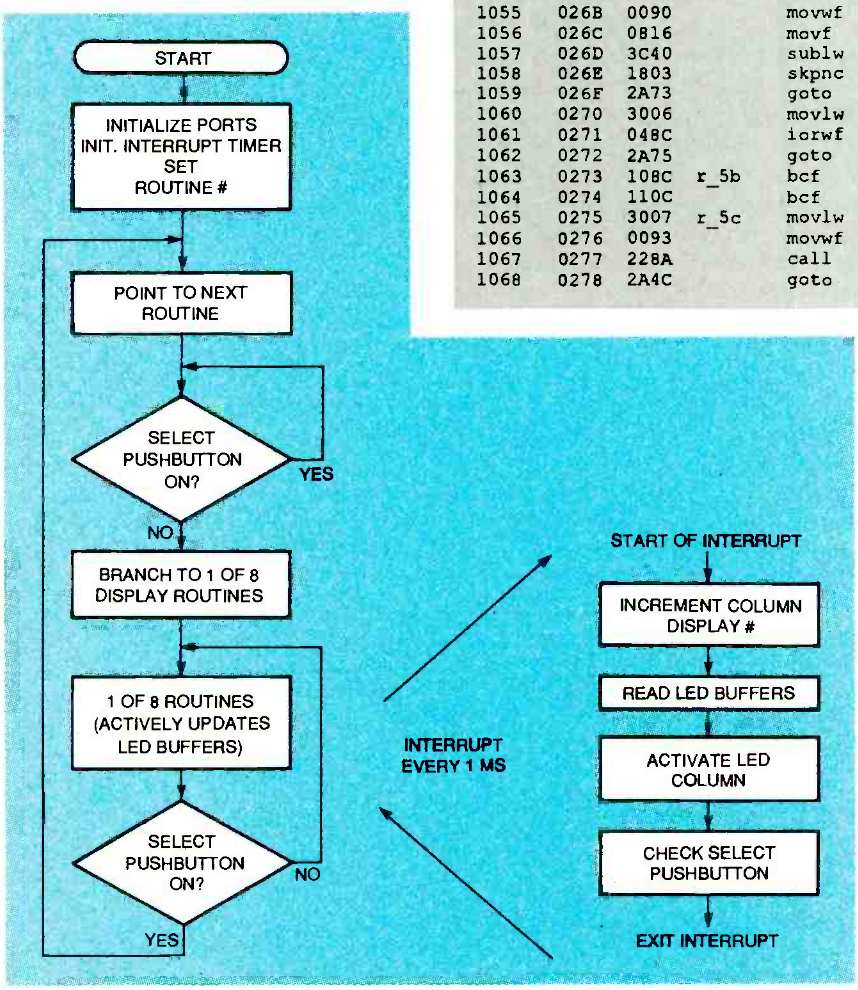



**FIG. 3—SIMPLIFIED FLOW CHART.** Immediately after power-up, an initialization routine presets and enables a timer within the microcontroller.

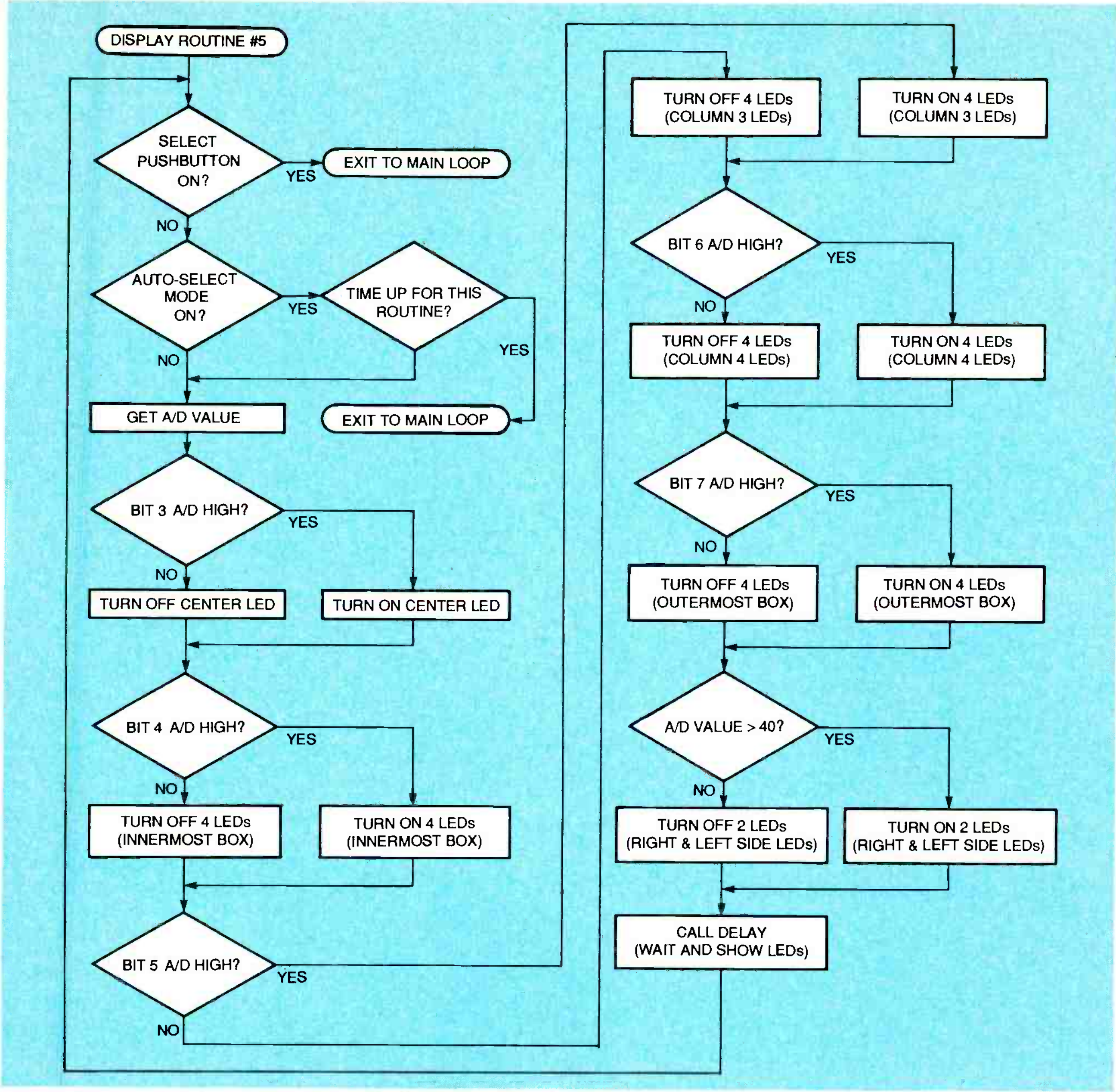



**FIG. 4—FLOWCHART for the Star From Center routine. The select pushbutton is checked near the top of the routine; if the button is pressed, the routine is exited.**

**TABLE 1—MICRO-LIGHTS ROUTINES AND FEATURES**

| Routine | Features | Effect of Sound |
|---|---|---|
| 1 | Spinning Bars | Triggers Speed & Direction |
| 2 | Random Single LEDs | Triggers Speed |
| 3 | Bar Graph | Increased LEDs with Amplitude |
| 4 | Random Lights | Triggers Speed |
| 5 | Star From Center | LEDs Extend from Center |
| 6 | Boxes Hold | Triggers Various Groups |
| 7 | Worms Run Rampant | Selects "Worm" and Rate |
| 8 | Bars Hold | Selects Bar to Display |

button is checked near the top of the routine; if the button is pressed, the routine is exited. Next, the autoselect mode is checked. If it is enabled it will cause the routine to be exited after approximately five minutes of operation.

A subroutine to read the A/D converter is then called to sample the sound amplitude. The main body of routine 5 then decides which LEDs to turn on, depending on the magnitude of the A/D value. If the magnitude is high (because of loud sound), all LEDs will be turned on; if the sound is low, only a few LEDs will turn on.

The testing is accomplished by checking each bit value in the A/D's byte. When all LEDs have been turned on, a delay

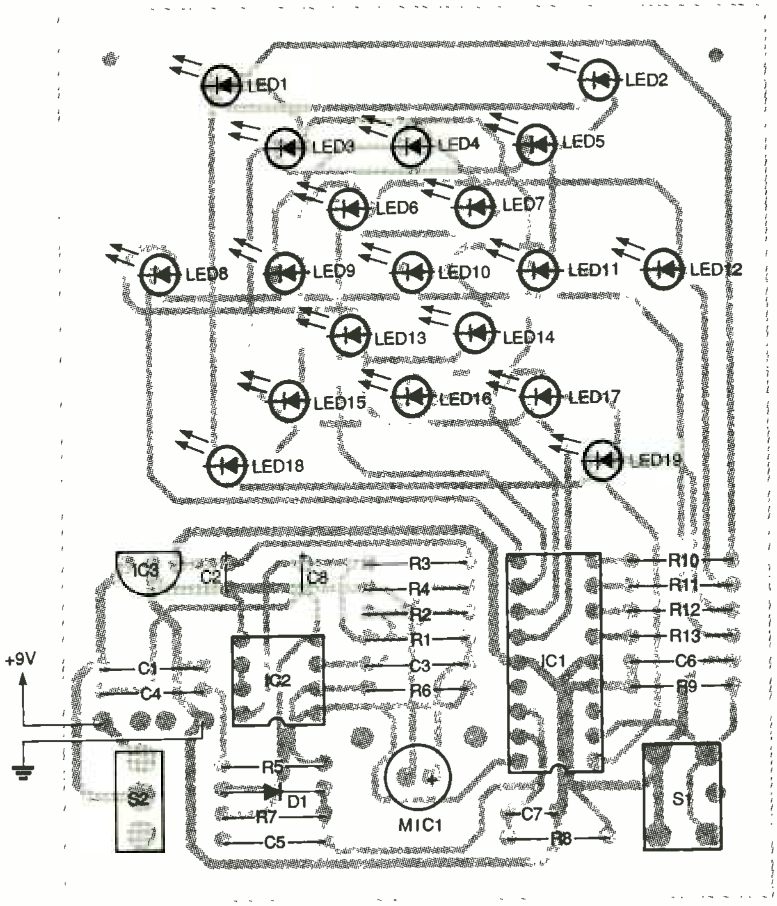



FIG. 5—PARTS-PLACEMENT DIAGRAM. Be sure to mount the LEDs flush with the board so that all cathodes face to the left.

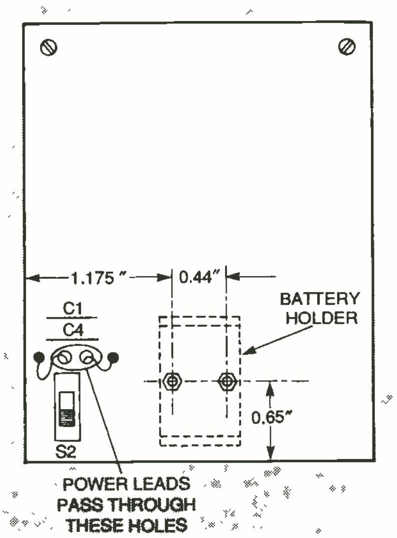



FIG. 6—DRILLING GUIDE. Four No. 2 screws and nuts hold the plastic backplate and battery holder in place.

routine is entered to freeze the display for a few milliseconds. The overall effect of routine 5 is a star that increases and decreases in size, according to sound intensity.

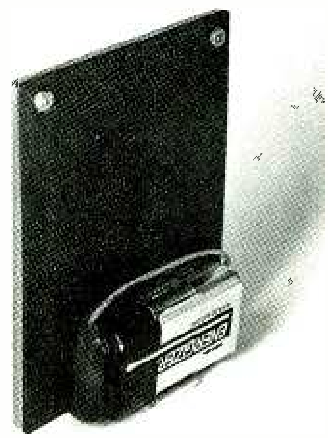


FIG. 7—THE 9-VOLT BATTERY and battery clip act as a stand.

## Construction

There are no critical requirements in the construction of this circuit. All of the components are available from the source given in the Parts List, including a pre-programmed PIC16C71 microcontroller and a double-sided silk-screened PC board. The parts are available from many other distributors, as well. For the best finished appearance of the project, a printed circuit board should be used. Foil patterns are provided here for those who wish to make their own boards. Note that Micro-Lights is designed so that it does not require an enclosure.

Figure 5 is the parts placement diagram for Micro-Lights. Be sure to mount all the LEDs with their cathodes facing to the left (as you view the component side of the PC board). Any brand of LED lamp will work, although the best is a bright, diffused-lens lamp in the standard 5-millimeter (T1¾) plastic, radial-leaded package. Standard LEDs have flattened edges on their bases to indicate the cathode lead. Mount the LEDs flush with the PC board to protect the leads from being bent if the LEDs are bumped. Install sockets for the PIC16C71 and the op-amp.

To protect your fingers from any sharp edges of cut off leads on the back of the PC board, and to help make Micro-Lights look more like a professionally made product, install a plastic backing on the PC board. Install a 1/16- to 1/10-inch thick ABS or acrylic plastic rectangular piece cut to the outline dimensions of the PC board. As shown in Fig. 6, drill four holes and attach the backing with No. 2 screws and nuts.

The two lower backplate mounting screws also secure the 9-volt battery holder in place. The 9-volt battery and battery clip act as a stand to support Micro-Lights when it is placed on a table for viewing (see Fig. 7). Be careful when positioning the holes for the battery holder. Their placement determines the angle at which the PC board will rest on a table. Figure 8 shows the completed Micro-Lights board.

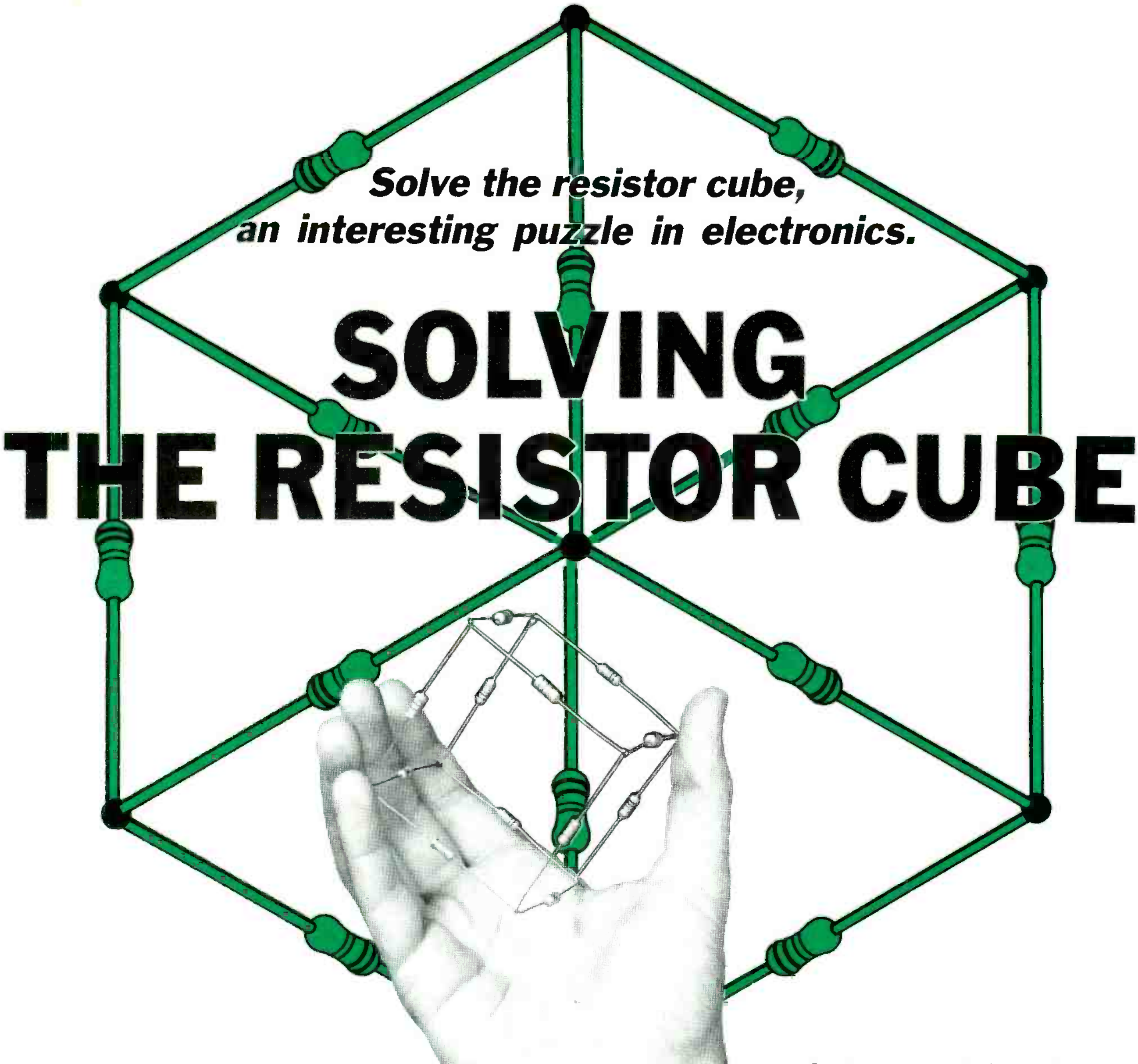
## Checkout

After you verify that all parts are installed correctly, connect a battery and turn on the power switch. Micro-Lights should immediately enter routine 1 and display a pattern of spinning bars. The bar's speed of rotation

*(Continued on page 66,*

*Solve the resistor cube, an interesting puzzle in electronics.*

# SOLVING THE RESISTOR CUBE



STANLEY T. MUNTZ

THE RESISTOR CUBE HAS BEEN A challenge for electronics students for many years. Basically the resistor cube is a three-dimensional construct of 12 resistors of equal value connected together to form the edges of a cube. It presents a challenge to electronics students and technicians to solve for the total resistance as measured from any two diagonally opposite corners.

For convenience in solving the problem, the value of each resistor chosen is usually a multiple of 10 such as 100 ohms, 1000 ohms, or 10,000 ohms. In this example there are twelve 1000-ohm resistors. This example, will be solved for total resistance, and all voltages and currents in the resistor cube network will be determined.

## Cube benefits

The resistor cube is an interesting challenge for electronics students and technicians and it is an excellent teaching aid as well. This beautiful example of electronic symmetry is very useful in illustrating the following principles:

- Ohm's Law
- Series, parallel, and compound circuits
- Bridge circuits
- Kirchoff's laws of voltage and current
- Power dissipation
- Network equations
- Electron flow
- Conventional flow
- Problem solving by a systematic approach

## Solving the cube

First I will give an overview of how the cube problem is solved. Then I'll go back over the diagrams with a detailed discussion of them.

**Figure 1.**
In any problem-solving situation, always draw a diagram and label all components and junction points. Make a list of all known values.

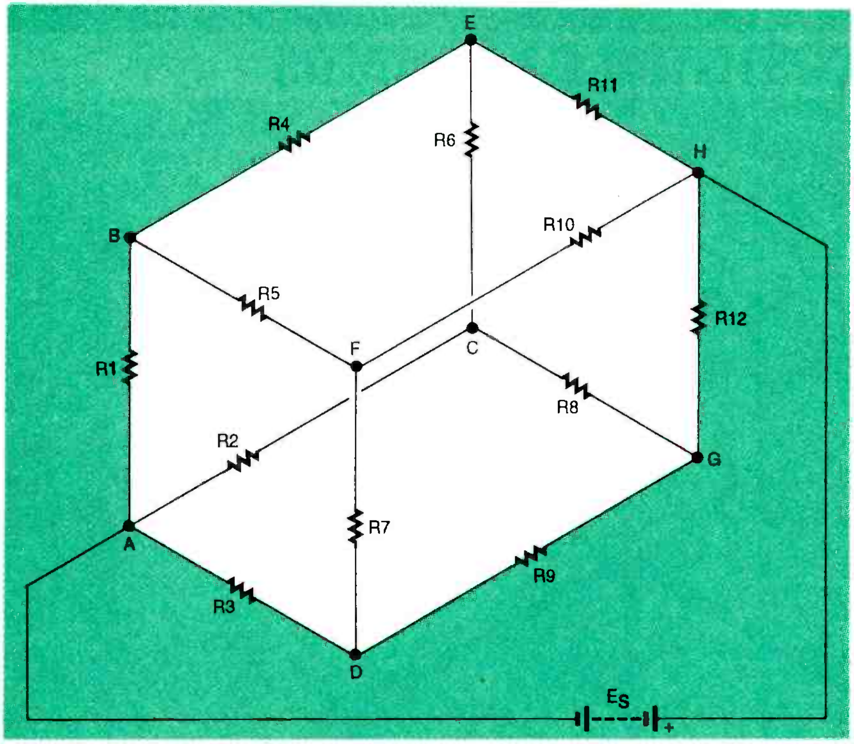



**FIG. 1—DRAW THE CUBE and label all resistors and junction points.**

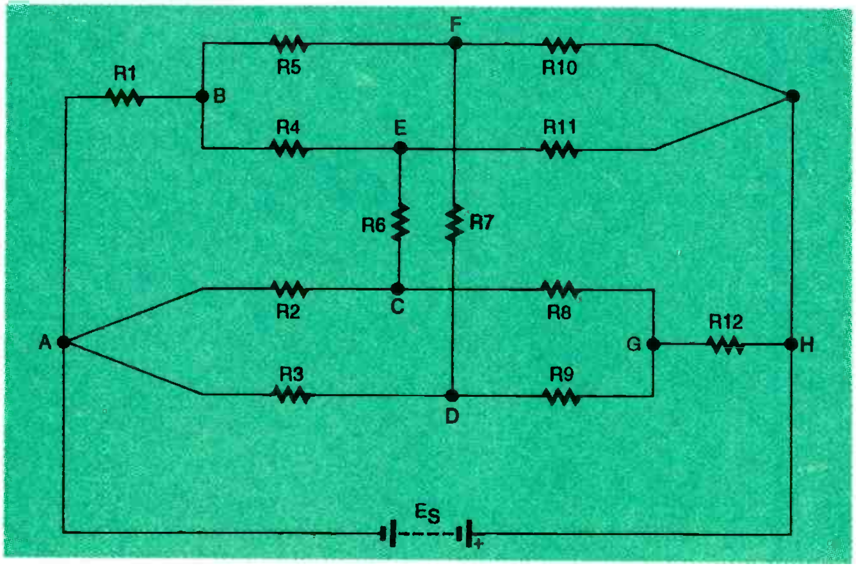



**FIG. 2—REDRAW THE CIRCUIT as a standard schematic.**

**Figure 2.**
Redraw the diagram as a schematic. Make sure that the schematic has two symmetrical but opposite series-parallel circuits, and two bridging resistors connecting them.

**Figure 3.**
Let $I_1$ represent the current through the four branches (R5-R10, R4-R11, R2-R8, and R3-R9). Because the resistors are all equal in value and the circuit is symmetrical, the currents will be equal. Draw the path of $I_1$ currents and identify the current through each resistor. (Note that R1 and R12 each have two branch currents flowing through them.) Mark the polarity of the voltage across each resistor: negative where current flows into the resistor and positive where the current flows out. This is an example of electron flow tracing around a circuit from negative to positive.

**Figure 4.**
The bridge currents flow from C and D to E and F because that is the path of least resistance from the negative terminal to the positive terminal of the battery. There are two resistors in series with each bridging resistor in this direction and four resistors in the other direction. Draw the bridging current paths of $I_2$ and identify the current through each resistor.

**Figure 5.**
Combine the $I_1$ and $I_2$ currents through each resistor. For example, R1 has two $I_1$ currents running through it and R2 has one $I_1$ and one $I_2$ current through it.

**Figure 6.**
Kirchoff's law of voltages states that the algebraic sum of voltages around a closed loop is zero. In other words, the voltage drops are equal to the voltage applied. Select two closed loops in the circuit to establish two equations containing the unknown quantities $I_1$ and $I_2$. The three requirements of the loops are: 1) that they not be identical because this would lead to identical equations and therefore no solution, 2) that they both contain $I_1$ and $I_2$, and 3) that they include the power source $E_S$. (A known value is needed to solve for our unknown quantities.)

For convenience, the potential of $E_S$ was chosen to be 10 volts because the resistors are a multiple of 10. However, any practical value could be used. The total resistance will turn out to be the same regardless of the value of $E_S$, but the voltages and currents will be dependent on the value of $E_S$. The voltages across each resistor are unknown. However, using the known resistance and known supply voltage, $E_S$, one can solve for $I_1$ and $I_2$ and eventually all other circuit values.

I used electron flow to establish the paths of the $I_1$ and $I_2$ currents and the polarity across each resistor. I will now use conventional current flow (from positive to negative) to establish the loop equations. The advantage of doing this is that with conventional current flow one

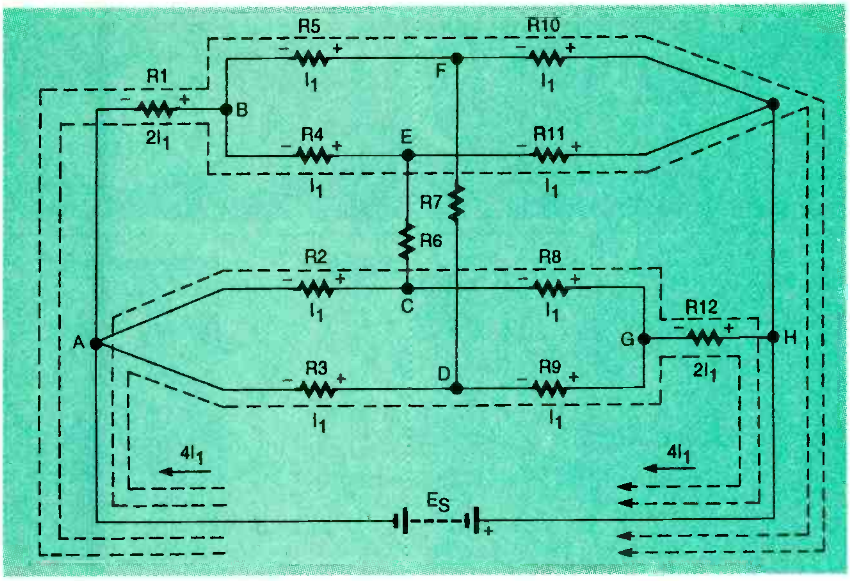



FIG. 3—TRACE THE BRANCH CURRENTS and label them as $I_1$.

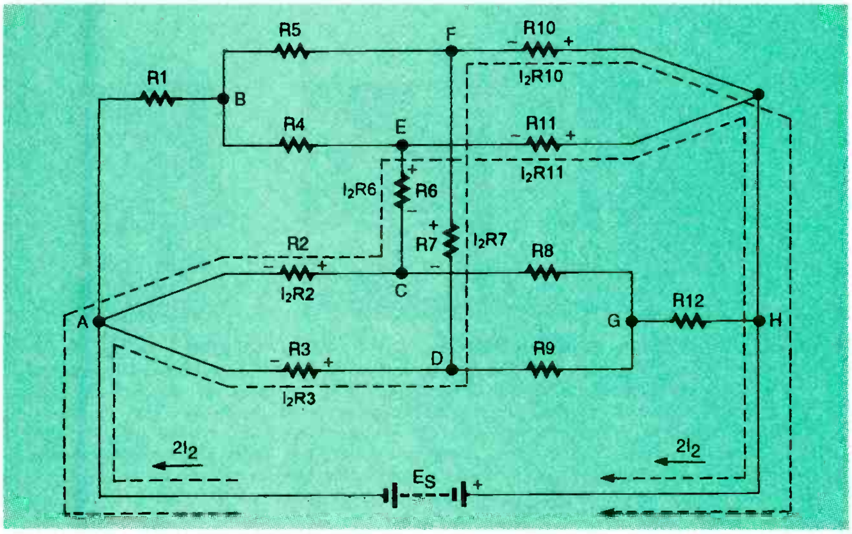



FIG. 4—TRACE THE BRIDGE CURRENTS and label them as $I_2$.

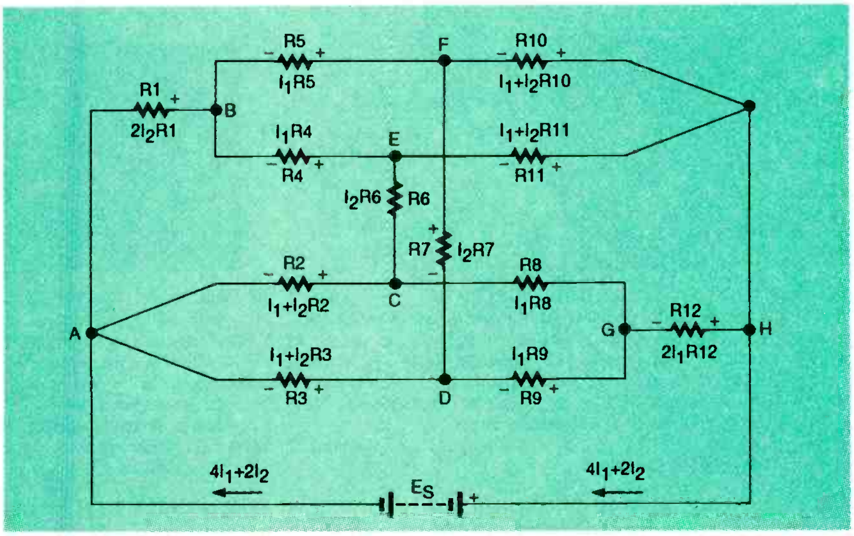



FIG. 5—COMBINE THE $I_1$ AND $I_2$ CURRENTS through each resistor.

will deal with numbers that are mostly positive because all but one resistor is approached from the positive end. The only negative values are those for R6 in equation 2 and $E_S$ in both equations.

**Equation 1**

Beginning at point X, proceed through points H, F, B, A, and through $E_S$ back to point X. The first equation is:

$(I_1+I_2)R+(I_1)R+(2I_1)R-E_S=0$

Multiplying $(I_1+I_2)$ by R and transposing $E_S$ gives:

$(I_1)R+(I_2)R+(I_1)R+2(I_1)R=E_S$

Combining like terms:

$4(I_1)R+(I_2)R=E_S$

Substituting R = 1000 ohms and $E_S = 10$, equation 1 becomes:

$4000(I_1)+1000(I_2)=10$

**Equation 2**

Beginning at point X, proceed through points H, G, C, E, B, A and through $E_S$ back to point X. The second equation is (note the minus sign for R6):

$2(I_1)R+(I_1)R-(I_2)R+(I_1)R+2(I_1)R=E_S=0$

Transposing $E_S$ and combining terms gives:

$6(I_1)R-(I_2)R=E_S$

Substituting R = 1000 and $E_S = 10$, equation 2 becomes:

$6000(I_1)-1000(I_2)+10$

**Solving for $I_1$ and $I_2$**

Add Equation 1 given earlier Equation 2 to eliminate $I_2$ and solve for $I_1$. The result is:

$10000(I_1)=20$

Solve for $I_1$ by dividing both sides of the equation by 10000:

$I_1 = 20/10000$
$= 0.002$
$= 2$ milliamperes

Now that we know the value of $I_1$, we can substitute this value into Equation 1 and solve for $I_2$:

$4000(I_1)+1000(I_2)=10$
$4000(0.002)+1000(I_2)=10$
$8+1000(I_2)=10$

Now subtract 8 from each side of the equation:

$1000(I_2)=2$

and divide each side by 1000

$(I_2) = 2/1000$
$= 0.002$
$= 2$ milliamperes

It can be seen that the branch currents and the bridge cur-

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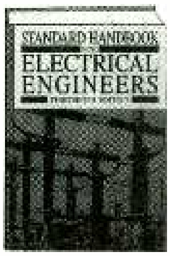


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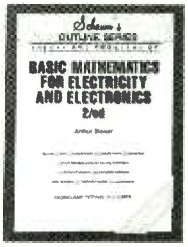


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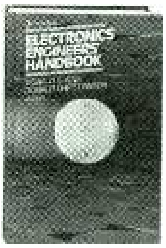


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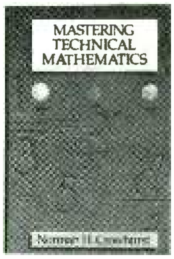


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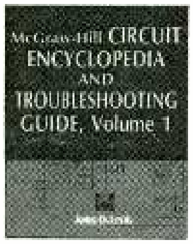


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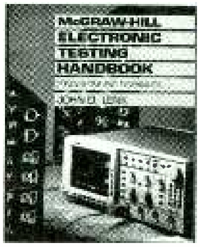


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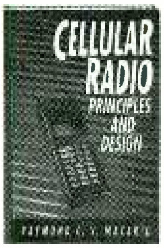


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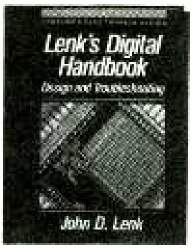


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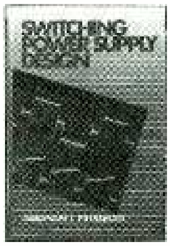


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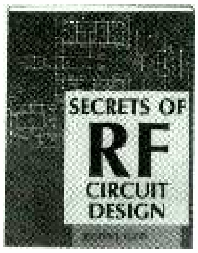


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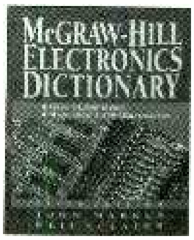


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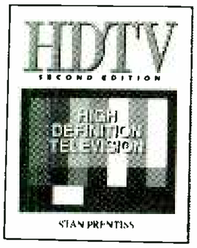


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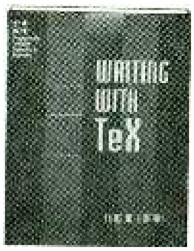


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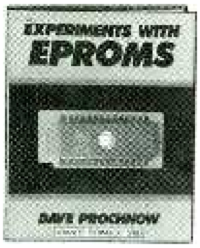


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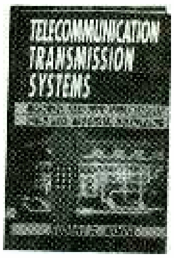


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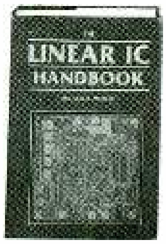


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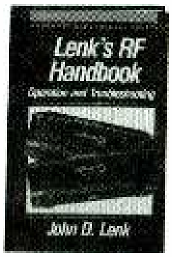


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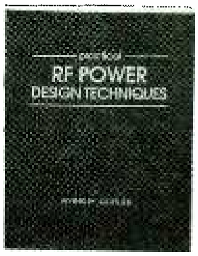


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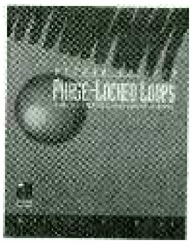


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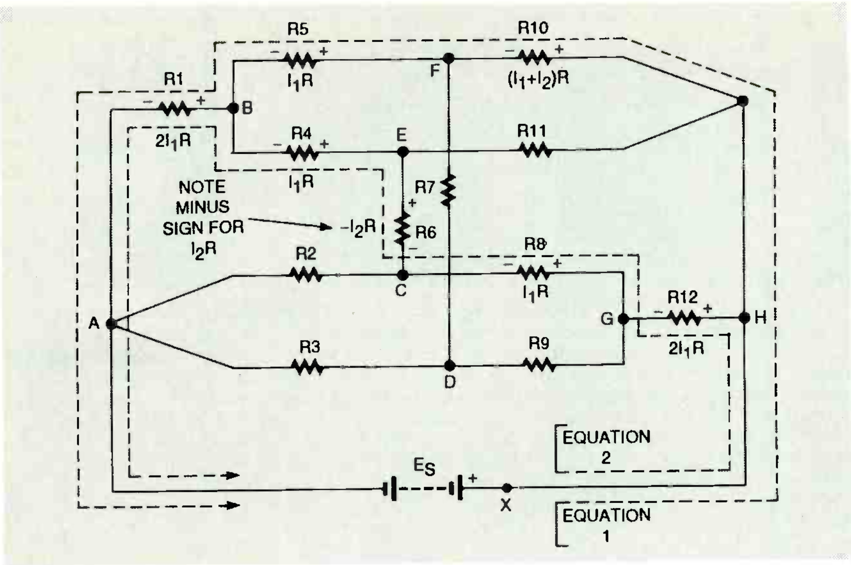



FIG. 6—SELECT THE PATHS for loop equations 1 and 2.

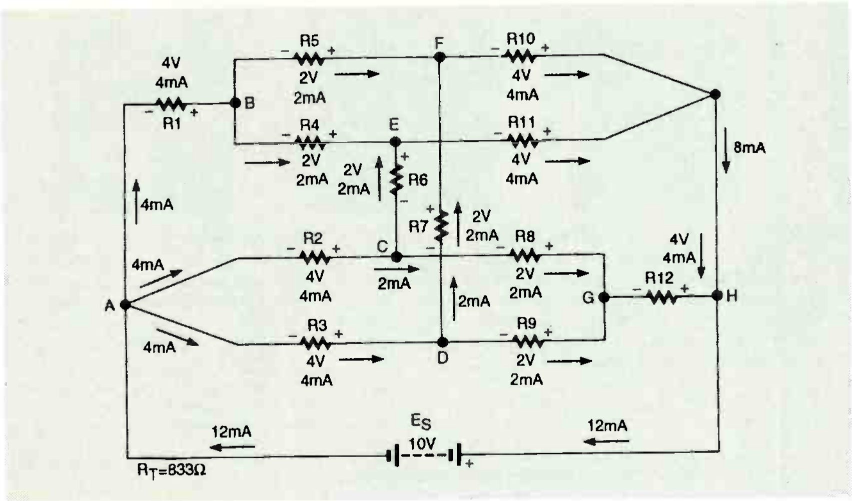



FIG. 7—AFTER FINDING THE VALUE OF R for each resistor and the current through each resistor, solve for the voltage across each resistor.

rents are equal. Both currents are equal to 2 milliamperes. Now solve for the total current supplied by $E_S$:

$I_T = 4(I_1) + 2(I_2)$
$= 0.008 + 0.004$
$= 0.012$
$= 12$ milliamperes

**Figure 7.**
With the values of R, $I_1$ and $I_2$ Ohm's law can be used to solve for the voltage across each resistor. As an example, calculate the voltage across R1

$E1 = 2(I_1)R$
$= 2(0.002)(1000)$
$= 4$ volts

One can also solve for the total resistance:

$R_T = E_S/I_T$
$= 10/0.012$
$= 833.3333333333$
$= 833$ ohms

**Figure 8.**
By using the schematic to solve for circuit values, transfer these values to the cube diagram in Fig. 8. Note the pattern of symmetry and flow of currents as they divide and then recombine. Figure 9 shows the same cube with conventional current flow.

**Solving new cubes**

The same procedure described here can be used to solve any resistor cube, provided that

*(Continued on page 66)*

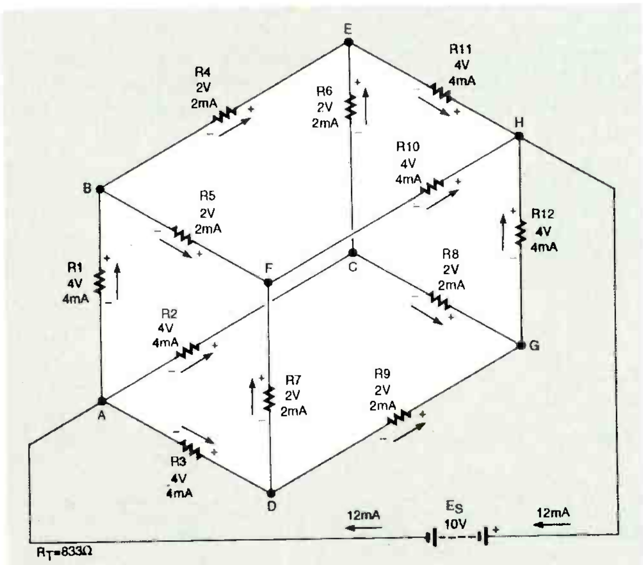



FIG. 8—TRANSFER CIRCUIT VOLTAGES and currents to the cube diagram.

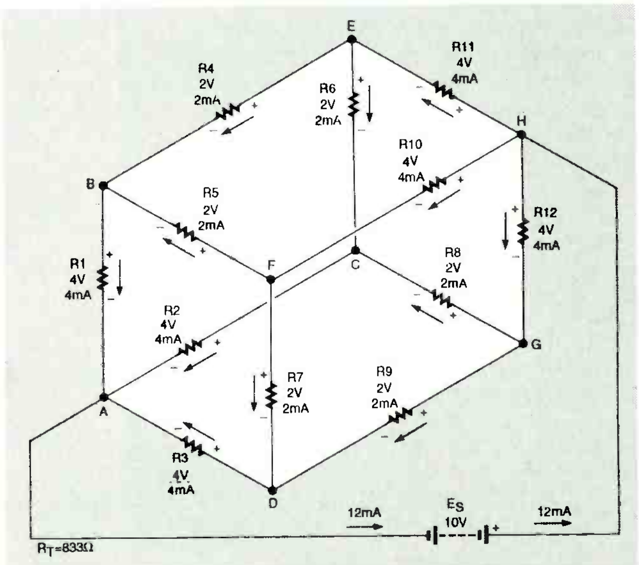
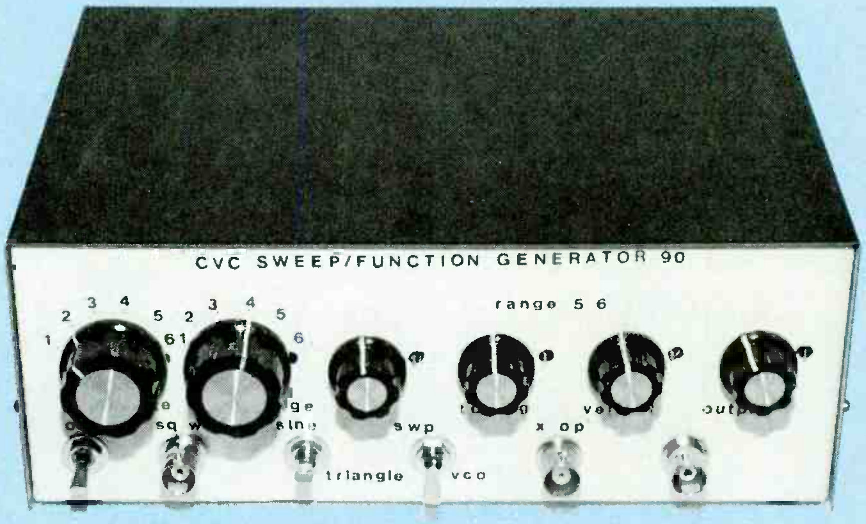



FIG. 9—THE SAME RESULTS CAN BE OBTAINED by following the rules of conventional current flow (from positive to negative).

C.V. CARLSON

# SWEEP/FUNCTION GENERATOR




***Build this sweep generator to create sine, triangle, and square waves and provide a horizontal sweep for an oscilloscope***

FUNCTION GENERATORS ARE VERY important and versatile test instruments capable of providing a variety of waveforms over a wide frequency range. The most common output waveforms are sine, square, triangular, and ramp. Most popular function generators have a frequency range that extends from tens of hertz to hundreds of kilohertz.

The function generator featured in this article meets all of these basic requirements, and it has a frequency range of 10 Hz to 800 kHz, making it a valuable addition to your workshop's suite of test and measurement instruments. In addition, the output can automatically sweep between two user-defined frequencies. The generator is based on two monolithic Exar XR2206 function generators. One produces the sine, triangle and square waveforms. The other is configured as a voltage-controlled oscillator (VCO) that sweeps the selected waveform between two frequency limits.

The sine, square, and triangular waveforms generated by this instrument can be used in verifying the design of prototype or brassboard circuits, and they can also be used in the diagnosis and servicing of consumer and industrial electronics products. The swept output, when displayed on an oscilloscope, can provide a way to measure a circuit's frequency response.

**Front panel controls**

The following are the manually operated front-panel controls of the sweep/function generator:

- SWEEP RATE rotary switch S5
- FREQUENCY rotary switch S2
- VCO control R30
- TUNING tuning control R28
- VERNIER tuning control R27
- OUTPUT level control R29
- ON-off switch S1
- SINE/TRIANGE switch S3
- SWEEP/VCO switch S4

Three coaxial output jacks are also located on the front panel:

- SQUARE-wave output J3
- HORIZ sweep output J2
- TRIANGLE output J4

**Circuit description**

Refer to Fig. 1, the schematic for the sweep/function generator. Both IC2 and IC4 are Exar XR2206 monolithic function generators: IC4 functions as a ramp generator, and IC2 functions as a generator of of sine, triangular and square waveforms. Dual operational amplifier IC1 produces a scaled, level-shifted ramp output that is capable of deflecting an oscilloscope's horizontal sweep. This ensures that the sweep generator and the oscilloscope's sweep circuit are always properly synchronized.

Any frequency of interest along the horizontal axis of an oscilloscope that is coupled to this function generator can be measured with an external frequency counter by manually tuning the function generator's VCO instead of sweeping it. The performance characteristics of the sweep/function generator are summarized in Table 1.

The generator's sweep rate and frequency can be set by front-panel rotary six-position switches, SWEEP RATE switch S5 and FREQUENCY switch S2. The VCO control R30 manually tunes the VCO. Table 2 lists the sweep ranges of the function generator. Sweep ranges not covered in ranges 1 to 4 can be set up as required on positions 5 and 6. Selecting the VCO setting on the front panel toggle switch S4 permits tuning any fixed frequency within the total frequency range of the instrument with both the FREQUENCY switch S2 and VCO control R30.

Sweep operation on the SWEEP/VCO setting for oscilloscope display and frequency measurement are explained later in this article.

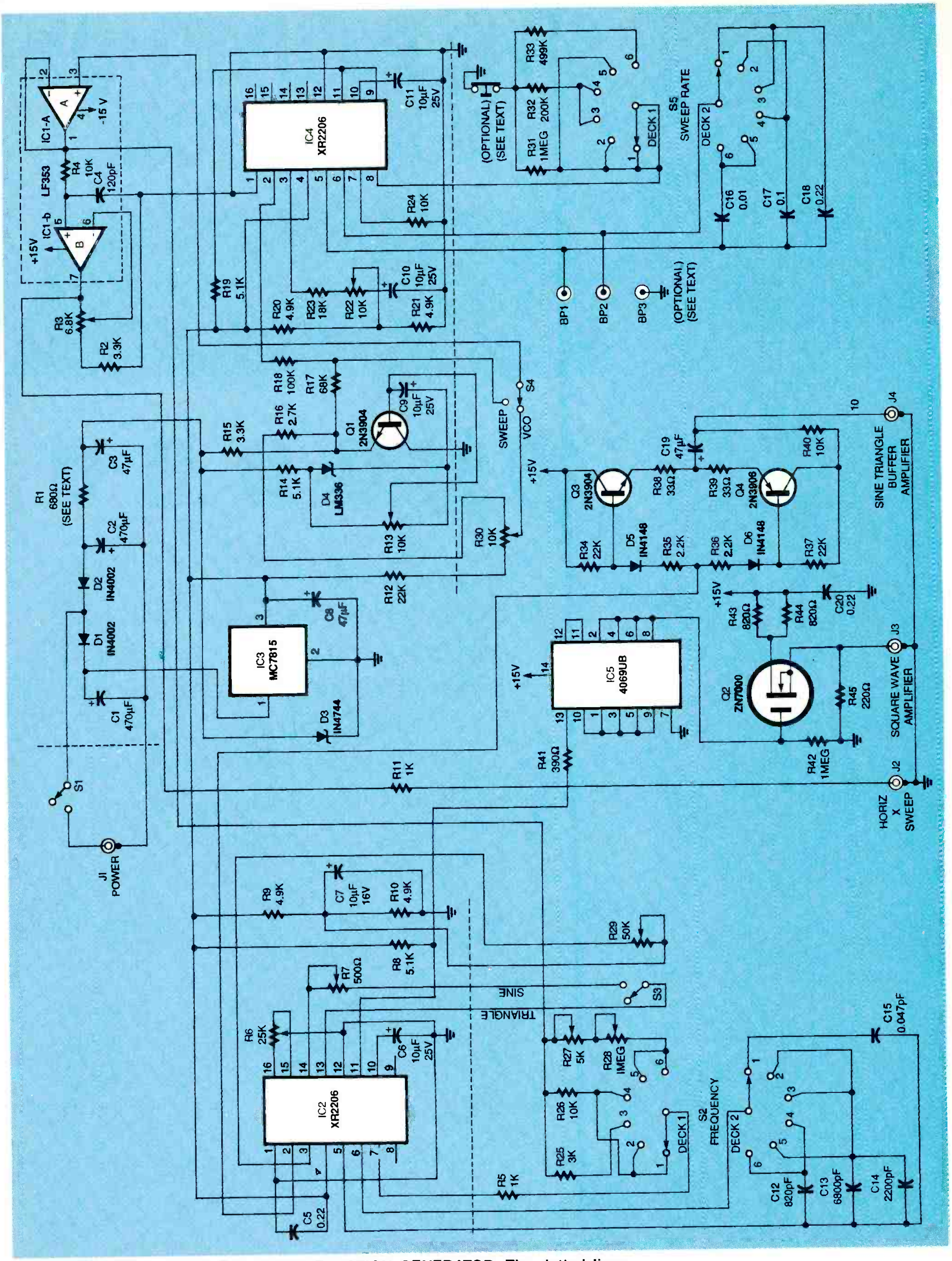



**FIG. 1—SCHEMATIC FOR THE SWEEP/FUNCTION GENERATOR.** The dotted lines separate circuitry on the board from that on the front and back panels of the case. Two Exar XR2206 monolithic function generators are included in the circuit.

**TABLE 1**
**FUNCTION GENERATOR CHARACTERISTICS**

| Waveform output | Maximum P-to-P | Frequency | Conditions |
|---|---|---|---|
| **Sine** (1) | 5V | 10 Hz-100 kHz | 1 V@800 kHz |
| **Triangle** (1) | 8 V | 10 Hz- 50 kHz | 1 V>500 kHz |
| **Square** (2) | 5 V | | Positive output DC-coupled, ground ref: rise/fall >50 ns |
| **Ramp** (3) | | | Descending, 6 rates |

(1) Output level variable frim min. to max.
(2) Output level not adjustable.
(3) X and Y amplitude internally adjustable.

**TABLE 2**
**SWEEP RANGES OF THE FUNCTION GENERATOR**

| Switch | Condition | Frequency range |
|---|---|---|
| 1 | Preset | 20Hz to >2kHz |
| 2 | Preset | <400Hz to >10kHz |
| 3 | Preset | <1kHz to >25kHz |
| 4 | Preset | 5kHz to >100kHz |
| 5* | Resistance tuned | 2kHz to 100kHz |
| | Resistance & VCO tuned | <10Hz to >100kHz |
| 6* | Resistance tuned | <40kHz to >800kHz |
| | Resistance & VCO tuned | <100Hz to >800kHz |

* Ranges show for positions 5 and 6 represent the total tuning range of the function generator and do not imply one continuous sweep.

The sweep rate or duration of the sweep ramp is selected by the rotary six-position SWEEP RATE switch S5. Table 3 lists the sweep rate durations for each of the six positions. Longer periods should be used for lower frequency sweeps.

**TABLE 3**
**SWEEP RATE OR DURATION**

| Sweep position | Period (milliseconds) |
|---|---|
| 1 | ~130 |
| 2 | ~ 60 |
| 3 | ~ 30 |
| 4 | ~ 15 |
| 5 | ~ 6 |
| 6 | ~ 3 |

### Sine-triangle amplifier

A sine-triangle buffer amplifier amplifies the sine and triangle waveforms so that the sweep generator can drive an output load as low as 50 ohms, with reduced output. The nominal load would be 1000 ohms. The amplifier consists of complementary symmetry NPN transistor Q3 and PNP transistor Q4. Resistors R34, R35, R36, and R37, in series with diodes D4 and D5, form the bias network.

Emitter resistors R38 and R39 bias NPN transistor Q3 and PNP transistor Q4. Aluminum electrolytic capacitor C19 and resistor R40 reference the output of the complementary pair to ground.

The amplifier has rise and fall times of 300 nanoseconds. As a result, the output is slew-rate limited above 100 kHz on the SINE setting of S3 and above 50 kHz on the TRIANGLE setting of S3 to about 1 volt at its highest frequency.

### Squarewave amplifier

The squarewave amplifier consists of MOSFET transistor Q2 and peripheral resistors and a capacitor. The rise and fall output times of an Exar XR 2206 are unequal, so this amplifier conditions the signal to correct that condition. A CD4069UB CMOS hex inverter, IC5,drives transistor Q2 to produce rise and fall times at the output with durations of less than 50 nanoseconds at 5 volts. The squarewave output becomes less symmetrical above 100 kHz, but it retains its fast rise and fall times.

The input to the squarewave amplifier MOSFET transistor Q2 (which has a relatively large and dynamically variable input capacitance) is conditioned by IC5. The input to pin 13 is squared up by the cascaded inverter sections IC5-e and IC5-f, and their output drives four paralleled inverter sections IC5-a, IC5-b, IC5-c, and IC5-d. The output at pin 8 of IC5 feeds the gate of MOSFET transistor Q2.

The output of Q2 is taken from the source across R45 to give a ground-referenced, DC-coupled signal. A complementary output of 9 volts appears at the drain. Capacitor C20 bypasses AC for Q2.

### Theory of operation

Refer to the schematic Fig. 1. Resistors R20 and R21, peripheral to IC4, and R9 and R10, peripheral to IC2, divide the voltage between the regulated +15 volts and ground for IC2 and IC4. The junction between the resistors is bypassed by aluminum electrolytic capacitor C10 for IC4, and C7 for IC2. Trimmer potentiometer R22 and resistor R23 set the voltage ramp output at pin 3 of IC4, as shown in Fig. 2, the functional block diagram of the XR2206.

Resistors R17 and R18 attenuate the ramp which is level-shifted by the negative bias voltage present at the emitter of Q1, the bias regulator. This voltage will be set to −2.5 volts during calibration by trimmer potentiometer R13. The negative bias voltage is developed across Zener diode D4 (an LM336 2.5-volt precision voltage reference IC in a three-pin plastic TO-92 package) by the current through R14 from the −15 volts developed across the 1N4744 Zener diode D3.

The resulting bias at the emitter of Q1 is more negative than the voltage set by R13. The negative voltage at Zener diode D3 for the dual operational amplifier IC1 is filtered by electrolytic capacitor C3. Resistor R1 in the filter sets the operating current through Zener diode D3. Capacitor C9 bypasses AC at the base of Q1 to ground, and ceramic disc capacitor C5 bypasses AC to ground between pins 1 and 4 of IC2.

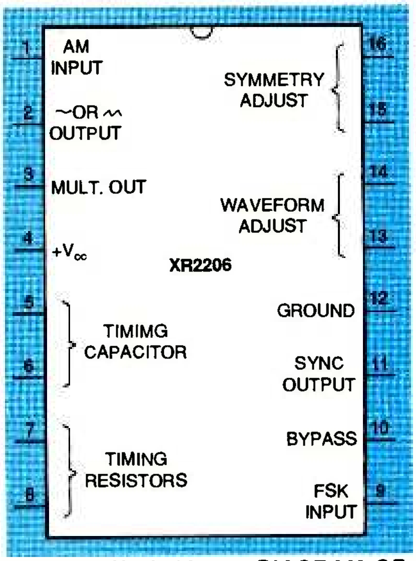



**FIG. 2—FUNCTIONAL DIAGRAM OF XR2206. It can produce sine, square, triangle, ramp, and pulse waveforms. This project contains two XR2206s.**

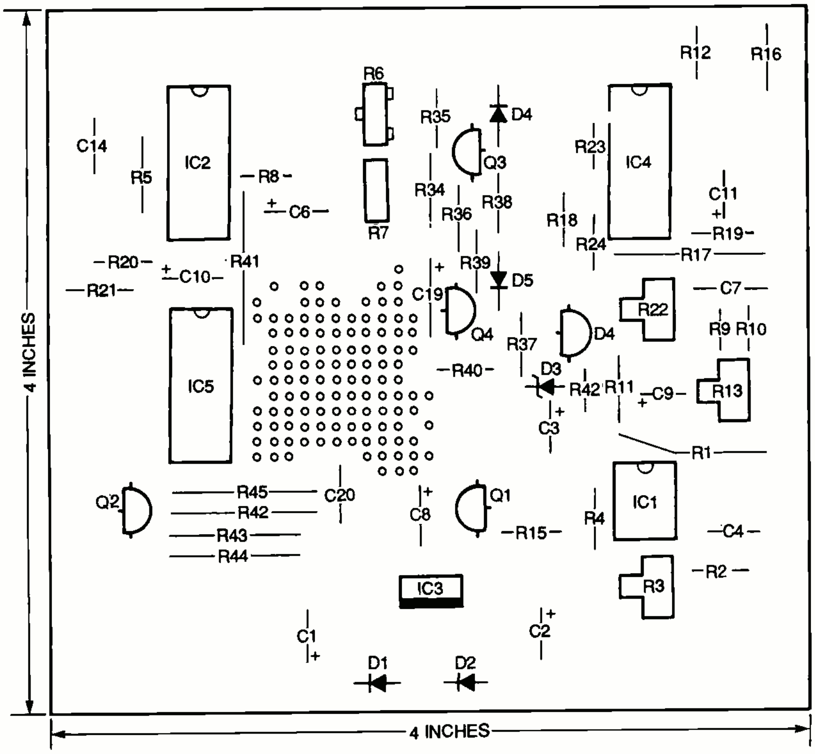



**FIG. 3—PARTS LAYOUT FOR POINT-TO-POINT WIRING. Position the components in the general locations shown to minimize wire lengths. All DIP-packaged ICs are mounted in sockets.**

The attenuated and level-shifted sweep-ramp voltage modulates the frequency output of IC2 linearly from low to high frequency. A network of one series and three parallel capacitors determines frequency. The output frequency of IC2 is determined by networks of capacitors and resistors connected between pins 5 and 6 and to pin 7, respectively. The timing networks are selected by switch S2, which provides six operating frequency ranges.

The frequency selected by the timing components can be modulated with another signal. Here, the frequency is controlled by applying the control voltage to pin 7. That control voltage is derived from IC4 through IC1-a.

Operational amplifier IC1-a is organized as a voltage follower to form a low-resistance current sink for the timing current. Non-inverting amplifier IC1-b provides a horizontal sweep output for an oscilloscope display. Trimmer R3 at output pin 7 sets the gain of IC1-b.

Resistor R4 (between the output of IC1-a and non-inverting pin 5 of IC1-b) and capacitor C4 form a low-pass filter to reduce any noise developed across the output impedance of IC1-a by internal timing current switching in IC2.

The sweep rate of ramp generator IC4 is determined by resistors R31, R32, and R33 as selected by two-pole, six-position rotary SWEEP RATE switch S5.

Resistor R32 has a value of 200 kilohms and R24 has a value of 10 kilohms. As a result, the flyback period will be between a maximum of 5% and a minimum of 1% of the period of the ramp. The ramp signal is repetitive and produces a continuous sweep output from IC1 except when VCO is selected by switch 4.

Resistor R11, trimmer potentiometer R30, and R15 form a voltage divider between the +15-volt supply and the negative bias at the emitter of transistor Q1. The voltage-controlled oscillator (VCO) voltage across R11 simulates the sweep ramp voltage. It can be adjusted to set any frequency within the range selected by switch S2 and potentiometer controls R27 and R28, when S4 is moved from SWEEP to VCO.

The horizontal sweep output also tracks the VCO setting so that a frequency of interest on a swept oscilloscope display can be read from an external frequency counter connected to squarewave amplifier output jack J3. The output of a circuit under test will remain visible as a vertical deflection at the same point on the oscilloscope display. It can be be fine tuned for peaks or nulls with the panel-mounted knob of the VCO linear control R30.

The frequency sweep produced by the function generator is linear, not logarithmic. Consequently, a sweep display can be positioned so that each horizontal sweep graticule division on the oscilloscope screen represents a frequency span of 1 kHz, 10 kHz, or more, depending on the sweep range selected.

The knob of VCO linear control R30 and the knob of panel OUTPUT linear control R29 adjust waveform symmetry, and internal trimmer potentiometer R6 can be adjusted to minimize distortion.

Load resistor R8 produces the squarewave input for the square-wave amplifier. Alumi-

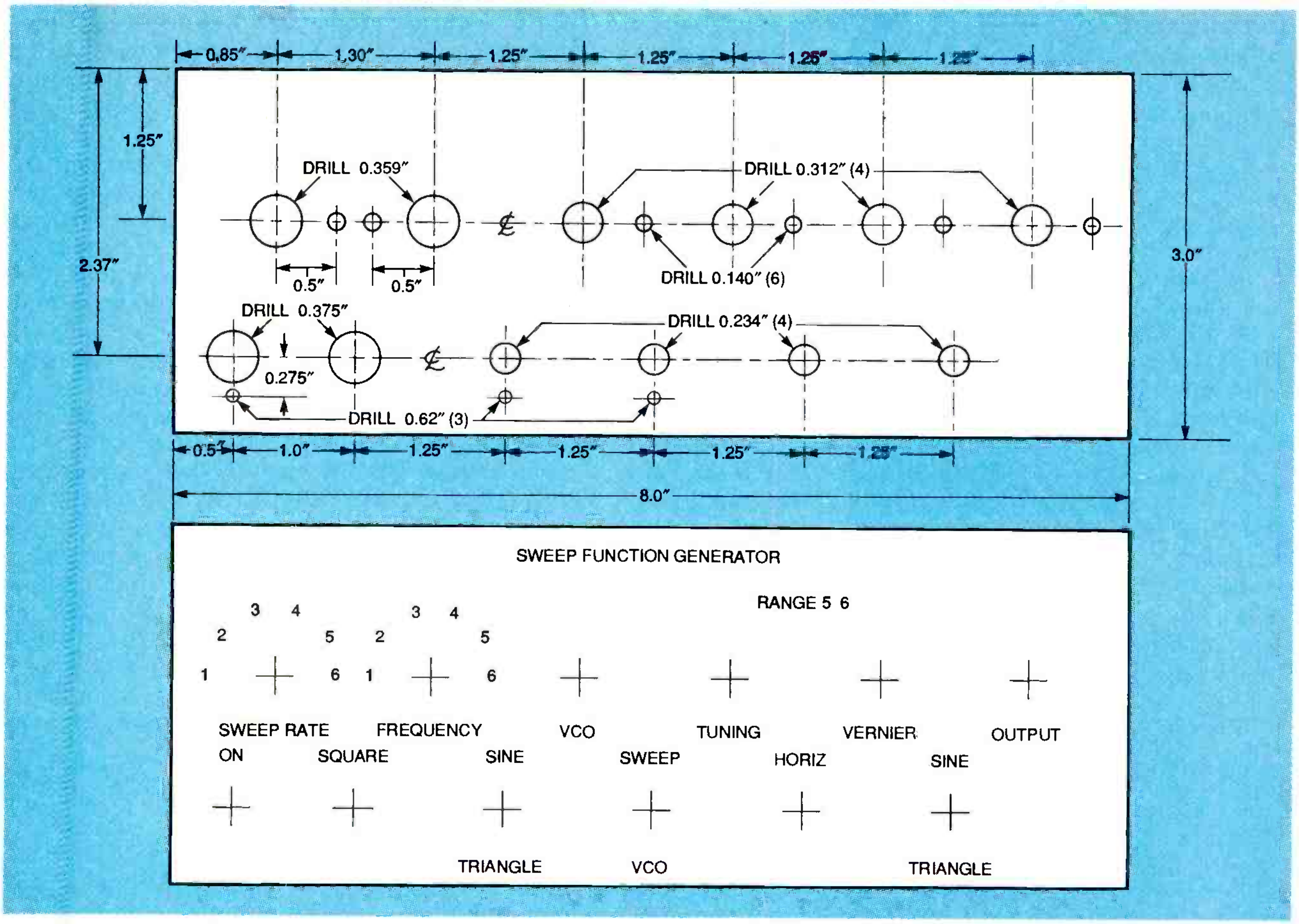



**FIG. 4—HOLE FORMING AND LABEL INSTRUCTIONS. Drill all holes as shown in (*a*) and apply function labels as shown in (*b*)**

num electrolytic capacitors C6 and C11 bypass the internal voltage references of IC2 and IC4, respectively.

## Power supply

The AC input is supplied by a 120-volt AC to 15-volt DC wall-outlet adapter. Diodes D1 and D2 in the power supply section provide both positive and negative outputs, which are filtered by aluminum electrolytic capacitors C1 and C2.

The positive 15 volt supply is regulated by a IC3, which is an MC7815 voltage regulator. The regulated +15 volts is filtered by aluminum electrolytic capacitor C8. Transistor Q1, functioning as the bias regulator, absorbs sweep modulation of the bias voltage.

NOTE: If your local utility does not provide adequate line-voltage regulation, obtain an 18-volt AC to DC adapter. Increase the value of R1 from 680 ohms to 820 ohms.

## Building the generator

The prototype sweep/function generator is housed in a two-piece metal project case that measures 8×6×3 inches. The sheet metal of the baseplate is folded at right angles to form the front and back panels. The metal of the cover is bent to form the two side panels, and it is fastened to the baseplate with sheet metal screws.

The circuit board in the prototype instrument was also a stock item with parallel edge contacts so that it could plug into a mating cardedge connector. This circuit board can be easily removed for maintenance, but any 4-inch square of 0.1×0.1-inch grid perforated circuit board material is also suitable for this project. Before mounting any components, drill holes in each of the four corners of the board so that it can be mounted on the base of the case with screws and insulating standoffs.

All of the electronic components with the exception of the Exar XR2206 function generator ICs are standard items readily available from most electronics retail stores or mail-order distributors. The Exar devices can be purchased in small quantities from Bell Account Development Group, Los Angeles, CA 90049 (1-800 289 2355).

All resistors specified in the parts list have 1 % tolerance because they are recommended for building precision instruments. Trimmer potentiometers R3, R13, and, R22 are circuit-board mounting, single-turn units.

## Parts placement

Refer to the parts placement diagram Fig. 3 for the general placement of all components on the perforated circuit board. Perform the wiring by point-to-point method, making use of the component leads, where practical, to interconnect other components.

Position the IC sockets in the locations shown in Fig. 3. Next, insert and solder the five trimmer potentiometers. Install the capacitors and other components, and bend the leads to assure that the components are positioned snugly against the component side of the board before soldering them on the solder side.

Refer to the schematic Fig. 1, and be sure to observe the polarities of all polarized electrolytic capacitors and the positions of the cathodes of all silicon and Zener diodes. Install the TO-220 packaged, three-leaded MC7815 regulator IC2 and bias regulator transistor Q1 and make all connections. Note that effective Zener diode D4 is actually an integrated circuit in a three-pin TO-92 plastic transistor package.

Solder all leads and trim excess lead lengths. Check to be sure that you have not made any inadvertent solder bridges or cold solder joints, and repair any that you find.

**Case hole drilling**

Figure 4-a is the pattern for drilling the holes in the front panel of the project case. This pattern can be enlarged to full size on a copying machine and taped or pasted to the panel. Follow standard practice in center-punching the holes in the sheet metal before drilling.

Cut out a square hole in the back panel of the case for mounting the power jack J1 approximately 1 inch above the base and 1 inch in from the edge for mounting the AC to DC adapter power jack J1. Drill the three holes for the three optional binding posts only if you intend to install them on the back of the case. These were drilled on the left side of the back panel of the prototype case.

Drill four holes in the baseplate with the same spacing as the holes drilled in the corners of the circuit board for mounting the completed circuit board on insulating standoffs above the base. After drilling all holes, deburr them.

Figure 4-b shows the positioning of the legends on the front panel of the project case. The legends can be applied to the front panel with water-soluble transfer lettering obtained from a stationery store or the labels can be embossed with a labeling machine on plastic adhesive-backed tape and fastened to the front panel in the appropriate locations with their adhesive.

Mount the BNC connectors in

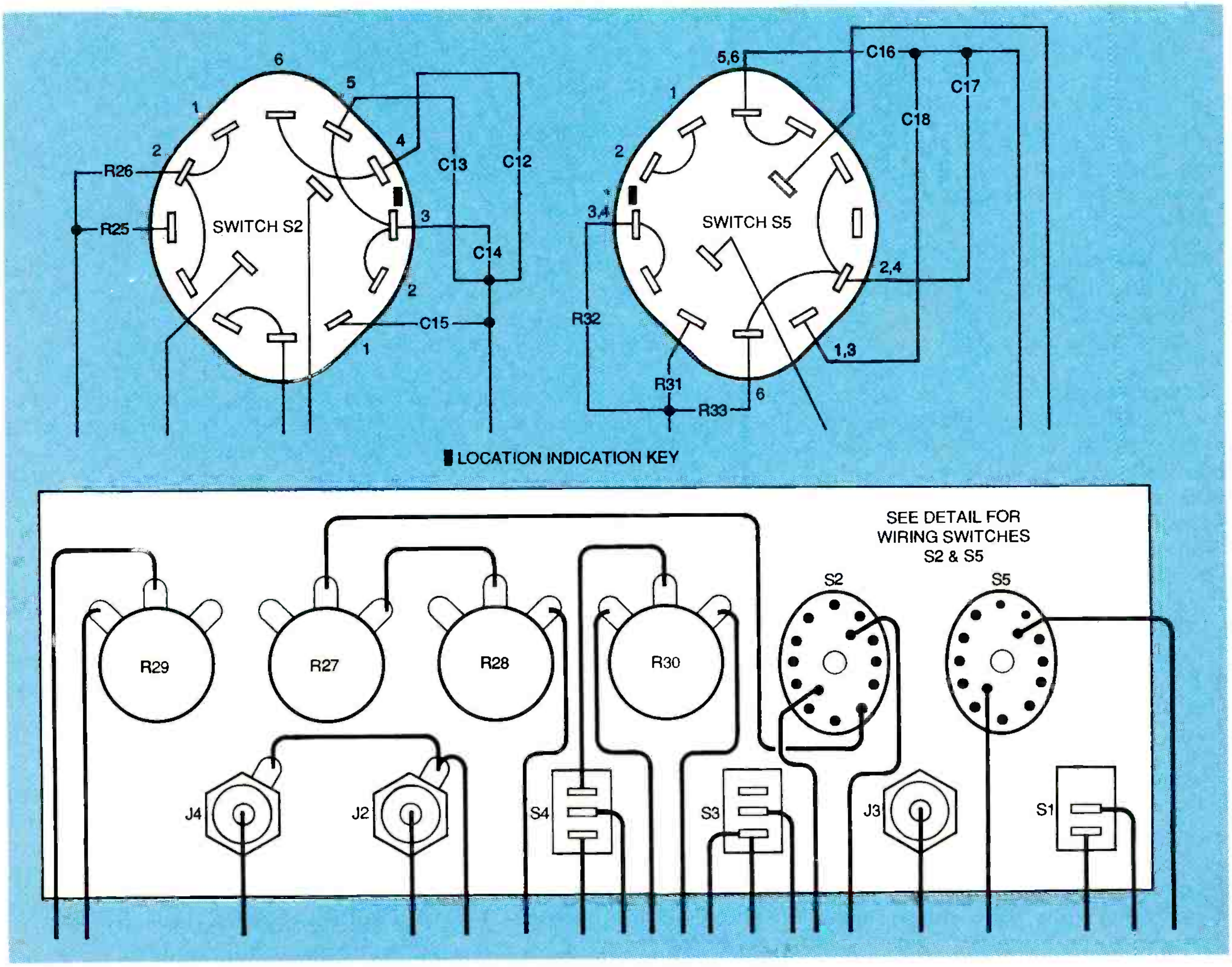
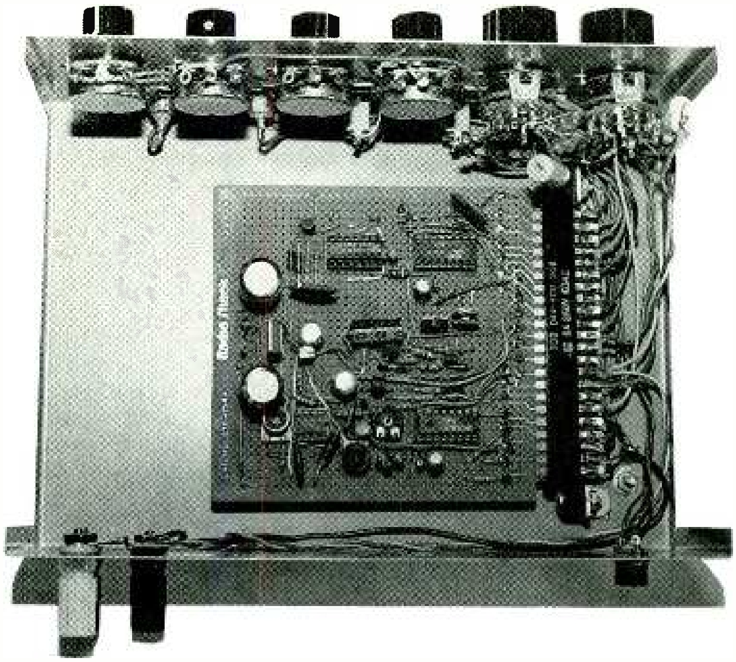



FIG. 5—WIRING FOR FRONT-PANEL-MOUNTED COMPONENTS. Wiring for rotary, two-pole switches S2 and S5 (*a*) and wiring for other controls, switches and jacks.(*b*)

the holes marked in Fig. 3-b with the ground lug and nut supplied. Mount the toggle switches in the holes with the keyed washer in front. Attach the power jack with the hardware provided. If you want to install binding posts in the drilled holes, install them at this time.

Form a wire ground from the BNC jack ground lugs to the cabinet ground lug, near the front mounting bracket. Perform all internal wiring not performed with component leads with No. 22 AWG insulated, stranded hookup wire. Make ground connections from No. 20 AWG bare solid or stranded copper wire to the closest case ground lug.

Form twisted pairs for wiring between the power jack J1, ON switch and the connections from FREQUENCY switch S2 and SWEEP RATE switch S5.



**INSIDE VIEW OF SWEEP/FUNCTION GENERATOR. Connections between board and panel circuitry were made with an edge connector in the prototype.**

**Back-panel wiring**

The wiring of the switches, potentiometers and coaxial jacks that are mounted on the back of the panel of the project case is shown in Fig. 5. Complete this wiring before mounting the switches to the panel of the project case. Cut excess lengths from the shafts of all panel potentiometers as necessary to permit the knobs to fit close to the ring nuts on the front face of the panel.

Position all bare wire jumpers and resistors, and solder the wires and resistors in place. Make the leads from the switches back to the circuit board from No. 22 AWG insulated stranded wire long enough to reach the connector terminals or controls.

**Test and checkout**

Test the power supply by connecting 15-volt DC on the circuit board. To test the voltages for the integrated circuits that are not yet installed, measure the voltages at the socket pins that correspond to the DIP package pins. The output voltages should be as shown in test voltages Table r:

If the measured voltages agree with those listed in Table 4, disconnect the power supply. Transistor Q4 is a 2N7000 MOSFET. Keep the terminals of MOSFET Q2 shorted together until it is soldered in place. Complete any other wiring or assemble any parts not yet installed.

Set trimmer potentiometer R22 to its midpoint, and monitor pin 2 of IC4 with an oscilloscope. Restore power and look for a negative sloping waveform with an amplitude of 6 to 9 volts peak-to-peak on all positions of SWEEP RATE control S5. Turn off the power, and insert the dual operational amplifier IC1 in its socket.

Restore power and monitor the output on coaxial connector J2 for the SWEEP RAMP output of 2 to 3 volts peak-to-peak. Set the horizontal sweep output of trimmer potentiometer R3 to its midpoint. The final adjustment of R3 will depend on the horizontal deflection sensitivity of the oscilloscope. This will be discussed under function generator sweep.

Set switch S4 to VCO and SINE-TRIANGLE buffer amplifier switch S4 to SINE. With power off, insert IC3. Select range 1 on the FREQUENCY switch S2, and observe the output of the sine/triangle buffer amplifier. Tune the output to 1 kHz with the VCO trimmer potentiometer control R30. Adjust trimmer potentiometer R6 for minimum sine wave distortion by visual examination.

Set trimmer potentiometer R5 with switch S3 set for TRIANGLE, and adjust for balanced rise and fall times on the waveform. Some compromise might be required here to avoid distorting the output.

The VCO tuning can be observed on each of the six ranges of FREQUENCY switch S2. However, expect the oscillator to stop oscillating at some position of counter-clockwise rotation of the rotary control. This is a normal condition, and it indicates the lowest frequency that can be tuned on that specific range. The lowest frequencies on ranges 5 and 6 are controlled by the setting of trimmer potentiometer R28 and, to a lesser extent, by vernier fine-tuning trimmer potentiometer R27.

The frequency range attained by the prototype was stated at the beginning of this article. However, because of variations in different XR2206 monolithic function generators, not all results will agree with the ranges stated. The output level can be adjusted with the OUTPUT panel control potentiometer R29.

## PARTS LIST

**All resistors are ¼-watt, 1% unless otherwise specified**
R1—680 or 820 ohms, ½watt (see text)
R2, R15—3,300 ohms
R3—6,800 ohms, trimmer potentiometer, PCB, horizontal slot
R4, R24, R40—10,000 ohms
R5,R11—1000 ohms
R6—25,000 ohms,trimmer potentiometer, PCB, vertical mount
R7—500 ohms, trimmer, PCB, vertical mount, Allen Bradley D or equiv.
R8, R14, R19—5,100 ohms
R9, R10, R20, R21—4,900 ohms
R12, R34, R37—22,000 ohms
R13—10,000 ohms, trimmer, PCB, vertical mount Allen Bradley D or equiv.
R16—2,700 ohms
R17—68,000 ohms
R18—100,000 ohms
R22—10,000 ohms, trimmer potentiometer, PC, horizontal mount
R23—18,000 ohms
R25—3,000
R26—10,000 ohms
R27—5,000 ohms, linear control, Radio Shack 271-1714 or equiv.
R28—1 megohm, linear control, Radio Shack 271-211 or equiv.
R29—50,000 ohms, linear control, Radio Shack 271-1716 or equiv.
R30—10,000 ohms, linear control, Radio Shack 271-1715 or equiv.
R31—1 megohm
R32—200,000 ohms
R33—499,000 ohms
R35, R36—2,200 ohms
R38, R39—33 ohms
R41—390 ohms
R42—1 Megohm
R43, R44—820 ohms
R45—220 ohms

**Capacitors**
C1, C2—470 µF, 35 volt, aluminum electrolytic
C3, C8—47µF µF, 25 volt, aluminum electrolytic, radial- leaded
C4—120 pF ceramic disc
C5, C20—0.22 µF, 16 volt, ceramic disc
C6, C9, C11—10 µF, 25 volt, aluminum electrolytic, radial leaded
C7, C10,—10 µF, 16 volts, tanatalum electrolytic, radial leaded, dipped
C12—820 pF, polypropylene film
C13—6800 pF, polypropylene film
C14—2200 pF, polypropylene film
C15—0.047 pF, polypropylene film
C16—0.01 µF, 100 volt, polypropylene film
C17—0.1 µF, 100 volt,polypropylene film
C18—0.22 µF, 100 volt, polypropylene film
C19—47µF, 25 volt, aluminum electrolytic, radial-leaded

**Semiconductors**
D1, D2—1N4002 diode, silicon rectifier
D3—1N4744, Zener diode, 15 volt, 1 watt
D4—LM336, 2.5 volt reference diode (Zener), National Semiconductor or equiv.
D5, D6—1N4148/1N914 silicon diode
Q1, Q3—2N3904 NPN bipolar transistor
Q2—2N3906 PNP bipolar transistor
Q4—2N7000 MOSFET transistor
IC1, IC4—XR2206 function generator, Exar
IC2—MC7815 positive fixed voltage regulator, Motorola or equiv.
IC3—LF353 dual JFET operational amplifier, National Semiconductor or equiv.
IC5—CD4069UB CMOS hex inverter, Harris or equiv.

**Other components**
S2, S5—switch, rotary 2-pole, 6-position, Radio Shack 275-1386 or equiv.
S3, S4—switch, miniature flat-lever toggle, 6 A, SPDT, Radio Shack 275-635 or equiv.
S5— switch, miniature toggle, 6 A SPST, Radio Shack 275-634 or equiv.
J2, J3, J4—BNC coaxial jack, panel mount, Radio Shack 278-415 or equiv.
J1—jack, AC to DC adapter, coaxial, Radio Shack 274-1565 or equiv.

**Miscellaneous:** AC-to-DC wall outlet adapter, 120-V AC to 15-V DC (see text); perforated circuit board, 0.1×0.1 inch hole spacing, 4×4-inches; metal project case, two-part, 8×6×3-inches,(see text); six panel control knobs in two sizes; four IC DIP sockets: two 16-pin, one 14-pin, one 8-pin; binding posts (optional, see text); No. 22 AWG insulated hookup wire; No. 22 AWG bare tinned copper hookup wire, solder

If all electrical measurements of the sweep/function generator are within the limits specified, and the circuit has responded correctly to all adjustments, start the procedure for calibrating the instrument with your oscilloscope.

### Function generator sweep

Set bias-trimming potentiometer R13 for −2.5 volts at the emitter of transistor Q1. Select Range 3 on FREQUENCY switch S2 and positions 1 or 2 on SWEEP RATE switch S5. Connect the HORIZONTAL output jack J2 of the sweep/function generator to the horizontal sweep input jack on the oscilloscope, and set the oscilloscope to EXTERNAL INPUT.

Set SWEEP-VCO switch S4 to SWEEP and SINE/TRIANGLE buffer amplifier switch S3 to SINE. Connect the SINE/TRIANGLE output jack J4 to the oscilloscope's vertical or Y-axis input jack, either with a probe or with a properly terminated coaxial cable.

Adjust OUTPUT panel potentiometer R29 for a Y deflection of 1 to 2 volts peak-to-peak on the oscilloscope screen. Center the band of horizontal X deflection with the oscilloscope's horizontal X-position control, and adjust trimmer potentiometer R3 at the output of operational amplifier IC1, the X deflection trimmer potentiometer for full (typically 10 division) oscilloscope deflection.

Adjust trimmer potentiometer R22 (adjacent to IC4) for maximum X deflection until the Y output ceases at the left edge of the oscilloscope screen because the sine oscillator has turned off. Back off trimmer potentiometer R22 until the oscillator starts to oscillate.

Readjust all the controls related to the X display to produce a band of sweep output that fills the full ten-division graticule width. Index the rotary SWEEP RATE switch S5 through all six positions to verify that the oscillator operates for the full sweep. (Its ability to do this could be limited by minor variations in the ramp output.)

If the SWEEP RATE switch does not perform correctly, readjust trimmer potentiometer R22 as previously described to produce the maximum sweep frequency width obtainable without stopping the oscillator.

Oscillation ceases when the most positive point on the sweep ramp reaches the nominal bias of +3 volts on pin 10 of IC2, preventing the flow of timing current. It might be necessary to set the sweep on one position of switch S5 and avoid sweep-rate positions 3 and 4 where oscillation is most likely to stop.

One or more horizontal lines at the left side of the oscilloscope screen indicate that oscillation has ceased. Maximum sweep width is achieved if this condition is avoided because some hysteresis exists between the stop and restart settings of the oscillator.

The sweep-frequency range obtained on positions 1 to 4 of FREQUENCY switch S2 can now be measured by setting the SWEEP/VCO switch S4 to VCO. Set VCO control potentiometer R30 so that the vertical deflection visible on the oscilloscope screen is on the first (left hand) graticule line.

The frequency measured by an external counter is the lowest frequency of the sweep, while the frequency measured on the extreme right graticule line of the VCO setting is the highest frequency. The frequency anywhere within the area bounded by the graticule can be read the same way.

Set the upper frequency on one of the first four ranges by adjusting trimmer potentiometer R13 and setting range 2 to 10 kHz or range 4 to 100 kHz. One setting affects all ranges.

Set the FREQUENCY range on positions 5 and 6 of rotary FREQUENCY switch S2 by adjusting front-panel TUNING control R28 or VERNIER tuning control control R27 to set the highest frequency. Set SWEEP/VERNIER switch S4 as described earlier with the trace on the right side graticule line.

## VCO control

The adjustment range of the VCO control R30 slightly exceeds

**TABLE 4**
**TEST VOLTAGES**

| Location | Volts ±10% |
|---|---|
| D1, cathode side of D1 | +25 |
| D2, anode side of D2 | −25 |
| IC1, pin 4 (1) | −15 |
| IC1, pin 8 | +15 |
| IC2, IC4, pin 4 | +15 |
| Q1, emitter (2) | |
| R9-R10 function | +7.5 |
| R20-R21 junction | +7.5 |

(1) With R1 installed.
(2) Depends on setting of trimmer R13

the voltage change of the sweep ramp. Slightly higher or lower frequencies can be set with switch S4 on the VCO setting than on the SWEEP setting without stopping the oscillator.

The VCO control can tune any single frequency within each of the six ranges of the sweep-function generator with simultaneous adjustment of TUNING control R28 and VERNIER control R27 on ranges 5 and 6.

The sweep can be offset to the left with the osilloscope's X-position control to put a selected frequency such as 1kHz on the left graticule line. Then the sweep can be adjusted to display a 1-kHz change on each following graticule line. This response can be demonstrated on SWEEP RATE range 2.

The sweep/function generator was designed for use with an oscilloscpe that has no horizontal gain control. To compensate for this, a negative ramp signal of about 4 volts for ten division deflection is required. If your oscilloscope has an X gain control, it can set sweep deflection, and trimmer potentiometer R3 at pin 7 of IC1 need not be adjusted. Once calibrated, the sweep performance shown on ranges 1 to 4 is repeatable without further manual adjustment.

If you intend to use the sweep/function generator with an X-Y or chart recorder, its sweep rate can be slowed with an external non-polarized aluminum electrolytic capacitor connected across pins 5 and 6 of IC4. A 100 microfarad, 15-volt capacitor will provide a range of sweep durations with SWEEP RATE switch S5 various positions:

- 68 seconds in positions 1, 2, and 5
- 14 seconds in positions 3 or 4
- 33 seconds in position 6

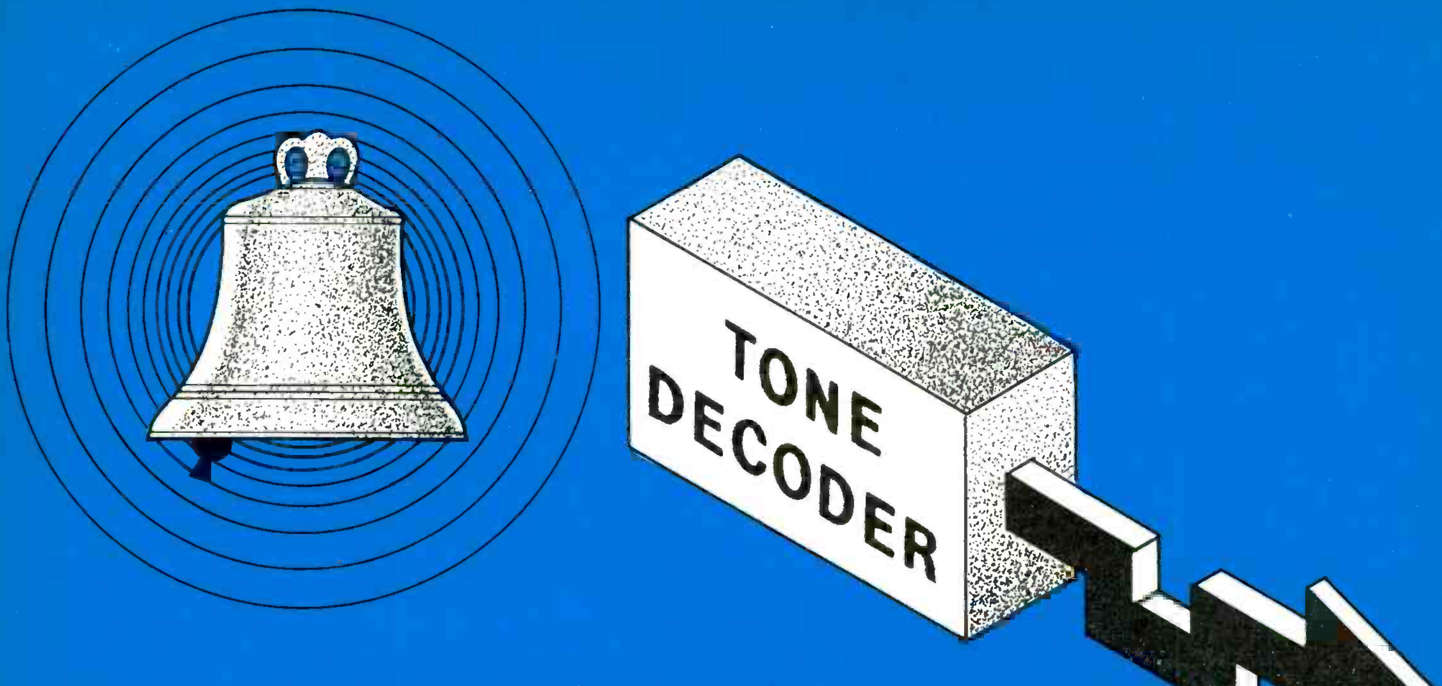
The output cuts off for several seconds after flyback because of longer than normal sweep. This can be minimized by readjusting trimmer potentiometer R22. A low-frequency sweep of 20 to 300 Hz can be obtained by selecting sweep range 5 and setting tuning and vernier controls for maximum resistance.

The sweep can be started at the same instant as the X-Y chart recorder by connecting the common lead to ground from resistors R31, R32, and R33 through a normally closed (NC) pushbutton switch shown on schematic Fig. 1. Connect a closed-circuit miniature phone jack, a plug, and cable to the pushbutton switch. Press the pushbutton and hold it as soon as the retrace is complete, and it will stop the sweep until you are ready to start recording.

The X-Y recorder will follow the sweep. Give the pen down command at the same time the pushbutton is released. Retrace will sweep in about 1 second. An AC voltmeter with a calibrated DC output (or other peak or envelope detector) will be required for X-Y or chart recording.

The squarewave output of the sweep/function generator is a useful signal source for bench or development tests on transistor-transistor logic devices or 5-volt CMOS logic devices. Clamp the input of those devices with a switching diode—anode to the input, cathode to supply voltage ($V_{CC}$ = 5 volts) to absorb any overshoot that might occur at the end of an unterminated coaxial cable when fast-switching input signals are applied.

The XR2206 is a versatile monolithic function generator, but its squarewave output is degraded at frequencies in excess of 100 kHz by a rise time of 250 nanoseconds and a fall time of 50 nanoseconds. The squarewave amplifier will provide some compensation for this shortcoming, but it will not correct the loss of symmetry. Ω




***Learn more about designing with the tone decoder, a versatile circuit that includes a phase-locked loop and responds to selected input frequencies***

# TONE DECODER

**RAY MARSTON**

THIS ARTICLE, THE FOURTH IN A SEries on phase-locked loops, is about a tone and frequency decoder monolithic integrated circuit. The tone decoder IC contains a stable phase-locked loop and a transistor switch that produces a grounded squarewave when a selected tone is introduced at its input. Tone decoders can decode tones at various frequencies. For example, it can detect telephone Touch Tones. The tone-decoder ICs are also found in communications pagers, frequency monitors and controllers, precision oscillators, and telemetry decoders.

The last three articles in this series explained the basic operating principles of the phase-locked loop and then went on to examine popular PLL ICs. Those included the Harris CD4046B PLL IC, the Philips (formerly Signetics) NE565 PLL IC, and the NE566 function generator IC.

This article is based on the Philips NE567 tone decoder/phase-locked loop. The device is a low-cost commercial version of the 567 packaged in an eight-pin plastic DIP. Figure 1 shows the pin configuration of that package, and Fig. 2 shows the internal block diagram of the device. It can be seen that its principal blocks are the phase-locked loop, a quadrature phase detector, an amplifier, and an output transistor. The phase-locked loop block contains a current-controlled oscillator (CCO), a phase detector and a feedback filter.

The Philips NE567 has an operating temperature range of 0 to +70°F. Its electrical characteristics are nearly identical to those of the Philips SE567, which has an operating temperature range of −55 to +125°. However, the 567 has been accepted as an industry standard tone decoder, and it is alternate-

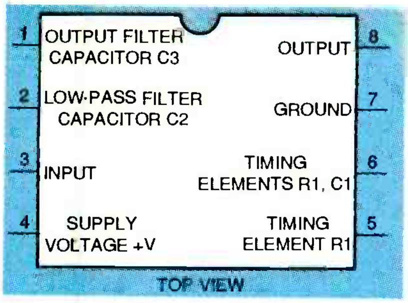



**FIG. 1—PINOUT FOR AN NE567 TONE decoder in a eight-pin DIP package.**

sourced by many other multinational semiconductor intergrated circuit manufacturers.

For example, Analog Devices offers three versions of its AD567, Exar offers five versions of its XR567, and National Semiconductor offers three versions of its LM567. All of the different brands and models of this device will work in the circuits described in this article. Because of the similarities between these devices, they will be referred to collectively as the "567" for the remainder of this tone decoder article.

## The 567 basics

The 567 is primarily used as a low-voltage power switch that turns on whenever it receives a sustained input tone within a narrow range of selected frequency values. Stated in another way, the 567 can function as a precision tone-operated switch.

The versatile 567 can also function as either a variable waveform generator or as a conventional PLL circuit. When it is organized as a tone-operated switch, its detection center frequency can be set at any value from 0.1 to 500 kHz, and its detection bandwidth can be set at any value up to a maximum of 14% of its center frequency. Also, its output switching delay can be varied over a wide time range by the selection of external resistors and capacitors.

The current-controlled oscillator of the 567 can be varied over a wide frequency range with external resistor R1 and capacitor C1, but the oscillator can be controlled only over a very narrow range (a maximum of about 14% of the free-running value) by signals at pin 2. As a result, the PLL circuit can "lock" only to a very narrow range of preset input frequency values.

The 567's quadrature phase detector compares the relative frequencies and phases of the input signal and the oscillator output. It produces a valid out-

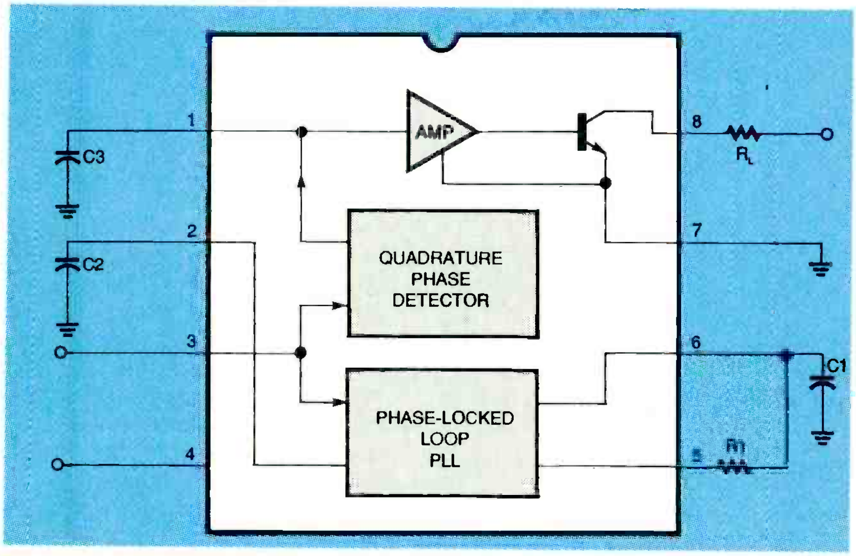



**FIG. 2 —BLOCK DIAGRAM OF AN NE567 TONE DECODER.**

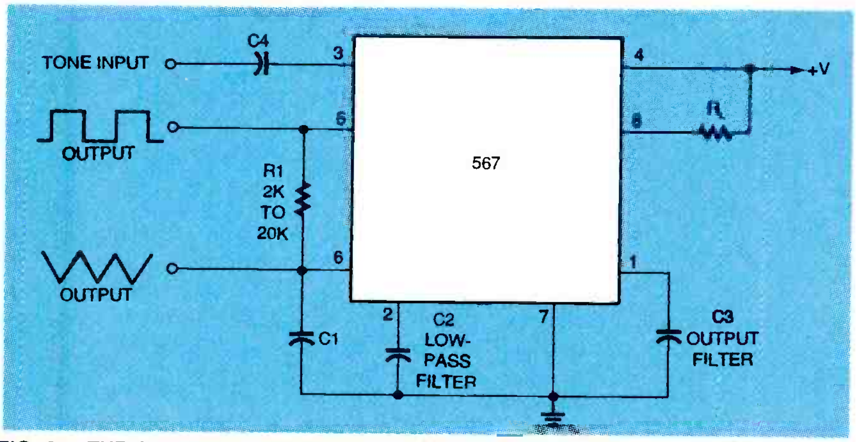



**FIG. 3 —TYPICAL CONNECTION DIAGRAM of a 567 tone decoder showing output waveforms at pins 5 and 6.**

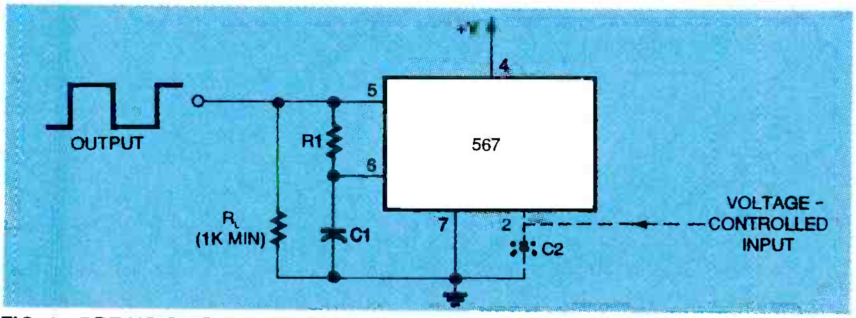



**FIG. 4—PRECISION SQUAREWAVE generator based on the 567's 20-nanosecond rise and fall times.**

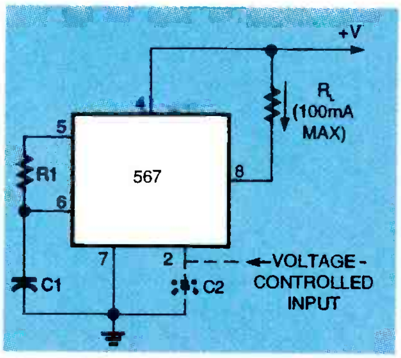



**FIG. 5 —PRECISION SQUAREWAVE generator based on a 567 configured for a high-current output.**

**TABLE 1—ELECTRICAL CHARACTERISTICS**

| PARAMETER | CONDITIONS | NE567 Min | Typ | Max | UNIT |
|---|---|---|---|---|---|
| **CENTER OF FREQUENCY** | | | | | |
| Highest center frequency ($f_O$) | | | 500 | | kHz |
| Center frequency stability | -55 to +125°C | | 35±140 | | ppm/°C |
| | 0 to +70°C | | 35±60 | | ppm/°C |
| Center frequency distribution | | -10 | 0 | +10 | % |
| Center frequency shift with supply Voltage | | | 0.7 | 2 | %/V |
| **DETECTION BANDWIDTH** | | | | | |
| Largest detection bandwidth | | 10 | 14 | 18 | % of $f_O$ |
| Largest detection bandwidth skew | | | 3 | 6 | % of $f_O$ |
| Largest detection bandwidth—variation with temperature | | | ±0.1 | | %/°C |
| Largest detection bandwidth—variation with temperature | $V_i$ = 300mVrms | | ±2 | | %/°C |
| **INPUT** | | | | | |
| Input resistance | | 15 | 20 | 25 | kΩ |
| Smallest detectable input voltage | $I_L$ = 100mA | | 20 | 25 | mVrms |
| Largest no-output input voltage | $I_L$ = 100mA | 10 | 15 | | mVrms |
| Greatest simultaneous outband signal to inband signal ratio | | | +6 | | dB |
| Minimum input signal to wideband noise ratio | $B_n$ = 140kHz | | -6 | | dB |
| **OUTPUT** | | | | | |
| Fastest on-off cycling rate | | | $f_O$/20 | | |
| "1" output leakage current | $V_8$ = 15V | | 25 | 0.01 | µA |
| "0" output voltage | $I_L$ = 30mA | | 0.2 | 0.4 | V |
| | $I_L$ = 100mA | | 0.6 | 1.0 | V |
| Output fall time | $R_L$ = 50Ω | | 30 | | ns |
| Output rise time | $R_L$ = 50Ω | | 150 | | ns |
| **GENERAL** | | | | | |
| Operating voltage range | | 4.75 | | 9.0 | V |
| Supply current quiescent | | | 7 | 10 | mA |
| Supply current—activated | $R_L$ = 20Ω | | 12 | 15 | mA |
| Quiescent power dissipation | | | 35 | | mW |

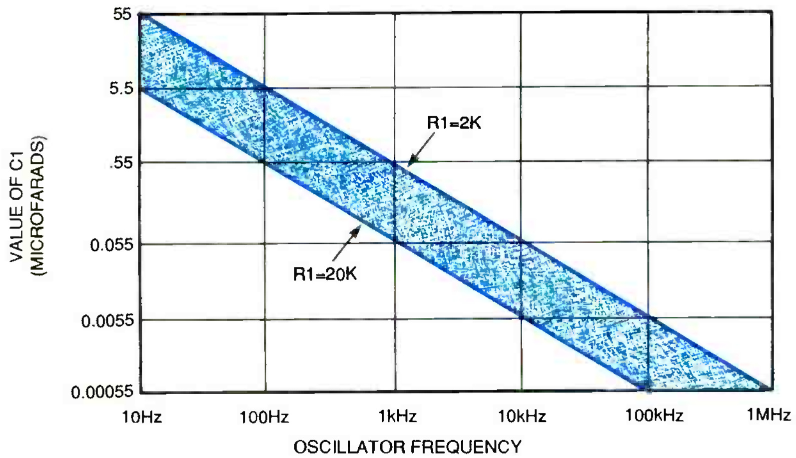



**FIG. 6—RESISTOR-CAPACITOR SELECTION GUIDE for the current-controlled oscillator section of the tone decoder.**

put-drive signal (which turns transistor Q1 on) only when these two signals coincide (i.e., when the PLL is locked). The center frequency of the 567 tone switch is equal to its free-running oscillator frequency, and its bandwidth is equal to the lock range of the PLL.

Figure 3 shows the basic connections for a 567 organized as a tone switch. The input tone signal is AC coupled through capacitor C4 to pin 3, which has an input impedance of about 20 kilohms. An external output load resistor ($R_L$) is inserted between pin 8 and a positive supply voltage whose maximum value is 15 volts.

Pin 8 is capable of sinking up to 100-milliampere load currents. Pin 7 is normally grounded, and pin 4 is connected to a positive supply with a minimum value of 4.75 volts and a maximum value of 9 volts. Pin 8 can also be connected to the same power source if that restriction is observed.

The center frequency ($f_o$) of the oscillator can be determined by the formula:

$$f_o = 1.1/(R1 \times C1) \quad (1)$$

Where resistance is in kilohms and capacitance is in units of microfarads

From this equation the value of capacitor C1 can be determined by transposing terms:

$$C1 = 1.1/(f_o \times R1) \quad (2)$$

With these formulas, values for resistance and capacitance can be determined. The value of resistor R1, which should be in the range of 2 to 20 kilohms, and C1 can be determined from formula 2.

The oscillator generates an exponential sawtooth waveform that is available at pin 6 and a square waveform that is available at pin 5. The bandwidth of the tone switch (and thus the lock range of the PLL) is determined by C2 and a 3.9 kilohm resistor within the IC. The ouput switching delay of the circuit is determined by the value of C3 and a resistor within the IC. Table 1 lists the electrical characteristics of the Philips NE567 which has nearly identical characteristics to all other brands of the 567.

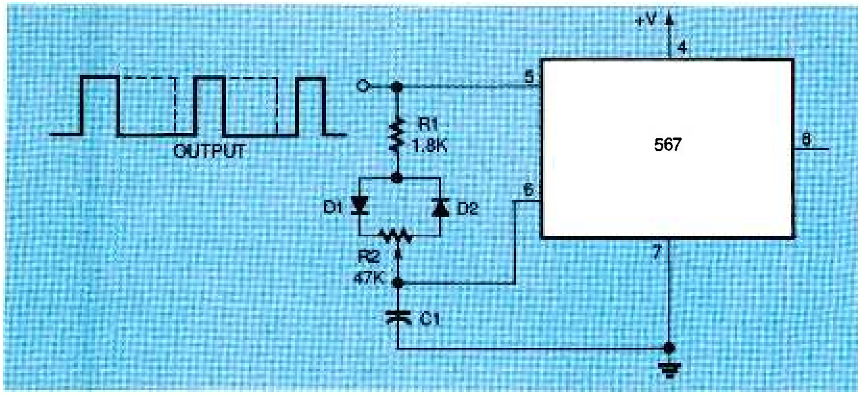



FIG. 7—SQUAREWAVE GENERATOR WITH A VARIABLE mark/space ratio output.

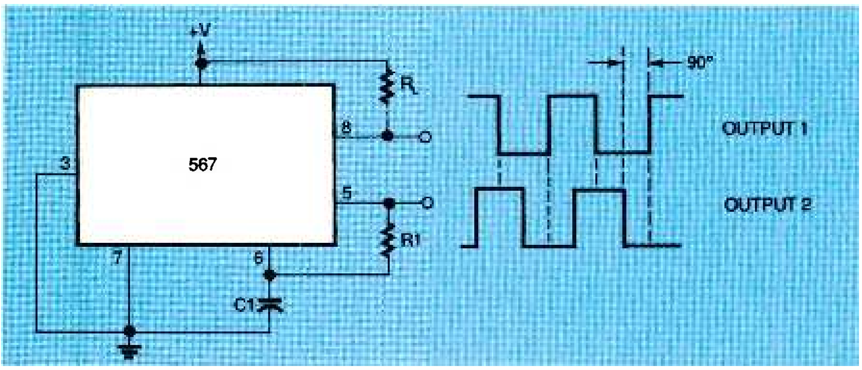



FIG. 8—SQUAREWAVE GENERATOR WITH quadrature outputs.

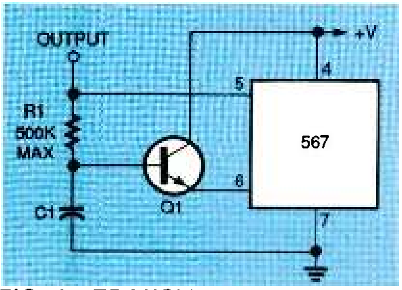



FIG. 9—TRANSISTOR BUFFER increases the permissible value of resistor R1.

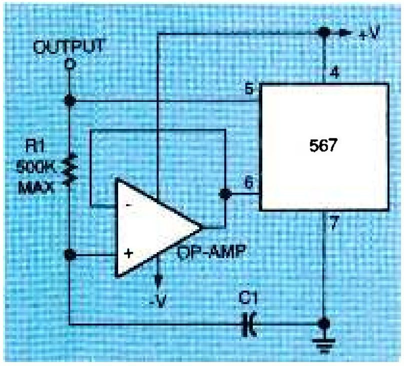



FIG. 10—OPERATIONAL AMPLIFIER buffer increases the permissible resistor value without waveform symmetry loss.

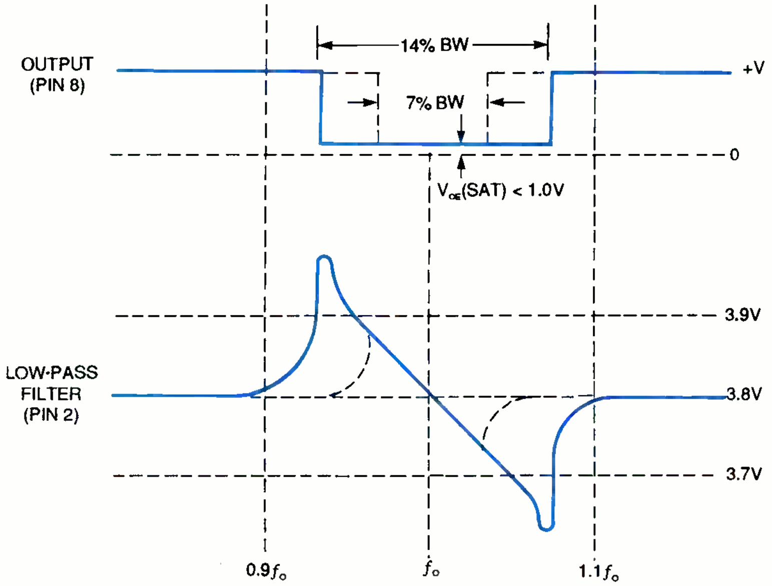



FIG. 11—WAVEFORMS AT PINS 2 AND 8 under in-band input voltage conditions.

## Oscillator design

Figures 4 and 5 illustrate how to obtain various precision squarewave outputs from the 567. The nonlinear ramp waveform available at pin 6 has only limited usefulness, but the squarewave available at pin 5 has excellent characteristics. As shown in Fig. 4, that output can have both 20-nanosecond rise and fall times.

This squarewave has a peak-to-peak amplitude equal to the supply voltage value minus 1.4 volts. It can be externally loaded by any resistance value greater that 1 kilohm without adversely affecting the circuit's function. Alternatively, the squarewave output can be applied (in slightly degraded form) to a low impedance load (at peak currents up to 100 milliamperes at pin 8 output terminal, as shown in Fig. 5

By applying formulas 1 and 2 for oscillator frequency and capacitance, respectively, as presented earlier, various values can be determined. Again, R1 must be restricted to the 2 to 20 kilohm range. To save time in making this determination, component values as they relate to oscillator frequency can be read directly from the nomograph, Fig. 6.

For example, if you want the decoder's oscillator to operate a 10 kHz, the values for C1 and R1 could be either 0.055 microfarads and 2 kilohms or 0.0055 microfarads and 20 kilohms, respectively.

The oscillator's frequency can be shifted over a narrow range of a few percent with a control voltage applied to pin 2 of the 567. If this voltage is applied, pin 2 should be decoupled by

*(Continued on page 68)*

## THE RISISTOR CUBE

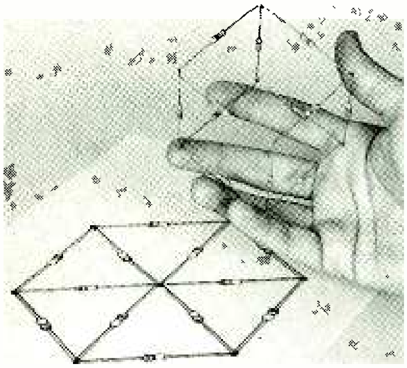
*continued from page 52*

all resistors in the cube have the same value. However, to solve any cube remember the following:

- $R_T$ will be 83.3% of the given resistor value.
- ⅖ (40%) of the applied voltage will be across the input/output resistors.
- ⅕ (20%) of the applied voltage will be across the other resistors.
- ⅓ (33%) of the total current will flow through each of the input/output resistors.
- ⅙ (16.7%) of the total current will flow through the other resistors.

As an example, consider a 100-ohm resistor cube with an applied voltage of 25 volts:

- $R_T$ = 83.3 ohms
- 10 volts will be across the input/output resistors.
- 5 volts will be across the remaining resistors.
- The total current will be 300 milliamperes.
- The current through the input/output resistors will be 100 milliamperes.
- The other resistors will have a current of one-sixth of 300 milliamperes, or 50 milliamperes each.



**BUILDING YOUR OWN resistor cube can be a fun exercise.**

As far as resistor power dissipation is concerned, the input/output resistors for this example will dissipate 1 watt (10V × 100mA)), so at least 2-watt resistors should be used. The other resistors will dissipate ¼ watt (5V × 50mA)), so at least ½-watt resistors should be used. Ω

## MICRO-LIGHTS

*continued from page 44*

and direction of spin will depend on the sounds in the room.

Cycle through the routines by pressing the select pushbutton and check to see that sound, and the absence of sound, affects each of the eight Micro-Lights routines. Perform the checkout in a quiet room.

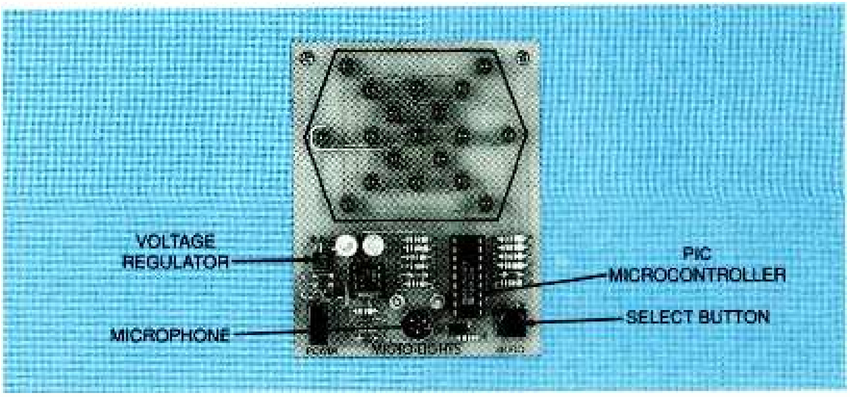



**FIG. 8—THE COMPLETED MICRO-LIGHTS BOARD. The board is designed so that it does not need a case.**

If nothing happens when power is applied, use a voltmeter to check for +5-volts DC at the output of the regulator, on pin 8 of the op-amp, and pins 4 and 14 of the PIC16C71. Verify that ground is present where it should be on both ICs. If you have an oscilloscope, check for an audio waveform (in the presence of sound) at the op-amp's output at pin 1. The voltage should swing from ground to about 3.6 volts.

To verify the circuit's overall current consumption, connect a multimeter (set on the 200-milliampere DC scale) in series with the 9-volt battery. A reading of 5 to 35 milliamperes, depending on how many LEDs are lit, is a normal measurement.

### Operation

Operate Micro-lights in a dimly lit room to obtain the most striking effects. A desk top, coffee table, or bookcase is a good location. If the battery cable is lengthened by several inches, the circuit board can be worn. Tuck the battery in your shirt or coat pocket and wear the board on your lapel.

Applying power to Micro-Lights always causes routine 1 to start. Pressing the select pushbutton always advances the operating routine to the next one. However, if power is applied and the select pushbutton is not pressed, Micro-Lights will automatically increment through all the routines, spending about 5½ minutes on each. The whole cycle repeats after approximately 45 minutes.

Although the circuit draws fairly low current, consider an AC-to-DC adapter for powering Micro-Lights, especially if you want it to operate continuously. The circuit draws an average of 15 milliamperes—about that of a small transistor radio. Expect 15 to 20 hours of operation from a fresh alkaline battery.

The circuit has no sensitivity control. The author believed the addition of one would detract from the simplicity and elegance of this project. A little experimentation with placement will resolve any problems related to noisy environments. In locations where there is consistently loud noise, a small piece of tape placed over the microphone will reduce the circuit's sensitivity. Check out the effect of music as well as voice on the sound routines.

Micro-Lights might not be as spectacular as the Northern Lights, or a fourth of July fireworks show, but it will provide you with your own miniature light show—and an understanding of microcontrollers. Ω

## RETRO REMOTE

*continued from page 38*

dress DIP switches open, address zero with all eight switches closed, or anything in between. Regardless of the address you select, be sure to set the same address on the receiver/decoder board.

Apply power to the receiver and connect a 9-volt battery to the transmitter. Test the training transmitter and receiver by aiming the transmitter at the receiver and pressing the transmit switch. If the circuit is working correctly, the valid transmission LED on the receiver will light up as long as you hold down the transmit switch. The VT LED should light regardless of the settings of the DATA DIP switches (S2 a–d). If the LED does not light, find and repair the mistake.

Follow the manufacturer's instructions for programming the learning remote. Operate the training transmitter as you would any other remote control. As discussed earlier, the power-on command is decoded by the receiver as decimal 15. But, because the training transmitter understands only BCD, set all four data DIP switches at logic high (1111).

Now activate the learning remote's learning mode, press the on button, and press the transmit button on the training transmitter until the learning remote indicates that it has received the command. Next set the mute function as decimal 14 (1110), volume-up as decimal 13 (1101), and volume-down as 12 (1100).

How you program the remaining 12 receiver command codes is your choice. You might want to map 0 through 9 to buttons 0 through 9 on the remote. That still allows for two additional commands. Don't forget to program all your other remote controls into the learning remote too. Ω

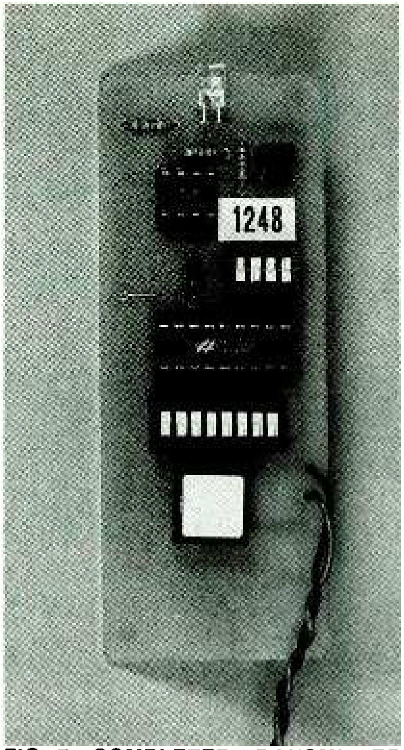



**FIG. 7—COMPLETED TRANSMITTER BOARD. This board allows unique coding that won't interfere with nearby remote-controlled equipment.**

## TONE DECODER

*continued from page 65*

C2, whose value should be approximately double that of C1.

The circuits in Figs. 4 and 5 can be modified in several different ways, as shown in Figs. 7 to 10. In Fig. 7, the duty cycle or mark/space ratio of the generated waveform is fully variable over the range of 27:1 to 1:27 with trimmer potentiometer R2. Capacitor C1 alternately charges through resistor R1, diode D1, and the left side of R2, and it discharges through resisor R1, diode D2, and the right side of R2 in each operating cycle. The operating frequency varies only slightly as the mark/space ratio is varied.

Figure 8 shows how the oscillator generates quadrature outputs. The squarewave outputs of pins 5 and 8 are out of phase by 90°. In this circuit, input pin 3 is normally grounded. If it is biased above 2.8 volts, the square waveform at pin 8 shifts by 180°.

Figures 9 and 10 show how the oscillator circuit can be modified to allow timing resistor values to be increased to a maximum of about 500 kilohms. This permits the value of timing capacitor C1 to be pro-

*(Continued on page 85)*

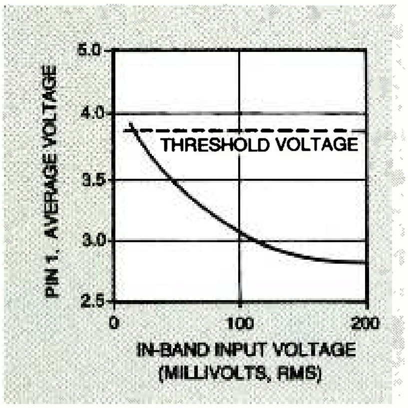



**FIG. 12—TRANSFER FUNCTION of average voltage at pin 1 with respect to in-band input voltage.**

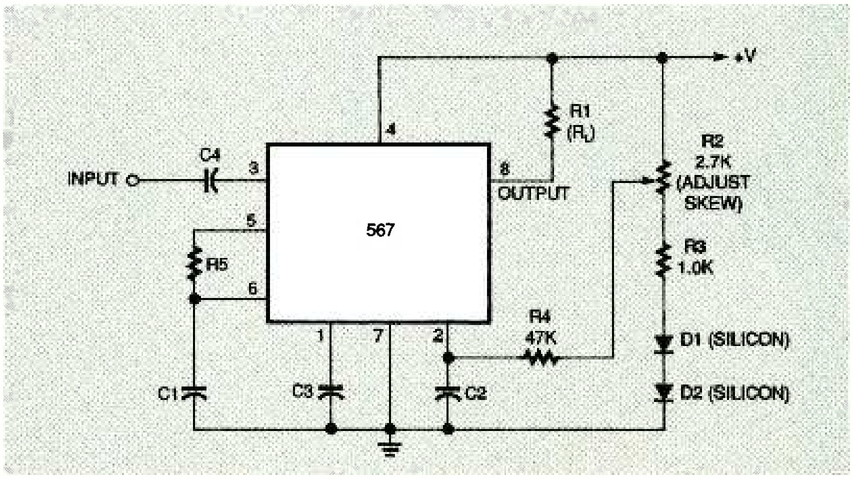
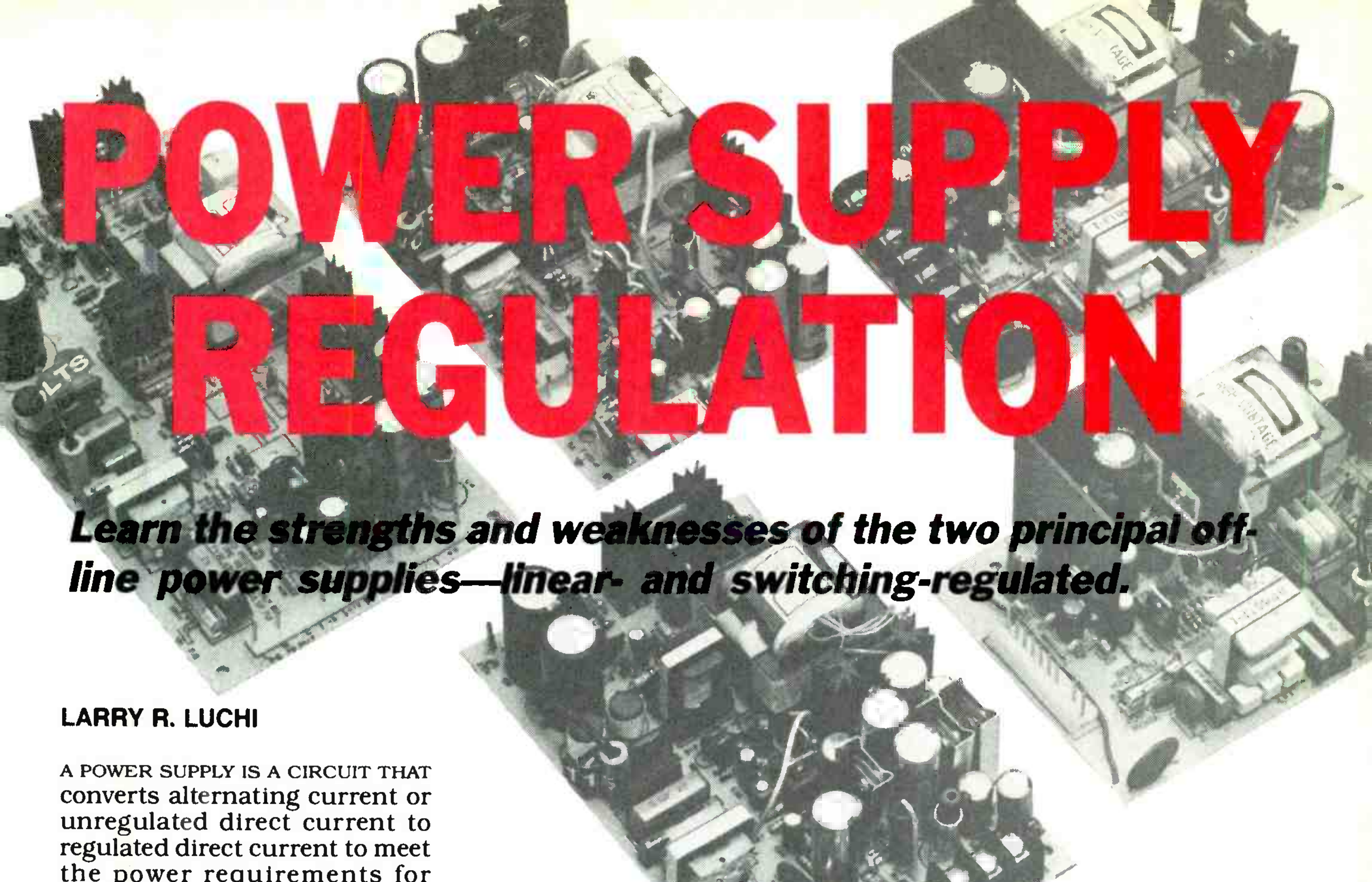



**FIG. 13—TONE SWITCH WITH A TRIMMER potentiometer adjustment for skew.**

# POWER SUPPLY REGULATION



***Learn the strengths and weaknesses of the two principal off-line power supplies—linear- and switching-regulated.***

**LARRY R. LUCHI**

A POWER SUPPLY IS A CIRCUIT THAT converts alternating current or unregulated direct current to regulated direct current to meet the power requirements for electronics. Most of today's solid-state electronic circuits are powered by voltages from 3 volts to 24 volts with +5 volts, ±12 volts and +24 volts DC most popular.

The two principal types of power supplies that accept input power from the AC power line and convert it to regulated DC power are *linear-regulated* and *switching-regulated* supplies. Many different linear and switching-regulator integrated circuits have been introduced to replace the discrete regulator circuits that were formerly used in power supplies. These have simplified the design and construction of all power supplies–military, commercial/industrial and build-it-yourself—and made them more reliable.

Commercial/industrial power supplies are made as stand-alone, catalog or off-the-shelf products. Low-power units might be encapsulated in small modular cases, mid-range supplies are likely to be made as open-frame modules on a single circuit board, and high-power supplies are typically packaged in enclosed metal cases. Stand-alone power supplies are included in computers, automated test equipment (ATE) and medical apparatus; the benchtop laboratory supply is another example.

However, power supplies in many consumer electronics products such as AC-powered radios, television sets, and VCRs are built on the same circuit board as other functional circuits. However many of the same components used in stand-alone supplies are included in these "embedded" supplies.

### Linear-regulated DC

Figure 1 is a simplified schematic for a linear power supply with a *series* voltage regulator. In this example, the AC line is isolated from the power supply by transformer T1. Full-wave diode bridge BR1 delivers unregulated DC with ripple on it to the filter capacitor C1. The filtered DC is delivered to pass transistor Q1, shown here in series with the load.

The series-pass regulator with a transistor pass element, as shown in Fig. 1, is the most common linear regulator topology. It regulates the voltage to assure that a constant output level is maintained despite variations in the power line voltage or circuit loading.

The basic linear series regulator consists of transistor Q1, reference resistor R1, sensing resistors R2 and R3, a voltage reference Zener diode D1, and an operational amplifier IC1, organized as an error amplifier.

Regulation is accomplished by varying the current through the series-pass transistor in response to changes in line voltage or circuit loading. Thus, the collector-to-emitter voltage drop across the pass transistor is varied by the base voltage to keep the voltage delivered to the load $R_L$ essentially constant.

The Zener diode D1 provides a fixed reference voltage at the positive input to the amplifier IC1. The output voltage of the supply establishes the emitter voltage and provides a feedback voltage for the negative terminal of the amplifier IC1. The changing difference between the base and the emitter voltages provides the base-emitter bias, which determines the resistance of the transistor.

The equation for the regu-

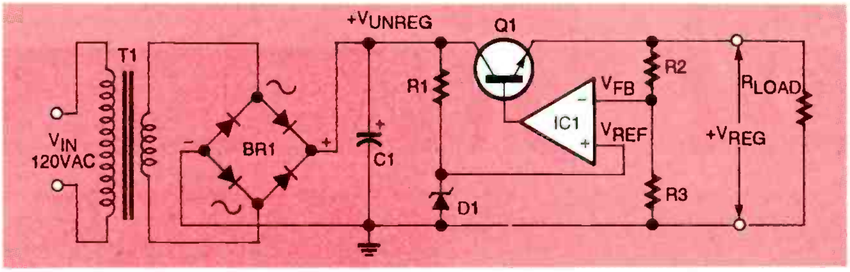



**FIG. 1—SERIES-REGULATED LINEAR** power supply has a series transistor as its pass element which conducts the load current.

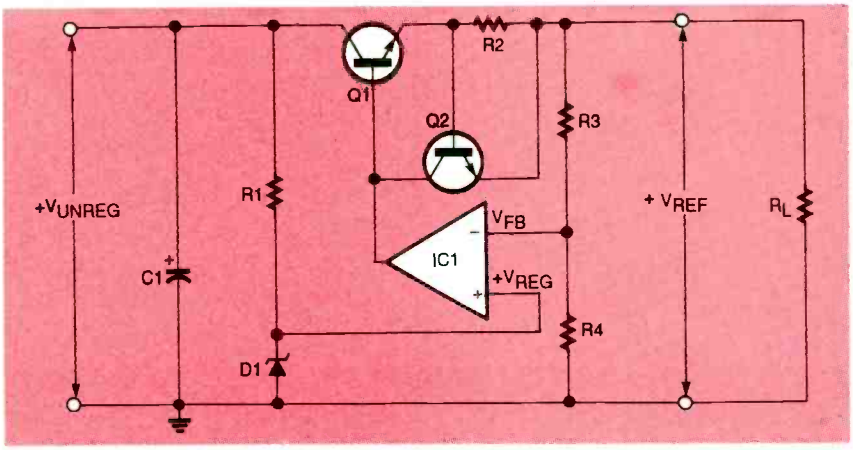



**FIG. 2—A CURRENT-LIMITING TRANSISTOR** and resistor protect the pass transistor and rectifier bridge in this linear supply.

lated output voltage is:

$V_{REG} = V_{REF}(1 + R1/R2)$

The series regulator shown in Fig. 1 has no short-circuit protection. If the current limitation of the series-pass transistor is exceeded, transistor Q1 could be damaged or destroyed. This can be prevented with the addition of a current-limiting transistor, as shown in Fig. 2.

When the current through Q1 becomes high enough, the voltage drop across R2 becomes high enough to forward-bias transistor Q2. When Q2 starts to conduct, its internal resistance decreases. When this occurs, the forward bias of Q1 is fixed, and its output is a constant current.

The current limiting transistor and resistor in Fig. 2 protect the pass transistor and rectifier diodes if the load terminals are accidentally short circuited. However, the addition of transistor Q2 increases the already high power dissipation in pass transistor Q1 when the load demand is high.

Linear power supplies can also have *shunt* or parallel regulators which function fundamentally in the same way as the series regulator, but they are not as efficient. The determination of whether the regulator is in series or shunt depends on how the pass element is arranged with respect to the load.

Linear supplies are inherently inefficient because all of the load current passes continuously through the pass transistor. As a result, the pass transistor, acting as a variable resistor, dissipates power equal to the load current times the Q1 collector-to-emitter voltage drop, wasting power. However, linear supplies generally offer better line and load regulation and lower output ripple than switching power supplies.

## Commercial products

Commercial linear power supplies with output ratings from about 3 to 100 watts are readily available off-the-shelf. They can have single as well as multiple outputs. In power ratings less than 20 watts, they might be packaged as enclosed modules suitable for many analog applications.

Linear supplies with ratings of less than 100 watts might be built on open circuit boards ready to plug into a card cage. They are still in wide use at the lower power ratings because their transformers are inexpensive. Higher power models, including laboratory instrument-grade units, are typically housed in metal cages or enclosures. Because of the size and weight of high-power 50/60-Hz transformers, high-power supplies are large and heavy.

Commercial linear power supplies offer close line and load regulation, often in the range of 0.02 to 0.1 %. They are highly reliable, insensitive to minor shifts in line frequency, and capable of tolerating up to about ±10% shift in input voltage. Their efficiencies are typically from 15 to 35 % but, some man-

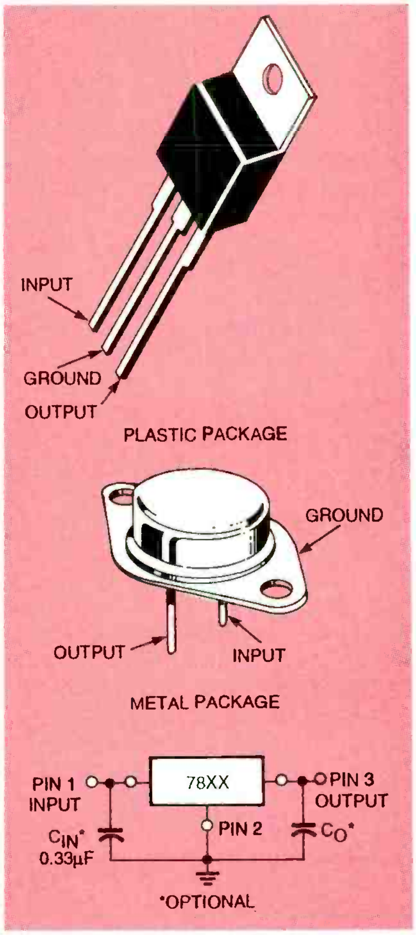



**FIG. 3—A THREE-TERMINAL** regulator has input, output and ground pins. Capacitors are optional external components. Pin arrangements are shown for the standard metal and plastic packages.

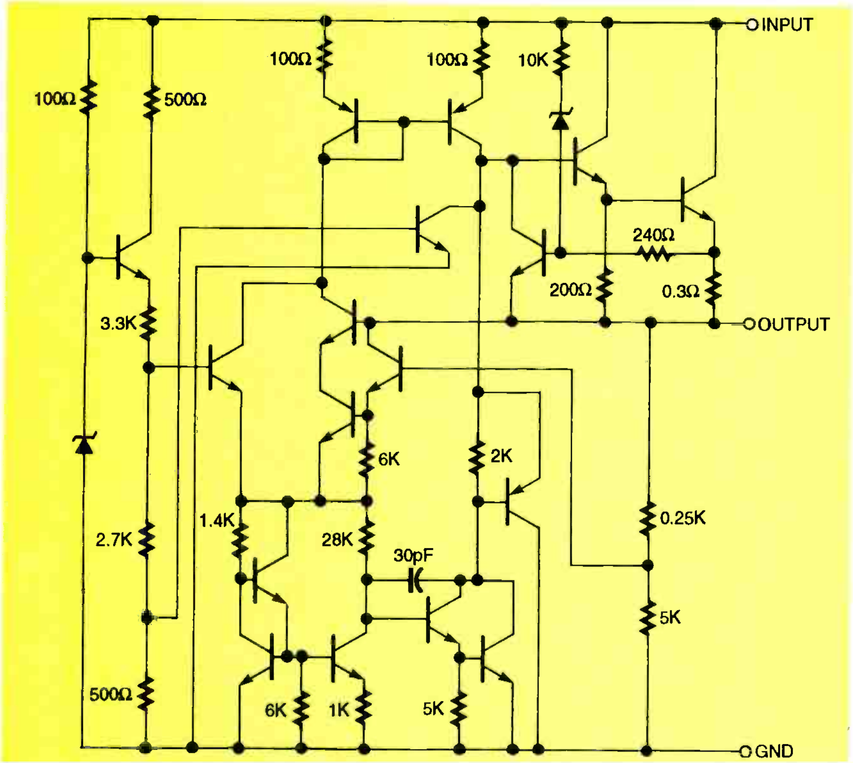



**FIG. 4—A REPRESENTATIVE SCHEMATIC DIAGRAM for the industry-standard 7800 series of voltage regulators.**

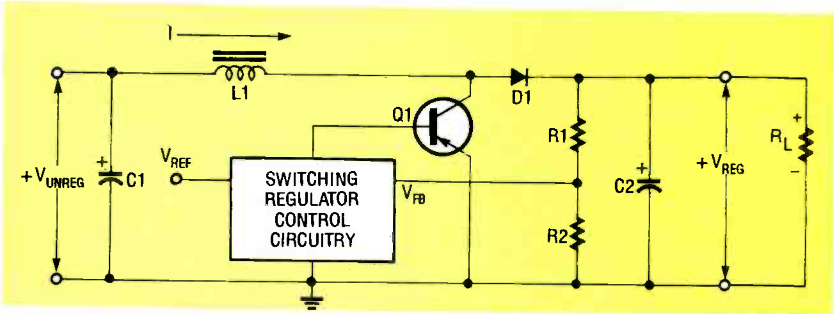



**FIG. 5—BOOST CONVERTER with a single switching transistor depends on the transformer for energy storage.**

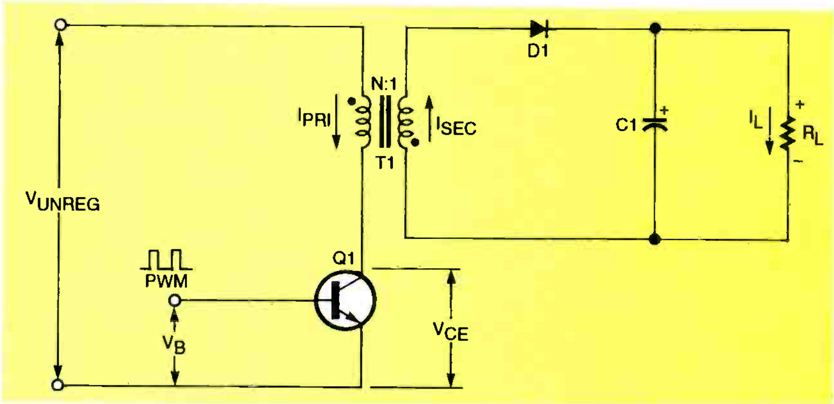



**FIG. 6—TRANSFORMER-COUPLED FLYBACK SUPPLY is cost effective for power output from 30 to 100 watts.**

ufacturers claim figures above 50% for low-power models.

## Linear regulator ICs

The 7800 three-terminal positive voltage regulator ICs are probably the most popular voltage regulator chips today. Figure 3 includes a three-terminal block diagram that applies to all of these devices.

Input pin 1 is for the unregulated input voltage, output pin 2 is for the regulated output voltage, and pin 3 is ground or common. An input and output capacitor might be needed under certain conditions. The pinout arrangements for the standard metal and TO-220-style plastic packages are shown in Fig. 3.

Although designed as fixed voltage regulators, adjustable voltages and currents can be obtained from 7800 series parts with the addition of external components. Internal short-circuit current limiting limits the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation.

If internal power dissipation becomes too high for the heat sinking, the internal thermal overload protection circuit shuts down the IC to prevent it from overheating. With adequate heatsinking, all parts in the 7800 series can deliver output currents in excess of 1.0 ampere.

Figure 4 is a schematic diagram for all devices in the 7800 series; they are available with eight different output voltages: 5, 6, 8, 9, 12, 15, 18, and 24 volts. The output voltage appears as the suffix (i.e., there are the 5-volt 7805 and the 12-volt 7812).

Input voltage is limited to 35 volts for 7805 to 7818 and 40 volts for the 7812. Originally developed by National Semiconductor, the series has become a standard, and it is widely alternate sourced by many semiconductor manufacturers including Motorola, SGS-Thomson, and Unitrode.

There are variations on the 7800 series including low-current (78L00), medium-current (78M00), and 3-ampere (78T00) versions. In addition to fixed-voltage, three-terminal positive voltage regulators, there are three-terminal negative versions such as the 7900 series. There are also adjustable positive and negative output regulators available.

There are also floating voltage and current regulators for laboratory power supplies, dual ±15-volt tracking regulators, and microprocessor voltage regulator/supervisory circuits.

## Switching regulators

The most popular power supplies today are off-line switching-regulated power supplies, also known as switchmode power supplies. These convert 120-volt AC line voltage to high-frequency square waves or pulses which are passed by a high-frequency transformer. The pulses are then rectified and filtered to produce the required DC voltage.

A basic switching regulator contains a pulse-width modulator (PWM). Switchmode supplies offer the advantages of smaller size, lighter weight, and higher efficiency than comparably rated series-regulated linear supplies. The PWM control stabilizes the output voltage by varying the duration of the pulses: wide pulse widths increase the DC output voltage; narrow pulse widths decrease the DC output voltage.

If the DC output voltage falls below its reference value because of increasing load, the width (duration) of the drive pulses to the switching transistor will be increased by the PWM circuit. This increases the ON time of the transistor (or transistors) to offset the drop in voltage.

Similarly, if the DC output voltage increases over the reference value due to decreasing load, pulse width will be decreased. This reduces the transistor ON time to offset the increase in output voltage.

In general, a switching-regulated power supply is more efficient than a series-regulated linear power supply because its regulator circuit operates intermittently rather than continuously. Power is drawn by the switcher only when the transistors are switching, and they do that at frequencies from 20,000 to 100,000 times per second (20 to 100 kHz) or more.

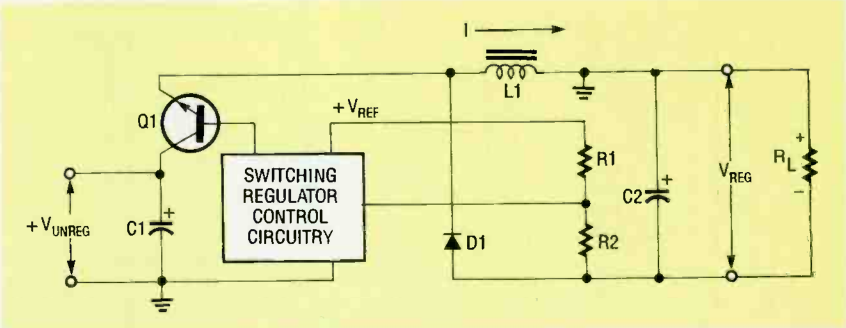



FIG. 7—BUCK CONVERTER with a single switching transistor depends on the coil for energy storage.

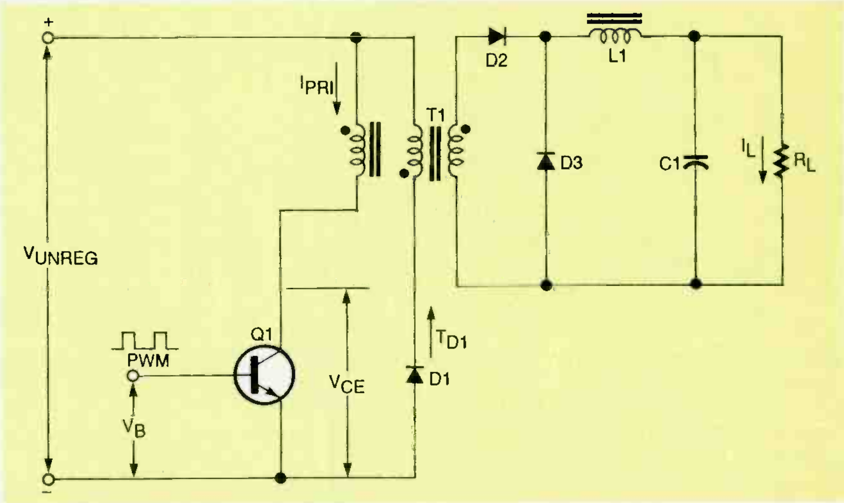



FIG. 8—TRANFORMER-COUPLED FORWARD CONVERTER is cost effective for power output from 80 to 200 watts.

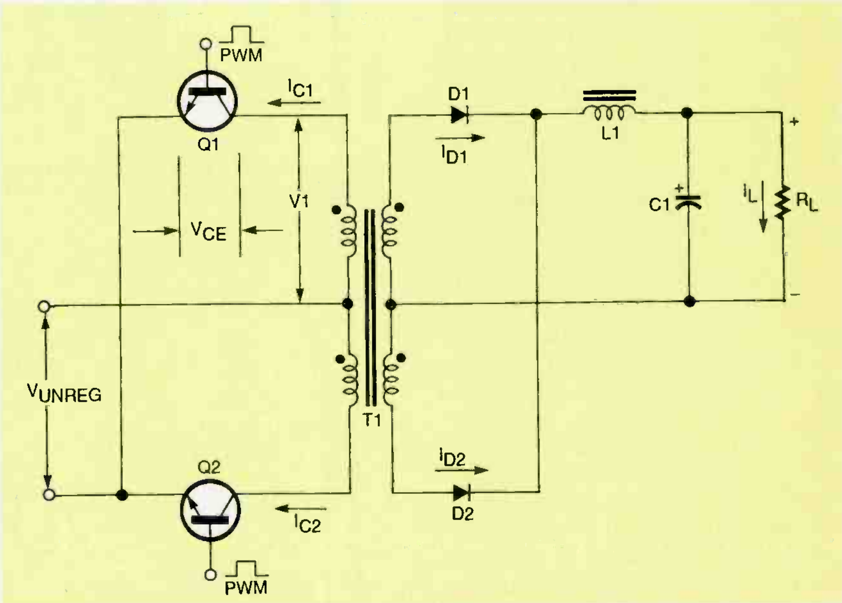



FIG. 9—PUSH-PULL CONVERTER offers increased efficiency in switching power supplies.

## Switching configurations

There are many different circuit configurations or to-

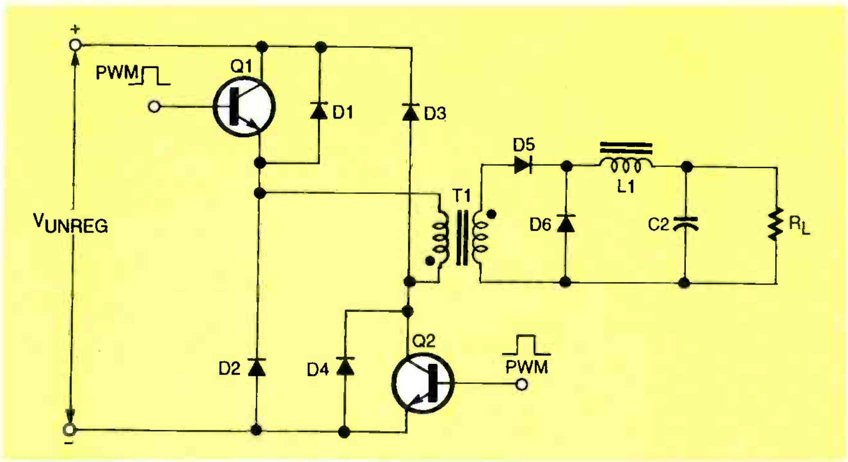



**FIG. 10—HALF-BRIDGE CONVERTER with two switching transistors is cost effective for power output of 150 to 500 watts.**

pologies for switchmode power supplies that have been adapted to a wide range of applications. The choice of topology for any application depends on such factors as output power requirement, available space in the host product, input line power available, and cost. Many simple, single-transistor designs have been developed to meet low power requirements (under 100 watts), such as those of personal computers and personal computer peripherals.

The *boost regulator* shown in Fig. 5 is a converter with a single switching transistor in parallel with the load and an input inductor that stores energy for transfer to the output when the transistor is turned off. This circuit accepts unregulated input voltage and produces a higher regulated voltage because the inductor output combines with the input from the AC line.

Figure 6 is a *flyback converter*, a variation on the boost regulator with a single switching transistor Q1 that eliminates the input inductor L1 of Fig. 5. This kind of off-line flyback switcher typically includes a bridge rectifier that converts the 120-volt AC line voltage to 150 volts DC for the switching section.

Current increases at a linear rate through the primary winding of transformer T1, which behaves like an inductor by storing energy in its core. As soon a Q1 cuts off, the magnetic field begins to collapse, and the winding polarities reverse. During the second half (*flyback period*) when Q1 is off, the energy is transferred to the secondary of transformer T1, charging capacitor C1 and feeding the output load.

A PWM loop controls Q1's conduction by comparing output voltage to a set reference. If the load demands more current, the *on* time is increased; it it demands less current, the *on* time is decreased.

The *buck regulator* shown in Fig. 7 is an alternative single-transistor converter. Series transistor Q1 chops the input voltage and applies the pulses to an averaging inductive-capacitive filter consisting of L1 and C1. The output voltage of this simple filter is lower than its input voltage.

Figure 8 is a simplified schematic for a transformer-coupled *forward converter*. Based on the buck converter, it is similar to the flyback converter. Inductor L1 rather than transformer T1 stores the energy.

When switching transistor Q1 turns on, current builds in the primary winding of transformer T1, storing energy. Because the secondary winding has the same polarity as the primary winding, energy is transferred forward to the output. Energy is also stored in inductor L2 through forward-biased diode D2. At this time flywheel diode D3 is back biased.

When Q1 turns off, the transformer winding voltage reverses, back-biasing diode D2. Diode D3 becomes forward-biased, causing current to flow through $R_L$ and delivering energy to the load through inductor L1. The third winding and Diode D1 return transformer T1's magnetic energy to the DC input when Q1 is off.

Both forward and flyback converters are low-power, low-cost switching power supplies, but the flyback converter is preferable to the forward converter because it saves the cost of an inductor. However, that advantage is lost if current demand is

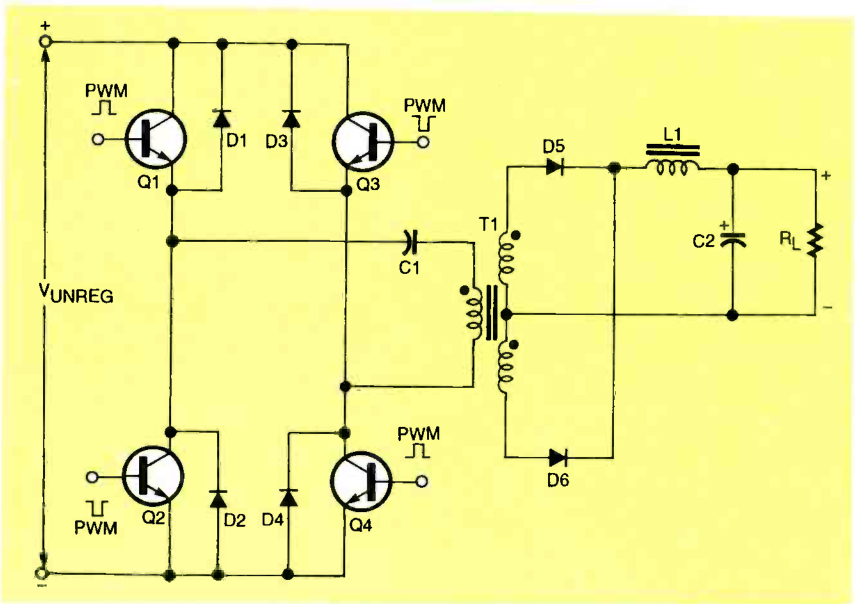



**FIG. 11—FULL-BRIDGE CONVERTER is cost effective for power output of 500 watts or more.**

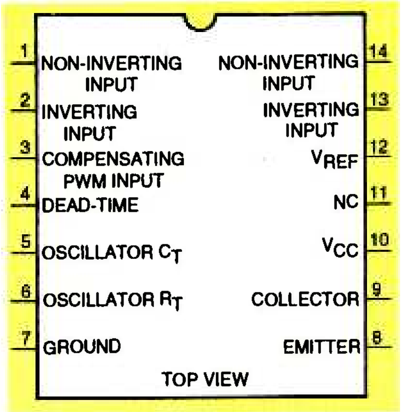



**FIG. 12—PINOUT DIAGRAM for an MC34060, 14-pin pulse-width modulated (PWM) control IC.**

high because the transformer must be larger, and that cancels the flyback supply's size and cost advantage.

The *push-pull converter* shown in Fig. 9 consists of two forward converters working 180° out of phase. Both halves of the push-pull converter deliver current to the load at each half cycle, and the inductor stores energy. Diodes D1 and D2 conduct simultaneously between transistor conduction, effectively short-circuiting the secondary isolation transformers. Acting as flywheel diodes, these siodes deliver useful power to the output.

These converters are manufactured commercially as stand-alone units in open-frame or enclosed modules. They are most cost effective in the 100 to 500-watt output range.

Another popular and established switching power supply topology is the *half-bridge converter* shown in Fig. 10. The same converter will work from either a 120- or 240-volt ac input by simply changing terminals. It is cost effective over the 150- to 500- watt range, and offers very good output noise characteristics and excellent transient response.

Today, most switching power supplies rated for more than 500 watts are variations on the the *full-bridge converter* topology shown in Fig. 11. This design has four transistors, and because diagonally opposite transistors are on at the same time, each transistor must have an isolated base drive. Full-bridge converters are usually manufactured as enclosed modules for such applications as powering mainframe and super computers.

Most switchmode supplies have lower regulation than linear supplies—about ±5%. This generally rules them out for use as benchtop laboratory power supplies, but is not a drawback for powering digital circuitry such as computers. Switching power supplies generate a lot of EMI and RFI. Although much of this interference can be filtered out or shielded, switching supplies are not generally used to power sensitive instruments.

### Factory-made switchers

The switchmode power supply was developed to save weight, space, and power in military electronic systems, particularly for radio, radar, navigational equipment, and weapons systems in aircraft and missiles. But these supplies have now become widely accepted for powering many commercial/consumer products such as personal computers.

The popularity of the switchmode supply increased as the price of the special components required for their reliable operation declined. These components include high-frequency bipolar and MOSFET power transistors, ferrite-core transformers, fast-recovery and Schottky rectifiers, and aluminum electrolytic capacitors with low equivalent-series resistance (ESR).

Because the switching reg-

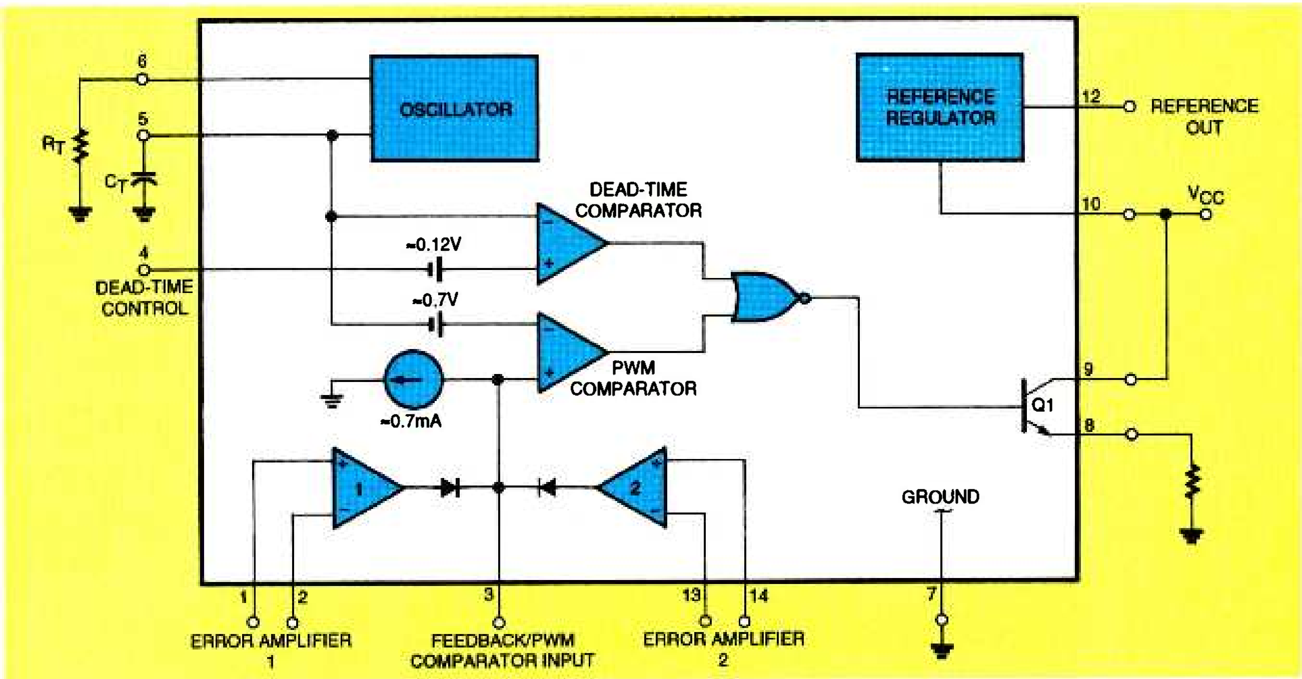



**FIG. 13—BLOCK DIAGRAM OF THE MC34060, a fixed-frequency PWM control circuit for single-output supplies.**

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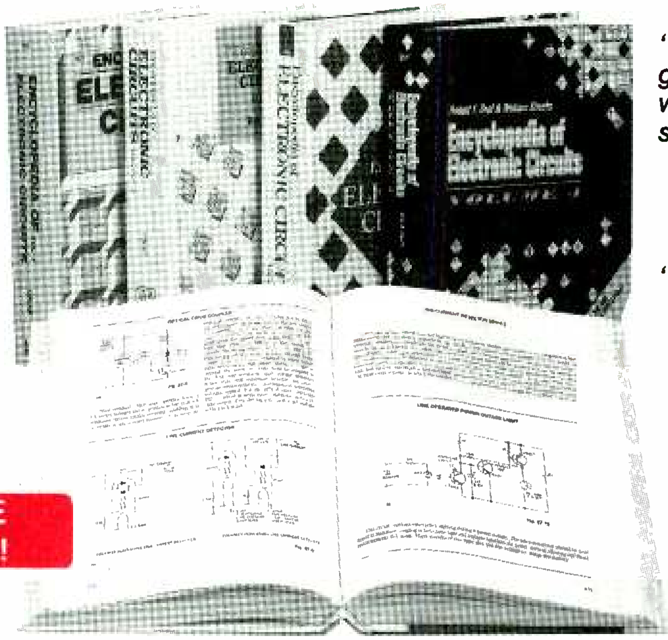

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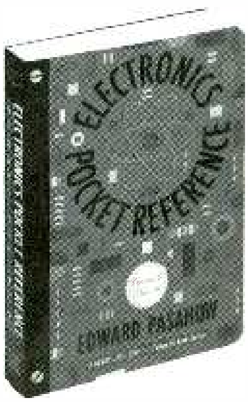


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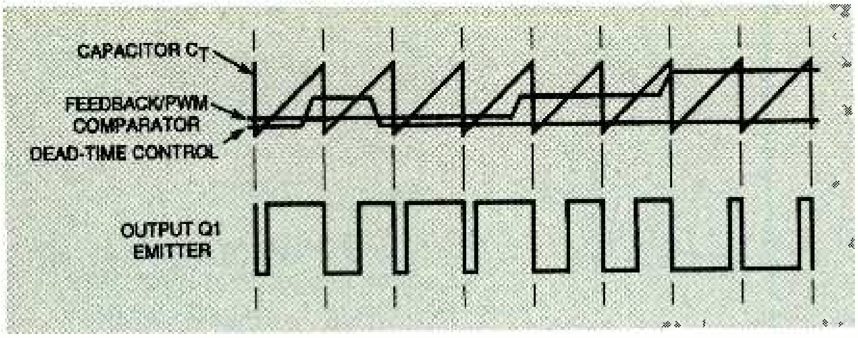


**FIG. 14—TIMING DIAGRAM FOR AN MC34060 PWM IC showing the relations between the oscillator sawtooth waveform, feedback waveform, and output pulses. A pulse is triggered when the ramp exceeds the feedback waveform.**

ulator power supply is switched at high frequency, its input transformer can be smaller and lighter than the 50/60-Hz transformers required in series-regulated linear power supplies. This transformer size and weight reduction permits comparably rated switching power supplies to be smaller and lighter than their linear counterparts—and their heat dissipation is lower.

Commercial switching regulators in supplies with 12 to 15-volts DC output can have efficiencies as high as 85%—double those of most linear power supplies. The efficiencies of linear power supplies can be affected if line voltage exceeds ±10 %, but for switchers the acceptable input range can be as wide as ±30%.

Power density is a measure of output power in watts divided by volume. For commercial linear supplies, a typical figure is 0.4 watts per cubic inch, compared with 4 watts per cubic inch for commercial switchers.

Switching power supplies have longer *holdup* times that linear supplies. Holdup time is the time that the DC output remains high enough for circuit operation after an AC input power brownout or outage. This time, on the order of 30 milliseconds, is usually long enough to permit backup batteries to take over and hold data in volatile semiconductor memories.

## Switching regulator ICs

Many semiconductor manufacturers offer switchmode pulse-width modulation (PWM) control integrated circuits with different features in a range of prices. The ICs are designed for single-ended and dual-or multiple-output switching supplies.

One example of a PWM control IC for fixed-frequency, single-ended switchmode supplies is Motorola's MC34060/35050. (The MC34060 has an operating temperature operating range of 0°C to +70°C, and the MC35060 has the standard military temperature range of −55°C to +125°C.)

Figure 12 is the pinout diagram for the 34060/35060 in either a 14-pin plastic or ceramic DIP package, and Fig. 13 is its simplified block diagram. The device contains an oscillator that produces a sawtooth waveform. It can be programmed by an external timing resistor ($R_T$) at pin 6 and a timing capacitor ($C_T$) at pin 5. The oscillator frequency is determined by:

$f_{OSC} = 1.1/(R_T \cdot C_T)$.

The output pulse width is modulated by comparing the positive waveform that appears across capacitor $C_T$ with either of the two control signals. The output is switched on only during that time when the sawtooth voltage exceeds the control signals. As can be seen in the timing diagram Fig. 14, an increase in control signal amplitude causes a corresponding linear decrease of output pulse width.

The control signals are external inputs that can be sent to the DEAD-TIME CONTROL (pin 4), the ERROR AMPLIFIER 1 (pins 1 and 2) and ERROR AMPLIFIER 2 (pin 13 and 14), or the FEEDBACK/PWM COMPARATROR INPUT (pin 3).

The dead-time control comparator has a 120-millivolt input offset that limits the minimum output dead time to about the first 4% of the sawtooth cycle time. Consequently, the maximum duty cycle is about 96 %. Additional output dead time can be obtained by setting the dead time control input to a fixed voltage from 0 to 3.3 volts.

The PWM comparator permits the error amplifiers to adjust the output pulse width from the maximum on time (set by the dead time control input) down to zero, as the voltage at feedback pin 3 varies from 0.5 to 3.5 volts.

Both error amplifiers have a common-mode input range from −0.3 volts to the power supply voltage $V_{CC}$ (typically 15 volts) −2 volts. That input range is sufficient to sense the power supply's output voltage and current. The error amplifier outputs are active high and OR ed together at the non-inverting input of the pulse-width modulator comparator.

As a result, if either amplifier 1 or 2 demands minimum output ON time, it dominates loop control. The MC34060 has an internal 5.0-volt reference regulator capable of sourcing up to 10 milliamperes of load current for external bias circuit. The reference has an internal accuracy of ±5%. Uncommitted output transistor Q1 can sink or source 200 milliamperes.

The Motorola PWM MC33060A/ 34060A/35060A series improves on the 34060/35060 series with higher reference accuracy of 1.5%, higher current ratring for Q1 of 500 milliamperes and the addition of an undervoltage lockout feature.

A popular PWM power control IC is the industry standard 1524 series that includes the 2524 and the 3524. These devices, in 16-pin plastic or ceramic DIP packages and in chip form, have separate outputs for single-ended and push-pull operation. The 1524 has the military temperature range and the 2524 and 3524 have commercial temperature ranges. Ω

# HARDWARE HACKER

## Powerful new PIC software, unique direct-toner decals, and long-range remote control.

DON LANCASTER

The FCC has long been strict about unlicensed transmitters. Most of the time, legal, unlicensed transmitters are not particularly useful. But there is one class of unlicensed transmitters that the FCC permits to operate at *ten times* the usual power.

Mark Gottleib and the rest of the folks at *Design Tech International* have come up with a new E series of remote-control modules that cry out for hardware hacking. While intended mostly for several channels of on-off control, they have a reliable and effective range as far as 300 feet. They work through car windshields or several walls.

The full set of FCC regulations appear as Title 47 in the *Code of Federal Regulations*. You will find several hundred parts to the regulations, usually offered in four or five volumes. They can be found at most large libraries, or can be ordered through the *US Government Bookstore*. There is much more on FCC regulations in general in the *Hardware Hacker* reprints and in HACK45.PS on *GEnie* PSRT. Of main interest to hardware hackers is Part 15, which covers unlicensed radiation. In particular, check section 15.231. It is summarized in Fig. 1.

A special class of service exists for *periodic* operation. This is defined as transmission that is never on for more than one second and never repeats at more than a 3% duty cycle. The two most popular periodic transmitters are automatic garage door openers and "where's my car?" keychain vehicle locators.

Operation is allowed in a narrow band around 40 MHz and anywhere above 70 MHz. At 330 MHz, a very generous signal strength of nearly 7000 microvolts per meter (specified at three meters) is permitted. The allowable bandwidth is 0.25 %, which translates into a very useful 800 kilohertz.

You are not supposed to transmit voice or music. Data is limited to ID code sequences. Control of toys is specifically excluded. "Scheduled" or timed non-random operation is also a big no-no. These restrictions are eased at lower power levels. In reality, if you are using one of these devices for personal and intermittent use, should be able to come up with interesting projects that operate within these restrictions.

## More details

The E system consists of a few receiver and transmitter modules. The three keychain-sized transmitter modules are electrically identical, except that the number of buttons (channels) can be from one to three.

In operation, pressing a transmitter button sends a repeating 24-bit AM pulse-modulated signal at 330 megahertz. Power is provided by a pair of long-lasting lithium cells. Codes are factory programmed to one of the 16 million possible values, selected at random. The codes are generated by a 16C54LP PIC CMOS microcontroller from *Microchip Technology*, that runs at eight megahertz.



The allowable frequencies of operation are 40.66 through 40.70 MHz or any frequency above 70 MHz.

Maximum transmitter "on" time is one second with a three percent duty cycle. Minimum time between shorter retransmissions is ten seconds.

Allowable signal strength at 330 MHz is 7000 microvolts per meter. Up to 12,500 microvolts per meter are permitted above 470 MHz.

Bandwidth is restricted to 0.25 percent below 800 MHz.

Data transmission is restricted to identification codes.

Music, voice, control of toys, or scheduled operations are not permitted.

**FIG. 1—THE FCC ALLOWS UNLICENSED OPERATION at ten times normal power levels for "periodic" transmitters. Here's a summary of the part 15.231 regulations.**

A three-transistor transmitter powers an internal small-loop antenna that is capacitively trimmed. Battery power is required only when a button is pressed. A light-emitting diode lights red, yellow, or green as the selected channel is activated. Operation is best over an unobstructed path. Surface-mount construction allows all this to be

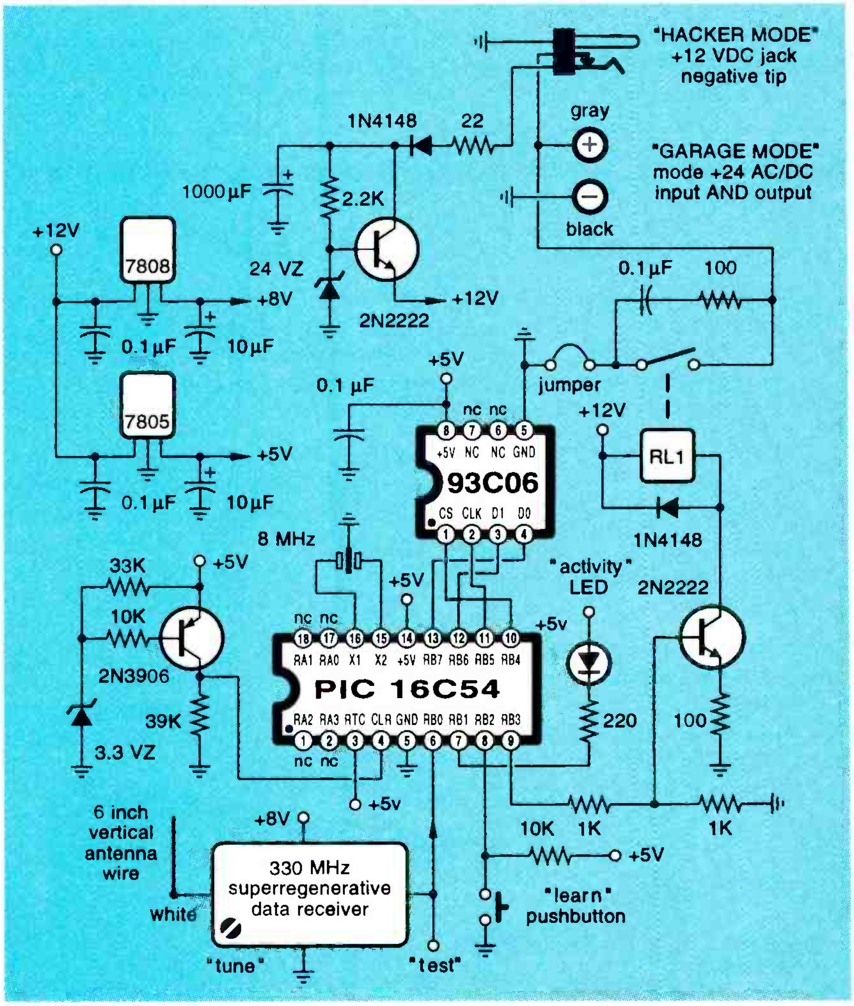


**FIG. 2—PARTIAL SCHEMATIC for the E-series universal remote-control receiver. Note the dual supply options. It can be taught up to four new input codes by pressing the "learn" button. There are 16,772,216 possible codes.**

packaged on just over *one square inch* of circuit board space.

Figure 2 shows most of the receiver schematic. It was originally intended as a long-range retrofit for existing garage-door openers. A new power jack has been added for general-purpose use.

For hacker purposes, the device is powered from a 12-volt *negative tip* DC wall-mounted power adapter, such as a *Radio Shack* No. 273-1652. The receiver's sensitivity drops off markedly if you substitute a lower supply voltage.

Each receiver contains a single relay, rated for one ampere at 30 volts. The relay contacts are closed for a half of a second and are then released. *Do not try to switch 120-volt AC power with these contacts!* Install an external relay or triac instead.

There are two sections to the circuit: digital and analog. Each has its own supply regulator; 8 volts for the receiver, and 5 volts for the processor. When used as a garage-door control, there is also a pre-regulator that limits input voltage peaks to 24 volts.

The receiver is a super-regenerative detector made from six transistors and an op-amp. The single tuning coil sets the center frequency. A six-inch vertical wire serves as the input antenna.

Any amplifier that is on the verge of oscillation can exhibit incredible gain, due to positive feedback. One older type was called a *regenerative* detector. But those are extremely touchy: Too little feedback results in low gain and poor selectivity. Too much feedback causes the curcuit to oscillate.

The old *superregenerative* detector scheme beats that by deliberately going into and out of oscillation. This is done by a signal called the *quench frequency*. The quench frequency is normally several tens of kilohertz. It "saws" the detector into and out of oscillation. The circuit stabilizes at an optimum sensitivity that needs no adjusting.

On any superregenerative detector, it is important to have a properly designed RF stage between it and the input antenna. Otherwise, noise is transmitted. The output of the receiver is a repeating digital code

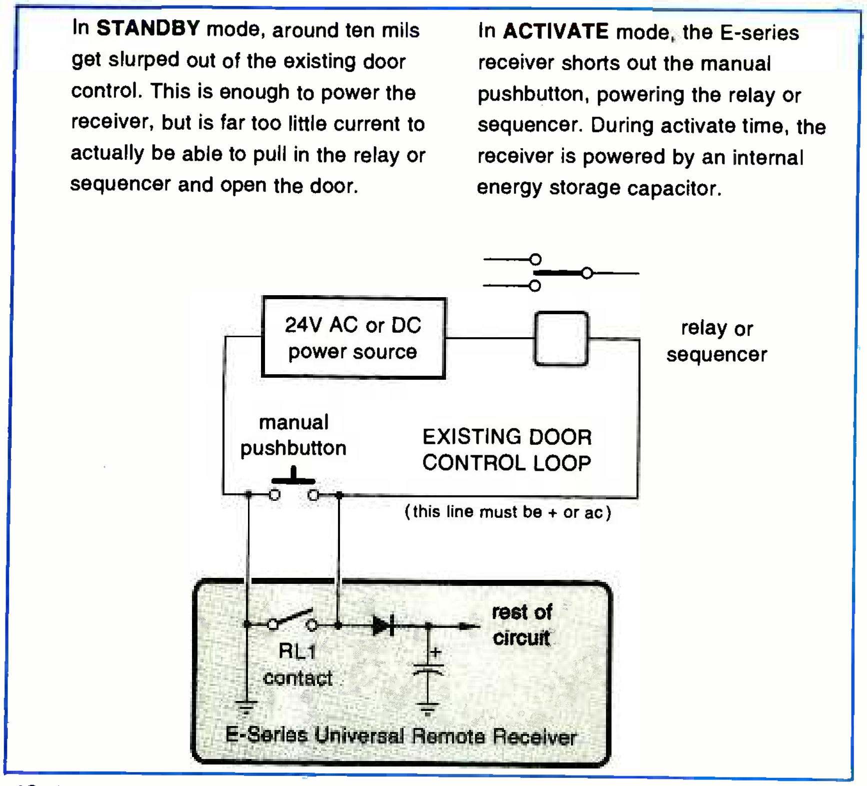


**FIG. 3—WHEN IN "GARAGE MODE," the E-Series receiver uses a two-wire hookup that pirates its supply power from the main system.**

that matches that of the activated transmitter.

The digital section of the circuit consists of a second 16C54LP PIC microcontroller, a small EEPROM serial memory chip, and a 2N2222 transistor relay driver. An 8-megahertz crystal sets the circuit's operating frequency.

The microcontroller works in two modes. In *normal mode*, the relay closes for half a second when one of four proper codes is received. The red LED also lights. A *click-clack* sound can be heard as the relay activates.

In the *program mode*, the receiver can be taught to recognize the codes of up to four transmitters. The "learn" button is pressed to activate the programming mode. The receiver's LED flashes twice to indicate that it has entered its program mode. Then the transmitter button is pushed. The receiver LED flashes three times to indicate that it has learned the transmitter's code. The process is similar to the one used for programming a universal TV/VCR remote.

There are two ways to use the receiver: *garage mode* and *hacker mode*. In the garage mode, an existing 24-volt AC or DC control loop provides 10 milliamperes of "pirated" current to the receiver *without* activating the main door relays. The receiver is installed in parallel with the manual switch.

During the off times, the receiver consumes about ten milliamperes of standby current. A 1000-microfarad capacitor stores enough energy to power the receiver during the brief "on" time when the relay short circuits the main control line. Details are shown in Fig. 3.

Not all older garage door openers are compatible. Sometimes swapping the two leads will work. Otherwise, the hacker mode must be used.

In the hacker mode, an external 12-volt DC *negative tip* supply is connected as shown in Fig. 2. The circuit can be altered slightly to isolate the relay contacts from the power supply. Details vary with the application.

Each transmitter comes from the factory permanently preprogrammed with one, two, or three unique codes out of 16 million. Each receiver can be taught to recognize any of four codes, all of which close the relay.

onsidering the sophistication performance of these units, they are surprisingly low in cost. They are probably a lot cheaper and more compact than any you could build. The No. 20051-E one-code transmitter sells for $44.95, the No. 30021-E one-relay, four-code receiver is priced at $49.95, the No. 30020-E factory matched transmitter-receiver pair is $79.95, and the No. 20061-E three code transmitter is $49.95. More specialized units with more control outputs are available. See the "Names And Numbers" box for DesignTech International's address and phone number.

### Get the #'$*% phone!

I had an immediate use for an E remote just as soon as it showed up. I operate *Synergetics* out of my home, helped along by Bee and a few associates. The building is L shaped and usually full of such noise generators as coolers, printers, rock music playing, dehumidifiers, and cat and dog philosophical discussions.

Getting me to the phone is usually a real hassle. And because of all the rooms and walls, there's no way that any ultrasonic or infrared remote will hack it. Figure 4 shows how I modified the receiver to drive a piezoelectric buzzer. I stash the receiver in my usual lair, and each person who answers the phone has a remote. This simple wireless annunciator setup works like a champ.

Offhand, I can think up hundreds of hacker applications for this really great system: robotics, construction sites, long driveways, fire departments, farms, and security access. But why don't you tell me instead, as part of this month's contest.

### This month's contest

Just tell me about a new or unusual use for a fairly secure, medium-range, wireless remote control. There will be a dozen or so of my *Incredible Secret Money Machine II* books going to the best entries, with one all expense paid *tinaja quest* (FOB Thatcher, AZ) for two going to the best of all. In addition, development units might be awarded to the most interesting or most unusual new applications. Just tell me why you want one. Send your *written* entries to me here at *Synergetics*, and not to Electronics Now editorial.

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Frank Miller of *DynaArt Designs* has just dramatically expanded his offerings for prototype and hobbyist printed circuits. He has many innovative wave etchers, shears, laminators, and support products. Many of them optimized for his improved version of the *direct toner method*. This lets you create printed circuit boards at home cheaply and quickly. A free catalog is offered.

I thought I'd zero in on a little-known use for Frank's products. His direct-toner transfer sheets can also be used to create high-quality decals in black and white *or* in full color. Obvious applications include panel artwork, dial plates, antique equipment restorations, and circuit board callouts.

There are two decal methods you might like to try: one cold and one hot. Frank's toner transfer film is the key to both. The paper film carrier is coated with a thin layer of high-temperature water-soluble glue.

Make a *reverse* of the artwork on this paper with, for example, a laser printer. You can use a color copier for some stunning effects. Then place the transfer film against a panel or blank circuit board and apply heat and pressure. The safest and surest way to apply just the right pressure for the right time is with one of Frank's new laminators, a modified Kroy Color machine, or a reworked laser-printer fuser assem-

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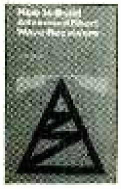

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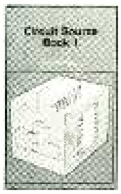


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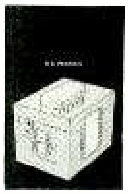

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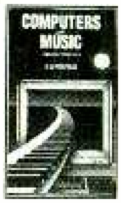


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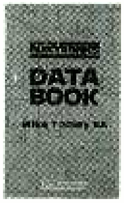


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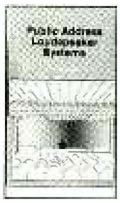


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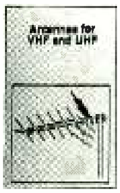


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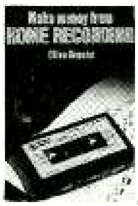


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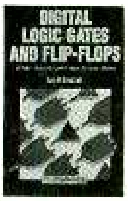


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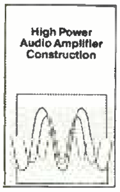


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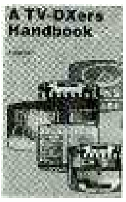


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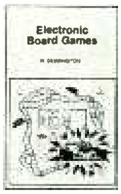


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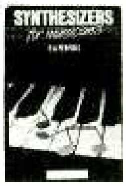


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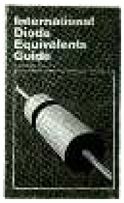


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- ☐ BP161—Tinto the QL Archive (database program)—$2.95
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bly. An iron will also work if you are *extremely* careful.

The heat and pressure melts the toner and bonds it to the circuit board or front panel. Soak the panel in warm water for a minute or so to dissolve the glue under the transfer sheet, allowing it to loosen and "float" off.

The cold method is better suited for traditional decals, which might be used in a model railroad layout or for arts and crafts.

As before, print the artwork on a transfer sheet, but this time print it right-reading. Spray three *light* coats of ordinary lacquer over the sheet and let it dry. Then cut out the artwork, leaving a small margin all around. When the decal is soaked in water it slides off the transfer sheet and can be applied to almost any surface just like regular decals. The careful use of a Q-tip cotton swab can remove any air bubbles. Once the decal is dry, you can remove the lacquer film with alcohol.

Polyethylene in the toner makes the hot method bond; this is a rugged bond. With the cold method, a water soluble adhesive does the bonding, but is less durable. Finished work by either method can be protected with suitable clear epoxy overcoats.

### Pseudoscience marches on

There's still a lot of ongoing helpline interest in pseudoscience topics. Because there are several major new products from the pseudoscience industry this month, I thought I do an update for this month's resource sidebar.

### PSEUDOSCIENCE RESOURCES

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(303) 833-4895

**High Energy Enterprises**
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Security CO 80931
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**KeelyNet BBS**
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Mesquite TX 75149
(214) 324-3501 BBS

**Lor'd Industries Limited**
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(715) 249-5611

**New Energy News**
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(801) 583-6232

**Phaedra Enterprises**
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(415) 359-0432

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(819) 777-9696

**Rex Research**
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Jean NV 89019

**Skeptical Inquirer**
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(716) 636-1425

**Smithsonian Institution Press**
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Washington DC 20560
(202) 287-3738

**Space Energy Newsletter**
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Clearwater FL 34616

**Super Science**
101 E Stroop Rd
Kettering OH 45429
(513) 298-7116

**Tesla Book Company**
Box 121873
Chula Vista CA 91912
(805) 646-3371

**Untapped Technology Review**
PO Box 5185
Mesa AZ 85211

Pseudoscience is best defined as "Tain't likely McGee" beliefs that lack credibility and are not reproducible by scientific tests. It often involves labwork that's "not even wrong," and typically includes hefty doses of conspiracy and paranoia.

Why bother with pseudoscience? Many readers continue to demand more coverage. I certainly like to encourage people to seek out oddball topics, and most pseudoscience reading is highly entertaining and wondrously bizarre fiction. It's also a good gauge of how close to "the edge" I get with my own designs and explorations. It's fun to research and, quite often, the closer I get to the original source documents, the more unusual things unravel.

I'd like to take all the psuedoscience, pile it up on a center stage somewhere, and shine a bright light on it. Then all of you could objectively conclude "Yup, that sure is a big pile all right."

Let's start with *Watch the Skies! A Chronicle of the Flying Saucer Myth* written by Curtis Peebles and published by the *Smithsonian Institution Press*. It traces the evolution of UFO lore, elegantly showing what came from where. The author's premise is that not one credible shred of hard evidence exists anywhere.

Although the book is obviously thorough and scholarly, much seems to be missing, such as the Gulf Breeze scams and the ongoing crop-circle hoaxes. The big intergalactic happy face on Mars is absent. The biggest international flap, Billy Meier, has but the briefest of mentions. And I believe that the crown jewels for all of UFOdom—Roswell 1947—were dismissed far too lightly. For some differing viewpoints, see *The Roswell Incident* or the brand new *Roswell* videos.

I think the best guide to the UFO industry is David Belevin's *Almanac of UFO Organizations and Publications*. Published by *Phaedra*, it appears as a combined Thomas Registry and Michelin Guide reference to UFOs.

*New Energy News* is an ongoing newsletter from the *Institute for New Energy*. Its focus is on cold

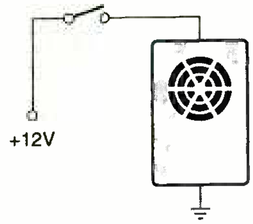


**FIG. 4—A WIRELESS ANNUNCIATOR is easily made by modifying an E-series receiver in its hacker mode.**

fusion developments, new free space energy generation, and rotating "over unity" machines. It seems to be best at book reviews and conference listings. It also mentions the *Space Energy Newsletter*, a *Free America Network*, and the *Electric Spacecraft Journal* newsletters.

Several helpline callers have asked me what a molecular frequency discriminator is. It's just a plain old power audio oscillator, a matching transformer, and two ground injection probes. Supposedly, these can be set to "magic" frequencies for gold, silver, platinum, and other metals, and then used with normal dowsing techniques to find those metals.

I know of no credible scientific basis for such a machine. And even if it does work, the $4000 system could be replaced by a $5 part such as the *Maxim* MAX238 or else the ML2035 from *MicroLinear*.

The Keelynet BBS has scads of files on pseudoscience topics. And more or less objective trashing of the entire field often shows up in the *Skeptical Inquirer*.

Last but not least, I have located the ultimate pseudoscience treasure trove—the mother lode, for sure. The *International Guild for Advanced Sciences* offers hundreds of books and videos on everything from alien contacts to perpetual motion to techno-shamanistic radionics. It will also gladly publish your very own books for you.

Neatest of all, however, are the antigravity machines, the time travel devices, teleportation systems, and even a cyborg cosimano helmet full of psychic energy-amplifying magic crystals. Off-the-shelf hardware, no less. Also off-the-wall. The Guild's free catalog is a must read.

## New tech lit

*The PIC Source Book* is a brand new $39 book and software package from *Scott Edwards Electronics*. It is for people who want to go beyond the *Basic STAMP* in developing their own fast machine language code for the superb PIC series of microcontrollers from *Microchip Technology*. This one is essential for the design of low-cost PIC circuits such as the E series remotes I just discussed.

Two new sets of free development software are available for the programmable logic devices: *FirstStep* from *Altera* and *PLDshell Plus* from *Intel*.

New light-emitting diodes that are *ten times* more efficient than regular ones are described on page 943 of the August 17, 1994 issue of *Science*. Microcavities are the secret. Since the best LEDs are now approaching incandescent efficiency, this is truly a major development. Nearly any color emission is available, *including* white!

A revolutionary new *virtual ways* machine tool technology appears on pages 58–61 of the August 15, 1994 issue of *Design News*. Unlike older conventional mills or lathes, *there's nothing that slides!* Only plain old bearings and six ordinary jackscrews or linear steppers are involved. There are no bending forces anywhere in the machine. All stresses are simple tension or compression, leading to outstanding stability and precision. And this one looks great for many different hacker CAM applications.

More on the radio broadcast data system (RBDS) appears in the July 27, 1994 *Radio World*. Included is a list of over a hundred FM RBDS stations in 32 states, and in-depth reviews of several new automobile and home receivers.

Two sources for multimedia books and software are *Media Magic* and *AP Professional*. They offer free catalogs.

The *Growing Community* is a well done newsletter on alternative and high-tech intentional communities. They are located mostly in the Western United States and mostly off of the utility power grid.

A 46-page *Video Battery Handbook* is available from *Anton/Bauer*.

A new book by John Huntington entitled *Control Systems for Live Entertainment* is published by the *Focal Press*. It covers the basics of theater, concert, and amusement-park systems for lighting, sound, special effects, and even pyrotechnics.

These days, it's a simple and easy matter to publish your own high-quality books. Or you can set up a service bureau to instant publish for others. Full details appear in my newly updated *Book-on-Demand Resource Kit*.

Also a reminder that reprints and preprints of all my columns, my free insider secrets catalogs, and instant technical help is available on *Genie* PSRT. A 10-hour free trial is available per the *Need Help?* box on this page.

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**TONE DECODER**

*continued from page 68*

portionately reduced. In both circuits, a buffer stage is connected between the junction of resistor R1 and capacitor C1, and pin 6 of the 567.

In Fig. 9 this buffer is an emitter-follower transistor stage. Unfortunately, this stage causes a slight loss of waveform symmetry. By contrast, the circuit in Fig. 10 includes an operational amplifier follower as the buffer. It, however, causes no waveform symmetry loss.

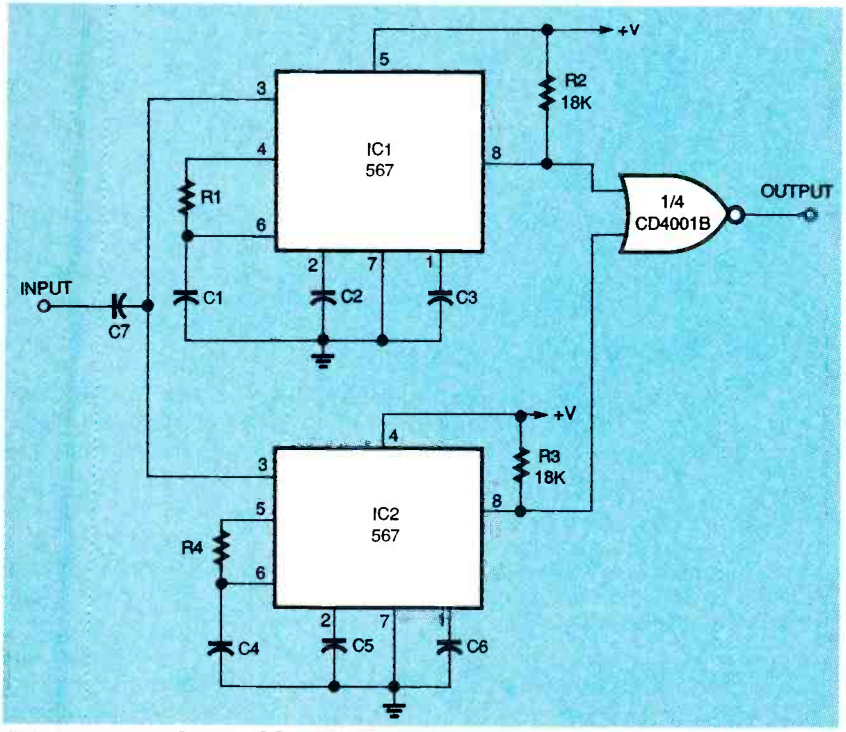


**FIG. 14—DUAL-TONE DECODER with a single output.**

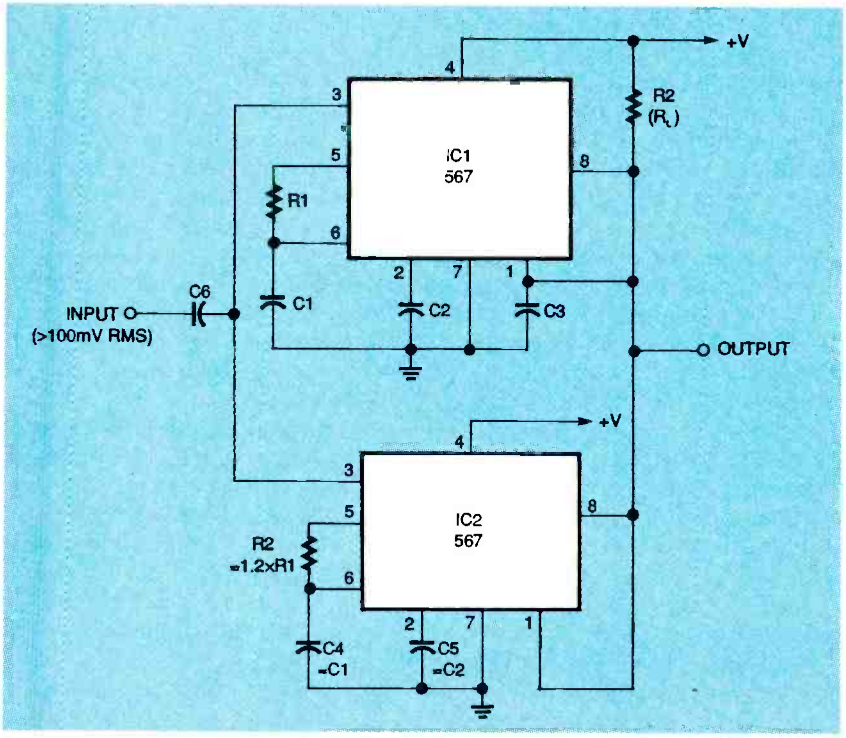


**FIG. 15—DUAL-TONE SWITCH with 24 % bandwidth.**

### Five 567 outputs.

The 567 has five output terminals. Two of these (pins 5 and 6) give access to the oscillator output waveforms. A third (pin 8) functions as the IC's main output terminal, as previously stated. The remaining two outputs are available on pins 1 and 2 of the decoder.

Pin 2 gives access to the phase detector output terminal of the PLL, and it is internally biased at a quiescent value of 3.8 volts. When the 567 receives in-band input signals, this voltage varies as a linear function of frequency over the typical range of 0.95 to 1.05 times the oscillator's free-running frequency. It has a slope of about 20 millivolts per percent of frequency deviation.

Figure 11 illustrates the time relationship between the outputs of pin 2 and pin 8 when the 567 is organized as a tone switch. The relationships are shown at two bandwidths: 14% and 7%.

Pin 1 gives access to the output of the 567's quadrature phase detector. During tone lock, the average voltage at pin 1 is a function of the circuit's in-band input signal amplitude, as shown in transfer graph Fig. 12. Pin 8 at the collector of the output transistor turns on when the average voltage at pin 1 is pulled below its 3.8-volt threshold value.

### Detection bandwidth

When the 567 is configured as a tone switch, its bandwidth (as a percentage of center frequency) has a maximum value of about 14%. That value is proportional to the value of in-band signal voltage in the 25 to 200 millivolt RMS range. However, it is independent of values in the 200 to 300 millivolt range, and is inversely proportional to the product of center frequency and capacitor C2. The actual bandwidth (BW) is:

$$BW = 1070\sqrt{V_i/(f_o \times C2)}$$

in % of $f_o$ and $V_i \leq 200$ millivolts RMS

Where $V_i$ is in volts RMS and C2 is in microfarads

*(Continued on page 88)*

# AUDIO UPDATE

## Listening to Digital Compression

LARRY KLEIN

For most audiophiles, compression implies a slightly disreputable and little-understood back-room engineering practice. In truth, however, it is a necessary fact of life faced by recording and broadcast engineers, who are daily forced to limit the high frequencies, low frequencies, and/or overall levels of their audio material. This is done to ensure that the program performs adequately within the inherent limitations of each media.

FM radio is particularly compression prone because of the FCC-mandated high-frequency preemphasis used in all FM broadcasts. With the best of intentions—i.e., noise reduction—the FCC decided it was a good idea to inject a specific high-frequency boost in audio signals before they are broadcast. All FM receivers have a complementary deemphasis circuit that restores the original high-frequency levels and, in the process, also cuts back high-frequency transmission noise by 10 to 15 dB.

The designers of this preemphasis/deemphasis process obviously assumed that broadcast transmitters could handle the high-frequency preemphasis boost without overmodulation problems. And perhaps that was a reasonable assumption in the days when microphones and recording technology in general seldom came within shouting distance of 10 kHz.

Unfortunately, the early FCC rule makers didn't anticipate the increasingly hot high end found on most pop recordings from the early sixties on. Most broadcasters were forced to install compression devices—of varying degrees of sophistication—designed to prevent transmitter overload while maintaining a reasonably loud signal. (Those devices were also used to produce heavily modulated transmissions with unnervingly high average signal levels—but that's another story involving limiters, clippers, and broadcast market-area coverage.)

FIG. 1. SONY'S MINIDISC (MD) digital audio format uses ATAC digital data reduction compression to fit the same amount of music on a 2.5-inch disc as is found on full-size compact discs.

When CDs, with their potential 90-dB dynamic range, hit the market, the situation worsened significantly, as I learned from direct experience. Early in 1983, I was instrumental in securing for WNCN (a now-defunct New York City classical music station) their very first CD player. I subsequently participated in three one-hour listener call-in programs designed to demonstrate and explain the technology to WNCN's audience. At the time, WNCN prided itself on using minimum signal compression in order to ensure that LP orchestral crescendos came through with reasonable dynamics. But since no good deed goes unpunished, WNCN also had the lowest average signal level of any station in the New York City area.

Before our first broadcast of a wide-range compact disc it was decided—based on the anticipated dynamic peaks in the music—to set the CD player's output somewhat lower than normal. While that avoided problems with transmitter overload, it caused some listeners to phone in complaining that at times the modulation level of the music was so low that they were having noise problems or couldn't get any indication on their recorder's meters.

For the second broadcast we ran a slightly higher average level. But, alas, on loud passages that had the transmitter's overmodulation indicator flashing like a demented firefly. A temporary solution was to manually gain ride the troublesome passages, which also provoked listener complaints. Obviously, a better solution was required. I don't recall how WNCN ultimately handled the problem, but I suspect that they, like everyone else, ultimately resorted to one of the highly sophisticated broadcast compressors designed to cope with the CD-engendered high-frequency overload problem.

As I mentioned earlier, FM isn't the only audio medium that resorts to compression to make their products real-world compatible. But aside from occasional grumbles from dynamic-range aficionados who usually bought accessory expanders for their systems, audio compression has never been a big issue—until lately.

### The new compressions

Most previous compression schemes made either the loud parts softer and/or the soft parts louder in an effort to reduce noise and avoid overload. Today, however, compression is employed in behalf of increasing the apparent data storage capability in a variety of media. I use the word "apparent" because it isn't that the storage medium can hold more data; rather it is the data that is reduced so that more program can be fitted into a given storage space.

Consumers are aware—but not as much as the manufacturers would like—of two recent audio products employing data reduction compression: the Philips Digital Compact Cassette (DCC) and the Sony MiniDisc (MD). The 2.5-inch MD has the playing time equivalent of a full-size CD through use of Sony's ATRAC (Adaptive Transform Acoustic Coding) digital-compression system. Simply stated, ATRAC—and the Philips system—works by constantly analyzing the audio signal and extracting and encoding only those elements that are audible under normal listening conditions.

In other words, frequencies that are psychoacoustically masked by other frequencies, or which for other reasons would not be heard, are discarded during the moment-to-moment analysis. All this manipulation is in the digital domain and, if done properly, substantially shrinks the space required by the digital program material with little or no loss in its subjective quality.

**Subjective/objective testing**

Unlike the situation in other areas of audio electronics, measurements aren't a lot of help when you are trying to design a transparent digital data reduction program. The main problem, of course, is making sure that whatever is dropped from the original program by a psychoacoustic coding algorithm won't be missed. We know a lot about masking and how to manipulate it to our ends, but, ultimately, trained ears listening under tightly controlled double-blind test conditions are needed to render final judgment: Is the sound of the compressed signal indistinguishable from that of the original?

Those of us who read the Journal of the Audio Engineering Society or attend the AES Conventions are aware of the new interest in fine tuning the methodology of listening evaluations brought about by the flood of psychoacoustic coding schemes. Certainly no one could object to contributions and suggestions toward that end. However, ...

A recent editorial open-letter to Pioneer Electronics in *Stereophile* magazine was brought to my attention by an outraged fellow writer. I quote: "We at *Stereophile* are most concerned about the audio quality that will be available on new Laserdiscs incorporating Dolby AC-3 digital compression, as announced by Pioneer and others. As you know, we care intensely about the sound quality of the sources we listen to." The editorial goes on to express its concern that "Pioneer and others will decide on an inferior sounding system ... before the system has been evaluated by the wider audio community, including us," and requests that the standard be delayed "until it has been more completely evaluated by keen eared listeners such as ourselves ..."

I'm far more amused than upset by *Stereophile's* self-serving letter. *Stereophile* is a publication that is both a source and repository of audio fads and fallacies. It has a core of equipment reviewers whose subjective evaluations are essentially prolix fantasies and who hear and describe in minute detail audio artifacts unheard by ordinary mortals—or by themselves in double-blind testing. For *Stereophile* to suggest that rigorously derived professional standards be held up until they can put in their two-cents' worth of probable nonsense is the height of absurdity, hubris, and chutzpah. Ω

## TONE DECODER

*continued from page 85*

To select a C2 value by an educated trial and error process, start by selecting a value that is twice that of C1. Then either increase its value to reduce bandwidth, or reduce its value to increase bandwidth.

**Detection band skew**

Detection band skew is a measure of how well the band is centered about the center frequency. Skew is defined as:

$(f_{max} + f_{min} - 2f_o)/2f$

Where $f_{max}$ and $f_{min}$ are the frequencies corresponding to the edges of the detection band.

If a tone switch has a center frequency of 100 kHz and a bandwidth of 10 kHz, and its edge of band frequencies are symmetrically placed at 95 kHz and 105 kHz, its skew value is zero %. However, if its range of band values is highly nonsymmetrical at 100 kHz and 110 kHz, its skew value increases to 5%.

The skew value can be reduced to zero, if necessary, by introducing an external bias trim voltage at pin 2 of the IC with a trimmer potentiometer R2 and 47 kilohm resistor R4, as shown in Fig. 13. Moving the wiper up will lower the center frequency, and moving it down will raise it. Silicon diodes D1 and D2 are optional for temperature compensation.

**Tone-switch design**

Practical tone-switch circuits based on the typical connection diagram Fig. 3 are easy to design. Select the resistor R1 and capacitor C1 frequency control component values by referring to the nomograph, Fig. 6. Select the value of C2 on an empirical basis as described earlier. Start by making it twice the value of C1 and then adjusting its value (if necessary) to give the desired signal bandwidth. If band symmetry is critical in your application, add a skew adjustment stage, as shown in Fig. 13.

Finally, to complete the circuit design, give C3 a value double that of C2, and check the circuit response. If C3 is too small, the output at pin 8 might pulsate during switching because of transients.

**Multiple switching**

Any desired number of 567 tone switches can be fed from a common input signal to make a multitone switching network of any desired size. Figures 14 and 15 are two practical two-stage switching networks.

The circuit in Fig. 14 functions as a dual-tone decoder. It has a single output that is activated in the presence of either of two input tones. Here, the two tone switches are fed from the same signal source, and their outputs are NORed by a CD4001B CMOS gate IC.

Figure 15 shows two 567 tone switches connected in parallel so that they act like a single tone switch with a bandwidth of 24%. In this circuit, the operating frequency of the IC2 tone switch is made 1.12 times lower than that of the IC1 tone switch. As a result, their switching bandwidths overlap. Ω

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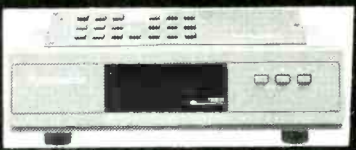

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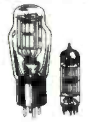

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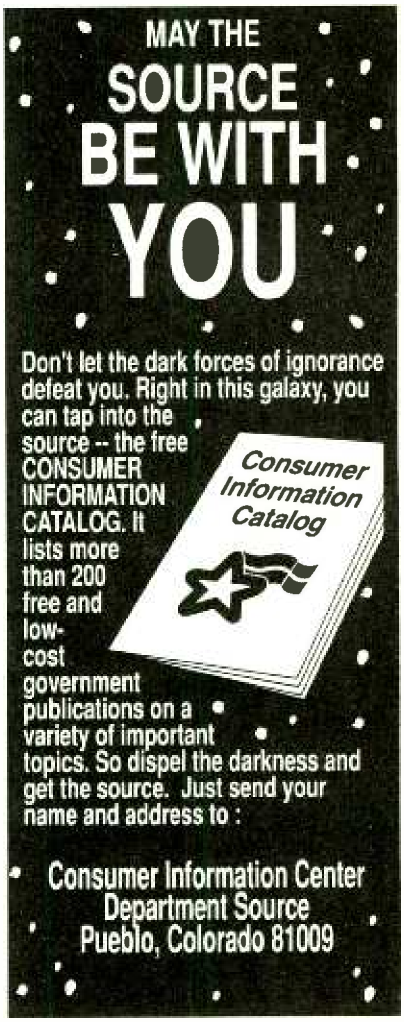

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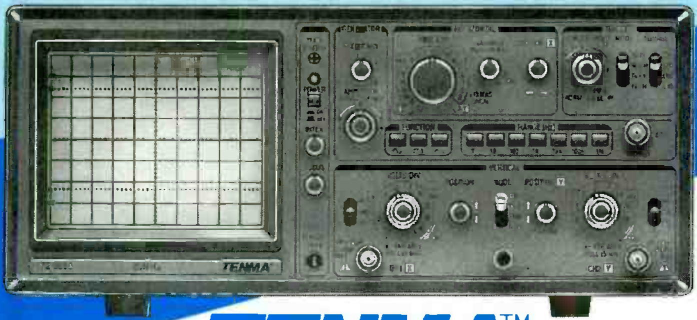


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# How to get surround sound without buying the theater...

*Chase Technologies brings you an amazing new patent pending surround sound decoder that turns your stereo into a five-channel home theater.*


*By Charles Anton*

As much as I love renting videos, it's just not the same as seeing a movie in a theater. I remember the first time I saw *Jurassic Park*—I nearly jumped out of my seat when the dinosaurs roared. One of the reasons movies seem so real is because surround sound makes it seem like you're actually there when events are happening. Now there's an incredible new device that lets you use a stereo receiver to get that same surround sound in your home.

It takes more than five speakers to get surround sound; there needs to be a way of separating the signals. The new Chase Technologies HTS-1 decoder does just that, and in a revolutionary way that rivals the best Dolby Pro-Logic and THX systems.

**Wins over critics.** In the September '94 issue of "High Performance Review," noted audio critic Daniel Kumin said "the HTS-1 can do quite a job of recreating a 3D theatrical experience...surround effects emanated with satisfying fullness... sound was clean at any level...with quite involving and natural sound ambience." Plus, John Sunier, the leading authority on surround sound and producer of *Audiophile Audition*, a nationally syndicated radio program for audio enthusiasts, says, "...the new Chase HTS-1, when used to decode the hidden ambience in all musical recordings, definitely outperforms all the Dolby and THX processors (which could cost you up to $3,000)...I am impressed!"

**Passive circuit.** Last year, audio industry veteran and Chase president Bob Rapoport invented a new five-channel "passive" circuit for decoding every surround sound encoded movie available. This new decoder can be used with two, three, four, or five channels of amplification, making it the most cost effective method for upgrading an existing stereo system to full home theater performance on the market today.

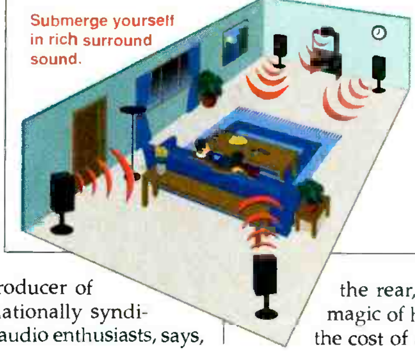
**Breakthrough.** The HTS-1 is able to decode the *Dolby Surround*™ signals in a stereo, videotape or laserdisc because the spatial and depth cues have been matrixed into the "out-of-phase" L minus R portion of the program. By decoding passively, the HTS-1 avoids costly and noisy signal processing. Plus you don't need any extra amps! Just connect the HTS-1 to your existing stereo, add two speakers for the rear, and you'll experience the magic of home theater at a fraction of the cost of all other systems.

### The secret of surround sound

Surround sound has become the rage of the 90's because it adds depth and realism to stereo sound, giving you the home theater experience. It makes you feel like you're actually at a concert or theater. To "fill a room" with surround sound, you need more than two channels. The HTS-1 provides five channels of sound from any two-channel stereo source.

**Free center channel.** By connecting your VCR or laserdisc player to your TV, you get sound from your TV speaker; this acts as the fifth or "center channel."

**Upgradeable.** The new HTS-1 gives you the ability to upgrade by adding the "Dialog" powered center channel speaker (instead of using your TV speaker.) The decoder can also feed an extra amp for the rear speakers if you want the ultimate in discreet five channel performance.


Submerge yourself in rich surround sound.

**Easy installation.** Hooking up the HTS-1 is easy—just connect the speaker outputs of your receiver or amp to the HTS-1, then connect speaker wire to the front and rear speakers. The rear channel speakers don't have to be big. We suggest the Chase ELF-1 in either black or white finish to match your decor.

**Center Channel.** The "Dialog" powered center channel speaker is the perfect add-on for home theater. It keeps voices and sound effects centered on screen for stunning localization and clarity.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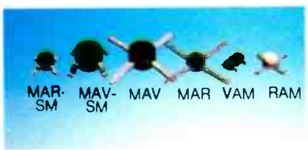


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| | MAR-1 0.99 | MAR-2 1.35 | MAR-3 1.45 | MAR-4 1.55 | MAR-6 1.29 | MAR-7 1.75 | MAR-8 1.70 | |
| Freq.MHz.DC to | 1000 | 2000 | 2000 | 1000 | 2000 | 2000 | 1000 | 1000 |
| Gain, dB at 100MHz | 18.5 | 12.5 | 12.5 | 8.3 | 20 | 13.5 | 32.5 | 12.7 |
| Output Pwr. +dBm | 1.5 | 4.5 | 10.0 | 12.5 | 2.0 | 5.5 | 12.5 | 17.5 |
| NF, dB | 5.5 | 6.5 | 6.0 | 6.5 | 3.0 | 5.0 | 3.3 | 3.6 |

Notes: + Frequency range DC-1500MHz ++ Gain 1/2 dB less than shown

**designer's kit, KH-1** available only $59.95 includes.
**40 AMPLIFIERS*** 10 MAR-1, 10 MAR-3, 10 MAR-4, 10 MAR-8
**150 CAPACITORS*** 50 100 pf, 50 1,000 pf, 50 10,000 pf
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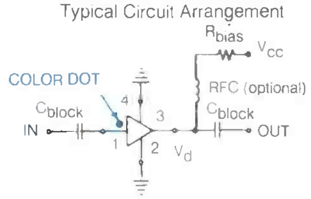
*values or models may be substituted without notice depending on supplies

Typical Circuit Arrangement

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